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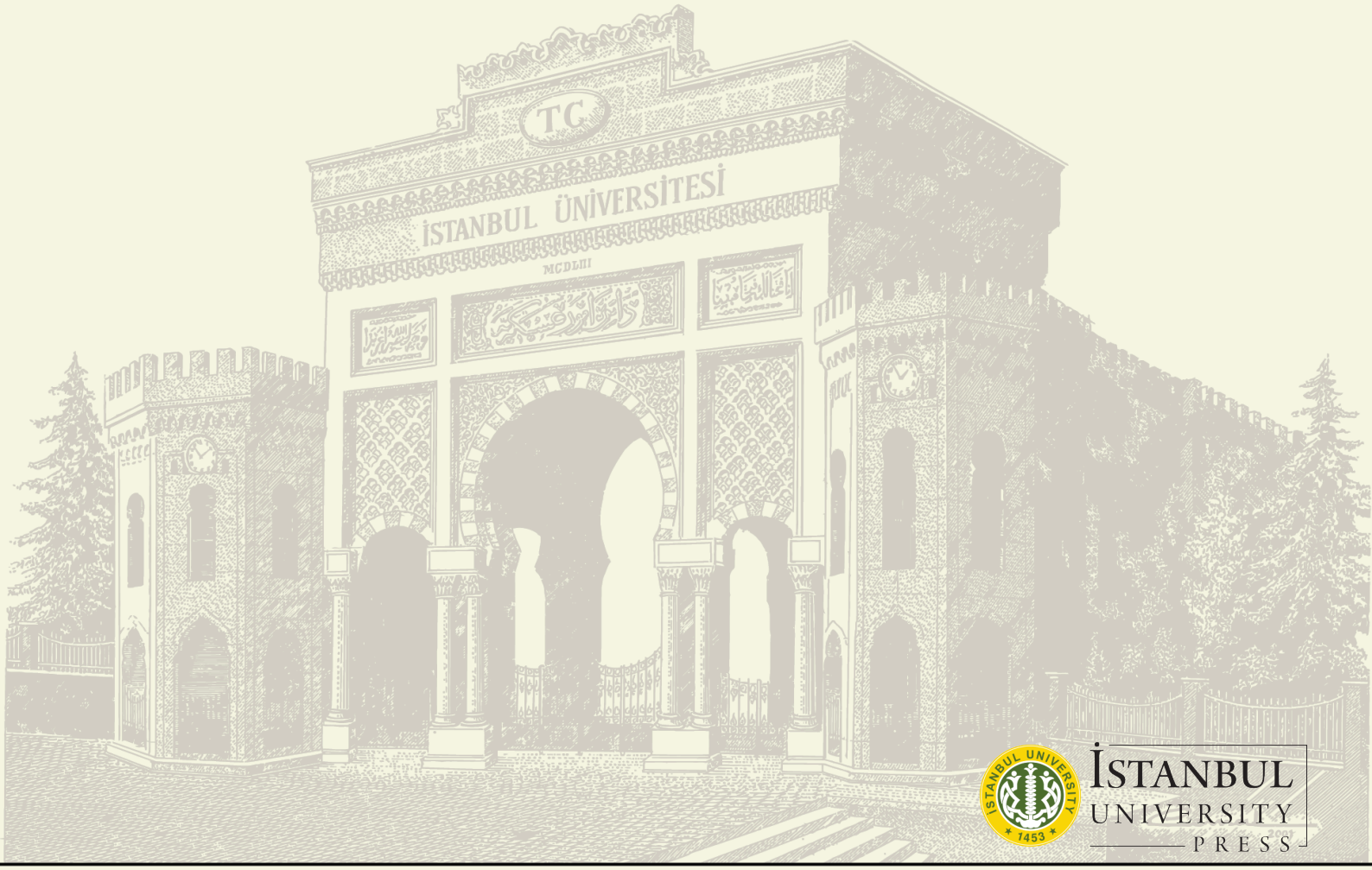

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Research Article

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Forecasting the Turkish Manufacturing Industrial Production Index: An Empirical Comparison of Time Series and Machine Learning Models

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Abstract Macroeconomic variables are important in both following cyclical economic developments and answering the questions of decision-makers and investors about the future. In this context, investigating the industrial production index dynamics over time provides rapid and important signals about the general economic prospects. Therefore, the effects of the COVID-19 outbreak on the forecasting performance of economic variables have been increasingly investigated in the literature. This study examines the forecasting performance differences between time series and machine learning models for the Turkish Manufacturing Industrial Production Index) across the pre- and post-COVID-19 periods. Using econometric and machine learning methods, we identified that the time series models performed better before COVID-19, while the machine learning models excelled post-COVID-19. According to the results for the pre-COVID-19 period, the ARDL model, which is a member of the time series model family, produces the best results in terms of forecast performance criteria, however the Principal Component Analysis model, which is a member of the machine learning model family, is found to be the best performing model for the post-COVID-19 period. This finding implies that the forecast performance of the time series and machine learning models is different depending on the COVID-19 outbreak. Time series models produce robust forecast performance before the COVID-19 period, whereas machine learning family member models produce robust results after the COVID-19 period for the Turkish Manufacturing Industrial Production Index variable. These results highlight the shifting utility of model families under economic disruption, offering insights for policymakers and forecasters.

Keywords Forecasting · Industrial production index · Time series models · Machine learning models

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Forecasting the Turkish Manufacturing Industrial Production Index: An Empirical Comparison of Time Series and Machine Learning Models

Recently, the importance of macroeconomic variables has been increasing, not only for following cyclical economic developments but also for answering the questions of decision-makers and investors about the future. In this context, scrutinising the changes in the industrial production indexes (IPI) over time provides rapid and important signals about the general economic prospects. Because manufacturing is one of the main drivers of the whole business cycle, the IPI index is one of the most important and widely analysed indicators for academics and market professionals (Bulligan et al., 2010). As manufacturing forms the backbone of industrial activity, forecasting the Manufacturing Industrial Production Index (M-IPI) is pivotal for evaluating the economy's trajectory, especially in emerging markets like Türkiye, where manufacturing plays a disproportionately large role in economic output.

The statistical offices publish the IPI on a monthly or quarterly basis to follow changes and developments industrial production. Although the IPI calculation varies depending on the country, it includes the sub-main sectors of mining, energy, and manufacturing. That said, the manufacturing sector's share industrial production in emerging countries is relatively high (Haraguchi et al., 2017). Therefore, forecasting the manufacturing industry production index (M-IPI) is fundamental in terms of future planning for economic development.

In the literature, various econometric models have been employed to predict the IPI or M-IPI. Accurate estimation of production indexes is quite sophisticated due to the scarcity of well-specified and variable-rich economic models. It is not possible to consider all the components of the economy's structural features in a country. Moreover, for variables obtained with short and different collection methods, data stationary, high noise ratios, and non-linear effects, etc. are some of the major obstacles in creating accurate time series models (Moody, 1995).

On the other hand, with recent advances in methodological and technological developments, long- or short-term forecasting methods employed in economic research are evolving and becoming widespread. Today, data science tools are employed together with standard econometric methods, and they produce very successful forecasting performance.

The outbreak of COVID-19 in early 2020 inevitably impacted Türkiye's manufacturing industry, mirroring its effects on the global economy. Imbalances in supply and demand conditions have left both permanent and temporary marks on the manufacturing industry. Therefore, the COVID-19 factor should be taken into account in forecasting the Turkish M-IPI.

This study aims to forecast the Turkish M-IPI using both standard econometric time series models and machine learning techniques, and to identify which kind of models are successful by comparing the forecasting performance of the alternative models. Accurate forecasting of macroeconomic indicators is vital for policymakers and investors. The Industrial Production Index (IPI) is a key economic indicator that reflects manufacturing trends. This study focuses on the Turkish Manufacturing IPI (M-IPI), comparing econometric and machine learning forecasting models. The COVID-19 pandemic underscored the need for robust models that adapt to economic disruptions. Using leading indicators like PMI and RSCI—despite their close timing to IPI—enhances short-term forecasting accuracy. Our study contributes by providing the first comprehensive

comparison of these model families in the context of COVID-19. A distinct aspect of this study is the selection of the following predictor variables: the Manufacturing Purchasing Managers Index (PMI) and the Real Sector Confidence Index (RSCI). Both indicators are timely, with the PMI published shortly after the end of the reference month and the RSCI announced a week prior. This makes them effective tools for real-time forecasting of the M-IPI, a perspective not sufficiently explored in the existing literature. The analysis period was divided into two sub-periods, namely the training period and the test period. Using the model parameters determined during the training period, the forecasts for the test period were calculated. The methodology applied in this study is comprehensive, utilising a wide array of models ranging from traditional econometric techniques, such as ARDL and Markov switching regressions, to advanced machine learning approaches like principal component analysis (PCA) and neural networks. The forecasting performance of these models is rigorously compared using multiple metrics, including RMSE, MAE, MAPE, and Theil's U.

This study in addition seeks to fill two critical gaps in the forecasting literature. First, it is an empirical investigation on the time series and machine learning models when predicting the Turkish M-IPI. While a plenty of research has been done in econometric approaches vis-a-vis machine learning algorithms in the forecasting of M-IPI models in the Turkish context, none has looked at the comparative perspective. Second, the analysis includes the effect of COVID-19 pandemic, which marked an unprecedented upheaval in economic systems. By distinguishing between Pre-COVID-19 and Post-COVID-19, we are seeking to analyse the impact of structural economic transformations on the application of these methodologies, thereby testing their stability under extreme situations.

To the best of our knowledge, this is the first paper in the literature comparing the forecasting performance of both time series econometric models and machine learning algorithms for the Turkish M-IPI. We contend that this is the first contribution of this study to the existing literature. This paper also employs two different estimation and forecasting periods in order to analyse the effect of the COVID-19 outbreak on the forecast performance of the alternative models for the Turkish M-IPI. As far as we know, this is the first paper in the literature analysing the effect of the COVID-19 outbreak on the forecasting performance of the Turkish M-IPI, which is the third contribution of this study to the existing literature.

This study consists of five sections. Following the introduction, the second section examines the existing literature. The third section presents the data and methodology employed. Section 4 shares the findings of the empirical analysis and discusses the results. Finally, the conclusion presents an evaluation of the findings and avenues for future research.

Literature Review

The literature on industrial production forecasting started with discussions about the calculation methods. Maher (1957) estimated the turning points in the series by examining linear regression models to compare the cyclical variations and time series in the American Federal Reserve board industrial production with the Diffusion Index developed by Moore (1950). According to his results, false signal formation in the upper and lower limits of fluctuations in the diffusion method and the use of a moving average method with indicators longer than the series negatively affect the forecasting. It has been observed that the linear regression model is more consistent in solving these problems. Stekler (1961) also examined the independent components of the series, as mentioned above, as well as the diffusion index method's prediction performance using leading series regression. The study tested whether leading series regression (LSR) is better at predicting turning points than the diffusion index. Since the independent variables in the LSR are

correlated, the impact of the independent components on the estimation was also examined. According to the research results, the diffusion index performed better than the LSR in predicting the turning points in industrial production. On the other hand, the leading basic components of the series have also been tested to be as good as LSR or even better in predicting turning points.

Davies and Scott (1973) examined 24 different sectors that form the industrial production index published by the Central Statistical Office (CSO) of the United Kingdom with naive econometric models vs regressions, and investigated which model successfully predicted turning points and acceleration and deceleration in growth. They divided the forecast performance of industry outputs into two categories, according to the kind of transfer of final expenditure on GDP, whether direct (food, tobacco, etc.) or indirect (cement, petroleum products, etc.). According to the results, regression analysis conducted on both categories predicted sectoral turning points more accurately than naïve methods.

Teräsvirta (1984) studied the Finnish Industrial production monthly time series using an econometric model with linear combinations for short-term forecasting. He compared the prediction success of the principal component analysis and transfer function models through various variables. According to his results, the principal components method predicted more accurately than the autoregressive integrated moving average (ARIMA) models, especially after various turning points in industrial production.

Bodo and Signorini (1987) estimated short-term Italian industrial production using the Holt-Winters and ARIMA models and a business survey and electricity consumption data series. According to their results, the estimation of univariate models is more successful than business surveys, although there is a delay of a few days on the electricity consumption data. However, the researchers stated that an accurate forecast would be provided by combining the models used in their estimation of both data sets with the weighted average method. Bodo et al. (1991) also used the Holt-Winters method to predict Italian industrial production in real-time before the end of the relevant month. In their results, data-based estimations and univariate models with the arithmetic means method provided the most accurate forecast of daily electric use. Bodo et al. (2000) stated that they predicted industrial production in the Euro-zone by using the ARIMA models, and although seasonal factors influenced the ARIMA models, they made a reliable and robust forecast. On the other hand, complex Vector Autoregression (VAR) models applied to increase forecasting success failed due to overparameterization problems. However, when the Eurozone as a single country and the US were included in the VAR models, there was a significant improvement in ARIMA's forecasts.

Moody et al. (1993) were the first to estimate the industrial production data (1950-1970 / 1980-1990) calculated monthly by the American Bureau of Economic Analysis using neural networks models, instead of standard linear autoregressive models. The study compared the predictors using a trivial predictor, a univariate linear autoregression (AR) model, a multivariate linear regression model, and two types of neural network models. Neural network models produced better estimates than the linear models. However, Moody (1995) stated that a single macroeconomic forecasting method would not be sufficient to reduce the estimation risk, and the combination of all models would show optimal performance in the estimation.

Thury and Witt (1998) predicted Austrian and German industrial production using ARIMA time series models. They found that basic structural models for univariate forecasting make more accurate estimations than ARIMA models.

Siliverstovs and van Dijk (2002) estimated industrial production growth rates in G7 countries using linear AR, non-linear and Structural Change models. They concluded that the Markov Switching Model (MSMH) is the best predictor in the short term and the Self-Exciting Threshold Autoregressive (SETAR) models are

better in the long term. In this sense, it has been stated that non-linear models give better results than linear models to identify uncertainties.

Bradley and Jansen (2004) state that despite the overfitting problem in non-linear models, it is successful in forecasting except for the Multiple-Regime Smooth Transition Autoregressive (MRSTAR) model.

Heravi et al. (2004) estimated industrial production in Germany, France, and England using neural network models over non-seasonally adjusted time series from 24 different sub-sectors. According to their results, it has been observed that non-linear models are more successful than linear models in determining the direction of change in forecasting. On the other hand, linear models are more successful in estimating the growth rate although neural network models outperform growth direction in the forecasting accuracy criterion.

Zhang and Qi (2005) predicted seasonal and trend time series with Neural Networks (NN), and concluded that NNs made more accurate predictions with deseasonalize data. In this sense, it is stated that well-preprocessed NNs can provide more accurate forecasting than traditional ARIMA models due to their ability to eliminate overfitting problems.

Aminian et al. (2006) predicted the American Real GDP and IP using NN. The study once again showed that NNs are significantly more successful in forecasting than linear regression. Stock and Watson (2006) estimated the US IP growth rate over 130 predictive variables through forecast pooling, dynamic factor, and Bayesian models. They found that multivariate estimation models and non-linear estimation became widespread and made more accurate forecasting in macroeconomic analysis.

In the literature, the Bayesian VAR (Aprigliano, 2020; Barışık & Yayar, 2012; Günay, 2018), VAR-X (Bianchi et al., 2010), ARIMA (Alencar & Rocha, 2016; Öncel Çekim, 2018) and Spectrum analysis (Hassani et al., 2009) methods continued to be employed for estimating industrial production. However, artificial neural network models are becoming quite common, especially in forecasting the parameters of the macroeconomic variables (Babkin et al., 2016; Heravi et al., 2004; Moody, 2012; Polat & Temurlenk, 2011).

Studies that focus on forecasting and predicting in different disciplines, including macroeconomic variables regarding the period before and during the COVID-19 pandemic, are also becoming widespread in this context (Altig et al., 2020; Bildirici et al., 2020; Depren & Kartal, 2020; De Santis & Van der Veken, 2020; Güngör et al., 2021; Jena et al., 2021; Kartal et al., 2021; Larson & Sinclair, 2021; Nikolopoulos et al., 2021; Primiceri & Tambalotti, 2020; H. Zhang et al., 2021). According to the related literature, a common view about the forecast performance of the models during the COVID-19 pandemic is an important challenge. Prior research extensively examined IPI forecasting using econometric models such as ARIMA and machine learning approaches such as Neural Networks. However, these studies rarely consider external shocks like COVID-19, nor do they compare the performance of these models under such conditions. This study fills these gaps by providing empirical evidence on how the pandemic alters the model effectiveness for Turkish M-IPI.

This study aims to forecast the Turkish M-IPI by using both standard econometric time series models and machine learning techniques, which is different from the papers in the existing literature.

Data and Methodology

In the study, we employed the monthly M-IPI (2015=100, seasonally and calendar adjusted) obtained from TURKSTAT as the target (dependent) variable. We employ the Manufacturing Purchasing Manager Index-

PMI (seasonally adjusted) and the Real Sector Confidence Index-RSCI (seasonally adjusted) variables as independent variables in order to explain M-IPI variable. The selection of PMI and RSCI as predictor variables is grounded in their leading indicator properties and strong correlation with IPI. PMI reflects forward-looking measures like new orders and production, which directly precede manufacturing activity. Similarly, RSCI provides insights into managerial expectations and confidence levels, which are pivotal for short-term IPI predictions (referencing Haraguchi et al., 2017; Bodo et al., 1991). Despite their publication shortly before the IPI data, these variables offer significant forecasting advantages due to their early availability.

PMI is an indicator produced for many countries using an internationally comparable method, obtained from surveys conducted on purchasing managers of leading companies in the manufacturing sector, especially on orders, production, and employment. RSCI also aims to reflect the short-term trends of the manufacturing industry by monitoring the evaluations of senior managers about the recent and current situation and their expectations for the future. PMI is disclosed by IHS-MARKIT with a delay of 1 or 2 days after the end of the reference month, while RSCI is announced by the Central Bank of the Republic of Türkiye (CBRT) one week before the end of the reference month. We contend that using RSCI and PMI to predict IPI will also contribute to early estimations of IPI.

Although M-IPI starts from 1986 and RSCI data starts from 2007, PMI data is only available from January 2012. For this reason, January 2012 was chosen as the starting date of the study. Therefore, this study will cover the period from January 2012 to September 2020, which includes 105 observations. Since the M-IPI index is not stationary at its level, annual growth rates, $(IPI_t - IPI_{t-12}) / IPI_{t-12,}$ are used.

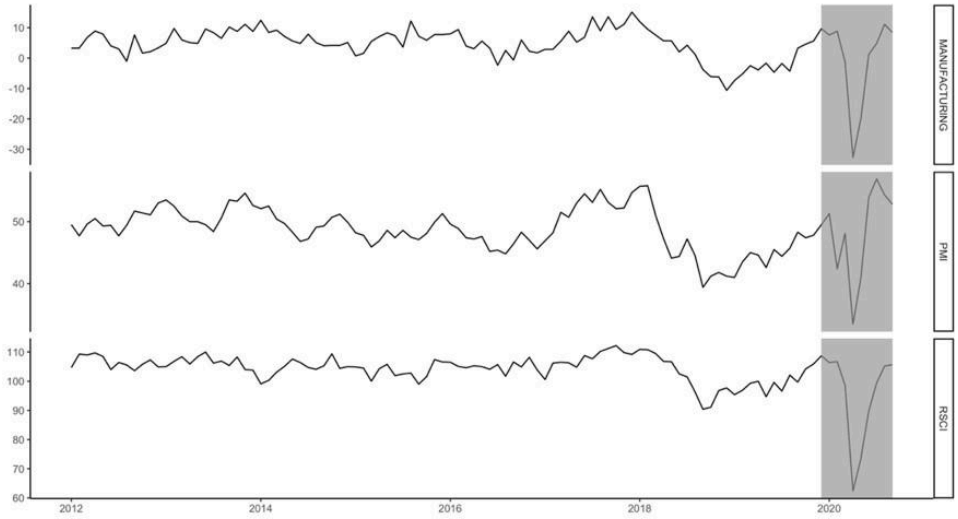
Our sample includes the period covering the COVID-19 (Severe Acute Respiratory Syndrome Coronavirus 2, SARS-CoV-2) outbreak. The COVID-19 outbreak has had a negative effect on the forecasting performance of the models (Altig et al., 2020; Güngör et al., 2021; Jena et al., 2021; Primiceri & Tambalotti, 2020). In order to consider the COVID-19 outbreak's distortion on the forecasting performance of the alternative models, we examined two different estimation and forecasting periods.

The forecasting periods were decided according to the date when the COVID-19 outbreak first appeared in Türkiye. The first COVID-19 case in Türkiye was seen on March 11, 2020. The first estimation and forecasting periods for the alternative models are January 2012-December 2019 and January 2020-March 2020, respectively. The first forecasting period coincided with the pre-COVID-19 outbreak period.

The second estimation and forecasting periods are January 2012-March 2020 and April 2020-September 2020, respectively. The second forecasting period covers the COVID-19 outbreak. By doing so, an attempt at examining the impact of the COVID-19 outbreak on the forecast performance of the alternative models is made. The variables employed in the empirical study are presented in Figure 1.

Figure 1

Turkish Manufacturing IPI, PMI and RSCI data for 2012 -2020



The models employed in the empirical study are presented in Table 1. The investigated models can be grouped under two main headings: time series and machine learning models. Static regression, dynamic regression, and univariate models were used for the time series models[1]. Tree-based, neural-network, advanced tree-based, and decomposition models were used for the machine learning models. The technical details about the investigated machine learning models are presented in the Appendix.

Table 1

Alternative Models

Family	Group	Models
Time series	Univariate	• ARMA
	Static regression	• OLS
		• Fully Modified OLS (FMOLS)
		• Threshold Regression (THRESHOLD)
	Dynamic regression	• Markov Switching Regression (MARKOV)
		• Dynamic OLS (DOLS)
		• ARDL
Machine Learning	Tree-based	• Bagged CART
		• CUBIST
	Neural-network	• Neural Network (NNET)
		• Bayesian Regularized Neural Networks (BRNN)
	Advanced Tree-based	• Random Forest (RF)
		• Quantile Random Forest (QRF)
	Decomposition	• Elasticnet (ENET)
		• Principal Component Regression (PCR)
		• Relevance Vector Machines with a Polynomial Kernel (RVMPOLY)

[1]See (Ertuğrul & Gebeşoğlu, 2020; Ertugrul & Mangir, 2015; Ertuğrul & Seven, 2021) for further technical information regarding the time series models.

After running the alternative models, we compared them according to their forecast performance by employing various performance criteria, namely RMSE, MAE, MAPE and Theil Inequality indicators. The lower the values of these indicators, the closer the forecasts that the model produces are to the observed trends. The forecast performance indicators are described in the Appendix.

Results and Discussion

In order to estimate the best fit model for the M-IPI index, we use alternative time series and machine learning models for the period from January 2012 to September 2020. We employ the PMI and RSCI variables as independent variables. We compare alternative models according to their forecasting performance criteria, including RMSE, MAE, MAPE and Theil Inequality indicators and define the best fit model.

We employed two different estimation and forecasting periods in order to analyse the effects of the COVID-19 outbreak on the forecast performance of the models. The first estimation and forecasting periods for the alternative models are January 2012-December 2019 and January 2020-March 2020, respectively. The second estimation and forecasting periods are January 2012-March 2020 and April 2020-September 2020, respectively. The first forecasting period coincides with the pre-COVID-19 outbreak period, while the second forecasting period covers the COVID-19 outbreak.

The forecast performance comparison of the alternative time series and machine learning models for the pre-COVID-19 period is presented in Table 2.

Table 2

Forecast Performance Comparison of Alternative Models for the Pre-COVID-19 Period

Pre Covid-19 Outbrek Period (Estimation Period: 2012m01-2019m12-Forecast Period: 2020M1-2020M3)					
Models	**Family***	**RMSE**	**MAE**	**MAPE**	**Theil Inequality**
ARDL (1,1,3)	TS	3,028	2,812	84,222	0,235
ARMA (1,1)	TS	4,988	3,364	239,353	0,347
ARMA (3,2)	TS	5,162	3,398	248,008	0,352
DOLS	TS	5,237	4,001	120,688	0,467
FMOLS	TS	6,012	4,565	141,32	0,520
MARKOV	TS	5,517	4,679	185,214	0,450
OLS	TS	5,111	4,371	193,644	0,429
THRESHOLD	TS	5,791	4,803	200,249	0,487
BAGGED CART	ML	7,496	6,385	236,731	1,106
CUBIST	ML	7,050	5,501	190,142	1,040
NEURAL NETWORK	ML	7,283	5,652	190,146	1,075
BAYESIAN REGULARIZED NEURAL NETWORKS	ML	6,497	5,006	166,934	0,959
RANDOM FOREST	ML	6,287	5,63	216,147	0,928
QUANTILE RANDOM FOREST	ML	5,58	5,019	225,508	0,823
ELASTICNET	ML	5,920	4,535	147,967	0,873
PRINCIPAL COMPONENT ANALYSIS	ML	4,241	3,331	103,435	0,326
RELEVANCE VECTOR MACHINES WITH POLYNOMIAL KERNEL	ML	5,924	4,544	147,992	0,877

*TS: Time Series, ML: Machine Learning

According to Table 2, the ARDL model (TS family) was found to be the best fit model for the pre-COVID-19 period according to all forecast performance indicators. All forecast performance indicators imply that the highest forecast performance can be achieved by employing the ARDL model. After the ARDL model, the PCA (principal component analysis. ML family) model was found to be the second best fit model according to all forecast performance indicators. The ARMA(1,1) model (TS family) was found to be the third best model according to three (RMSE, MAE and Theil Inequality Coefficient) out of four forecast performance indicators.

The three least successful forecasting models for the Turkish M-IPI for the pre-COVID-19 period are the Bagge Cart, Cubist, and the Neural Network models. All three unsuccessful models are members of the ML family.

Hence, TS family models performed better than ML family models during the pre-COVID-19 outbreak period.

The forecast performance comparison of alternative time series and machine learning models for the post-Covid-19 periods is presented in Table 3.

Table 3

Forecast Performance Comparison of Alternative Models after the COVID-19 Period

After Covid-19 Outbrek Period (Estimation Period: 2012m01-2019m3-Forecast Period: 2020M4-2020M9)					
Models	**Family***	**RMSE**	**MAE**	**MAPE**	**Theil Inequality**
ARDL (1,1,3)	TS	17,578	10,54	100,718	0,691
ARMA (1,1)	TS	16,449	11,518	66,438	0,862
ARMA (3,2)	TS	19,067	12,733	75,098	0,892
DOLS	TS	5,011	4,056	64,899	0,166
FMOLS	TS	5,717	4,605	77,179	0,193
MARKOV	TS	6,972	5,439	72,771	0,25
OLS	TS	10,695	7,771	73,839	0,459
THRESHOLD	TS	25,208	19,947	429,497	0,772
BAGGED CART	ML	13,543	8,997	106,947	0,806
CUBIST	ML	6,388	4,908	69,138	0,380
NEURAL NETWORK	ML	11,855	8,110	93,001	0,706
BAYESIAN REGULARIZED NEURAL NETWORKS	ML	11,239	7,645	83,878	0,669
RANDOM FOREST	ML	12,797	9,021	121,259	0,762
QUANTILE RANDOM FOREST	ML	13,144	9,438	146,814	0,783
ELASTICNET	ML	5,684	4,412	59,802	0,338
PRINCIPAL COMPONENT ANALYSIS	ML	4,372	3,338	27,875	0,160
RELEVANCE VECTOR MACHINES WITH POLYNOMIAL KERNEL	ML	6,003	4,587	54,336	0,357

According to Table 3, the PCA model (ML family) was found to be the best fit model for the post-COVID-19 outbreak period according to all forecast performance indicators. All forecast performance indicators show that the highest forecast performance can be achieved with the PCA model. After the PCA model, the DOLS model (TS family) was found to be the second best model according to three (RMSE, MAE and Theil Inequality Coefficient) out of four forecast performance indicators. The Elasticnet model (ML family) was found to be

the third most successful forecasting model according to three (RMSE, MAE and MAPE) out of four forecast performance indicators.

The three least successful forecasting models for the Turkish M-IPI for the post-COVID-19 period are the Threshold, ARMA and ARDL models. All three unsuccessful models are members of the TS family.

Hence, ML family models demonstrated superior performance compared to TS family member models during the post-COVID-19 outbreak period. The post-COVID-19 period witnessed significant shifts in economic patterns, including non-linear disruptions and higher volatility. Machine learning models such as PCA and Elastic Net excelled due to their ability to uncover underlying data structures and adapt to these non-linear patterns. Traditional time series models, constrained by their reliance on historical linear trends, struggled to adapt to the new economic dynamics introduced by the pandemic (Zou & Hastie, 2005; Moody, 1995).

The differences in the performance of the models may mean that these forecasting tools are effective in certain contexts and therefore are informative in the selection of tools in the event of economic shocks. Given the short- and long-run characteristics of the ARDL model and its ability to capture the co-integration aspect of the DOLS model, they are more ideally suited for periods of economic stability. However, these models had difficulty responding to the new circumstances and times of COVID-19. Restrictions on the use of linear relationships and the inability to employ non-linear patterns were the major constraints. The results indicate that econometric models can be useful for forecasting in normal times but less so in periods of structural breaks and high degree of uncertainty.

With regard to Machine learning models findings, in particular PCA and Elastic Net, these also demonstrated their promise in the time after the COVID-19 pandemic. These models have been designed to conceivably outperform conventional econometric models in moments of economic stress because they are excellent at uncovering underlying architectures and functional non-linearities in data. It is this property of PCA, which allows for reduction in dimensions of data without losing vital components, which enabled predictions to be made during the chaos introduced by the pandemic. Likewise, with the Elastic Net, being able to incorporate regularisation techniques improved the performance of models by resolving multicollinearity and overfitting problems. While machine learning models reach their zenith in complex and crisis situations, they must be provided in input with variables, which are as rich as possible to be able to demonstrate their best.

The forecast performance was evaluated using RMSE, MAE, and MAPE metrics, with additional robustness checks. Empirical results indicate ARDL's robustness in stable conditions, while PCA adapts well during periods of volatilities such as COVID-19 disruptions. These findings indicate that time series models are suitable for predictable environments, whereas machine learning models perform better under structural breaks and economic uncertainty. The results indicate that the forecast performance of the TS and ML models is different depending on the COVID-19 outbreak. The TS family member models produced robust forecast performance before the COVID-19 period, while ML family member models produced robust results after the COVID-19 period for the Turkish M-IPI variable.

Conclusion

Macroeconomic variables are important both for following cyclical developments within economies and for answering the questions that decision-makers and investors have about the future. In this context, investigating IPI over time provides rapid and important cues about the general economic prospects.

Obtaining a robust forecast for M-IPI for emerging countries such as Türkiye could thus contribute to the forecast of the country's overall economy.

COVID-19 disrupted supply chains and altered demand patterns, fundamentally changing PMI dynamics. Due to a lack of literature on this topic, we compared the forecast performance of both econometric time series and machine learning models for the Turkish M-IPI for pre- and post- COVID-19 outbreak. The forecast performance of the models was compared according to various forecast performance criteria that are employed the most in the empirical literature for the period between January 2012 and September 2020. Traditional models struggled to adapt to these rapid shifts, while machine learning approaches leveraged their flexibility to better capture non-linear trends.

According to the model results for the pre-COVID-19 period, the ARDL model, PCA model, and ARMA(1,1) model were found to be the best performing models according to the forecast performance comparison for the Turkish M-IPI variable. Both ARDL and ARMA models are under the time series family, whereas the PCA model is under the machine learning family. The Bagge Cart, Cubist and Neural Network models were found to be the most unsuccessful models according to the forecast performance comparison for the Turkish M-IPI. All three unsuccessful models are within the family of machine models for the pre-COVID-19 period.

The PCA, DOLS and Elasticnet models were found to be the best performing models according to the forecast performance comparison for the Turkish M-IPI variable in that specific order in the post-COVID-19 period. Both the PCA and Elasticnet models fall under the machine learning family and the DOLS model falls under the time series family. Threshold, ARMA and ARDL models were found to be the most unsuccessful models according to the forecast performance comparison for Turkish M-IPI in that order. All three unsuccessful models fall under the time series family for the post-COVID-19 period.

According to the model results, the forecast performance of the time series and machine learning models differed depending on the COVID-19 outbreak. Time series family member models showed robust forecast performance before the COVID-19 period, while machine learning family member models produced robust results after the COVID-19 period for the Turkish M-IPI variable.

The study's limitations are the combinations of variables to explain manufacturing IPI, the selected period coverage, and the selected performance indicators. Expanding the range of predictor variables to include additional macroeconomic and sector-specific indicators could enhance model robustness. While this study does not explicitly incorporate confidence intervals or additional robustness checks, the performance metrics employed (RMSE, MAE, MAPE) provide reliable indicators of model accuracy. Future research could address this by implementing bootstrapped confidence intervals or alternative testing procedures to further validate the findings. The limited number of explanatory variables (PMI and RSCI) may constrain the performance of the machine learning models, which generally benefit from larger feature sets. Expanding the variable set could enable these models to better capture complex relationships and improve the forecasting accuracy. This limitation is acknowledged as a potential avenue for future research. Combination forecasts obtained from the best performance time series and machine learning models can be investigated as alternative models within the framework of further research. Also, forecast performance comparisons for alternative machine learning/time series models using high frequency (daily or intra day) variables are thought to be important for future research. Future research could expand the predictor variable set to include additional macroeconomic indicators, such as energy prices or export data, to enhance the robustness of the machine learning models. This study acknowledges the potential benefits of incorporating a richer variable set, particularly for machine learning approaches, in improving prediction accuracy. Finally,

extending the analysis to post-COVID-19 recovery periods could provide insights into the long-term impacts of the pandemic on industrial production forecasting methodologies.

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Appendix

Machine Learning Models

The time series and machine learning model types discussed in this study have very detailed explanations in the literature and thus it is not possible to detail it further due to scope limitations. This is particularly the case for the many specifications/estimation options for each model. Therefore, the models used in this study are explained briefly in this section.

Bagging Classification and Regression Tree (Bagging CART)

One of the most well-known decision tree algorithms is the classification and regression tree (CART) algorithm proposed by Breiman et al.(1984). Each decision tree aims to divide the training data set into subgroups. It is essential that these subgroups are homogeneous within themselves; however, intergroup heterogeneity is desirable. A fixed coefficient estimate (e.g. average) is made for each group. Groups essentially contain data corresponding to simple yes-no answers. "Bagging" means that more than one CART model is renewed and combined with the bootstrap method (Breiman, 1996).

Random Forests (RF)

Random forests can be defined as "bagged decision trees". To put it more clearly, it is the merging of unrelated decision trees by analysing different dimensions of the dataset. As applications, they have become simplified algorithms. The algorithm proposed by Breiman (2001) is very popular. The random forests approach can be defined as bringing together unrelated trees or reducing the correlation between trees by adjusting the level of randomness. The difference from the Bagged decision tree is that more trees are brought together in this method.

Quantile Random Forest (QRF)

The QRF is an extension of the random forest approach proposed by Breiman (2001) for percentiles. It uses not only the performances on the output but also the mean and variances in the tree leaves as a target when making predictions. In the QRF method, empirical percentage estimates are used during the estimation.

CUBIST

In this study, the cubist method is a prediction-oriented regression model that combines the studies in Quinlan (1992) and Quinlan (1993). It also creates rules, as seen previously in the decision tree approach, and learns the relationship between the input and output variables as rules. Although similar to decision tree models, its most prominent feature is that it estimates a regression model for each rule.

Neural Network (NNET)

The artificial neural networks method consists of applying an approach used in computer science to statistical problems. The NNET algorithm learns the match between inputs and outputs and applies feedback through a continuous control mechanism. This approach differs in how neurons are modelled. Although it is difficult to represent and explain the complex structure of neurons, it is stated in the literature that it is quite successful in many statistical problems. The algorithm developed by Ripley (1996) and Venables & Ripley (2002) was used in this study.

Bayesian regularized artificial neural networks (BRANN)

Bayesian regularized artificial neural networks (BRANNs) are the more robust version of the classical neural network. Bayesian regularization is a method similar to ridge regression, which is useful in cases of multicollinearity. The algorithm used in this study fits a two-layer neural network as described in MacKay (1992) and Dan Foresee & Hagan (1997). It uses the Nguyen & Widrow algorithm (1990) to assign initial weights and the Gauss-Newton algorithm to perform the optimisation.

Elastic Net (ENET)

The Elastic Net method proposed by Zou & Hastie (2005) was used in this study. This method includes regularisation and feature selection approaches. According to Zou & Hastie (2005), this method, which is claimed to have a superb predictive power, essentially uses the grouping approach. Zou and Hastie (2005) claim that it is superior to other methods when the number of exogenous variables is greater than the number of observations.

Principal component regression (PCR)

Principal component regression (PCR) is a method based on principal component analysis (PCA). In the principal components regression approach, instead of using the exogenous variables directly, the principal components obtained from them are used as exogenous variables in the regression model (Jolliffe, 1982). Often, every possible combination is tried, and the best performing components are used instead of using all of the main components (Bair et al., 2006). The PCR model used in this study uses the singular value decomposition algorithm developed by Martens and Næs (1989).

Relevance Vector Machines with a Polynomial Kernel (RVMPOLY)

The Support Vector Machine (SVM) method performs generalisation operations over the dataset by kernel representation. However, the "Relevance Vector Machine" model used in this study is a Bayesian model and predicts the regression model with an algorithm identical to the support vector machine. It has a stingier parameter specification compared to SVM models (Tipping, 2001).

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Testing the Quantity Theory of Money for the Turkish Economy: Evidence from the Maki Co-integration Test

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Abstract In this study, the validity of the quantity theory of money is tested for the Turkish economy over the period 2006:01-2022:12. For this purpose, the unit root and co-integration tests that do not neglect structural breaks are employed. Findings from the Maki co-integration test reveal that M1, M2, and M3 money supplies are co-integrated with the inflation rate. Then, the breaks from the Maki test are integrated into the DOLS model for the long-run coefficients. According to the DOLS estimator, a 1% increase in M1, M2, and M3 causes an increase in the inflation rate by 0.24, 0.58, and 0.81 percent, respectively, in the long-run. Finally, the causality analysis also verifies the unidirectional relationship from the money supply to the inflation rate. The results indicate that the quantity theory of money is largely valid for the Turkish economy.

Keywords Inflation · Money supply · Quantity theory of money

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Testing the Quantity Theory of Money for the Turkish Economy: Evidence from the Maki Co-integration Test

In order to understand the importance of money, it is necessary to consider its functions. The fact that money is a unit of account provides savings at the knowledge level by providing fewer prices in the market. Thanks to being a medium of exchange, more trade volume is reached with fewer trade points. Being a store of value encourages savings, investment, economic growth, and welfare. Money, especially by promoting trade, connects nations and even hostile nations, and increases the division of labour and productivity, thus contributing to the development of civilisation. Davies (2002: 47) points to the existence of a close relationship between money and civilisation.

The history of monetary theory is engrossing. Mercantilist economists have associated the wealth of countries entirely with precious metals such as silver and gold, which are used as money. Although they attached great importance to money, they could not develop a systematic monetary theory. Classical and Neoclassical economists associated the wealth of countries with the amount of production and did not attach much importance to money. Surprisingly, however, they made a significant contribution to monetary theory (Paya, 2007: 8).

David Hume, influenced by Aristotle and the Salamanca school, evaluated money within the framework of quantity theory (Ekstedt, 2012: 32). He stated that monetary expansion only leads to a proportional increase in the general level of prices, not a change in relative prices. Hume (1895) saw money as a practical tool that facilitated exchange and likened it to oil, which made the wheels turn more easily. According to him, the amount of money in the economy is not that important. Even if the amount of oil is less or more than the optimum level, the wheels continue to rotate.

The quantity theory is generally represented as in equation 1.

$$MV = PY \quad (1)$$

In equation 1, *M* is the nominal money stock, *V* its velocity, *P* the general price level, and *Y* the real income or output level. The right side of the equation represents monetary income. Classical and neoclassical economists generally concentrate on the left side (Rousseau, 2007: 266). *V* and *Y* are assumed to be fixed in the short-run.

The quantity theory is analysed in two different ways: the direct mechanism and the indirect mechanism. Monetary expansion raises the individual cash balance above the desired level. In the direct mechanism, at this stage, the Cambridge effect emerges and aggregate expenditures increase (Paya, 2007: 217). In the indirect mechanism, the supply of funds increases and so the interest rate decreases. A low interest rate encourages consumption rather than saving, and aggregate expenditure increases. After all, in both mechanisms, the general price level increases at the same rate as the money supply.

The most renowned versions of the direct mechanism are the Fisher and Cambridge equations. The equation proposed by Fisher (1911) can be presented as follows:

$$M = \frac{1}{V}PT \quad (2)$$

Where *T* shows the volume of trade. The Cambridge form of the quantity theory can be presented as follows (Marcuzzo, 2017: 260):

$M = kPY, k = \frac{1}{V}$ (3)

Where *k* shows the desired amount of money. Equation 3 can be represented as follows:

$\frac{\Delta M}{M} = \frac{\Delta P}{P} + \frac{\Delta Y}{Y} - \frac{\Delta V}{V}$ (4)

$\frac{\Delta M}{M} = \frac{\Delta P}{P}, \frac{\Delta Y}{Y} = \frac{\Delta V}{V} = 0$ (5)

V and *Y* are assumed to be fixed and hence *M* and *P* increase in equal proportion. Additionally, the direction of causality is from M to P (Humphrey, 1997: 72).

The quantity theory is also valid in modern economies. Friedman and Friedman (1980:255) stated that inflation is a monetary phenomenon, but there is no one-to-one relationship between monetary expansion and inflation. The difference between monetary expansion and inflation arises from real GDP growth. Therefore, they examined the relationship between the quantity per unit of output and the inflation rate in Japan, Germany, the USA, the UK and Brazil for the period 1964-1977. The investigations showed that the two aforementioned variables act together in all five countries (Friedman & Friedman, 1980: 257-261).

New Zealand was the first country to implement inflation targeting in 1990. The strategy began to be widely used in a short time because it reduced exchange rate pass-through, interest rates, inflation volatility, and inflation level, and also promoted stable economic growth (Mishkin & Schmidt-Hebbel, 2007). Turkiye did not immediately adopt this new strategy. However, due to the impact of the 2001 financial crisis, the implicit inflation targeting regime was introduced in 2002 and the explicit inflation targeting in 2006 (Kara, 2006).

Table 1

Monetary Growth and Inflation Rate in Turkiye

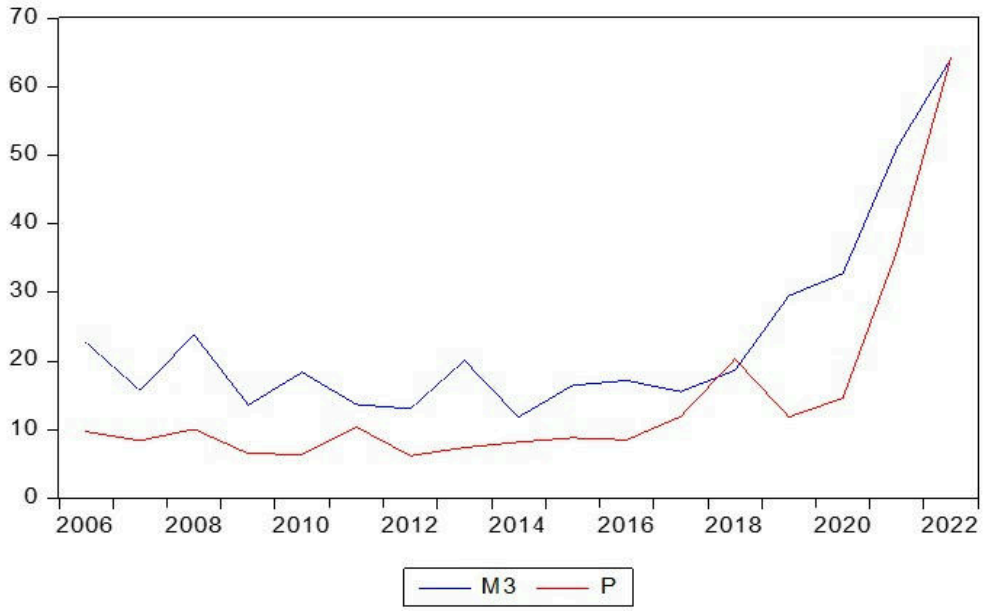
Year	M1	M2	M3	Inflation Target	Inflation
2006	16.51	25.02	22.72	5	9.7
2007	7.64	15.98	15.71	4	8.4
2008	7.35	25.85	23.86	4	10.1
2009	28.39	13.78	13.59	7.5	6.5
2010	25.07	18.98	18.35	6.5	6.4
2011	10.88	13.24	13.68	5.5	10.4
2012	22.55	12.54	13.06	5	6.2
2013	23.86	21.48	20.07	5	7.4
2014	11.83	11.92	11.8	5	8.2
2015	23.82	17.4	16.45	5	8.8
2016	22.55	17.64	17.17	5	8.5
2017	17.6	15.49	15.52	5	11.92
2018	13.99	19.44	18.65	5	20.3
2019	39.08	26.64	29.52	5	11.84
2020	71.13	35.3	32.75	5	14.6
2021	71.92	52.23	51.11	5	36.08
2022	49.3	62.25	64.13	5	64.27

Source: Central Bank of the Republic of Turkiye

Table 1 presents the annual increase rates of the M1, M2, and M3 growth rates and the annual inflation rate in Turkiye. The correlation coefficients of the inflation rate with the growth rates of M1, M2, and M3 are 0.54, 0.9, and 0.92, respectively. In the explicit inflation targeting regime, the inflation target was reached only twice. These years are 2009 and 2010, after the global crisis that shrunk aggregate demand. Peker (2011) associated with external shocks the fact that the explicit inflation targeting regime was not as successful as the implicit inflation regime. However, if there is a failure, the reasons for this are probably related to monetary facts.

Figure 1

Monetary Expansion and Inflation Rate



Source: Central Bank of the Republic of Turkiye

Figure 1 presents the annual increase rates of M3 and the general price level in Turkiye over the period 2006-2022. Here, three facts attract attention: First, the series is generally compatible with each other. Second, the monetary expansion rate is higher than the inflation rate due to real economic growth. Third, the volatility in the inflation series is lower.

This study tests the validity of the quantity theory for Turkiye. For this purpose, the unit root and co-integration tests that take structural breaks into account are preferred. In the next part of the study, we present a summary of the relevant literature. In the other section, information is given about the dataset and the method used. Then, empirical findings are obtained and finally these findings are discussed.

A Review of the Empirical Literature

It is possible to epitomise the literature on the relationship between the monetary aggregate and inflation in Turkiye as follows:

Cesur (2006) investigated the period 1994:Q1-2004:Q4 with the regression analysis. The findings showed that the inflationary effect of the broad money supply is greater than M0, M1, and M2 money supplies. Özmen and Koçak (2012) analysed the period 1994:Q1-2011:Q4 using the ARDL approach and the Granger test. According to the study, the increase in the broad money supply causes a 42 percent increase in inflation. Alper (2018) evaluated the years 1971-2016 using the Bayer Hanck cointegration test, and Kara and Sağır

(2021) assessed the period 2006:Q1-2020:Q2 using the ARDL bounds test approach. Both studies found that the quantity theory of money is largely valid.

In the study carried out by Karpat Çatalbaş (2007), the period 1999Q1-2006Q3 was surveyed with the non-parametric regression technique. According to the findings, an increase in inflation increases the M2 money supply. Similar findings were obtained in the surveying by Erdoğan (2023), who examined the period 2006:Q1-2022:Q3 with the VAR analysis. Inflation affects M1 according to the Granger test results and M2 according to the Pairwise Granger test results.

Çiçek (2011) and İslatince (2017) examined the periods 1987:Q1-2007:Q3 and 1988Q1-2016:Q4, respectively, using the Johansen and Granger tests. Both researchers found that there is a bidirectional relationship between the monetary aggregate and inflation. Şahin and Karanfil (2015) analysed the period from 1980 to 2013 with the same tests and stated that there is no causality between M2 and inflation. On the other hand, Gabaçlı (2020) investigated the period 2000:Q1-2017:Q2 using the same methods and revealed a unidirectional causality relationship from M2 to inflation.

In the studies conducted by Kaya and Öz (2016) and Kılavuz and Altınöz (2020), the periods 1980:Q1-2014:Q4 and 2006:Q4-2018Q4, respectively, were investigated through the ARDL test. The first study revealed that M2 affects inflation negatively in the short-run and positively in the long-run. The second study showed that M1 and M3 money supplies are not effective on inflation, while the increase of M2 money supply causes inflation by only 29 percent.

Bağcı (2021) examined the relationship between M0, M1, M2, and M3 money supplies and inflation using the 2008:03-2020:08 monthly time series. According to the findings obtained from the quantile on quantile regression approach, the relationship between monetary aggregate and inflation is not homogeneous. Eroğlu and Yeter (2022) analysed the period 2007:01-2022:06 with the time-varying causality test and reached similar results.

The studies focusing on different countries in this field can be summarised as follows:

Simwaka, Ligoya, Kabango and Chikonda (2012) analysed the comparative importance of monetary variables on inflation in Malawi for the period 1995:01-2011:03. The findings showed that monetary expansion leads to inflation after three to six months. Sean, Pastpipatkul and Boonyakunakorn (2019) investigated Cambodia for the period 2009:10-2018:04 with the Bayesian VAR analysis. They found that the money supply impacts inflation and is dependent on its previous period.

Kiganda (2014) surveyed the relationship between the monetary aggregate and inflation in Kenya using the VECM and the Granger test. In the study covering the years from 1984 to 2012, it was determined that there is a long-run relationship between the series and a unidirectional causality relationship from money supply to inflation. Mbongo, Mutasa, and Msigwa (2014) researched Tanzania for the period 2000:01-2011:12 through the Augmented Engle-Granger cointegration and Granger causality tests and reached the same results. Ofori, Danquah, and Zhang (2017) investigated Ghana for the period 1967-2015 using the OLS method. The findings showed that monetary growth increases inflation by 71 percent. Sasongko and Huruta (2018) examined Indonesia for the period 2007:01-2017:07 with the Granger test and determined a unidirectional relationship between monetary aggregate and inflation. Hicham (2020) analysed Algeria using both symmetric and asymmetric causality and co-integration tests. The paper spanning the period from 1970 to 2018 confirmed the Monetarist view. Madurapperuma (2023) researched the Sri Lankan economy over the period from 1990 to 2021 using the Johansen and Granger tests and found that M2 affects inflation.

Amassoma, Sunday and Onyedikachi (2018) investigated Nigeria using the Johansen and Granger tests. According to the study covering the years from 1970 to 2016, money supply affects inflation neither in the short-term nor in the long-term. Moreover, they stated that there is no relationship between the mentioned variables. Doan Van (2020) analysed China and Vietnam for the period from 2012 to 2016. According to the study employing the ANOVA method, money supply leads to inflation in the long-run but not in the short-run. Jawo, Jebou and Bayo (2023) perused Gambia over the period 1985-2021 using the Gregory-Hansen co-integration test and the ARDL bounds test approach. The findings indicated that the M2 money supply influences inflation negatively in the short-term and positively in the long-term. Stylianou, Nasir and Waqas (2024) examined Pakistan through the ARDL bounds testing approach. In this paper, which covers the years from 1981 to 2021, it was determined that the money supply stimulates inflation both in the short-run and in the long-run.

Lee and Yu (2021) analysed China for the period 1980-2018 with the ARDL test, and Titei (2022) examined Romania over the period 2005-2021 using the Engle-Granger cointegration test. Both revealed that the M3 money supply is associated with inflation in the long-term. Long, Hien and Ngoc (2024) evaluated Vietnam and China using regression analysis and found that the money supply has an effect on inflation. It was emphasised that this effect is greater in China because of its large economic scale.

Data and Methodology

Data

This study utilises monthly data covering the period between 2006:01 and 2022:12. The consumer price index (2015=100) attained from the FRED is used to represent inflation. The paper also employs three different money supply indicators, M1, M2, and M3. The ratio of these money supply indicators to the industrial production index (2015=100) is taken into account, all of which are retrieved from the Central Bank of the Republic of Turkiye. All series were converted to logarithmic form after being seasonally adjusted by the TRAMO/SEATS method.

Empirical Methodology

This study employs the unit root and co-integration tests that do not ignore the structural breaks in series. The unit root test proposed by Lumsdaine and Papell (1997), unlike the unit root test proposed by Zivot and Andrews (1992), permits two structural breaks in the series. While model AA allows structural breaks only in the level, model CC allows structural breaks in both the level and trend. The Lumsdaine-Papell unit root test can be identified as follows (Lumsdaine & Papell, 1997: 212):

$$\Delta y_t = \mu + \beta_t + \theta DU1_t + \gamma DT1_t + \omega DU2_t + \psi DT2_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \epsilon_t \quad (6)$$

In Equation 5, $DU1_t$ and $DU2_t$ are dummy variables that represent the break in the level, and $DT1_t$ and $DT2_t$ are dummy variables that represent the break in the trend. The smallest t-value is taken into account and the null hypothesis that the variable has a unit root is tested ($\alpha=1$) against the alternative hypothesis that the variable does not have a unit root ($\alpha<1$). The break dates chosen in this test are the dates that give the strongest backing to the alternative hypothesis (Konya, 2000: 8).

We employed the Maki co-integration test developed by Maki (2012) to test the co-integration relationship between LM1, LM2, LM3, and LCPI in this study. This test, based on the tests suggested by Bai and Peron (1998) and Kapetanios (2005), unlike the tests proposed by Gregory and Hansen (1996) and Hatemi-J (2008), takes into account five structural breaks. Moreover, it does not require a priori knowledge and determines

both the number and date of breaks endogenously. The following equations were used to perform the test (Maki, 2012: 2011-2012):

$$y_t = \mu \sum_{i=1}^{k} \mu_i D_{i,t} + \beta' x_t + \mu_t \quad (7)$$

$$y_t = \mu \sum_{i=1}^{k} \mu_i D_{i,t} + \beta' x_t + \sum_{i=1}^{k} \beta_i' x_t D_{i,t} + \mu_t \quad (8)$$

$$y_t = \mu \sum_{i=1}^{k} \mu_i D_{i,t} + \gamma t + \beta' x_t + \sum_{i=1}^{k} \beta_i' x_t D_{i,t} + \mu_t \quad (9)$$

$$y_t = \mu \sum_{i=1}^{k} \mu_i D_{i,t} + \gamma t + \sum_{i=1}^{k} \gamma_i t D_{i,t} + \beta' x_t + \sum_{i=1}^{k} \beta_i' x_t D_{i,t} + \mu_t \quad (10)$$

Where $D_{i,t}$ represents the dummy variable and μ_t the error term. If t is greater than the break year in the variable, the dummy variable takes the value of 1 (Maki, 2012: 2012). Equations 7 and 8 show Model 0 and Model 1, respectively, which include no trend. Model 1 makes allowances for structural breaks not only in the constant but also in the coefficient. Equations 9 and 10 depict Model 2 and Model 3, respectively, which include the trend. Model 3, unlike Model 2, takes into account both the trend and structural breaks in the trend (Model 3, unlike Model 2, takes into account structural breaks in the trend (Rafindadi & Usman, 2019: 267). Maki (2012: 2012) defines a six-step procedure to administer the test. At the end of the process, the null hypothesis that the variables are not co-integrated is tested against the alternative hypothesis that they are co-integrated. Maki (2012: 2013) tabulates the critical values needed for the test.

Empirical Findings

First, the ADF test is used to test the stationarity of the variables. Table 2 presents the results:

Table 2

ADF Test Results

Variable	Constant	Constant and Trend
LCPI	2.512	2.632
LM1	2.256	−0.296
LM2	1.545	−0.128
LM3	1.326	−1.252
ΔLCPI	−3.809*	−4.437*
ΔLM1	−16.010*	−16.386*
ΔLM2	−11.481*	−11.636*
ΔLM3	−11.361*	−11.495*

Note: * indicates the significance at the 1 % level.

The results in Table 2 indicate that all the series have a unit root in their levels, while they do not have a unit root in the first differences. However, this test does not provide reliable results because it ignores structural breaks. Therefore, we used the LP unit root test and submitted the findings in Table 3.

Table 3

LP Multiple Structural Break Unit Root Test Results

Variable	Test Static	Optimal Lag Length	Breakpoints
Model AA			
LCPI	1.020	7	2011:04; 2020:01
LM1	−4.753	0	2011:04; 2020:01
LM2	−3.418	0	2011:06; 2020:01
LM3	−3.476	0	2011:06; 2020:01
ΔLCPI	−5.484	6	2018:07; 2020:01
ΔLM1	−6.215***	8	2009:10; 2019:11
ΔLM2	−13.132*	1	2008:10; 2018:06
ΔLM3	−12.795*	1	2008:10; 2018:06
Model CC			
LCPI	−3.629	3	2017:02; 2020:01
LM1	−5.527	0	2018:03; 2019:12
LM2	−5.323	0	2008:08; 2017:05
LM3	−5.436	0	2008:08; 2016:06
ΔLCPI	−7.377*	6	2018:02; 2019:12
ΔLM1	−6.498***	8	2009:01; 2016:05
ΔLM2	−13.421*	1	2008:10; 2018:06
ΔLM3	−12.970*	1	2008:10; 2018:06

Note: * and *** indicate the significance at the 1 % and 10 % levels, respectively. Critical values for model AA and model CC, respectively: −6.94 (1 %), −6.24 (5 %), −5.96 (10 %); −7.34 (1 %), −6.82 (5 %), −6.49 (10 %).

Table 3 shows that the three variables for model AA and all the variables for model CC are stationary in their first differences. Since the series contain trend and constant, it would be more appropriate to decide based on model CC rather than model AA. Therefore, all the series are accepted to be I(1). We employed the Maki test to survey the existence of a long-term relationship between LM1, LM2, LM3, and LCPI. Table 4 presents the results:

Table 4

Maki Co-integration Test Results

Independent V.	Models	Test Statistic	Breakpoints
LM1	Model 0	−4.745	2011:08; 2016:07; 2018:08; 2020:03; 2021:07
	Model 1	−6.213*	2018:08; 2021:07
	Model 2	−6.357**	2006:12; 2010:11; 2012:01; 2017:11; 2021:07
	Model 3	−7.156***	2009:03; 2016:08; 2017:10; 2018:12; 2021:09
LM2	Model 0	−6.410*	2006:12; 2008:11; 2009:10; 2011:09; 2016:07
	Model 1	−5.867*	2018:08; 2020:05; 2021:05
	Model 2	−7.277*	2011:11; 2021:07
	Model 3	−7.470**	2009:01; 2016:10; 2018:08; 2019:07; 2021:04
LM3	Model 0	−5.866**	2010:11; 2011:09; 2016:07; 2020:05; 2021:07
	Model 1	−5.949**	2010:10; 2018:08; 2020:05; 2021:07

Independent V.	Models	Test Statistic	Breakpoints
	Model 2	−5.907*	2020:03; 2021:07
	Model 3	−7.558**	2009:01; 2016:10; 2018:08; 2019:07; 2021:04

Note: *, **, and *** show the significance at the 1 %, 5 %, and 10 % levels, respectively.

When Table 4 is examined, it is observed that there is no long-term relationship only for model 0 in models where LM1 is the independent variable. There is a long-term relationship in all models where LM2 and LM3 are independent variables. Therefore, it is possible to state that LM1, LM2, and LM3 are co-integrated with LCPI. We use the DOLS method to estimate the long-run coefficients. Table 5 presents the results:

Table 5
DOLS Estimations

Independent V.	Coefficient	Std. Er.	t-Statistic	Prob.
LM1	0.243	0.041	5.974*	0.000
LM2	0.578	0.033	17.306*	0.000
LM3	0.813	0.025	33.081*	0.000

Note: * indicates the significance at the 1 % level.

As seen in Table 5, the long-run coefficients are all positive and statistically significant. A 100 percent increase in LM1, LM2, and LM3 increases LCPI by 24 percent, 58 percent, and 81 percent, respectively. It is noteworthy that the coefficient grows when there is a broader definition of money. Finally, we apply the Granger test. Table 6 presents the results:

Table 6
Granger Test Results

Dependent Variable	Independent Variable	Statistic	Prob.
LCPI	LM1	6.711*	0.010
LM1	LCPI	1.662	0.197
LCPI	LM2	3.945**	0.047
LM2	LCPI	2.573	0.109
LCPI	LM3	6.606**	0.024
LM3	LCPI	1.640	0.146

Note: * and ** show the significance at the 1 % and 5 % levels, respectively

Table 6 shows that the null hypothesis is rejected in models where LCPI is the dependent variable. On the contrary, the null hypothesis is not rejected in models where LCPI is the independent variable. This finding confirms the findings from the Maki co-integration test. The findings obtained show that there is a unidirectional relationship between money supply and inflation in Turkiye and that the quantity theory is substantially valid.

Conclusion

For centuries, the relationship between the quantity of money and the general price level has been discussed within the framework of quantity theory. Although the neutrality of money hypothesis was rejected during the period when the Keynesian approach was dominant, it has been accepted to be valid, at least in the long-run, for the last half century.

This study tested the validity of the quantity theory in Turkiye. For this purpose, the monthly data covering the period 2006:01-2022:12 for M1, M2, and M3 money supplies and the inflation rate series were employed. Unit root analysis showed that all series are I(1). The Maki co-integration test was implemented to survey the existence of a possible long-term relationship between the series. The findings showed that the money supply series are co-integrated with the inflation rate. According to the DOLS estimator, a 1% increase in M1, M2, and M3 leads to a rise in the inflation rate by 0.24, 0.58, and 0.81 percent, respectively, in the long-run. The causality analysis also confirmed the unidirectional relationship between these series. Therefore, the money supply must be kept under control to ensure price stability.

In contrast to the studies conducted by Karpat Çatalbaş (2007), Çiçek (2011), and İslatince (2017), the results are similar to the studies carried out by Cesur (2006), Özmen and Koçak (2012), Kaya and Öz (2016), Alper (2018), Gabaçlı (2020), and Kara and Sağır (2021). This paper reveals that the quantity theory is largely valid for Turkiye. However, the validity of the theory may vary depending on the definition of money used. Broader monetary aggregates have a greater impact on the general price level. For this reason, the central bank should focus on the broad money supply, not the narrow money supply. Focusing on the narrow money supply can create the false notion that money is not neutral. This leads to a misjudgment of the effectiveness of monetary policy. For further studies on this issue, implicit and explicit inflation targeting experiences in Turkiye can be compared empirically. Such an analysis can be a guide for determining the optimal monetary policy.

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Mauss's Gift Theory and the Edgeworth Box Diagram

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Abstract In this study, the gift cycle of archaic societies is tried to be explained with the Edgeworth box diagram. The main objective of the study is to investigate whether the "giving, receiving, reciprocating" behavior works in a similar way in today's societies, based on the gift mechanism seen in archaic societies. For this purpose, Francis Ysidro Edgeworth's "Mathematical Psychics: An Essay of the Application of Mathematics to Moral Sciences", one of the important works of economics, and Marcel Mauss's "The Gift", one of the leading works of social anthropology, are discussed with their common aspects. Mauss's gift theory offers the opportunity to understand human behavior on exchange or trade. A significant part of the economic elements in the Gift system seen in archaic societies is similar to today's societies. Although gift-giving is not simultaneous, it is consistent with the barter system if it takes place within the framework of all its rules. The Edgeworth box diagram provides a simple model for reciprocal exchange. In the article, the diagram is used to illustrate how the agents can reach equilibrium in their preferences. It also provides an insight into loss aversion, decision making under uncertainty, social preferences and reciprocity in the gift cycle from a behavioral economics perspective.

Keywords Behavioral economics · Mauss's gift theory · Edgeworth box diagram

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Mauss's Gift Theory and the Edgeworth Box Diagram

Francis Ysidro Edgeworth (1845-1926) is considered one of the most influential figures in early neoclassical economics. Edgeworth made important contributions to various areas of economics such as contract, exchange theory and the theory of monopoly (Drakopoulos, 2015, p. 33). Edgeworth's work is now seen as an important underpinning for neuroeconomics studies using brain scans (Colander, 2007, p. 224). Edgeworth's "Mathematical Psychics: An Essay of the Application of Mathematics to Moral Sciences" forms the basis of the methodological approach in economics (Drakopoulos, 2015, p. 33). This work was an important book of its time due to its emphasis on mathematical formalism and the application of utilitarian analysis to economic and political issues (Samuels, 1992, p. 168). This work is based on the identification of the maximum energy of physics with the maximum pleasure of economic calculation (Drakopoulos, 2015, p. 37). The study also provided an integrated approach between economics and psychology (Neumärker, 2007, p. 61).

"The Gift" (1925), in which sociologist Marcel Mauss (1872-1950) analyses the phenomenon of gifts in archaic societies, is an important work of social anthropology. This work has been of interest to researchers for many years. In his work, Mauss deals with the nature of the commercial relations of pre-modern societies. Mauss also points out that the economic elements embedded in the daily life of archaic societies do not show a very different structure from today's societies. The focus of the study is on "giving, receiving and returning gift exchanges, which are voluntary in theory and obligatory in reality". It is possible to see many phenomena such as utility, property, trade, peace, profit, legal bond, division of labour, reciprocity, contract, fairness (Mauss, 2018; Özüşen & Kösekahyaoğlu, 2023; Sahlins, 2010, p. 159; Weber, 2018, p. 29), invisible hand (Douglas, 2002, p. xviii), loss aversion, decision-making under uncertainty, social preferences and rational choice in the gift mechanism.

The simplest general equilibrium model in economic theory is that of a pure exchange economy with no production. The Edgeworth box is a basic analytical tool used to examine general equilibrium in economics. In this model, there are two individuals who come face to face to exchange goods. In an economy with two consumers and two goods, it is assumed that consumers are willing to exchange goods between themselves. Edgeworth's diagram is in line with Mauss's theory of the gift as explained in his work. Even if the exchange is not simultaneous, the return of the gift will occur within a reasonable time. If the return of the gift is not a good or service, peace will be established, at least between the two parties. Gift giving is a multifaceted and complex chain of economic, legal, social and individual phenomena. This article uses the Edgeworth box diagram, a pure exchange model for the gift cycle. The article took the analysis of gift giving a little further, as proposed by Mauss (2018, p. 257). The Edgeworth box diagram provides only a simple model for explaining the complex chain of facts in Mauss's gift theory. As a matter of fact, this complexity is also the case for contemporary societies. Only this method can show the basic similarities between archaic and present-day societies in the simplest way. For this reason, in the Edgeworth box diagram, social norms, legal obligations, the spirit of the gift (hau), and moral or aesthetic values constitute the limitations of the study. First, Mauss's gift theory, behavioral economics and Edgeworth box diagram are explained in the article. Then, the gift cycle in archaic societies is shown in the Edgeworth box diagram. In the last part of the article, we try to provide a behavioral insight for the gift cycle, focusing on decision making under uncertainty, loss aversion, reciprocity and social preferences.

Mauss's Gift Theory

Mauss's famous work "The Gift" explains the causes and forms of exchange in archaic societies through gifts. In his work, he clearly states that the legal and economic systems of contemporary societies are not far from the systems of archaic societies. According to him, there is no great distinction between archaic and contemporary societies. On the contrary, the questions that law and economics seek answers to can be answered in archaic societies. Mauss does not define the boundaries of his work with precise lines and leaves the researcher a field of study (Mauss, 2018). As a matter of fact, the field offered to researchers in the work has brought along the interdisciplinary feature of the work (Özüşen & Kösekahyaoğlu, 2023, p. 405). Alain Caillé also states that the obligation to give, receive and reciprocate is not unique to primitive archaic societies. Caillé explains that this cycle of obligation is constitutive in terms of social relations in order to make further analyses (2007, p. 173). Mauss indicates that the societies before us were not deprived of an economic market in their commercial relations. He aims to show how the contract and sale are made, how the exchange, how the market functioned before money, and how morality and economics are at the basis of all societies in these transactions. This idea of Mauss is seen in various parts of the work, and he summarises the subject with the following words (2018, p. 191-245-258):

"...They are economic. The idea of value, utility, self-interest, luxury, wealth, the acquisition and accumulation of goods—all these on the one hand—and on the other, that of consumption, even that of deliberate spending for its own sake, purely sumptuary: all these phenomena are present everywhere, although we understand them differently today."

While evaluating his work from an economic point of view, Mauss emphasises that the phenomena in the gift mechanism should be well analysed. He even stated that this analysis applies to today's societies. Mauss states that only the concepts of economic actions show a complex structure. He explains that the words necessity, luxury, savings, interest, benefit and even gift are too complex for these societies (Mauss, 2018, p. 247). However, this situation is also valid for today's societies. As a matter of fact, the concept of "utility" or "utilitarianism", which has been discussed for many years, is a chain of very complex phenomena.

Utilitarianism is the heuristic idea that utility is the basis of morality and especially of fairness. All thinkers who advocate utilitarianism have adopted this idea (Rossen, 2003, p. 1). In utilitarianism as a moral theory, an action is considered right if it produces the greatest amount of happiness for the greatest number of people (Driver, 2014). Every school of thought within the utilitarian tradition recognises, in every detail of morality, the effective and dominant power of actions on happiness (Mill, 2017, p. 54). The uncertainty of happiness, which varies from individual to individual, shows that its utility will be debated for many years to come. Due to the difficulty of distinguishing between mind and emotion, it is difficult to determine whether an individual performs an action whose goal is not utility. It follows that in the gift cycle, whether in the short or long term, utility is always encountered. According to Mauss, the gift cycle is far from being within the framework of utilitarianism. However, the fact that the gift starts to wait for its return from the moment it is given, that it is "voluntary in theory and obligatory in reality" and that the obligation increases as the period extends shows that it is not completely far from utility maximisation. Mauss's view that the gift cycle is far from the economics' understanding of utility stems from his belief that the theory of utility is based solely on self-interest (Özüşen & Kösekahyaoğlu, 2023, p. 409). For economics, however, this is only an assumption. Utilitarianism is not only a moral and political philosophy but also a philosophy of action. The thought in the utilitarian philosophy of action and the thought in utilitarian moral philosophy are exactly parallel (Baujard, 2013, p. 2). Utility is inseparable from emotion, and emotions are triggered by changes (Kahneman,

2003, p. 1457). Mauss also divides his work into ethics, economics, sociology and political economy. He tries to determine that morality and economics operate deeply in today's societies (Mauss, 2018, p. 74).

Mauss's work is based on the cycle of giving, receiving and reciprocating gifts, which in theory are voluntary and gratuitous, but in reality are obligatory and self-interested. In the mechanism of the gift, there are three principles of obligation: giving, receiving and reciprocating. Although the gift may appear to be voluntary and non-reciprocal on the appearance, over time it turns into a system of exchange that requires reciprocity within a reasonable period of time. According to Mauss, what enables this cycle is the bond of spirits formed through objects, that is, the legal bond in Maori law, which he analyses (Mauss, 2018, p. 92-156). Kant's views on goodness offer a similar explanation for the establishment of this connection. He states that a person who accepts a favour is no longer free and that the favour places the individual under obligation. According to Kant, no one can force anyone to do a favour. However, individuals still feel an obligation. The party doing the favour has an active obligation. The party who owes the favour is passively liable (2022, p. 49).

Exchange in archaic societies is a moral behavior. The return of a gift is uncertain. The person who receives the gift will decide when to return and to what extent to reciprocate, according to their own means. The return of the gift occurs over a short or long time. Regardless of this process, it favours a social relationship of balanced exchange. In the long run, it even extends to inter-tribal relations (Sahlins, 2010, s. 268). Mauss does not explicitly define market exchange, but his views indicate that market transactions involve voluntary exchange that utility both parties (Gill & Thomas, 2023, p. 75).

The generosity shown by the first party to give the gift has an economic and social significance. This behavior first shows a willingness to trade and this generosity leaves the other side behind. Even if it is not reciprocated at the moment, eventually the accounts can be balanced. As long as the gift mechanism continues within the framework of the triple obligation, the relationship is maintained, albeit with slight imbalances (Sahlins, 2010, p. 290-291). Sahlins (2010, p. 294-295) states that at the end of the reciprocity strategy, an equilibrium is determined, but it is difficult for archaic societies to determine the exact economic determinants of this equilibrium. However, he explains that "generosity" has similar properties on the rate of exchange as the elements that form the price in the market. If goods that provide more utility force the buyer to be more generous, this is equivalent to the fact that, in a market system, the price tends to increase with demand. The economic determinants of natural scarcity, difficulty of production, social utilisation of goods and substitution possibilities apply to all societies and will produce similar effects. Only the mechanisms are different.

In markets where exchange occurs simultaneously, there is a close equivalence between the two goods subject to exchange. The return of the gift should be at least the equivalent of the gift received. In this mechanism, it is usually expected that the return will be more than the equivalent of the gift. In particular, if the reciprocity is not realised within a reasonable time, it should be returned at a value higher than the equivalent. However, Sahlins (2010, p. 297) states that the exchange rate is not left to fluctuate even if the temporal rate is delayed. The fact that the gift starts to wait for its return from the moment it is given, that it is "voluntary in theory and obligatory in reality" and that the obligation to give back increases as the time is extended shows that it is not far from utility maximisation. This is also a sign that the first step has been taken for the start of trade.

In the gift cycle, we encounter an unwritten contract and Mauss calls these contracts as anonymous contracts. This contract constitutes the beginning of the commercial relationship. The contract and contractual

commercial relationship consists of a total of three obligations: obligations to give, receive and reciprocate gifts. First, the property right of the gift giver makes it obligatory to return the gift. If this obligation is not fulfilled, the commercial relationship and legal bond is not established. (Mauss, 2018, p. 73-200). In the gift cycle, although there is no written contract, there is an obligation to return "at maturity" within a reasonable period of time, and if this period is exceeded, the return is expected to be of more than equivalent value.

Mauss states that societies or individuals succeed in developing to the extent that their relations stabilise giving, receiving and reciprocating. He states that for this, it is first necessary to know how to let go of the spears. According to Mauss, there is no need to look for goodness and happiness far away. Nations, peoples, families or individuals are happy if they can sit around common wealth. He explains that joint and regular work, mutual respect, mutual generosity, redistributed wealth and peace will bring happiness. According to him, a purpose of the gifts offered to people is to provide an environment of peace with each other. Individuals and societies have succeeded in developing to the extent that they have stabilised giving, receiving and reciprocating in their relationships (Mauss, 2018, p. 103-264). A gift is the first step of a mutual relationship based on trust. Gift giving, in accordance with Kahneman and Tversky's definition (1984, p. 341), is a risk-free decision-making process. The initial giver has made a choice on the uncertainty of whether the gift will be returned or not. Perhaps it was intended to meet the expectation of minimising the risk of conflict if the gift was not returned. Conflict is an important element of loss for both individuals and societies. In this case, since losses have a greater impact on preferences than gains (Tversky & Kahneman, 1991, p. 1039), the giver of the gift chooses to avoid losses at least

According to Hume, the interdependence of human beings exists in all societies and is quite high. Hardly a human action is performed without reference to the actions of others. As people make their communication more complex, they perform various actions that they hope to be co-operated with within the framework of their own life plans. Their past experiences help them take precautions, and the gains from their current actions preserve their belief in the tendency to continue these actions (2021, p. 87-88). Smith, on the other hand, states that human nature has a tendency to exchange one thing for another. He states that this tendency will inevitably result in the emergence of the division of labour after a while. According to him, individuals obtain a significant part of the good things they need through exchange, , agreement or purchase. Through the desire for exchange, both individuals and societies acquire the products of different skills (2020, p. 35-38). What is important is that individuals or societies choose to defend their mutual interests without resorting to weapons (Mauss, 2018, p.263). As a matter of fact, Plato calls war "the source of evils" and states that war is caused by an ambition arising from acquiring more property than others (2022, p. 61). Therefore, the gift supports peace through sharing.

Mauss observes the existence of group loyalty when examining reciprocity in the gift-giving model. Beyond a dyadic relationship, Mauss reveals an intergenerational solidarity that he calls "alternate and indirect reciprocity" (Ramel, 2018, p. 165). Mauss believes that reciprocity is one of the main elements of social relations and peace. However, classical and structural anthropology has always considered reciprocity as one of the fundamental social processes that will guarantee stability and peace in human societies (Vinolo, 2015, p. 97). International ties of reciprocity have gained importance in various fields such as the environment and economic development (Ramel, 2018, p. 165). The exchange of gifts can contribute to the establishment of stable peaceful cooperation between states and individuals in the international community (Heins, Unrau & Avram, 2018, p. 129).

Behavioral Economics

Classical economics conceptualises a rational and self-interested world (Kenning & Plassmann, 2005, p. 343). Behavioral economics, on the other hand, introduces deviations from classical economic theory and explains the interaction between economic principles and behavioral change (Reed, Niileksela & Kaplan, 2013, p. 51). Behavioral economists adopt the basic principles of modern economics and seek to develop these ideas to make them more empirically accurate. In particular, they apply psychological insights to economics (Angner & Loewenstein, 2007, p. 38). The insights generated are realised with the belief in making better forecasts. This belief does not mean a complete rejection of the neoclassical economic approach based on utility maximisation, equilibrium and efficiency (Camerer & Loewenstein, 2004, p. 5-6). Although it introduces new methods and insights, the ideas of behavioral economics go back as far as classical economics. Adam Smith's concept of the 'invisible hand' and his work 'The Theory of Moral Sentiments' offer important economic insights.

Smith begins his book with these words:

"*How selfish soever man may be supposed, there are evidently some principles in his nature, which interest him in the fortunes of others, and render their happiness necessary to him, though he derives nothing from it, except the pleasure of seeing it. Of this kind is pity or compassion, the emotion we feel for the misery of others, when we either see it or are made to conceive it in a very lively manner. That we often derive sorrow from the sorrows of others, is a matter of fact too obvious to require any instances to prove it; for this sentiment, like all the other original passions of human nature, is by no means confined to the virtuous or the...*" (2018, p. 13).

Smith's work also includes issues such as loss aversion, justice (Ashraf, Camerer & Loewenstein, 2005, p. 132), altruism and virtue, which are the focus of behavioral economics. The insights of J. Bentham (2021), who wrote extensively on the concept of utility and its determinants, has remained important until today. According to Bentham, human behavior is guided by the feelings of increasing pleasure and avoiding pain. In his work, he includes issues such as empathy, antipathy and morality that guide human actions. Despite these psychological foundations, economics ignored psychology for a long time and neglected the role of emotions in decision-making (Bechara & Damasio, 2005, p. 336-337). Today, however, behavioral economics offers new approaches to economics with evidence from psychology and neuroeconomics with evidence from neuroscience. The theories in behavioral economics are usually based on the rational model. Assumptions about cognitive limitations have been added to these theories to account for certain anomalies (Kahneman, 2003, p. 1469).

Bounded rationality (Simon, 1956), decision making under uncertainty and risk, loss aversion (Kahneman, 2022), overconfidence, self-control, fairness, and mental accounting (Thaler, 2016) are among the topics of behavioral economics. Behavioral economics also focuses on time and social evaluations while examining human behavior (Lee, 2021, p. 209). Thus, complex human behaviors are tried to be analysed.

Individuals show deviations from perfect rationality when they make judgements under uncertainty. Many decisions are based on beliefs about the probability of uncertain events due to a choice. These beliefs are expressed in numerical form as ratios or subjective probabilities. People rely on heuristic principles in tasks such as assessing probabilities and estimating values (Tversky & Kahneman, 1974, p. 1124). According to prospect theory, people are not guided by general utility expectations, but by the immediate emotional impact of gains and losses. Losses and disadvantages have a greater influence on preferences than gains

and advantages. The asymmetry of pain and pleasure is the ultimate justification for loss aversion in choice. Because of this asymmetry, for a decision maker aiming to maximise the utility experienced, it would be expected to give more weight to negative rather than positive outcomes (Tversky & Kahneman, 1991: 1039). Many applications of economic theory assume that individuals only care about their own wealth and will not make sacrifices for others (Camerer, 1999, p. 10576). However, individuals do not always prioritise their own interests and make sacrifices. They prefer fair distribution instead of unfairness (Solek, 2014, p.36). In this regard, laboratory experiments such as the ultimatum game have a distinctive feature in revealing social utility (Camerer, 1999, p. 10576).

Edgeworth Box Diagram

Edgeworth's economic thought is about the impact of classical physics on economics. (Drakopoulos, 2015, p. 31). In the introduction to his work "Mathematical Psychics", Edgeworth proposes an analogy between the "Maximum Happiness, Utilitarian or Egoistic Principles", which constitute the first principles of ethics and economics, and the "Maximum Energy Principles", one of the highest generalisations of physics and economics. The next step provides a detailed methodological justification for the analogy between physics and the social sciences, especially economics. According to him, the first argument supporting the use of mathematical physics methods in the social sciences assumes that every social phenomenon accompanies a physical phenomenon . He argues that the lack of quantitative data and functional relationships in economics does not preclude the application of mathematical methods. (Edgeworth,1881, p. v-5).

Edgeworth states that the purpose of economics is to maximise happiness (Ansa Eceiza & Gómez García, 2019). According to him, the central concept of utilitarian analysis is the greatest happiness, the greatest possible sum of pleasures accumulated through sensibility throughout all time. The greatest happiness is the result of the right action and means expedient (Edgeworth, 1881, s. vii). Adhering to the utilitarian philosophy, Edgeworth carried out his studies toward applying mathematics to the pleasure-trouble calculation (Kazgan, 2021, p. 178). He argued that utility was directly measurable and that new developments in "physio-psychology" would make it possible to develop a "hedonimeter" that would allow economists to develop a solid physiological basis for utility. According to Edgeworth, the calculus of pleasure is divided into two categories: economics and utilitarian ethics. Economic Calculus investigates the balance of a system of hedonic forces, each tending towards maximum individual utility. The utilitarian calculus is on the balance of a system that tends to provide maximum universal utility to each and all (1881, p.15). Edgeworth's hedonimeter also addressed the neurological underpinnings of pleasure, providing insight into how people respond to different events (Colander, 2007, p. 216).

Edgeworth states that pleasure accompanies energy. Energy is also the main idea of mathematical physics. It tries to explain the complexity in social sciences with maximum energy. According to him, there is pleasure at every moment of time, whether it is self-interested or benevolent. When these pleasures come together for rational action, they resemble the accumulation of pleasure. In a material cosmos, each particle movement is part of the maximum sum of the accumulated energy. Thus, the actions of each soul, whether selfishly or sympathetically related, may be constantly interconnected. Just as the electromagnetic force is directed towards maximum energy, the pleasure force is directed towards maximum energy. The energy produced by the pleasure force is the physical accompaniment and measure of the conscious feeling of pleasure (1881, p. 11-12).

In the first part of his work, Edgeworth attempted to demonstrate the possibility of mathematical reasoning without numerical data. He then gives a mathematical theory of a contract determined by competition in a perfect market. He argues that when the number of competitors is limited, the market is imperfect and the contract is uncertain. In the case of mergers (unionism) and cooperatives, a similar situation is likely to occur in personal service contracts (1881, p. v-vi).

While Edgeworth's work was important for the development of economic analysis, his thoughts on exchange are also invaluable for his contributions to economics. Edgeworth's indifference curves and the contract curve focus on the optimality conditions for "efficient" exchange between two individuals (Creedy, 1979, p. 163-172). The Edgeworth box diagram represents various distributions of economic resources. Humphrey (1996, s. 37) calls the box diagram "one of the most ingenious geometric structures ever devised in economics" and "a powerful tool". The diagram is used to analyse trade in goods in general equilibrium analysis (Pavlov, 2013, p.1).

Mauss's Gift Theory with the Edgeworth Box Diagram

People start to exchange and trade when they gain mutual utility. Entering the exchange is voluntary. Economic activities realised through voluntary exchange produce "win-win" results. The assumptions of this model are that there is no fraud in the market and that the expected utility is obtained through the realisation of the transaction (Browning & Zupan, 2014, p. 161). Edgeworth's diagram shows the reciprocal utility gains from voluntary trading using indifference analysis (Beaulier & Prychitko, 2010, p. 55).

The pure exchange model is an efficient model for studying the two sides of market transactions. It is based on two goods in a given quantity, two consumers and an exchange system. The model is useful for two main reasons. First, it allows the explanation of utility, one of the most important topics in economics. This principle states that "voluntary exchange or trade is reciprocal utility to the parties involved in the transaction." The second is the principle that allows us to explain the concept of economic efficiency, which is also one of the basic principles of economics. It is the distribution of goods between consumers in a situation where a consumer may not be able to improve himself without harming another consumer. The Edgeworth model explains the preferability of such a distribution of goods and the incentive for competitive markets to promote efficiency in exchange (Browning & Zupan, 2014, p. 159).

The exchange process considered by Edgeworth consists of successive exchanges between individuals until a position is reached where no exchange is possible for the betterment of each individual (Uzawa, 1962). The Edgeworth box diagram includes all non-wasteful allocations when there are two consumers and two goods and no production. The Eaceh point in the box represents the full allocation of two goods to two consumers. Consumers have endowments and preferences and can exchange goods to increase their utility. Each of the two agents maximises their utility. In terms of the total demand of the two agents, the total demand must equal the total endowment of the two goods (Pavlov, 2013, p. 1). Each point in the Edgeworth box shows the alternative use baskets that both parties can consume (Browning & Zupan, 2014, p. 162).

The exchange rates for the diagram are derived from Sahlins' "Stone Age Economy". Sahlins explains that in archaic societies, a rate of exchange will occur, albeit through gift exchange. Exchange rates in archaic societies tend to remain constant in the short run, even when there are significant changes in supply and demand. In the long run, they change (Sahlins, 2010, p. 283).

There are two goods: bowls and bags

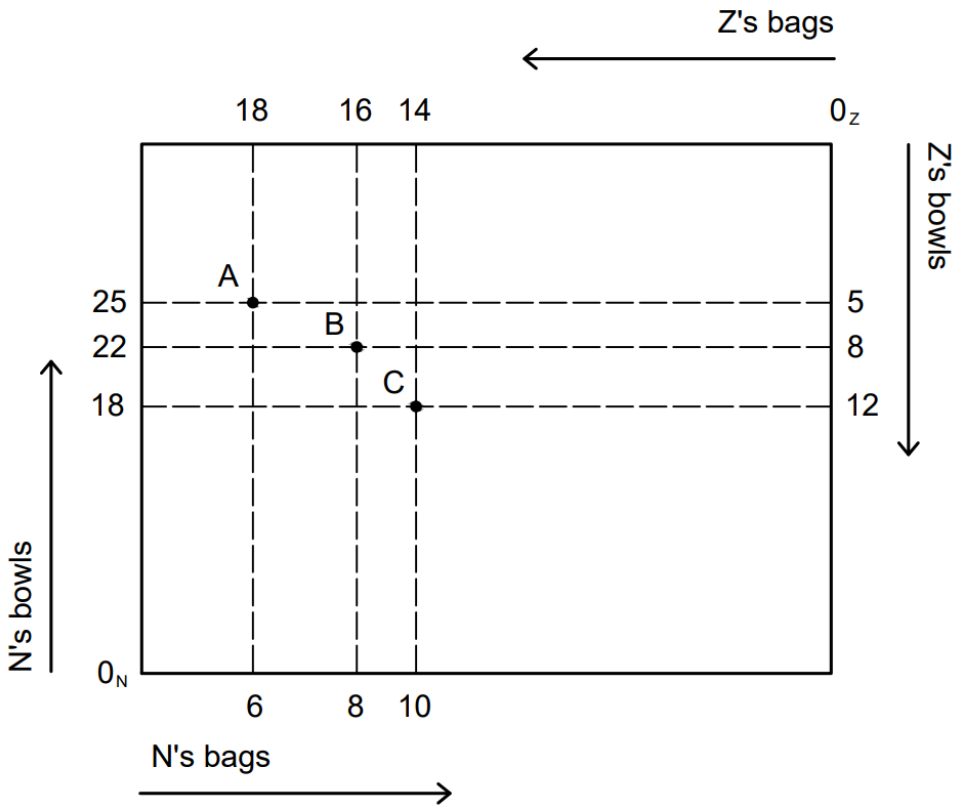
There are two agents: N and Z

The initial endowment is: N = (25, 6), Z = (5, 18)

The lengths of the sides of the rectangular box are equal to the fixed quantities of the two goods. The width of the box indicates the total amount of bags and the height indicates the total amount of bowls.

Figure 1

The Edgeworth Box



Two types of goods, bowls and bags, and the gifts to be made by the two partners on mutual visits, N and Z, were discussed. The Edgeworth box is used to analyse the allocation of a fixed total quantity of two goods between two consumers. The box can show all possibilities of allocating 30 bowls and 24 bags between N and Z. The vertical dimension of the box shows the quantity of 30 bowls and the horizontal dimension shows the quantity of 24 bags. "O_N" is the origin of the diagram used to measure the bowls and bags owned by N. "O_Z" is the origin point of the diagram used to measure the bowls and bags owned by Z.

Point A shows N's market basket of 25 bowls and 6 bags and Z's market basket of 5 bowls and 18 bags. Point A also represents the initial state. In the first round, N visits Z and gives him the first gift of 3 bowls. Subsequently, within a reasonable time in the gift exchange, Z gives N 2 bags as a gift. At the newly formed point B, N has 22 bowls and 8 bags, and Z has 8 bowls and 14 bags. In accordance with the nature of the gift, 2 bags are more valuable than 3 containers. However, the return is not always expected to be of greater value, especially if the return is achieved within a reasonable time.

Initial Market Basket

N/25 bowls + 6 bags

Z/5 bowls + 18 bags

After-Gift Market Basket (1st round)

N/22 bowls + 8 bags

Z/8 bowls + 16 bags

In the gift cycle, the gift may not be reciprocated at a value greater than the equivalent of the gift or after a certain point, there may not be a more valuable gift. As a matter of fact, Sahlins also proceeds from the fact that in this relationship in which the rate of exchange can be determined, the gift may not always be received with more than its equivalent. It is expected that N will give 3 more bowls to Z in the next round. Assuming that the gift will not always be met with more than its equivalent, Z gives 2 more bags to N in return for the 4 containers that N gives to Z. At the end of the second round, N had 18 bowls and 10 bags, and Z had 12 bowls and 14 bags.

After-Gift Market Basket (2st round)

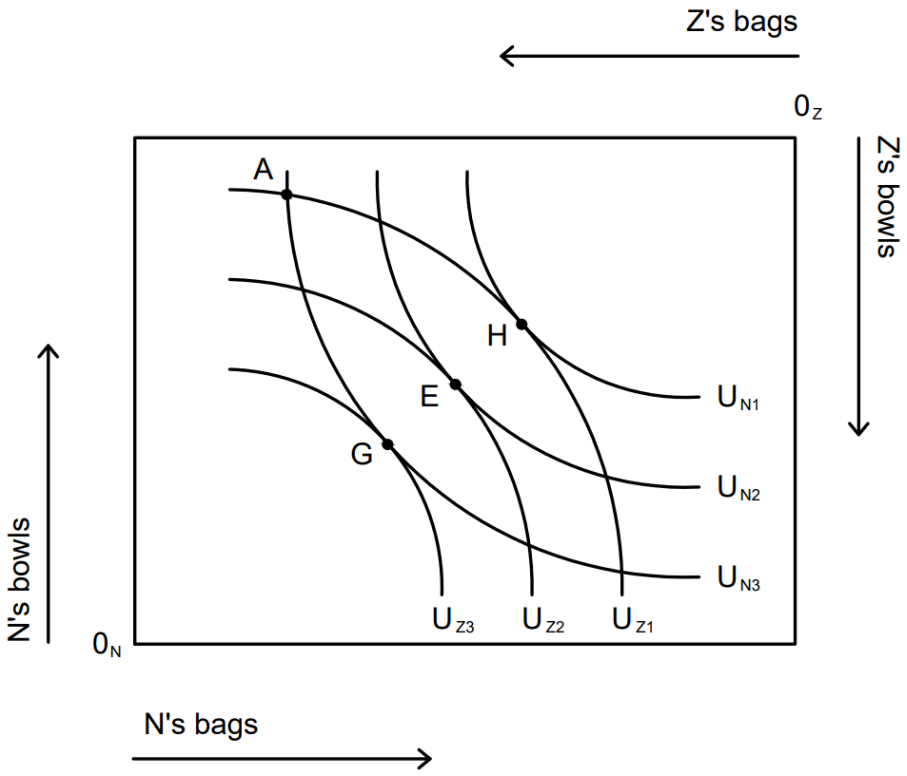
N/18 bowls + 10 bags

Z/12 bowls + 14 bags

Sahlins states that although the reciprocity strategy is quite complex, an equilibrium can eventually be determined. The exchange rate is the result of a compromise between the parties. During the reciprocity process, it becomes clear at which rate the trade should continue. If there is a misunderstanding, the partnership will be broken (2010, p. 292). Here, the exchange ratio is set at 2:1. This example is only one of the possible results of determining the exchange ratio.

Figure 2

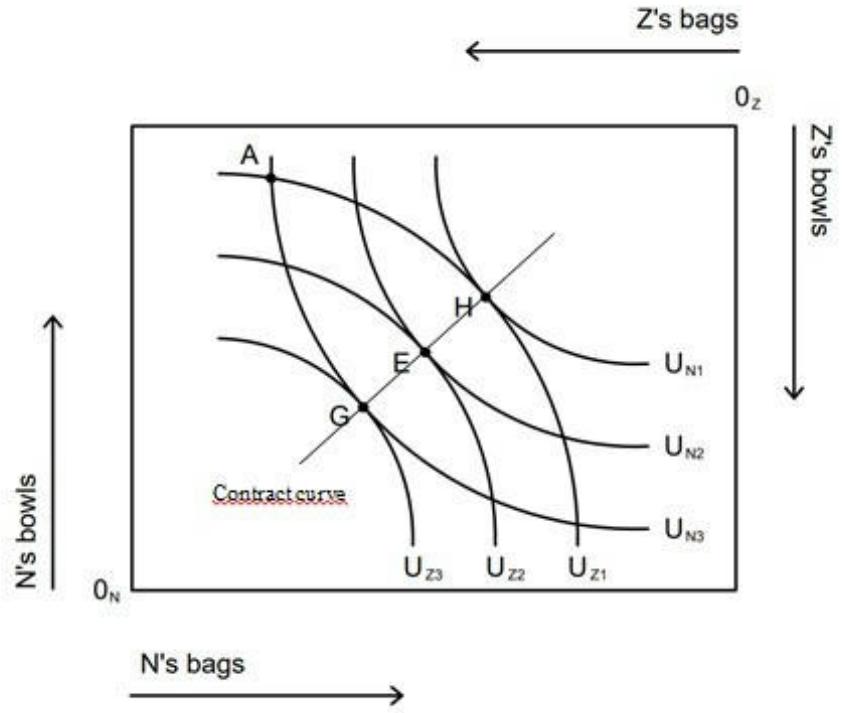
The efficient points



Point A shows the initial allocation of goods. U_{N_1}, U_{N_2} and U_{N_3} are N's indifference curves and represent N's preferences between alternatives. Uz_1, Uz_2 and Uz_3 are indifference curves of Z and represent Z's preferences between alternatives. The indifference curves of N and Z intersecting at this point form a lenticular area. Both parties' utility from the allocation of goods as long as it takes place within this area. On the other hand, when point E is reached, where the indifference curves are tangent, it is not possible to make another exchange that will utility both parties. E is a Pareto efficient allocation. The theory does not allow predicting where in the lenticular area consumers will terminate the exchange (Browning & Zupan, 2014, p. 165). This is also true for the gift cycle.

Figure 3

A conract curve showing all the Pareto-efficient possibilities



The tangency of the indifference curves means that the marginal rate of substitution for the two consumers is equal. At the point where the indifference curves are tangent, there is no other possibility of an exchange that is of utility for both parties. The tangent points of the indifference curves explain the effective distributions. The contract curve shows several effective distributions joining the tangent points of the indifference curves.

Mauss's Gift Theory from the Perspective of Behavioral Economics

In embedded social relations, individuals often exchange gifts and favours. This is part of the commercial exchanges (Mathews, 2017, p. 90). Analysing the factors of embedded relations in isolation can make it difficult to look at the issue holistically. For this reason, Mauss's gift theory is interpreted through a micro-economic analysis and the principles of behavioral economics.

Loss aversion is a core topic in behavioral economics (Ashraf, Camerer, & Loewenstein, 2005, p. 132) and shows the tendency of individuals to prefer to avoid losses rather than gain (Pindyck & Rubinfeld, 2014, p.

191). The gift system seen in archaic societies explains a mechanism that although theoretically voluntary, expects reciprocity. Although this response cannot always be provided, it fulfils the feature of eliminating the risk of a potential conflict for the party giving the gift. This shows the existence of a loss aversion tendency. As a matter of fact, conflict can mean both losing what you have and not being able to maintain social peace. The gift-giving cycle is an important contribution to social peace.

Social peace is the desired state of a social community. Societies with individual and social peace thrive and their economies grow. The absence of peace jeopardises the lives of individuals as well as social co-existence and decision-making systems (Kunze & Schlatterer, 2018, p. 30). The gift relationship is a mechanism that secures individual and social peace. As a matter of fact, Mauss also said: "*To refuse to give, to neglect to invite, likewise to refuse to receive, is tantamount to a declaration of war; it is a rejection of alliance and community*" (2018, p. 94). At the basis of the rights of societies is the right to social order. The origin of this right is based on contracts (Rousseau, 2016, p. 57). The equivalent of the social contract in archaic societies is the gift. (Sahlins, 2010, p. 167). Smith also states that societies will obtain what they need through exchange, contract or purchase (2000, p. 36-38).

Emotions and mental events that drive benevolent behavior, such as sympathy or altruism, are central topics in behavioral economics and neuroeconomics (Neumärker, 2007, p. 61). Social interaction is a unique feature of human behavior (Robson, Repetto, Gountouna & Nicodemus, 2020, p. 67). Experimental evidence on ultimatum games, dictator games, gift exchange games, and games for the common good has shown that many people are not only interested in maximising their own material payoffs, but also in social comparisons, fairness, and reciprocity (Fehr & Schmidt, 2003, p. 208). Gift giving is based on reciprocity. Refusing a gift indicates that a social relationship cannot be established. Refusal to reciprocate indicates future unreliability (Mathews, 2017, p, 100).

A significant part of behavioral economics research focuses on decision-making under risk and uncertainty. When choosing between alternative courses of action, people rarely know with certainty what outcomes these actions will lead to (Loewenstein, Rick & Cohen, 2008). In the gift mechanism, the first person to give the gift decides under uncertainty. The first uncertainty for the giver is whether there will be a return. The second uncertainty is whether a friendship can be established in the absence of a return. Even if the gift is not returned and a lasting friendship cannot be established, at least hostile feelings will not be harboured thanks to this mechanism. Dolfsma et al. (2009, p. 318) also argued that gift exchange plays a vital role in initiating and maintaining relationships with individuals and groups. Frequent gift exchange or appropriate exchange will lead to reduced uncertainty and positive emotions.

Conclusion

New methods and new understandings expand the fields of economics. The behavioral models or decision mechanisms that people show in their survival strategies diversify the fields of research. The Edgeworth box diagram is a pure exchange economy model. It is based on two consumers, two goods and a simple exchange system with no production. This diagram provides a simple model for the gift cycle in archaic societies. In the gift cycle, the gift given is expected to be reciprocated within a reasonable time. The return of the gift is expected to be equivalent within a reasonable time. If the return exceeds a reasonable time, it will have to be more than equivalent. In this mechanism, even if each return is more than its equivalent, an exchange rate is automatically realised. Moreover, in the continuity of this mechanism, the situation of being more than equivalent cannot be expected to be unlimited. The process of giving, receiving

and reciprocating gifts offers insights for behavioral economics together with the microeconomic model. Decision-making under uncertainty, loss aversion, reciprocity and social preferences, which are principles of behavioral economics, can be seen in the gift-giving cycle.

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Portfolio Selection Analysis with a Fermatean Fuzzy-type AHP

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Abstract This study aims to tackle decision-making problems on interval-valued Fermatean fuzzy sets; the current research proposed an approach based on the AHP method. The interval-valued Fermatean fuzzy set is a mathematical framework used in decision-making and modelling scenarios that involve uncertainty and imprecision. The interval-valued Fermatean fuzzy set extends traditional fuzzy sets by incorporating an additional layer of flexibility and expressiveness, particularly in cases where precise membership degrees are difficult to assign. The AHP method makes the problem more understandable by dividing it into a hierarchy of targets, criteria, sub-criteria, and alternatives, comparing and prioritizing options, and checking consistency. Multi-attribute decision-making algorithms are well-suited for portfolio selection problems. Complex subjective preferences and diversified financial indices affect investment decisions within the multi-attribute decision-making paradigm. For the investment portfolio selection problem, an algorithm implementation based on an interval-valued Fermatean fuzzy set is chosen. The S&P 500 companies are examined. Ten criteria are established for choosing investment portfolios. The investment portfolios were selected using a multi-attribute decision-making method based on interval-valued Fermatean fuzzy sets. The algorithm based on interval-valued Fermatean fuzzy sets and the portfolio decision-making process using these criteria is suitable for choosing the right options. A model that illustrates how choices about investment portfolios should be made using this procedure was created using a grounded theory methodology. The results show that efficient decision-making methods for investment portfolios create a portfolio mindset and assist in concentrating selection efforts on the appropriate projects. Additionally, it enables extremely flexible decision-making within the investment portfolio. These findings offer managers an evidence-based method for making decisions about their portfolios.

Keywords Portfolio selection · Interval-valued Fermatean Fuzzy Set · MADM · AHP

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Portfolio Selection Analysis with a Fermatean Fuzzy-type AHP

The contemporary portfolio theory is a helpful method for selecting investments to maximize overall returns while retaining a reasonable level of risk. An investment portfolio is built to optimize expected return given a specific level of risk using this mathematical framework. Modern portfolio theory offers that instead of concentrating just on an investment's inherent risk and return characteristics, one should also consider how the pooled investment affects the risk and return of the overall portfolio. As stated differently, an investor can assemble a portfolio that includes diverse assets that will generate more significant returns without entailing greater risk. Selecting a portfolio is the unifying process in Modern Portfolio Theory. However, there is considerable debate on the best approach. Markowitz is credited with developing most of the modern portfolio theory. He proposed that the best way to choose assets for each portfolio would be to use quadratic programming to create a collection of efficient portfolios. According to Markowitz, an efficient portfolio comprises investments that produce the best returns for a given risk. High levels of uncertainty and risk, or a lack of relevant information, impair the decision maker's ability to conduct an appropriate analysis.

Numerous models, including the multi-period mean-variance model, the continuous-time model, the anticipated utility model, the dynamic asset allocation model, and the behavioural mean-variance model, have been created since Markowitz (1952) established the well-known mean-variance model in portfolio selection. One of the drawbacks of using variance to quantify risk, according to Markowitz (1959), is that the variance calculations consider both high and low returns. Furthermore, investors should view less-than-anticipated returns as undesired returns. As a result, variance is only a good risk indicator when the underlying return distribution is symmetrical with second-order moments. Otherwise, strong returns will be viewed as risk by variance-based models. The renowned mean-variance model of Markowitz (1952), which quantifies the variability of returns below the mean, is the most significant of the numerous models created to address this issue. Many studies have employed the mean-variance model because it aligns with investors' sense of risk. Uncertainty has always been the biggest issue for decision-makers who have looked for solutions. Numerous fuzzy set (FS) models have been created to describe uncertainty.

Selecting or optimising the optimal portfolio among portfolio alternatives is crucial for decision-makers in today's competitive landscape. Under restricted resources and limits, these choices or optimizations are made based on several criteria. The issue of multi-attribute decision-making (MADM) in portfolio selection arises from this circumstance. The inability of decision-makers to make wise choices among options when faced with inaccurate or inadequate information is another challenge when choosing a portfolio. Therefore, using the FS theory can be a promising way to deal with the different uncertainties that come with portfolio selection. Fuzzy methods in portfolio selection models have drawn more attention recently.

How people reason and form ideas in real-world situations is the field of study of academic disciplines such as psychology, philosophy, cognitive science, and artificial intelligence. Various statistical and mathematical models usually describe these processes; therefore, decision-making (DM) becomes essential. Behaviour management is the choice of behaviour types an individual or organisation needs to work on to accomplish a specific goal. Research proposes that while many judgments in daily life may be made without conscious thought, complicated and meaningful decisions require a more significant amount of thought and effort. When there are well-defined and limited options in a separate scenario, multi-attribute decision-

making (MADM) is employed. The quantity of solutions for the MADM problems is set. MADM techniques are frequently used while making decisions, including rating, comparing, and selecting possibilities. These methods are commonly selected because they enable quick DM without requiring intricate package software or mathematical computations. The MADM approach only manages to accomplish one objective. The goal is to resolve the choice issue in the best possible way—least expensively and most favourably.

Uncertainty is the state in which various outcomes of a particular occurrence are feasible but their probability is unknown. As a result, understanding uncertainty is essential to the DM process. Understanding the probability that events will occur in reality requires time and effort. As a result, there is some degree of ambiguity during the whole DM procedure. Fuzzy logic theory provides a strong foundation for logical reasoning in imprecise and unclear data (Zadeh, 1965). Fuzzy logic theory has allowed computers to interpret human language and use human knowledge. It switches from using numerical expressions to using symbols at this point. Fuzzy sets (FS) are symbolic expressions of this type. Choice variables are a part of FSs, much like the probability states. FSs are generated when an objective membership degree(MD) is assigned to each alternative instead of the associated probability values.

Analysing various factors, such as market indications and financial performance, is necessary when investing in mutual funds. When choosing a portfolio, the Markowitz model considers risk and return. However, choosing a mutual fund is a MADM challenge because it involves several funds and criteria. Various MADM techniques have been employed to select portfolios.

When choosing a portfolio, decision-makers need to consider the most effective criteria and how they interact with one another. IVFFS is often applied in MADM problems with imprecise or uncertain decision criteria. It helps handle subjective judgments by representing membership and non-membership degrees as intervals. When dealing with datasets with inherent uncertainty or incomplete information, IVFFS provides a framework to model and reason with interval-valued degrees of membership and non-membership. IVFFS is suitable for systems that rely on human input, such as expert systems or human-centric decision models. Humans often provide uncertain or interval-based assessments rather than precise values. In situations involving multiple stakeholders or experts, IVFFS can aggregate diverse opinions by considering interval-valued degrees of agreement and disagreement. IVFFS can model systems with ambiguous or vague operational parameters, such as robotics or process control. IVFFS is used in applications requiring robust handling of ambiguous or overlapping patterns, such as image processing or data clustering. IVFFS supports decision-making in sustainability and environmental management, where data uncertainty is prevalent.

Myers and Alpet (1968) created the AHP, and Saaty refined it as a viable instrument for solving DM issues in 1977. AHP is an MCDM method that can evaluate quantitative and qualitative criteria in DM, including group or individual preferences, experiences, intuitions, knowledge, judgments, and thoughts in the decision process, and solve complex problems by considering them in a hierarchical structure. In DM, the decision-maker might include objective and subjective thinking. As a result, this circumstance allows decision-makers to identify their DM mechanisms. In AHP, there are at least three levels of hierarchy. The purpose is at the top of the hierarchy. A sub-level comprises the main criterion and any sub-criteria that fall within the main criterion, if any. There are DM possibilities at the bottom level. The number of criteria and each criterion's definition must be accurate for pairwise comparisons to be consistent. The criteria ought to be grouped by their shared traits. AHP can be used for different types of criteria. It is an excellent technique for collaborative DM. The flexibility of the outcome can be examined thanks to the sensitivity analysis. Due to the

subjectivity in creating pairwise comparisons and hierarchy matrices, skilled and knowledgeable individuals are required.

Objectives

Investors have various possibilities thanks to the market's abundance of investment tools. These investment tools can be used to construct several different portfolio alternatives. The key consideration here is how investors will select between these portfolios. In 1952, Harry Markowitz described the Modern Portfolio Theory's tenets, which were created in finance literature against the Traditional Portfolio to solve the portfolio selection problem. In addition to ignoring the relationship between the securities included in the portfolio and failing to adequately address numerical approaches in investment instrument selection, traditional portfolio theory is based solely on the principles of securities selection and over-diversification by sector. Modern portfolio theory addresses The diversification strategy quantitatively, which is supported by statistical tools. When risk is not considered, a portfolio based solely on the predicted return is not ideal.

Accordingly, the securities to be included in the portfolio must have a negative correlation with one another to reduce risk through diversification. Put another way; diversification will no longer have the same risk-reducing impact if the returns of the investment instruments in the portfolio move in the same direction and with the same intensity. This is where the most important distinction between the traditional and modern portfolios becomes apparent. Currently, contemporary portfolio theory aims to either maximise return at a given risk level or reduce risk at a given return level. In order to choose the best portfolio, it is first important to identify the efficient portfolios that may be made from all of the market's securities and to ascertain their efficient limitations. The primary benefit of contemporary portfolio theory is its ability to demonstrate how investment instruments with varying weights in the portfolio can produce the same expected return at a reduced risk level. According to the finance literature, high risk should be taken for a high projected return. Even if this is typically the case, it is important to demonstrate the risk-return ratio that the generated portfolio will yield, the appropriate weighting, and how various combinations of the same portfolio at the same risk level might yield higher returns. In any event, there will be a limit to the projected return and the amount of risk that may be taken. Eugene Fama proposed this limit in the Efficient Markets Hypothesis. According to the relevant hypothesis, high-risk assets must be added to the portfolio at a specific rate to achieve better returns than the efficient frontier.

Despite its effectiveness, the mean-variance model developed by Markowitz in 1952 does not adequately address the financial applications of today. Large fund managers today may make mistakes because of their limitations. This model does not entirely account for transaction costs, sector-related concerns, regulatory standards, and floor and ceiling practices in stock transactions and limits such short selling in portfolio fund selection. As a result, fund managers, practitioners, and regulators are starting to take notice of multi-objective portfolio optimisation models that consider several additional restrictions, including transaction costs.

Our groundbreaking study tackles Interval-valued Fermatean FSs (IVFHFSs) for multi-objective portfolio selection and successfully overcomes several potential fund management limitations. In order to create a thorough portfolio, it also incorporates several limits.

Necessity

Some researchers have used the mean-half variance concept in fuzzy environments since fuzzy theories work so well. IVFFS is one of the fuzzy theories that can better capture decision-makers' hesitancies and

represent unclear information with various values. Using various fuzzy theories and approaches, numerous studies have examined portfolio models to capture investors' risk attitudes. Investors can naturally select portfolios with high membership degrees under the score and low MD variability when evaluating them using utility criteria.

IVFFS meet data representation requirements for investment portfolio selection. Rarely does an expert tend to identify the problem in specific settings. Uncertainty may arise from a lack of confidence in communicating investment portfolio selection criteria, or imperfection leads to doubt about the value of a variable, a decision to be made, or a conclusion to be drawn for the actual criterion. Multiple factors, such as incomplete knowledge, stochasticity, or acquisition errors, could lead to uncertainty. As a result, the IVFFS approach would contain indeterminate traits and behaviours, as well as unpredictable situations, implying that indeterminacy plays a role. When a decision-maker must weigh several factors when selecting options, the issue becomes one MADM that can be resolved with relevant tools. IVFFSs and AHP techniques are appropriate tools in this regard. These make sense for the following reasons, which can be explained:

1. It can evaluate portfolios based on various criteria;
2. It is capable of accounting for the interrelationships between the DM criteria;
3. It can use language to convey the decisions made by decision-makers.

Based on these thoughts, we defined the study's research question as follows: Can IVFFS approaches with financial indicators assist in choosing an investment portfolio that outperforms the market benchmark?

Originality

A method called MADM is used to prioritize the problem of portfolio selection. This work's fuzzy methodology catches the false information that separates decision-makers' assessments. Portfolio selection has been extensively studied in various domains, including machine learning, artificial intelligence, and traditional and quantitative finance. The general aim of portfolio selection is to devote money to a group of assets to achieve specific long-term goals. As with other investment consulting problems, portfolio selection is affected by many direct and indirect factors. In this sense, academics, managers, investors, and practitioners have faced challenges in identifying, evaluating, and choosing criteria for assessing and choosing portfolios. This study's numerical application intends to create a portfolio selection model to assist account holders who intend to make the correct decisions and demonstrate the model's uses in financial markets. According to the IVFF-AHP process, a method has been proposed for MADM to provide planners with more reliable options. Because of its pliable build, the proposed approach is a valuable instrument that may be implemented for various complex decision problems with several competing criteria. Using MD and ND, FFSs, as opposed to IFS and PFS, more effectively convey the ambiguity of inaccurate information. The expert team is expected to assess the needs and weigh possible options regarding the requirements. Based on experts' opinions, the IVFF-AHP was used to calculate the weights of the evaluation criteria.

Calculating statistical parameters requires much data, which is a drawback of portfolio models. However, non-statistical methods have been devised as time series data might not be available for some new financial products, like stocks. Numerous studies in the literature have used data-based methodologies, including experimental research, genetic algorithms, artificial neural networks, and stochastic programming. Even though the studies only require a modest quantity of quantitative data, data are necessary to create models and determine the best portfolio among the preferences in the aforementioned ways. As a result, this study

introduced and employed qualitative data from experts or decision-makers to identify the best possible portfolio.

Research Gap

Professionals assess several investment options based on various criteria, which can be regarded as a MADM issue when evaluating investment portfolio selection. It is crucial to employ several techniques and choose the most effective outcome to overcome the challenges posed by the evaluation environment's complexity and ambiguity, professional psychological conduct, and cognitive uncertainty. The model developed using AHP based on IVFHFS is anticipated to have less uncertainty.

Contribution

This paper presents an MADM model consisting of an AHP based on IVFFSs. The new methodology selects the best options to include in an investment portfolio by evaluating alternatives based on several financial variables. A methodology based on IVFHFSs has been devised to rank the options for investment portfolio selection according to the research's methodological part. A MADM problem has been examined in the selection problem. Furthermore, comparative analyses were performed to confirm the veracity of the recommended options and methodology.

This article's primary goals are to:

- Create a new MADM method in an IVFHF environment;
- Use the AHP technique according to the IVFHFS framework in the new technique;
- Apply the proposed approach to study investment portfolio selection;
- Test the effectiveness and benefit of the new model through a comparative analysis.
- The superiority of the model and its implications for investment portfolio selection are given.

Literature

Every day, increasingly money is put into mutual funds. According to contemporary portfolio theory, the goal of the approach is to build a portfolio that maximises expected return given a specific amount of market risk and minimises risk for risk-averse investors given a specified level of expected return. Markowitz (1952) completed this ground-breaking research. Markowitz (1959) conducted a second excellent portfolio selection study, employing a two-stage method. Goldfarb and Iyengar (2003) developed a robust portfolio selection method to fully combat the optimal portfolio's susceptibility to statistical and modelling errors in anticipating relevant market factors.

Making a selection becomes more challenging when choosing an asset because it requires carefully analysing several factors. Therefore, some academics have chosen assets for investment using a range of MADM strategies. Joshi and Kumar (2014) and Vetschera and De Almeida (2012) introduced the PROMETHEE and TOPSIS techniques in the portfolio selection process. Biswas et al. (2019) used the Data Envelopment Analysis technique to select relatively superior portfolios from a portfolio collection. Ultimately, the portfolios were sorted by five-year annualised return, net asset value, information ratio, beta, R-squared, Jensen's alpha, Sharpe ratio, and Sortino ratio. In this case, the MABAC approach was used. When choosing portfolios for DM, several research papers (Karmakar, Dutta & Biswas, 2018; Ogryczak, 2000; Ronyastra, Gunatra & Ciptomulyono, 2015) employed a multi-criteria method. The capacity to consider various elements and options leads to the adoption of MADM methods in portfolio selection. The hybrid strategy that uses

the ELECTRE method of building a course portfolio was created by (de Araujo Costa et al., 2022; Mellem et al., 2022). The fuzzy-AHP technique (Gupta et al., 2014) has been applied to derive each asset's ethical performance score based on investor preferences. Based on investor ratings of the financial criteria, a fuzzy multi-criteria DM algorithm was used to determine each asset's financial quality score.

An MD's ambiguity and vagueness were shown using the idea of a fuzzy set(FS), as put out by Zadeh (1965). By associating an element's membership degree (ND) with an item, Atanassov's (1986) intuitionistic FS (IFS) provides a more comprehensive explanation of the assessment data. Yager (2013) introduced the Pythagorean FS(PFS) concept to extend the range of MD and ND such that $MD^2 + ND^2 \leq 1$, considering the IFS weakness previously discussed. Therefore, PFS offers professionals more evaluation opportunities to express their opinions on various objectives. The complexity of the DM framework increases the difficulties specialists have in providing reliable evaluation data. By including the cubic total of MD and ND, the Fermatean FS(FFS) was the first to broaden the reach of information statements. As a result, FFS handles ambiguous choice problems more effectively and practically than IFS and PFS. According to Senepati and Yager (2020), the FFS was developed. Owing to its benefits in clarifying information and offering professionals more options, scholars have pushed for the development of numerous DM systems to address real-world DM and assessment issues. Research on FS, IFS, and PFS is extensive and includes studies (Akram & Naz, 2018; Akram, Shareef & Al-Kenani, 2024; Garg, 2019; Garg, Majumder & Nath, 2022; Garg et al. 2024; Kirisci, 2019; Kirisci 2020; Yager & Abbasov, 2013). Studies on FFS took their place in the literature in a short time(Akram et al., 2022; Kirisci, 2022a, 2022b, 2023, 2024a, 2024b; Senapati & Yager, 2019a, 2019b, 2020; Simsek & Kirisci, 2023).

Preliminaries

The IVFFS is a mathematical framework used in DM and modelling scenarios that involve uncertainty and imprecision. The IVFFS extends traditional FSs by incorporating an additional layer of flexibility and expressiveness, particularly in cases where precise MDs are difficult to assign. It is beneficial in the following instances: IVFFS is often applied in MCDM problems with imprecise or uncertain decision criteria. It helps handle subjective judgments by representing MD and ND as intervals. IVFFS provides a framework to model and reason with interval-valued MD and ND when dealing with datasets with inherent uncertainty or incomplete information. IVFFS is suitable for systems that rely on human input, such as expert systems or human-centric decision models. Humans often provide uncertain or interval-based assessments rather than precise values. In situations involving multiple stakeholders or experts, IVFFS can aggregate diverse opinions by considering interval-valued degrees of agreement and disagreement. IVFFS can model systems with ambiguous or vague operational parameters, such as robotics or process control. IVFFS is used in applications requiring robust handling of ambiguous or overlapping patterns, such as image processing or data clustering. IVFFS supports DM in sustainability and environmental management, where data uncertainty is prevalent.

The reasons for choosing IVFFS over other fuzzy models can be summarised as follows: IVFFS provides a more flexible structure by allowing MD, ND, and hesitation degrees to be expressed as intervals. Better suited for cases where precise values for membership are unavailable. It is useful in real-world problems where uncertainty is an intrinsic characteristic. When decision-makers have incomplete information or doubt the accuracy of information from different sources, IVFFS provides a more flexible model. It is especially preferred when the uncertainty in the evaluations of experts needs to be expressed in intervals. IVFFS offers a more flexible representation for each criterion when many criteria need to be evaluated. Working with interval values produces more realistic results when human judgments or preferences are uncertain. If

information is uncertain due to the time-varying nature of a particular system, intervals can better reflect the variable conditions. IVFFS is used in fuzzy logic-based artificial intelligence systems, intensive learning, or data analysis processes to model uncertain data. In systems that work with incomplete data, uncertainty can be expressed with interval values. IVFFS applies when uncertainties need to be expressed comprehensively in project management, financial analysis, or security risk assessment.

By combining the advantages of FFSs (which allow more extensive ranges for MD and ND than IFSs) and interval-valued representations, IVFFS provides a robust mathematical framework for dealing with complex uncertainty. This method allows DEs to express and cope with uncertainties in the broader spectrum, thus enabling more robust and reliable decisions.

Let X be a non-empty set.

The set

$$A = \{(x, \zeta_A(x), \eta_A(x)) : x \in X\} \tag{1}$$

Is called an IFS, where the functions $\zeta_A, \eta_A : X \to [0,1]$ define the MD and ND of an element to the sets A. ($0 \leq \zeta_A(x) + \eta_A(x) \leq 1$, for $\forall x \in X$).

The hesitancy degree $\theta_A(x) = 1 - \zeta_A(x) - \eta_A(x)$.

The set

$$B = \{(x, \zeta_B(x), \eta_B(x)) : x \in X\} \tag{2}$$

Is called a PFS, where the functions $\zeta_B, \eta_B : X \to [0,1]$ defined the MD and ND of an element to the sets B ($0 \leq \zeta_B^2(x) + \eta_B^2(x) \leq 1$, for $\forall x \in X$).

The hesitancy degree $\theta_B(x) = \sqrt{1 - (\zeta_B^2(x) + \eta_B^2(x))}$.

The set

$$C = \{(x, \zeta_C(x), \eta_C(x)) : x \in X\} \tag{3}$$

Is called FFS, where the functions $\zeta_C, \eta_C : X \to [0,1]$ defined the MD and ND of an element to the sets C ($0 \leq \zeta_C^3(x) + \eta_C^3(x) \leq 1$, for $\forall x \in X$).

The hesitancy degree $\theta_C(x) = \sqrt[3]{1 - (\zeta_C^3(x) + \eta_C^3(x))}$.

The set

$$D = \{(x, \zeta_D(x), \eta_D(x)) : x \in X\} \tag{4}$$

Is called IVFFS, where the functions $\zeta_D, \eta_D \subseteq [0,1]$ define the MD and ND of an element to the sets D.

For each $x \in X, \zeta_D(x)$ and $\eta_D(x)$ are closed intervals, and their lower and upper bounds are denoted by $\zeta_D^L(x), \zeta_D^U(x), \eta_D^L(x), \eta_D^U(x)$, respectively. Therefore, D can also be expressed as follows:

$$\zeta_D(x) = \left[\zeta_D^L(x), \zeta_D^U(x)\right] \subseteq [0,1]; \eta_D(x) = \left[\eta_D^L(x), \eta_D^U(x)\right] \subseteq [0,1] \tag{5}$$

where the expression is subject to the condition $0 \leq \left(\zeta_D^U(x)\right)^3 + \left(\eta_D^U(x)\right)^3 \leq 1$.

For each $x \in X$, $\theta_D(x) = \left[\theta_D^L(x), \theta_D^U(x)\right]$ is called the hesitancy degree in IVFFSs, where

$$\theta_D^L(x) = \sqrt[3]{1 - \left[\left(\zeta_D^L(x)\right)^3 + \left(\eta_D^L(x)\right)^3\right]}; \theta_D^U(x) = \sqrt[3]{1 - \left[\left(\zeta_D^U(x)\right)^3 + \left(\eta_D^U(x)\right)^3\right]}. \tag{6}$$

Consider the three IVFFNs $D = \left(\left[\zeta_D^L(x), \zeta_D^U(x)\right], \left[\eta_D^L(x), \eta_D^U(x)\right]\right)$, $D_1 = \left(\left[\zeta_{D_1}^L(x), \zeta_{D_1}^U(x)\right], \left[\eta_{D_1}^L(x), \eta_{D_2}^U(x)\right]\right)$, $D_2 = \left(\left[\zeta_{D_2}^L(x), \zeta_{D_2}^U(x)\right], \left[\eta_{D_2}^L(x), \eta_{D_2}^U(x)\right]\right)$. Then,

$$D_1 \boxplus D_2 = \left(\begin{bmatrix} \sqrt[3]{\left(\zeta_{D_1}^L\right)^3 + \left(\zeta_{D_2}^L\right)^3 - \left(\zeta_{D_1}^L\right)^3 . \left(\zeta_{D_2}^L\right)^3} \\ \sqrt[3]{\left(\zeta_{D_1}^U\right)^3 + \left(\zeta_{D_2}^U\right)^3 - \left(\zeta_{D_1}^U\right)^3 . \left(\zeta_{D_2}^U\right)^3} \end{bmatrix}, \left[\eta_{D_1}^L . \eta_{D_2}^l, \eta_{D_1}^u . \eta_{D_2}^U\right] \right), \tag{7}$$

$$D_1 \boxtimes D_2 = \left(\left[\zeta_{D_1}^L . \zeta_{D_2}^l, \zeta_{D_1}^u . \zeta_{D_2}^U\right], \begin{bmatrix} \sqrt[3]{\left(\eta_{D_1}^L\right)^3 + \left(\eta_{D_2}^L\right)^3 - \left(\eta_{D_1}^L\right)^3 . \left(\eta_{D_2}^L\right)^3} \\ \sqrt[3]{\left(\eta_{D_1}^U\right)^3 + \left(\eta_{D_2}^U\right)^3 - \left(\eta_{D_1}^U\right)^3 . \left(\eta_{D_2}^U\right)^3} \end{bmatrix}, \right), \tag{8}$$

$$\lambda D = \left(\left[\sqrt[3]{1 - \left(1 - \left(\zeta_D^L\right)^3\right)^\lambda}, \sqrt[3]{1 - \left(1 - \left(\zeta_D^U\right)^3\right)^\lambda} \right], \left[\left(\eta_D^L\right)^\lambda, \left(\eta_D^U\right)^\lambda\right] \right), \tag{9}$$

$$D^\lambda = \left(\left[\left(\zeta_D^L\right)^\lambda, \left(\zeta_D^U\right)^\lambda\right], \left[\sqrt[3]{1 - \left(1 - \left(\eta_D^L\right)^3\right)^\lambda}, \sqrt[3]{1 - \left(1 - \left(\eta_D^U\right)^3\right)^\lambda} \right] \right). \tag{10}$$

The IVFF weighted average operator is a mapping $IVFFWA : D^n \to D$, where

$$IVFFWA(D_1, D_2, ..., D_n) = (\left[\sqrt[3]{\left(1 - \prod_{i=1}^{n} \left(1 - \left(\zeta_{D_i}^L\right)^3\right)^{\omega_i}\right)}, \sqrt[3]{\left(1 - \prod_{i=1}^{n} \left(1 - \left(\zeta_{D_i}^U\right)^3\right)^{\omega_i}\right)} \right] \tag{11}$$

$$\left[\prod_{i=1}^{n} \left(\eta_{D_i}^L\right)^{\omega_i}, \prod_{i=1}^{n} \left(\eta_{D_i}^U\right)^{\omega_i} \right]). \tag{12}$$

The IVFF-weighted geometric operator is a mapping $IVFFWG : D^n \to D$, where

$$IVFFWG(D_1, D_2, ..., D_n) = (\left[\prod_{i=1}^{n} \left(\zeta_{D_i}^L\right)^{\omega_i}, \prod_{i=1}^{n} \left(\zeta_{D_i}^U\right)^{\omega_i} \right] \tag{13}$$

$$\left[\sqrt[3]{\left(1 - \prod_{i=1}^{n} \left(1 - \left(\eta_{D_i}^L\right)^3\right)^{\omega_i}\right)}, \sqrt[3]{\left(1 - \prod_{i=1}^{n} \left(1 - \left(\eta_{D_i}^U\right)^3\right)^{\omega_i}\right)} \right]). \tag{14}$$

Portfolio Selection

Let ω_j be the vector set that is used to specify the criterion's weights. The linguistic terms and their corresponding IVFF values are shown in Table 1.

Method

Establish the problem's objective, decision-making alternatives, and available options. The linguistic terms and their related interval-valued fuzzy numbers are shown in Table 2.

The consistency ratio is defined as

$$CRT = \frac{CIX}{RIX} \tag{15}$$

where $CIX = \frac{\delta_{\max}}{n-1}$, RIX is the consistency index and $\delta_{\max}$ is the random index and principal eigenvalue for CRT, respectively.

Step 1: Establish the criteria and options before building the hierarchical structure.

Step 2: According to the expert judgments in Table 2, create the pairwise comparison matrix $Z = \left(z_{ij}\right)_{m \times m}$. For $z_{ij} = \left(\left[\zeta_{ij}^L, \zeta_{ij}^U\right], \left[\eta_{ij}^L, \eta_{ij}^U\right]\right)$,

$$Z = \begin{bmatrix} z_{11} z_{12} z_{21} & z_{22} & \cdots z_{1m} \cdots & z_{2m} \\ \vdots\vdots z_{m1} & z_{m2} & \ddots\vdots\cdots & z_{mm} \end{bmatrix} \tag{16}$$

Table 1

Linguistic terms and IVFFN values

Linguistic Terms	IVFFN values			
	m_L	m_U	n_L	n_U
Certainly High Importance(CH)	0.95	1	0	0
Very High Importance(VH)	0.8	0.9	0.1	0.2
High Importance(H)	0.7	0.8	0.2	0.3
Slightly More Importance(SM)	0.6	0.65	0.35	0.4
Equally Importance(EI)	0.5	0.5	0.5	0.5
Slightly Less Importance(SL)	0.35	0.4	0.6	0.65
Low Importance(L)	0.2	0.3	0.7	0.8
Very Low Importance(VL)	0.1	0.2	0.8	0.9
Certainly Low Importance(CL)	0	0	0.95	1

Step 3: Verify each pairwise comparison matrix's (Z) correctness. Here, we compare the sharp numbers acquired after defuzzifying to the IVFFNs listed in Table 2 using Saaty's scale to gauge the consistency of expert opinions. After that, Saaty's method for classical consistency is used.

Step 4: Aggregate the judgments of experts.

The pairwise comparison matrix created by each expert is aggregated using the IVFFWG aggregation algorithm.

$$IVFFWG(z_1, z_2, ..., z_k) = \left(\left[\prod_{k=1}^{K} \left(\zeta_k^L\right)^{\omega_k}, \prod_{k=1}^{K} \left(\zeta_k^U\right)^{\omega_k} \right] , \right. \tag{17}$$

$$\left. \left[\sqrt[3]{\left(1 - \prod_{k=1}^{K} \left(1 - \left(\eta_k^L\right)^3 \right)^{\omega_k} \right)}, \sqrt[3]{\left(1 - \prod_{k=1}^{K} \left(1 - \left(\eta_k^U\right)^3 \right)^{\omega_k} \right)} \right] \right). \qquad (2) \tag{18}$$

Step 5: Using Equations (3) and (4), obtain the difference matrix $D = \left(d_{ij}\right)_{m \times m}$ between the lower and upper points of the MD and ND.

$$d_{ij}^L = \left(\zeta_{ij}^L\right)^3 - \left(\eta_{ij}^U\right)^3 \qquad (3) \tag{19}$$

$$d_{ij}^L = \left(\zeta_{ij}^U\right)^3 - \left(\eta_{ij}^L\right)^3 \qquad (4) \tag{20}$$

Step 6: Using Equations (5) and (6), compute the interval multiplicative matrix $S = \left(s_{ij}\right)_{m \times m}$.

$$s_{ij}^L = \sqrt[3]{1000^{d_{ij}^L}} \qquad (5) \tag{21}$$

$$s_{ij}^U = \sqrt[3]{1000^{d_{ij}^U}} \qquad (6) \tag{22}$$

Step 7: Find the indeterminacy value $T = \left(t_{ij}\right)_{m \times m}$ of z_{ij} using Equation (7).

$$t_{ij} = 1 - \left(\zeta_{ijU}^3 - \zeta_{ijL}^3\right) - \left(\eta_{ijU}^3 - \eta_{ijL}^3\right) \qquad (7) \tag{23}$$

Step 8: Equation (8) can produce the matrix of un-normalised weights $R = (r_{ij})_{m \times m}$ by multiplying the indeterminacy degrees by the $S = (s_{ij})_{m \times m}$ matrix.

$$r_{ij} = \left(\frac{s_{ij}^{L} + s_{ij}^{U}}{2} \right) t_{ij} \qquad (8) \qquad (24)$$

Step 9: Equation (9), when applied, yields the normalised priority weights ω_i.

$$\omega_i = \frac{\sum_{j=1}^{m} r_{ij}}{\sum_{i=1}^{m} \sum_{j=1}^{m} r_{ij}} \qquad (9) \qquad (25)$$

Step 10: Rank the options according to the normalised priority weights you acquired in Step 9.

Algorithm

Algorithm 1 IVFF-AHP

Input: Number of evaluation criteria and pairwise comparison matrices.

Output: Normalised priority weights.

Begin

For j=1; m **do**

1. Input: Pairwise comparison matrix using the Table 1.
2. Convert the linguistic terms into the corresponding IVFFNs.
3. Check the consistency analysis

   For all Z **do**

   CRT using Equation 1.

   End for

4. **If** CRT>0.1

   Return to Step 1.

   Else

   Go to Step 5.

   End if

5. Compute the IVFFWG using Equation 2.

End for

6. Calculate the difference matrix using Equations 3 and 4.
7. Compute the multiplicative matrix using Equations 5,6.
8. Using Equation 7, determine the cij's indeterminacy value.
9. Equation 8 can be used to obtain the un-normalised weight matrix.
10. Determine the normalised priority weights using Equation 9.

11. Rank the options according to the normalised priority weights.

End

The flowchart of Algorithm 1 is given in Figure 1.

Problem Design

Due to the abundance of investment possibilities and the different elements that impact the market, including news, political unpredictability, and economic events, investors are concerned about portfolio optimisation and selection (Wang et al., 2011). Many studies have used various criteria to compile and choose investments because there are many things to consider when establishing an investment portfolio.

A mind map has been developed according to the research to aid in understanding the aspects involved in choosing an investment (Moccellin et al., 2021; Wu et al., 2022). This tool aids in visually organising criteria and problem structure (Hassan & Banerjee, 2021). The variables that affect investment choice are volatility(A), profitability(B), valuation(C), and liquidity(D). These divisions are displayed in Figure 2. Figure 2 evaluates the asset based on fundamental indicators, which evaluate the enterprise's fundamentals by examining the performance of the business and the macroeconomic environment in which the asset is situated (Trzebinski & Majerowska, 2019). This is based on studies (Moccellin et al., 2021; Wu et al., 2022). Volatility, the degree and frequency of value changes in a particular asset over time, is another subject covered in the mind map (De Blassis, 2023). In addition to the criteria, the variety of investment possibilities is a consideration that should be emphasised while choosing a portfolio.

In addition to the criteria, the variety of investment possibilities is a consideration that should be emphasised while choosing a portfolio. Companies listed in the S&P 500 were considered for the study. After 68 S&P 500 businesses had their data removed due to anomalies, 432 companies were evaluated. A 36-month observation period was obtained by collecting data from the S&P 500 website between January 1, 2021, and January 1, 2024.

Criteria: A_{11}, Return Variation, A_{12} – Market Uncertainties; B_{11} – Dividend Yield, B_{12} – Return; C_{11} – Indepedness, C_{12} – Ebitda; D_{11}, Current Liquidity, D_{12} – General Liquidity.

These criteria are determined as cost/benefit as follows: EBITDA and volatility return are costs, and the other criteria are benefits.

MADM is a process that builds and addresses judgmental and planning issues, determines the most practical choice based on expert opinions, and preserves given attributes. Professionals usually base their conclusions on various study approaches and theoretical frameworks based on their knowledge of these scenarios. For this reason, MADM is essential to achieving the highest quality model with the highest level of professional agreement. Here, we propose a new MADM method that the IVFFSs have developed.

Figure 1
Flowchart

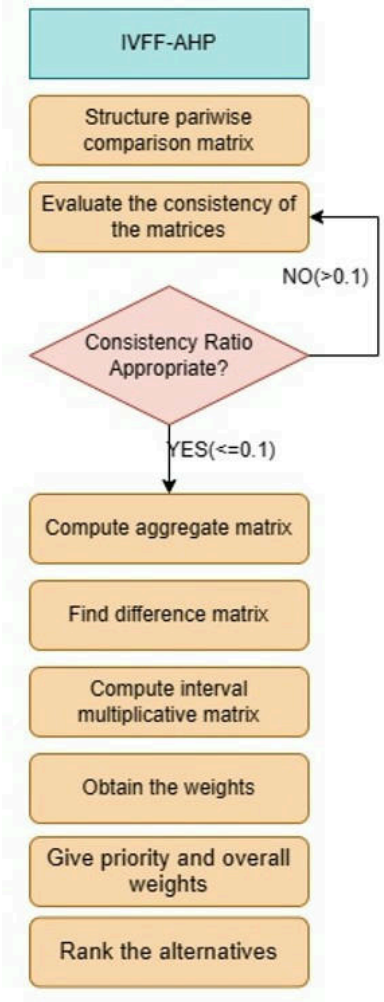

Figure 2
Hierarchy Trees of Portfolio Selection

Computations

Three experts developed paired comparison matrices to evaluate these options and criteria using the language concepts listed in Table 1. The pairwise comparison matrices of language terms for the primary criteria, secondary criteria, and alternates are displayed together with the consistency ratio in Tables 1-6. The consistency ratios of the paired comparison matrices were computed using the linguistic scale and the related numerical values listed in Table 1. The subsequent phases of the created technique are displayed on the significant criterion due to space limitations. Matrix conversion to IVFFNs using the appropriate scale is followed by the IVFFWG operator, which aggregates each expert's opinion according to the linguistic terms in the pairwise comparison. Table 7 displays the total IVFF results for the main criteria. Next, the IVFF-AHP was used to determine the criterion weights and alternatives. Equations (3) and (4) were used to determine the lower and upper values of the MD and ND. The difference matrix between these values is shown in Table 8. To compute the interval multiplicative matrix in Table 9, apply equations (5) and (6). Equation (7) uses the indeterminacy values given by Equation (8) to produce the matrix of weights before normalisation, as shown in Table 10. The final overall criteria weights are shown in Table 11.

Table 2

Pairwise comparison matrix of the main criteria

	Expert1				Expert2				Expert3			
	A	**B**	**C**	**D**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
A	EI	VH	H	H	EI	H	H	H	EI	VH	VH	VH
B	SL	EI	VH	VH	EI	EI	VH	CH	SL	EI	VH	VH
C	SM	H	EI	H	H	H	EI	VH	SM	SM	EI	H
D	SL	SM	H	EI	SM	H	VH	EI	EI	H	H	EI
CRT	0.035				0.008				0.053			

Table 3

Pairwise comparison matrix of Volatility

	Expert1		Expert2		Expert3	
	$\mathbf{A_{11}}$	$\mathbf{A_{12}}$	$\mathbf{A_{11}}$	$\mathbf{A_{12}}$	$\mathbf{A_{11}}$	$\mathbf{A_{12}}$
$\mathbf{A_{11}}$	EI	SL	EI	L	EI	L
$\mathbf{A_{12}}$	VH	EI	CH	EI	VH	EI
CRT	0.094		0.047		0.049	

Table 4

Pairwise comparison matrix of Profitability

	Expert1		Expert2		Expert3	
	$\mathbf{B_{11}}$	$\mathbf{B_{12}}$	$\mathbf{B_{11}}$	$\mathbf{B_{12}}$	$\mathbf{B_{11}}$	$\mathbf{B_{12}}$
$\mathbf{B_{11}}$	EI	SM	EI	SL	EI	EI
$\mathbf{B_{12}}$	VH	EI	CH	EI	VH	EI
CRT	0.061		0.085		0.39	

Table 5

Pairwise comparison matrix of the valuation

	Expert1		Expert2		Expert3	
	C_{11}	C_{12}	C_{11}	C_{12}	C_{11}	C_{12}
C_{11}	EI	L	EI	SL	EI	SL
C_{12}	H	EI	VH	EI	VH	EI
CRT	0.058		0.042		0.06	

Table 6

Pairwise comparison matrix of the liquidity

	Expert1		Expert2		Expert3	
	D_{11}	D_{12}	D_{11}	D_{12}	D_{11}	D_{12}
D_{11}	EI	H	EI	VH	EI	H
D_{12}	CH	EI	CH	EI	VH	EI
CRT	0.077		0.073		0.088	

Table 7

Aggregated IVFFSs for the main criteria

	A	B	C	D
A	([0.50, 0.50], [0.50,0.50])	([0.21, 0.13], [0.92,0.90])	([0.86, 0.79], [0.22,0.27])	([0.16, 0.19], [0.88,0.85])
B	([0.18, 0.26], [0.89,0.77])	([0.50, 0.50], [0.50,0.5]0)	([0.75, 0.72], [0.38,0.35])	([0.84, 0.80], [0.35,0.30])
C	([0.75, 0.71], [0.32,0.29])	([0.54, 0.48], [0.60,0.63])	([0.50, 0.50], [0.50,0.50])	([0.91, 0.79], [0.22,0.27])
D	([0.82, 0.78], [0.33,0.30])	([0.42, 0.37], [0.65,0.72])	([0.89, 0.83], [0.13,0.24])	([0.50, 0.50], [0.50,0.50])

Table 8

Difference matrix

	A	B	C	D
A	(0.00, 0.00)	(-0.72, -0.78)	(0.62, 0.48)	(-0.61, -0.67)
B	(-0.45, -0.69)	(0.00, 0.00)	(0.38, 0.32)	(0.57, 0.47)
C	(0.40, 0.33)	(-0.10, -0.11)	(0.00, 0.00)	(0.73, 0.48)
D	(0.52, 0.44)	(-0.30, -0.22)	(0.70, 0.57)	(0.00, 0.00)

Table 9

Interval multiplicative matrix

	A	B	C	D
A	(1.00, 1.00)	(0.20, 0.17)	(4.17, 3.02)	(0.25, 0.21)
B	(0.35, 0.20)	(1.00, 1.00)	(2.40, 2.09)	(3.72, 2.95)
C	(2.51, 2.14)	(0.80, 0.78)	(1.00, 1.00)	(5.37, 3.02)
D	(3.31, 0.75)	(0.50, 0.60)	(5.01, 3.72)	(1.00, 1.00)

Table 10
Weights

	A	B	C	D
A	1.0	1.96	1.94	9.32
B	0.52	1.0	1.94	9.32
C	0.52	0.52	1.0	4.55
D	0.09	0.09	0.22	1.0

Table 11
Priority and overall weights

Main Criteria	**A**		**B**		**C**		**D**	
Weights	0.24		0.27		0.23		0.26	
Sub-criteria	A_{11}	A_{12}	B_{11}	B_{12}	C_{11}	C_{12}	D_{11}	D_{12}
Weihgts	0.34	0.13	0.25	0.1	0.33	0.18	0.29	0.36
Overall	0.09	0.12	0.11	0.15	0.09	0.18	0.16	0.1

Equation 8 was utilised to determine the weights, which are displayed in Table 10, before normalisation. Following the application of the results of all these computations to the sub-criteria, Table 11 displays the ultimate priority weights for the primary and secondary criteria. With a weight of 0.27, the results show that "profitability" needs are the most crucial. With a weight of 0.23, "valuation" is the least significant.

Discussion

Portfolio selection is the assembly of an investment portfolio that maximises a shareholder's expected return while minimising risk. The aim of portfolio selection is to find the asset combination that will provide the maximum return at a given risk level or the lowest risk, given the desired rate of return. Selecting a portfolio is complex and requires a deep understanding of financial markets, risk management strategies, and investment techniques. Many investors seek the assistance of certified financial counsellors or portfolio managers to guide them through the process. The process of selecting the optimal portfolio involves several steps:

Establish investment goals: The investor's financial objectives, investment horizon, and risk tolerance are ascertained in the first step.

Identify asset allocation: Asset allocation is the process of dividing an investment portfolio among several asset classes, such as stocks, bonds, and cash. The ideal asset allocation depends on the investor's financial goals, risk tolerance, and market conditions.

Choose individual investments: The next step in each asset class is to choose individual assets. Examining the characteristics of certain assets, such as their volatility, correlation with other investments, and past returns, is necessary to achieve this.

Portfolio optimisation: After the individual assets have been chosen, the portfolio needs to be adjusted by changing the weights of each investment to achieve the desired risk and return profile. Quantitative methods such as current portfolio theory or mean-variance optimisation can accomplish this.

Last, the portfolio should be periodically evaluated and rebalanced as needed to preserve the desired asset allocation and risk profile.

Developing a long-term investment strategy is one of the most important and challenging tasks that will enable you to invest with confidence. Investment planning does not have to be difficult.

The more stocks available for investment, the more difficult and computationally complex portfolio optimisation becomes. With expert judgments and MADM, the proposed study aims to give investors the best possible outcome when choosing an investment portfolio. Effective roles are chosen from the literature, and the reality of the criteria is considered when making the decision. Taking into account the previously described processes yields the selected result.

Comparison

The data from the example presented in sub-sections 4.3 and 4.4 will be analysed using the techniques found in studies in (Atanassov, & Gargov, 1989) and (Liang, Zhang, & Liu, 2015).

The IFS is generalised in the spirit of regular IVFSs. The IVIFS is the name of the novel idea. IVIFSs (Atanassov, & Gargov, 1989) are a fascinating and valuable tool for problem modelling in practical applications. In artificial intelligence, socioeconomic systems, data analysis, and decision-making, ranking IVIFSs is essential.

In parallel with Atanassov's IVIFS, Liang et al. (2015) created IVPFS, a new extension of PFS, to handle imprecise and uncertain information in real-world group decision-making issues. A novel DM technique based on IVPFNs is presented in this paper to solve MCGDM issues in an IVPF setting.

According to the ranking alternatives in Table 12, B is the most suitable alternative.

Table 12

Ranking of the alternatives

Method	Ranking
IVIFS (Atanassov, & Gargov, 1989)	B > C > D > A
IVPFS (Liang, Zhang, & Liu, 2015)	B > D > C > A
Our Methods	B > D > A > C

Advantages of IVFFSs and Decision-Making Aprroach

The FFS extends the traditional set, which consists of the FS, IFS, and PFS. The degree of satisfaction that members and nonmembers have with the criteria when their total squares are ≤1 distinguishes PFS, one of the most popular extensions. To ensure that the sum of the squares is more than 1, the decision-maker may occasionally provide the MD and ND of a particular characteristic. As a result, the PFS needs to manage this situation more expertly. The FFS theory seeks to address this issue. It is among the most thorough theories that can handle inconsistent, ambiguous, and incomplete information—all commonly encountered in real-world scenarios. Therefore, the Fermatean fuzzy information is more appropriate for DM in fundamental scientific and technical implementations.

Unlike classical fuzzy sets or traditional FFSs, IVFFSs represent MD, ND, and hesitation degrees as intervals rather than precise numbers. This provides a richer and more flexible way to capture uncertainty. The FF framework allows membership and non-membership values whose cubes sum to at most 1, generalising IFSs and PFSs. Using intervals for these values further enhances this expressiveness, accommodating a wider range of uncertainty. By modelling the hesitation degree (the uncertainty between membership and non-membership) as an interval, IVFFSs provide more nuanced, valuable information in real-world

scenarios where exact hesitation is challenging to pinpoint. The additional flexibility and expressiveness help DM models better capture experts' opinions, incomplete information, or ambiguous data, leading to more reliable and robust decisions. The additional flexibility and expressiveness help DM models better capture experts' opinions, incomplete information, or ambiguous data, leading to more reliable and robust decisions. IVFFSs generalise many existing fuzzy sets models, such as IFSs, PFSs, and FFSs, making them versatile for various applications.

IVFFSs offer a powerful and flexible tool to model uncertainty with intervals on membership, non-membership, and hesitation degrees under the FF framework, which enhances the modelling capacity and accuracy in fuzzy-based decision-making and information processing.

Limitations

The portfolio selection problem, which aims to distribute capital among financial assets most effectively to maximise return and minimise risk, is one of the fundamental problems in finance. The accuracy and dependability of the data used to create asset allocation is the most significant limitation when selecting a portfolio. Although mean-variance optimisation models use long-term capital market assumptions, there is no guarantee that returns, risks, and correlations will remain stable over the long term. Transaction fees may be incurred when different assets in the portfolio are purchased and sold often. These transaction costs comprise commissions, brokerage fees, and charges associated with trading shares. These costs can lower your investment returns and decrease the profitability of your portfolio. When choosing a portfolio, this scenario could produce deceptive outcomes. In addition, among the constraints that arise when deciding on portfolio selection are:

- High fees and costs.
- The difficulty of consistently outperforming the market.
- An increased risk of underperformance.

These portfolio selection criteria may impact the overall investment returns. Therefore, before choosing a portfolio, carefully considering fees and possible returns is crucial.

Potential challenges in choosing a portfolio at the decision point: The challenge of balancing the chosen portfolio in terms of crucial factors like risk and completion time, the existence of multiple and frequently conflicting goals, some of which may be qualitative, uncertainty, and risk, the possibility of interdependencies among assets, and the number of applicable portfolios can all influence decisions. In addition to these difficulties, resource restrictions frequently necessitate considering limitations such as money, personnel, and facilities or equipment. Resource limitations are not usually included correctly in the portfolio selection process, which is the primary cause of some portfolios being chosen but not yet finished. When resource constraints are erroneous in a portfolio decision that fails, a choice model that considers resource limitations can help the decision-maker steer clear of such mistakes. When resource supply and consumption diverge, portfolio DM may become more complicated.

One drawback of this model is that most research has shown that securities yields do not always follow the normal distribution. However, the method is challenging to compute, particularly for the multiple-project portfolio problem. This computation is much more intricate.

Despite being a specific type of uncertainty avoidance, risk aversion is typically required because it can be challenging to determine the exact probabilities of a theoretical, time-consuming, multi-variable task

such as optimal portfolio selection. This study still has several problems. First, risk and uncertainty are not the same thing. The impacts of risk choice, rather than uncertainty preference, are the main emphasis of this study. One strategy for avoiding uncertainty is risk aversion. This is even more important because it might be challenging to determine the exact likelihood of real-world problems. Beyond the benefits of the proposed IVFFS-based method, its incapacity to generate a thorough assessment of the available options restricts its application in particular DM circumstances.

Furthermore, when there are several criteria and possibilities, developing IVFFSs might become difficult. By contrasting it with other approaches, the study's DM algorithm's superiority is illustrated, and its benefits are articulated. Risk preference was operationalised in this study. However, more thorough analysis techniques must be developed to estimate the likelihood of dangerous features when choosing an investment portfolio.

Implications

Researchers have made several changes to Markowitz's classical framework to improve its practical applicability after seeing how poorly it reflects the dynamics in the actual world. Various approaches have been put out to deal with the problem, particularly regarding decision-making methods. The study's findings demonstrate that an investor's portfolio that receives decision-making information from a panel of experts under uncertain circumstances can be solved using the proposed fuzzy portfolio model.

The study's conclusions have consequences for managers, decision-makers, and practitioners. Defining the criteria, measuring their significance, putting them into practice using IVFFS, and reviewing the outcomes constitute a methodical process for choosing and evaluating portfolios. Significantly, other real-world issues can also be solved using this idea. Experts in the field, such as managers, investors, and engineers, can select the best industrial stock portfolios using the measurements, methodology, and research framework created for this study. After reviewing the research findings, offering a few theoretical and practical conclusions is acceptable. This study's main academic goal was to illustrate the model-development process for the relationships between DM and project portfolio management. Therefore, more research must concentrate on and look into crucial subjects. From a practical standpoint, it is possible to confirm that the profitability and return on investment transactions were the most critical pieces of information the stakeholders relied on when making decisions during the portfolio management process. The objectives are to reduce the risks of investing alternatives while maintaining an all-encompassing viewpoint when choosing a portfolio and reacting promptly and suitably to possibilities and hazards in the ever-changing market environment. Managing and keeping track of many products on the market makes portfolio DM more difficult. This article's research on the effectiveness of DM in portfolio selection can offer a framework for weighing the advantages and disadvantages of each asset, which can aid in choosing investments. For instance, an autocratic leadership style, an excessive dependence on subjective judgement, and a lack of procedures to provide more evidence-based inputs likely result in poor portfolio decisions. Companies may simultaneously focus on developing a portfolio mindset and balancing their portfolio decision process towards evidence-based DM to increase the efficacy of their portfolio decisions and, ideally, their long-term company performance. This could be achieved by encouraging cross-functional cooperation, encouraging critical thinking exercises, and implementing market immersion tactics. By choosing an appropriate portfolio and promptly removing gains that become marginal due to market fluctuations, agility in DM can help optimise returns. Feedback loops may develop in addition to any interactions between the DM processes. The process has been modelled linearly. Conversely, the DM process for a portfolio is continuous.

Fuzzy MADM techniques are recommended for investors and portfolio managers to handle unclear and ambiguous data effectively. By using these cutting-edge strategies, stakeholders can improve the accuracy and robustness of their portfolio selection procedures while managing risks and uncertainties. Its performance is compared to competing models to ensure that the proposed model is robust. To help the financial sector adopt these innovative methods, policymakers should establish rules and guidelines that support the fuzzy MADM models. Financial institutions may be eligible for incentives and training programs to improve their investment strategies and create a more stable and effective market environment if they integrate sophisticated decision-making tools into their operations. The study's conclusions show that to achieve the most significant result, the investment portfolio's choices must be sensible, reliable, and well-balanced. Since the most significant disadvantage of investing is the inability to choose the best solutions, investors worry about profitability. Investors may consequently grow reluctant to choose a portfolio. These studies' recommendations serve as a guide for scholars and businesses alike. Given the outcomes, prospective investors must be capable of selecting a profitable portfolio, making wise choices, and can turn a profit.

Conclusion

The FS, IFS, and PFS are all generalised into the FFS. One of the most popular FS expansions, PFS, requires that the sum of an object's MD and ND squares must equal or be less than one. In certain instances, the decision-maker may indicate the extent of an MD or MD so that the sum of the squares is more significant than 1. As a result, the PFS mishandles this scenario. Among the most comprehensive theories is FFS. It can handle inconsistent, ambiguous, and fragmentary data often found in real-world environments. The Fermatean fuzzy information DM is more appropriate for respectable applications in science and engineering.

Making decisions concerning real-world problems and producing solutions takes time and effort. Therefore, it is critical to reduce uncertainty when choosing the optimal course of action. Effective management of the relationships between the inputs is also necessary for DM to be most beneficial.

Over the long term, value investments in the stock market yield higher returns than cash deposits. This paper proposes an MDM framework for portfolio selection based on the financial performance of enterprises. The following are the algorithms for the MDM approach employing the AHP methodology and IVFFS. The decision model that had been built was put to the test through portfolio selection. Its efficacy was confirmed using comparative and sensitivity analysis. The model is successful in supporting investment decisions, according to the results.

In future studies, it is necessary to discuss whether it is possible to use different parameters found in the literature and the impact on the results when used. The approach presented in this study can also be extended to additional uncertain fields(linguistic term sets, probabilistic linguistic term sets, etc.) in future research. In addition, this method can be studied together with methods such as TOPSIS and the Chouqet integral.

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Identification of Factors Determining Female's Labour Force Participation in the World: A Factor Analysis Approach

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Abstract The objective of this study is to identify the factors that determine female labour force participation rates in 87 countries across different levels of development, namely developed, developing, and less developed over the period from 2015 to 2019. To achieve this, the study employs exploratory factor analysis to uncover the underlying factors that explain the determinants of female labour force participation. Exploratory factor analysis is a particularly suitable method, given the absence of a comprehensive, established theory in the literature regarding female labour force participation. Furthermore, this study addresses the theoretical gap by utilising a multidimensional dataset, which includes 20 observable variables covering potential determinants such as economic conditions, health, education, technological infrastructure, institutional frameworks, natural resources, and energy consumption. The findings from the exploratory factor analysis reveal several independent factors influencing female's labour force participation, including the level of development of the countries, their reliance on agriculture as a traditional mode of production, their dependence on strategic natural resources, and the extent of renewable energy consumption. The results from the regression analysis using these identified factors as independent variables demonstrate that the level of development and reliance on agriculture as a traditional mode of production have a positive effect on female labour force participation. In contrast, dependence on strategic natural resources is found to have a negative effect. However, the amount of renewable energy consumption did not show a statistically significant impact. These results have important implications for both academics studying gender and labour force dynamics and for policymakers aiming to design effective interventions to increase female labour force participation.

Keywords Female Labour Supply · Female Labour Force Participation · Exploratory Factor Analysis

Jel Codes C18, J21, J78, O3

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Identification of Factors Determining Female's Labour Force Participation in the World: A Factor Analysis Approach

Achieving gender equality and reducing existing social inequalities is a significant issue that necessitates a thorough examination of the factors influencing female participation in the labour force. In this regard, the identification of barriers to female participation in business life and the formulation of policy recommendations to overcome these barriers represent a pivotal step towards sustainable and inclusive development. While the historical background provides an important basis for understanding the roots of gender inequality, in the contemporary era, analysing the effects of this inequality on female's labour force participation and developing solutions has become a major necessity in terms of social justice and sustainable development goals. The disparities experienced by women in economic life have a long-standing history, dating back to the earliest days of human civilisation. With the Neolithic Revolution, sedentary life and agricultural production redefined gender roles and limited women's position in economic life. From this point of view, history began with the deterioration of gender equality to the detriment of women after the Neolithic Revolution. This is the date on which gender inequality began. However, the course of history is moving towards the ideal of a more just world in which women have equal rights with men, after women have become the second sex in almost all areas, including participation in the labour force (De Tocqueville, 2000). Toffler posits that three significant waves have characterised the evolution of human history. The initial wave corresponds to the Neolithic Revolution, marking the advent of agricultural production and sedentary life. The second wave is characterised by a period of mass production and industrialisation, typified by the Industrial Revolution. The third wave signifies the structure of the post-industrial society, characterised by technological and digital advancements. The aforementioned waves not only elucidate the transformation of modes of production and labour dynamics but also furnish an indispensable framework for comprehending the impact of these structural changes on women's roles in social and economic life (Toffler, 2008: 16). Consequently, historical and economic transformations have exerted a direct influence on the trajectory of the struggle for gender equality.

The way of life developed by primitive communal societies to meet their basic needs led to the emergence of the social division of labour. This period, often termed "primitive communism", was characterised by a predominant gender-based division of social labour (Bebel, 1976: 30; Haviland et al., 2008: 332). Within these communities, based on a hunter-gatherer economy, women were responsible for gathering activities, while men engaged in hunting. This division of labour was shaped by biological differences between the sexes (Aytaç et al., 2002: 18). Women's roles encompassed domestic responsibilities such as pregnancy, childbirth, and breastfeeding, while men specialised in hunting. This division of labour increases the productivity of the community (Şenel, 1995: 52). While the maternal and domestic roles of women were not negated by their gathering activities, their lives were made more challenging (Giddens, 2012: 369). The frequent presence of female figures in Palaeolithic cave paintings demonstrates that women were not only symbols of fertility

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but also played an active role in economic activities. This phenomenon indicates the elevated status of women within the community, both in terms of belief systems and economic activities (Michel, 1993: 25). In this period, before the development of private property and power structures, and with nomadic life being the dominant way of life, a matriarchal social order prevailed (Ertürk, 2008: 7).

The advent of the agricultural revolution, along with the domestication of animals and the development of agricultural tools, led to a reduction in the need for labour, consequently diminishing the significance of hunting. This shift redistributed gender roles, with men increasingly engaged in agricultural production and women dedicated to domestic chores and handicrafts. The dissemination of iron ploughs, a key innovation in agricultural technology, further solidified the position of men in agricultural production while simultaneously diminishing the economic importance of women (Suğur et al., 2006: 79). Property and inheritance systems operated in a manner that effectively prevented women from owning land and excluded them from decision-making mechanisms (Karkıner, 2006: 25). The development of the settled agricultural system subsequently facilitated the establishment of villages, trade in agricultural products, and the emergence of cooperatives and commercial networks (Gimpel, 1997: 40). The increasing need for security led to the emergence of the state concept. While slave labour was commonplace in agriculture and building projects in antiquity, the serfdom system came to the fore in the Middle Ages. While the serfs were tied to the land, both male and female serfs participated in production on equal terms. Although both male and female serfs were bound to the land, women nevertheless retained a low social status (Bloch, 1983: 299; Huberman, 2014: 15). The inheritance system, which favoured males, further restricted women's economic rights and perpetuated the patriarchal structure (Ecevit, 1994: 100-101).

From the 10th to the 15th century, agricultural productivity remained stable, and with surplus production, craftsmen organised around guilds. In this structure, the division of labour between professions such as farmers, merchants, craftsmen, and soldiers was established in society (Gimpel, 1997: 43). While the urban population and commercial volume increased, women participated in areas such as tailoring, shoemaking, baking, and beer production, but they could not be effective in the political field (Aytaç et al., 2002: 19). In the aristocratic and bourgeois classes, women had limited access to education and professional opportunities, being restricted to roles such as lineage continuation and property transfer (Kersey, 1980: 190). With the large-scale development of trade and fair economies, domestic production became widespread, and low labour costs and new production techniques supported the continuity of this system. While the monopolistic policies of the guilds prevented the establishment of new workshops, families turned to production within the home and relied on rural labour (Huberman, 2014: 18-32). As Marx indicated, the Industrial Revolution did not occur through a natural transition from the manufactory to the factory, but rather as a result of families seeking to produce in opposition to the monopoly and impositions of the guilds (Berg, 1994: 208). Braudel, who refers to the period between the 15th and 18th centuries as the "pre-industrial" era, divides it into four categories: scattered family workshops, interconnected scattered workshops, centralised manufactories, and mechanised large workshops (Braudel, 2017: 263-265). This period coincides with the emergence of modern industrial production standards and the shaping of modern gender identity definitions. While appropriate masculinity and femininity were defined in society, instead of defining them by sexual activity and especially the gender of a person's sexual partner, assumptions about acceptable behaviour in visible urban spaces became significant (Ezell, 1999: 629). Women, although limited, gained economic independence through professions such as teaching and participated in public political and social activities. However, these activities have generally been overlooked in historical writing (Ezell, 1999: 630).

Contemporary Dynamics of Female Labour Force Participation

The industrial revolution marked the first time women worked for wages in the modern sense (Özer and Biçerli, 2003: 56). Prior to this, women were economically dependent on men during the feudal era, but the industrial revolution significantly reduced this dependency. Women began to work outside the home, contributing to the development of gender-specific job sectors. They were no longer confined to agriculture but entered both the industrial and service sectors. However, due to lower educational qualifications, women were often seen as substitutes for male labour in many sectors, forced to work under poor conditions for low wages (Kocacık & Gökkaya, 2005: 196). Women migrating from rural areas to cities were employed in the textile industry, the leading sector of the time, working an average of 12 hours a day for low wages. The rise of mechanisation and the greater efficiency of female labour compared to male labour contributed to the concentration of female labour in this sector (Altan & Ersöz, 1994: 21). The development of production techniques, which made tasks more standardised and simpler, allowed women to be employed at lower wages, as they were easier to manage and adapted more readily to the work environment, which further increased their participation in the workforce (Yüksel, 2016: 9). However, changes in demand conditions during the 1960s affected mass production (Lipietz, 2001). The new mode of production, which emphasises flexibility, simplicity, variety, and quality, is known as the post-Fordist production model. Rapid technological advancements have had a significant impact on post-Fordist production and the restructuring of the labour market. Innovations such as automation systems, artificial intelligence, microchips, data storage systems, cloud computing, open-source software, coding, 3D printers, and similar technologies have substantially reduced the need for human labour in the production process. Female workers have been disproportionately affected by these changes, as the new production systems demand higher skill levels, leading to increased unemployment among women. In traditional and patriarchal societies, women often possess lower levels of human capital than men, which hinders their ability to acquire the skills required by the evolving labour market. Nevertheless, the growth of the service sector—a result of changes brought about by mass production—has led to a notable increase in female employment in this sector (Esping-Andersen, 1999). With the growth of the service sector, a white-collar workforce emerged, consisting of professionals specialised in their respective fields. While the white-collar segment of the labour market typically held skilled, well-paid, and secure jobs, the blue-collar segment, employed in the industrial sector, was often confined to low-skilled, low-paid, and precarious positions. As the service sector expanded, more women entered the labour force. However, they frequently had to settle for unskilled jobs in the informal sector. This situation contributed to gender-based occupational stratification, largely stemming from women's lower levels of education and limited occupational experience compared to men (Becker, 1962).

The presence of women in the economic sphere is measured by the female labour force participation rate. This rate is calculated as the ratio of the female labour force of working age to the total female population of working age and is typically expressed as a percentage in statistical reports. Countries such as the United Kingdom, France, Germany, Sweden, and Norway, where female labour force participation rates are high, also rank prominently in terms of economic development. In these countries, the gender gap in labour force participation rates is narrower compared to other nations. This indicates a direct correlation between increased female labour force participation and a country's level of development. Therefore, a high female labour force participation rate can be considered an indicator of a nation's economic advancement. Table 1 presents the changes over time in female labour force participation rates for a selection of representative countries.

Table 1

Changes over Time in the FLFP Rates of Representative Countries*

		1995	2000	2005	2010	2015	2019	2020	2023
Panel A									
Developed Countries	United States	57.61	58.86	58.20	57.60	56.00	56.88	55.70	56.51
	Germany	47.69	48.88	51.15	53.05	54.70	56.59	55.56	56.45
	France	48.17	49.07	50.35	51.37	51.64	51.25	50.62	52.78
	Canada	57.47	59.40	61.65	62.40	61.21	61.43	59.50	61.14
Panel B	Brazil	47.66	50.67	55.59	53.68	52.96	55.13	50.19	53.13
Developing Countries	India	28.49	30.52	30.14	28.78	26.97	26.46	25.95	32.68
	Russian Federation	53.57	54.62	55.04	55.96	55.55	54.95	54.81	54.45
	Türkiye	30.81	26.49	23.08	26.94	31.30	34.21	30.77	35.35
Panel C	Mozambique	87.12	85.76	83.42	80.87	78.11	78.34	77.60	78.41
Less Developed Countries	Zimbabwe	60.27	60.65	60.86	60.85	60.66	60.73	59.84	60.39
	Kenya	70.19	70.48	70.77	71.06	71.37	71.94	71.25	72.20
	Cameroon	77.76	77.93	78.08	70.49	67.04	67.18	66.54	67.29
World		50.47	50.65	49.80	48.83	48.19	47.96	46.75	48.67

Source: World Bank Databank

*The statistic displays the proportion of women aged 15 and over who are economically active relative to the total female population.

The female labour force participation rates of the representative countries in Table 1 generally exhibit an upward trend. However, by 2020, this trend either slowed down or declined compared to 2019 due to the COVID-19 pandemic. The data for 2023 indicate a recovery in female labour force participation rates, with some countries experiencing a rapid rebound while others showing a slower pace of recovery. The COVID-19 pandemic had a disproportionately negative impact on female employment, leading to a so-called "she-cession" (Bluedorn et al., 2023). She-cession is a term used to describe the economic situation during the COVID-19 pandemic, where women experienced a higher rate of job loss compared to men. This was due to factors such as the fact that contact-intensive sectors (hotels and restaurants, retail trade, leisure and entertainment, and social services), in which women are concentrated, were more severely affected by the crisis, the increased burden of childcare, and women's greater involvement in temporary and part-time work (Fabrizio et al., 2021). In the second quarter of 2020, approximately two-thirds of the 38 developed and emerging economies examined witnessed larger declines in female employment rates compared to men. However, this phenomenon, termed she-cession, was generally short-lived, persisting for an average duration of one or two quarters (Bluedorn et al., 2023).

The United Nations adopted 17 sustainable development goals in 2015 as a global call to action. The economic dimension of the global goal on gender equality aims to eliminate gender-based discrimination, abuse, and all forms of violence in the workplace by supporting females' participation in the labour force (United Nations, 2015). Efforts by national and international institutions and organisations to increase female employment and female labour force participation have been accompanied by a growing body of academic literature. The importance of female's labour force participation has been demonstrated through action plans, calls for action, legal regulations, research projects, and vocational training activities. In this context, developing and underdeveloped countries have recognised the significance of female participation in the labour force to achieve their development goals and close the development gap with developed

countries. Female's labour contributes to increased production opportunities and capacity, with positive effects on the national product, welfare, and development levels of countries.

This study analyzes the factors affecting female's labour force participation rate in 87 developed, developing, and less developed countries. The potential contribution of this study to existing literature is as follows: Unlike previous studies that examined a limited number of factors, this study uses a multidimensional dataset that covers potential determinants of female's labour force participation such as economy, health, education, technological infrastructure, institutional framework, natural resources and energy. The dataset covers a comprehensive set of exploratory variables that have not been previously addressed in existing literature. To the best of our knowledge, this is the first study to use exploratory factor analysis to examine the female labour force participation rate. This methodological approach facilitates the analysis of abstract and non-directly measurable factors through observable concrete variables, thus providing a deeper understanding of the factors affecting female's labour force participation. The use of exploratory factor analysis facilitated more comprehensive and reliable results by linking abstract variables with concrete data. This multidimensional and innovative approach makes a significant contribution to the existing literature. In addition to the categories that are commonly used in the empirical literature, the study also classifies studies on female's labour force participation or employment into micro- and macro-studies. This classification system is designed to offer researchers a comprehensive understanding of the findings of the studies.

"The remainder of this study is organised as follows: First, theoretical approaches to female labor supply and the empirical literature on the subject, including studies at both the micro and macro levels, are comprehensively reviewed. Subsequently, the data set employed in the research and the methodology adopted are presented in detail. This is followed by the application conducted in line with the chosen method and a discussion of the findings obtained. Finally, the main results and conclusions of the study are presented."

Literature Review

Theoretical frameworks on female's labour force participation seek to examine and analyse the underlying causes and consequences of inequalities and discriminatory practices observed between men and women in the labour market. Labour constitutes a fundamental component of goods and services production, and it is expected that the income derived from labour should correspond to individual performance. Wage differentials arising from variations in skills and occupational roles among individuals can be considered justifiable within the framework of income equity. However, when individuals receive unequal wages or income despite contributing equally and demonstrating comparable performance-due to factors such as gender, these disparities adversely affect females' participation in the labour market (Ölmezoğulları et al., 1999: 185-193). Women are among the groups subjected to discrimination in the labour market, and gender-based economic discrimination negatively impacts their participation in the workforce. Research findings that theoretically explain the discrimination women face in economic life are crucial for understanding the depth, dimensions, and effects of this issue, as well as for developing future strategies. In the literature, approaches to female's labour force participation are generally categorised under four main headings: the neoclassical approach, the institutional approach, the Marxist approach, and the feminist economics approach.

The neoclassical approach, in its analysis of the labour market, has developed solutions based on efficiency and productivity through mathematical methods. However, this approach has resulted in the neglect of social and institutional factors. Neoclassical analysis is grounded in rationality, objectivity, and mathematical modelling. According to this framework, the wage disparity between men and women and the low participation of women in the labour force are not fundamentally caused by gender differences but by the assumption that men are more productive in the labour market than women. This productivity gap arises from the fact that women, traditionally responsible for household chores and childcare, find it more difficult to engage in activities aimed at increasing human capital accumulation compared to men (Durmaz, 2016: 46). The institutionalist approach is one of the heterodox schools of thought that have been critical of neo-classical economic paradigms. This theoretical framework asserts that the political economy of contemporary societies is predicated on social stratification rather than on the pursuit of individual benefits. Contrary to the neo-classical approach, the institutionalist perspective posits that economic actors are not merely rational individuals; rather, they are institutional structures that give rise to macroeconomic policies and legal regulations. Institutional actors exert a form of influence over the decisions of individuals, operating on the premise of limited rationality (Hodgson, 2007: 12). Accordingly, this approach calls for the integration of other social science disciplines, including psychology, sociology, and anthropology, to facilitate more precise analyses of human and institutional behaviour. Marxist theory examines the layered structure of society shaped by capitalist production and the struggle between economic classes within a historical and cultural context. According to the Marxist approach, capitalism views female's labour as cheap and suitable for part-time work, while simultaneously adopting a patriarchal stance that expects women to remain at home and take on the responsibility of reproducing labour (Ecevit, 1985: 92). Marxist theory links women's subordinate position in society and the family to private property, arguing that in bourgeois families, women are dependent on men and are confined to roles such as bearing and caring for children. These roles are viewed as a reflection of the capitalist social structure, analogous to the strategies employed by the capitalist system in the labour market. According to the feminist approach, the root cause of females' lower participation in the labour market and the discrimination they face lies in patriarchy. Patriarchy is a social structure in which men play a dominant role in setting norms and establishing institutions, thereby legitimising male social and economic superiority based on gender (Moore & Ghilarducci, 2018: 34). The persistence of gender discrimination and conditions that negatively affect female's labour force participation under market conditions has led feminist economics to propose anti-market economic policies. These policies include laws against discrimination, equal pay for equal work, and state-provided childcare services (Conway, 2000: 15-20).

Theoretical studies aim to analyse the causes and consequences of gender-based discrimination in the labour market, which undermines social justice and has additional economic costs. Empirical studies reveal the determinants of female employment and provide findings on the accuracy and validity of theoretical approaches. Both types of studies are necessary to understand the effects, depth, and dimensions of discrimination that still exist today. Empirical literature contains a disproportionately higher number of micro-studies compared to macro-studies. Despite the small number of macro-studies compared to micro-studies, their contribution to literature is of greater importance, and this has led to the adoption of the macro-approach in practice. In this study, micro- and macro-studies were categorised to ensure integrity in the researchers' understanding of the subject.

Micro-studies have found that female's labour force participation rate is determined by various factors, including marital status, education level, husbands' income level, fertility level, availability of childcare

services, patriarchal systems in society, and religious and cultural values. Education has a significant and positive impact on females' participation in the labour force. This includes increased productivity, social benefits, intergenerational redistribution, and income equality (Schultz, 1993). Key studies on this subject include Leibowitz et al. (1988); Connelly (1992); Averett et al. (1997), and Anderson & Levine (1999). Recent studies include Kimmel & Powell (2006), Falzone (2010), Steiber & Haas (2012), Doss et al. (2014), Addabbo et al. (2016), An & Kazuyo (2018), and Pattnaik & Lahiri-Dutt (2020). Table 2 presents micro-level empirical studies on the determinants of female labour force participation, which complement the pioneering studies mentioned above.

Table 2

Empirical Studies at the Micro Level

Study	Period and Sample	Methodologies	Results
de Laat and Sevilla-Sanz (2011)	1970-2005, 23 Organisation for Economic Co-Operation and Development (OECD) countries	Cohort Analysis and Probit Model	Men's increased involvement in household production increases female's labour force participation.
Bilijan Et al. (2013)	70 observations between 1996 and 2005 in Croatia and 15 EU countries	Cohort Analysis	Although the employment rates of women in part-time jobs are increasing, they face more challenges in securing full-time employment compared to men.
Hall and Zoega (2014)	The World Values Survey covers 5 Nordic countries.	Covariance Analysis	The primary factors influencing female labour force participation are cultural and value-based considerations.
Uunk (2015)	The 2008 European Values Survey covers 33 countries in Europe	Multilevel Logit Model	The probability of individual female's labour market attachment is significantly positively and independently affected by a country's egalitarian gender role attitudes.
Arrazola and Hevia (2016)	1994-2000-2006 the European Living Conditions Survey was conducted, Spain	Probit Model	The data indicates that Spanish women tend to have higher reservation wages and lower offer wages compared to men, which could be a contributing factor to the low participation of female in the labour market.
Atasoy (2017)	2013 Türkiye Demographic and Health Survey, Türkiye	Probit and Logit Models	In traditional cultures, women are less likely to participate in the labour force and find employment, particularly in the services sector and among regular/wage earners.
Alam Et al. (2018)	2010 census data for Indonesia	Logit Model	In urban areas, married Hindu women are 31% more likely to work than married Muslim women. In rural areas, married Confucian women are 31% less likely to work than married Muslim women.
Islam Et al. (2020)	The 2009-2016 World Bank Entrepreneurship Survey covers 126 developed and developing countries and 46,000 firms	Decomposition Analysis	In the manufacturing sector, firms managed by women have lower capital and labour costs than those managed by men.
Klasen Et al. (2021)	Household surveys are suitable for deriving most of the variables used by Klasen and Pieters (2015) in 8 low- and middle-income non-OECD countries	Probit Model	The constraints that shape female labour force participation are largely country specific. However, it can be concluded that rising levels of education and falling fertility rates have consistently increased the rate of female labour force participation.

Alvi (2023)	From 1983 to 2012, the India National Sample Survey and the India Human Development Survey were conducted every five years, each covering 100,000 to 120,000 households	Decomposition Analysis	The research indicates that poverty and economic distress are the primary drivers of higher labour force participation among Hindu women. Additionally, the study finds that increasing incomes decrease female labour force participation across all groups.

Source: Compiled by the authors.

Among the macro-level empirical studies in the literature, the largest group focuses on the relationship between economic development, progress, growth, and female labour force participation. These studies use female labour force participation as an explanatory variable in econometric models. Hill (1983), Mincer (1985), Pampel & Tanaka (1986), Psacharopoulos & Tzannatos (1989), Schultz (1991), Goldin (1995), Tansel (2002), and Tam (2011) are all authors who have contributed to this topic. Some studies (Hill, 1983; Mincer, 1985; Pampel & Tanaka, 1986; Psacharopoulos & Tzannatos, 1989) have examined the relationship between development and female labour force participation. They found that female labour force participation rates are higher in high-income and low-income countries than in middle-income countries. The high female labour force participation in underdeveloped countries can be attributed to the fact that women can still find a place in agriculture, while in developed countries, women are already working in the industrial sector. However, in countries with intermediate levels of development, the transition from agriculture to industry has made it difficult to employ women in both sectors. Similarly, previous studies have highlighted that females' participation in the labour force is low during the initial stages of economic growth. Additionally, it has been observed that female's labour force participation follows a U-shaped pattern with increasing economic growth (Goldin, 1995; Özdamar Giovanis et al., 2018).

In contrast, there are few macro-studies that use econometric models to explain female's labour force participation and include economic growth as an explanatory variable. Some examples of such studies include Galor & Weil (1996), Klasen (1999), Cavalcanti & Tavares (2007), Klasen & Lamanna (2009), and Torçun (2018). Klasen's (1999) findings suggest that female's increased participation in the labour force, particularly in the formal sector, has a positive impact on economic growth. Additionally, Klasen & Lamanna (2009) and Galor & Weil (1996) found that wage discrimination has a negative effect on economic growth. Torçun (2018) found that the interaction term between the female labour force participation rate and savings variables does not close the investment-savings gap, which does not lead to economic growth. Table 3 presents macro-level empirical studies on the determinants of female employment, which complement the pioneering studies mentioned earlier.

Table 3

Empirical Studies at the Macro Level

Study	Period and Sample	Methodologies	Results
Kneip and Bauer (2007)	1960-2005, 18 EU countries	Time Series Analysis	As the risk of divorce increases, female labour force participation also increases.
Bloom Et al. (2009)	1960-2000, 97 developed and developing countries	Panel Data Analysis	The research indicates a positive correlation between education and female labour force participation.
Mishra and Smyth (2010)	1980-2005 and 1995-2005, 28 OECD countries	Panel Data Analysis	There exists an inverse relationship between the rate of female labour force participation and the total fertility rate.

Önder and Önder (2012)	1980-2009, Türkiye	Time Series Analysis	The participation of women with higher levels of education in the labour force increases, indirectly impacting long-term economic growth.
Lee and Lee (2014)	1971-2009, Japan	Time Series Analysis	Long-term equilibrium relationships were discovered between the rate of female labour force participation, birth rate, and childcare status.
Siah and Lee (2015)	1970-2010, Malaysia	Time Series Analysis	The data indicate that mortality rate changes have a significant and positive long-term impact on fertility rates.
Belke and Bolat (2016)	1991-2014, 148 developed and developing countries	Panel Data Analysis	Econometric research supports the validity of the U-hypothesis, which suggests a non-linear relationship between female labour force participation and economic development.
Özdamar Giovanis Et al. (2018)	1991-2014, 31 developing and less developed countries	Panel Data Analysis	Research has not found evidence to support the idea that increased female labour force participation has a positive impact on domestic savings.
Sikirić (2021)	2005-2015, 28 EU countries	Panel Data Analysis	It is emphasised that part-time work can place women in a financially subordinate position to men, weaken their bargaining power at home, affect their future retirement, and prevent them from fully utilising their work and intellectual capacities.
Irandoust (2023)	1991-2021, 17 Arab countries	Panel Data Analysis	Female labour force participation is affected by both structural and cyclical factors related to job opportunities.

Source: Compiled by the authors.

This study aims to address a significant lacuna in the extant literature by offering a multidimensional perspective on female's labour market participation. Previous macro-studies have largely confined their assessments of the female labour force participation rate to a limited number of factors, based their analyses primarily on some EU or OECD countries. In contrast, the present study distinguishes itself by incorporating 20 observational variables representing multiple dimensions, including the economy, health, education, technology, institutional structure, and energy. Furthermore, the intangible variables obtained using the exploratory factor analysis method were evaluated in a regression model in which the female labour force participation rate was designed as the dependent variable. This methodological approach enabled the analysis of abstract and non-directly measurable factors through observable concrete variables, thus providing a deeper understanding of the factors affecting female labour force participation. The study's original contribution lies in its use of exploratory factor analysis, a novel approach in the field, to explore female labour force participation. Additionally, it incorporates a comprehensive set of variables that have not been previously considered in the related literature. The employment of this method has yielded more comprehensive and reliable results by associating abstract variables with concrete data. This multidimensional and innovative approach makes a significant contribution to the existing literature.

Methodology and Data

Research Method: Factor Analysis

Factor analysis is a multivariate analysis technique that aims to identify some meaningful factors from a large set of observable variables that are believed to be interrelated. Technically, it is an analysis developed to obtain some independent factors by examining the covariance structures of a group of variables (Johnson & Wichern, 2007). This analysis reveals new structures by manipulating the number of variables and examining the relationships between them. It is assumed that all variables are interrelated, and those

with stronger correlations are combined using the correlation matrix to form factors. The size of the factor loadings is analysed to comment on the factors (Seber, 1984).

Multivariate statistical analyses involve expressing many interrelated variables with some mathematically derived factors that provide the least loss of information. This approach simplifies the explanation of the relationship between variables that are thought to be related to each other in large and multidimensional data. The factors obtained in this stage of the analysis can be used in subsequent stages, such as regression, correlation, and decomposition (Kline, 1994). In the factor analysis, the variables are ranked by weight according to their importance. The next stage of the analysis is then initiated. In this study, exploratory factor analysis is employed, as it is a method that aims to obtain new and meaningful factors based on the relationships between variables. This analysis is particularly useful in cases where the factor structure is not predetermined in the dataset and an exploratory approach is required. Exploratory factor analysis enables the identification of latent constructs without imposing a preconceived structure, making it especially suitable for research contexts where theoretical guidance is limited or the dimensionality of the data is unknown. The objective of this study is to ascertain the dimensions in which the factors affecting female labour force participation are grouped and to analyse the effects of these factors on the female labour force participation rate. Therefore, exploratory factor analysis is a method that is particularly well-suited to the nature and purpose of this research.

However, it is important to note that while exploratory factor analysis is effective for uncovering the underlying factor structure, it does not provide evidence regarding the generalizability or validity of this structure in other samples or contexts. For this reason, confirmatory factor analysis should be conducted following exploratory factor analysis to test whether the identified factor structure holds in an independent sample or aligns with theoretical expectations. Confirmatory factor analysis allows for the statistical evaluation of the model fit and the verification of hypothesised relationships among the observed variables and latent constructs. As emphasised in the literature, "Exploratory factor analysis is used for the exploration of factor structures, whereas confirmatory factor analysis is necessary for confirming and testing the adequacy of these structures. These two analyses should be used sequentially, and the findings obtained from the exploratory factor analysis should be validated through the confirmatory factor analysis in an independent sample" (Brown, 2015).

Factor analysis establishes linear relationships between concrete-observational variables $z_1, z_2, \ldots, z_p$ and abstract-fictional variables and abstract-fictional variables $F_1, F_2, \ldots, F_p$ through loading values $z_j = a_{j1} \cdot F_1 + a_{j2} \cdot F_2 + \ldots + a_{jp} \cdot F_p$. The equations of factor analysis can be understood as a regression of concrete variables on abstract variables. Since creating *p* number of factors for *p* number of dependent variables is not a gain in terms of simplicity, the linear relationship between dependent variables and factors is established as follows for $m < p$: $z_j = a_{j1} \cdot F_1 + a_{j2} \cdot F_2 + \ldots + a_{jm} \cdot F_m + \varepsilon_j$, $j = 1, 2, \ldots, p$ (Harman, 1967). A comparable scenario applies to the principal component analysis (PCA). Principal components with eigenvalues of at least one are considered significant according to Equation 1 of the principal components model; the number of these principal components is indicated by *m* .

$$\xi i = t_{i1} \cdot z_1 + t_{i2} \cdot z_2 + \ldots + t_{ip} \cdot z_p, \quad i = 1, 2, \ldots, m. \tag{1}$$

The most important stage of factor analysis in terms of research is the naming and interpretation of the factors obtained. In naming and interpreting the factors, it is necessary to consider the observed variables

that are strongly affected by them and to ask what would affect them so strongly. Once the naming and interpretation is complete, the explanation of the variable of interest now manifests itself as the interpretation of a regression equation.

Data

This study aims to identify the factors that contribute to female employment on a global scale. The study used data on 20 variables from 87 countries for the period of 2015-2019. The selected time frame was due to the limited availability of data, particularly for recent years. To avoid excluding countries with little missing data, we took five-year averages of the relevant years to obtain the maximum number of observations. This ensures that the analysis includes as many countries as possible, despite the missing data.

Factor analysis is used to identify the independent variables that are assumed to be independent in the panel data analysis, but the level of independence could not be determined to ascertain whether they were truly independent or fictitious. Although the number of omitted variables in the factor analysis method used in the study is small, it neglects country-specific unobservable unit effects, such as religious and cultural factors, which are particularly important in studies using the panel regression method. However, the fact that most of the observed variables used to derive the factors have structural magnitude and do not change over time, and the remaining variables have small variances, makes the problem of omitted variable bias less problematic and thus prevents the construction of an incorrect model.

The countries used in the analysis are as follows: United States of America, Armenia, Spain, Mongolia, Sri Lanka, Germany, Estonia, Sweden, Moldova, Saudi Arabia, Argentina, Morocco, Switzerland, Mozambique, Chile, Albania, Philippines, Italy, Namibia, Tanzania, Australia, Finland, Japan, Niger, Thailand, Austria, France, Cameroon, Nicaragua, Tunisia, Bangladesh, Gabon, Canada, Norway, Türkiye, Bahrain, Ghana, Kazakhstan, Pakistan, Uganda, Belgium, Guatemala, Kenya, Panama, Ukraine, Brazil, South Africa, Colombia, Paraguay, Uruguay, Botswana, Croatia, Costa Rica, Peru, Jordan, Bulgaria, India, Latvia, Poland, Vietnam, Czechia, Netherlands, Lithuania, Portugal, Greece, China, Republic of Honduras, Luxembourg, Romania, Zambia, Denmark, Iraq, Hungary, Russian Federation, Zimbabwe, Dominican Republic, United Kingdom, Malaysia, Senegal, El Salvador, Iran, Mexico, Slovakia, Indonesia, Ireland, Egypt, and Slovenia. As can be seen, in selecting the countries, an effort was made to create a balanced dataset, since they are in different geographical regions of the world and have, as far as possible, different economic levels. Table 4 shows the variables used in the application. Data on the variables were obtained from several sources: World Bank Databank (WB); PRS Group-International Country Risk Guide (ICRG); International Labour Organisation (ILO); and United Nations Development Program (UNDP).

In this study, the factor analysis method was used to obtain factors to explain the determinants of female employment. To test the suitability of the data for factor analysis, the correlation matrix was calculated, and the Kaiser-Meyer-Olkin (KMO) criterion and Bartlett test statistics were used. PCA was used as a factor extraction method. With the help of PCA, the factors were derived by revealing the maximum variance in the dataset. To determine the number of factors, the total variance ratio and eigenvalue statistic were analyzed, respectively. As a rotation method, quartile method was selected from the orthogonal rotation methods.

Table 4

Variables Used in the Application

Symbol	Variable	Description	Source
HATST	Harmonised student test scores	It measures the relative performance of countries on international student achievement tests based on a harmonised database of scores obtained on internationally standardised student achievement tests in various subject areas.	WB
TOWPC	Total wealth per capita	Produced capital is calculated as natural capital, human capital, and net foreign assets divided by the population. Values are measured at market exchange rates in constant 2018 U.S. dollars.	WB
GDPPC	Gross Domestic Product (GDP) per capita	GDP is divided by the population at mid-year. It is measured at market exchange rates in constant 2015 U.S. dollars.	WB
AGVAL	Agriculture value added to GDP	Agriculture includes forestry, fishing, crop production, and animal production. It is expressed as a percentage of GDP.	WB
INVAL	Industry value added to GDP	This variable reports the contribution of industrial production, including construction, to the overall GDP. The percentage of GDP is used as the unit of measurement.	WB
CORRU	Level of corruption	It assesses corruption in the political system. High scores are given to countries with low levels of corruption.	ICRG
BURQU	Bureaucratic quality	Countries with weak bureaucracies tend to score low due to the potential for government changes to disrupt policy formulation and administrative functions.	ICRG
INPRO	Investment profile	This is an evaluation of investment risk factors that are not addressed by other political, economic, and financial risk components.	ICRG
UINON	Online shopping	The percentage of female respondents over the age of 15 who reported using the internet to make an online purchase in the last 12 months.	WB
UMOIN	Use of the internet or mobile money	Percentage of female respondents aged 15+ with a financial institution account or mobile money account who reported using their mobile phone or the internet to make payments, make purchases, or send or receive money through their financial institution account in the past 12 months.	WB
AGDER	Age dependency ratio	The ratio of dependents to the working-age population is presented as the number of dependents per 100 working-age individuals.	WB
MAMOR	Maternal mortality rate	It is represented by 100,000 live births in a year, regardless of the duration and location of the pregnancy.	WB, UNDP
FERRA	Total fertility rate	The total fertility rate indicates the average number of children a woman would give birth to if she were to live to the end of her childbearing years and experience the age-specific fertility rates of the given year.	WB
ADOFE	Adolescent fertility rate	The adolescent birth rate is defined as the number of births per 1000 women aged 15–19 years each year.	WB, UNDP
EMAGF	Female employment rate in the agriculture sector	This indicator measures the proportion of employed women who work in agriculture, hunting, forestry, and fishing activities. It is expressed as a percentage.	WB, ILO
OILRE	Ratio of oil rents to GDP	Oil rents are defined as the gap between the value of crude oil production at regional prices and the total production costs, expressed as a percentage of GDP.	WB

Symbol	Variable	Description	Source
NACPC	Natural capital per capita	The total natural resource rents refer to the combined value of oil, natural gas, coal, mining, and forest rents, all measured in constant 2018 US dollars and divided by the total population.	WB
RECON	Renewable energy consumption	Terajoules of energy obtained and consumed from all renewable sources such as hydro, solid, biofuels, wind, solar, liquid biofuels, biogas, geothermal, marine, and waste.	WB
LFPRF*	Female labour force participation rate	The statistic displays the proportion of women aged 15 and over who are economically active relative to the total female population.	WB, ILO

*It was used as a dependent variable in the regression analysis but was not included in the exploratory factor analysis.
Source: Compiled by the authors.

Application and Discussion

Application

Before proceeding to the exploratory factor analysis in this study, we examined whether the variables to be used in the analysis met the assumption of normality. For this purpose, skewness and kurtosis values were calculated for each variable, and the findings are presented in Table 5. In the literature, it is stated that skewness and kurtosis values within the range of ±2 are considered acceptable for normal distribution (Tabachnick & Fidell, 2019).

The results indicate that the assumption of normality is satisfied for 10 variables, whereas it is not satisfied for the remaining 10 variables. This was considered in the selection of the analysis method, and PCA, which is less sensitive to the normality assumption in factor extraction, was therefore preferred. The main reason why PCA is less sensitive to the assumption of normality is that it constructs principal components based solely on the covariance or correlation matrix of the variables. In other words, the goal of PCA is to identify the linear components that best explain the total variance in the data; therefore, the normality of the variable distributions is not a strict requirement in this process. As a result, PCA results are generally considered reliable even when the variables are not normally distributed (Jolliffe & Cadima, 2016).

Before conducting exploratory factor analysis, it is imperative to assess the suitability of the data for factor analysis, i.e., to evaluate the validity of applying factor analysis. In this context, it is necessary to examine the KMO criterion, the Bartlett's test statistic, the anti-image matrix, the communalities, and the residual matrix (Hair et al., 1998; Field, 2024). When the correlation matrix is equal to the unit matrix, it indicates that there is no relationship between the observational variables. In this case, all the observational variables are independent, and factor analysis is unnecessary because linear relationships cannot be established between them. The correlation matrix coefficients and significance levels indicate that the observational variables are appropriate for factor analysis. At the 0.00 significance level, Bartlett's test statistic was calculated as 1903.965, leading to the rejection of the null hypothesis that the correlation matrix is equal to the unit matrix (Hair et al., 1998). The next stage involved using the KMO sampling adequacy measure to determine if there were enough observational variables. The KMO value of 0.868 indicates that the sample size is sufficient for factor analysis (Kaiser, 1974). Table 6 displays the results of the KMO criterion and Bartlett's test statistics.

Table 5

Skewness and Kurtosis Values for Assessing the Normality of Variables

		Statistic	Std. Error			Statistic	Std. Error
CORRU	Skewness	0.689	0.258	AGDER	Skewness	1.559	0.258
	Kurtosis	−0.585	0.511		Kurtosis	2.636	0.511
BURQU	Skewness	0.386	0.258	AGVAL	Skewness	1.624	0.258
	Kurtosis	−0.838	0.511		Kurtosis	2.878	0.511
INPRO	Skewness	0.431	0.258	EMAGF	Skewness	1.389	0.258
	Kurtosis	0.242	0.511		Kurtosis	0.837	0.511
MAMOR	Skewness	2.222	0.258	FERRA	Skewness	1.888	0.258
	Kurtosis	4.429	0.511		Kurtosis	3.958	0.511
HUCPC	Skewness	1.676	0.258	GDPPC	Skewness	1.926	0.258
	Kurtosis	1.967	0.511		Kurtosis	3.763	0.511
TOWPC	Skewness	1.795	0.258	INVAL	Skewness	0.812	0.258
	Kurtosis	2.723	0.511		Kurtosis	0.952	0.511
UMOIN	Skewness	0.768	0.258	OILRE	Skewness	4.628	0.258
	Kurtosis	−0.422	0.511		Kurtosis	24.168	0.511
UINON	Skewness	0.831	0.258	RECON	Skewness	4.610	0.258
	Kurtosis	−0.643	0.511		Kurtosis	22.545	0.511
HATST	Skewness	−0.151	0.258	NACPC	Skewness	5.072	0.258
	Kurtosis	−1.162	0.511		Kurtosis	31.394	0.511
ADOFE	Skewness	1.408	0.258	LFPRF	Skewness	−1.098	0.258
	Kurtosis	2.027	0.511		Kurtosis	0.511	0.511

Source: Calculated by the authors.

Table 6

Results of the KMO Criterion and Bartlett's Test Statistic

KMO measure of sampling adequacy		0.868
Bartlett's test of sphericity	Chi-square	1903.965
	Degrees of freedom	171
	Significance level	0.000

Source: Calculated by the authors.

The anti-image correlation matrix was examined as another indicator of suitability for factor analysis. The anti-image matrix displays the partial correlations of each variable with other variables, with particular emphasis on the Measure of Sampling Adequacy (MSA) values on the diagonal. MSA values allow for the individual assessment of each variable's suitability for factor analysis.

Table 7

Anti-image Correlation Matrix

	1 CORRU	2 BURQU	3 INPRO	4 MAMOR	5 HUCPC	6 TOWPC	7 UMOIN	8 UINON	9 HATST	10 ADOFE	11 AGDER	12 AGVAL	13 EMAGF	14 FERRA	15 GDPPC	16 INVAL	17 OILRE	18 RECON	19 NACPC
1	**0.91**[a]	0.26	−0.4	−0.01	−0.10	−0.04	−0.12	−0.15	0.28	0.21	−0.03	0.18	−0.13	0.02	0.05	−0.00	0.28	0.27	−0.08
2	−0.26	**0.96**[a]	−0.05	−0.01	−0.07	0.04	−0.04	−0.04	0.05	0.26	−0.17	−0.04	0.06	0.08	−0.17	−0.06	−0.02	−0.12	0.09
3	−0.40	−0.05	**0.90**[a]	0.00	−0.07	0.07	0.17	0.01	−0.16	−0.09	−0.13	−0.22	0.30	0.03	−0.15	−0.13	0.09	−0.09	−0.17
4	−0.01	−0.01	0.00	**0.93**[a]	0.11	−0.03	−0.33	0.14	0.00	−0.26	−0.15	−0.12	−0.13	−0.23	−0.08	0.00	0.11	−0.16	0.00
5	−0.10	−0.07	−0.07	0.11	**0.89**[a]	−0.71	−0.12	−0.17	−0.02	−0.27	0.11	0.07	0.03	−0.09	−0.00	0.19	−0.02	−0.18	0.26
6	−0.04	0.04	0.07	−0.03	−0.71	**0.85**[a]	−0.06	0.02	0.09	0.14	−0.22	−0.13	0.02	0.19	−0.53	−0.14	0.01	0.02	−0.41
7	−0.12	−0.04	0.17	−0.33	−0.12	−0.06	**0.89**[a]	−0.34	−0.26	0.04	0.08	0.13	−0.09	−0.10	0.18	−0.00	0.05	0.10	−0.09
8	−0.15	−0.04	0.01	0.14	−0.17	0.02	−0.34	**0.92**[a]	−0.41	0.06	−0.11	−0.16	0.19	0.01	−0.10	−0.10	−0.05	−0.30	0.00
9	0.28	0.05	−0.16	0.00	−0.02	0.09	−0.26	−0.41	**0.89**[a]	0.25	−0.25	0.08	−0.09	0.32	−0.05	−0.06	0.066	0.28	−0.00
10	0.21	0.26	−0.09	−0.26	−0.27	0.14	0.04	0.06	0.25	**0.92**[a]	−0.18	0.07	0.00	−0.10	0.00	−0.09	0.13	0.15	−0.01
11	−0.03	−0.17	−0.13	−0.15	0.11	−0.22	0.08	−0.11	−0.25	−0.18	**0.72**[a]	0.28	−0.24	−0.70	0.30	0.44	−0.13	0.13	0.24
12	0.18	−0.04	−0.22	−0.12	0.07	−0.13	0.13	−0.16	0.08	0.07	0.28	**0.85**[a]	−0.56	−0.33	0.24	0.36	0.06	0.06	0.02
13	−0.13	0.06	0.30	−0.13	0.03	0.02	−0.09	0.19	−0.09	0.00	−0.24	−0.56	**0.86**[a]	0.11	−0.17	−0.24	0.05	−0.26	0.00
14	0.02	0.08	0.03	−0.23	−0.09	0.19	−0.10	0.01	0.32	−0.10	−0.70	−0.33	0.11	**0.83**[a]	−0.23	−0.36	−0.08	0.03	−0.17
15	0.05	−0.17	−0.15	−0.08	−0.00	−0.53	0.18	−0.10	−0.05	0.00	0.30	0.24	−0.17	−0.23	**0.89**[a]	0.18	−0.08	0.208	0.22
16	−0.00	−0.06	−0.13	0.00	0.19	−0.14	−0.00	−0.10	−0.06	−0.09	0.44	0.36	−0.24	−0.36	0.18	**0.58**[a]	−0.37	−0.06	0.02
17	0.28	−0.02	0.09	0.11	−0.02	0.01	0.05	−0.05	0.06	0.13	−0.13	0.06	0.05	−0.08	−0.08	−0.37	**0.62**[a]	0.08	−0.49
18	0.27	−0.12	−0.09	−0.16	−0.18	0.02	0.10	−0.30	0.28	0.15	0.13	0.06	−0.26	0.03	0.20	−0.06	0.08	**0.16**[a]	0.02
19	−0.08	0.09	−0.17	0.00	0.26	−0.41	−0.09	0.00	−0.00	−0.01	0.24	0.02	0.00	−0.17	0.22	0.02	−0.49	0.02	**0.62**[a]

Source: Calculated by the authors. a: Measure of sampling adequacy.

As shown in Table 7, the MSA values on the diagonal of the anti-image matrix range from 0.58 to 0.96, excluding the RECON variable (renewable energy consumption). Although the renewable energy consumption observational variable does not exhibit characteristics suitable for factor analysis, it was included in the analysis to examine its effect on the female labour force participation rate. Because only the observational variable related to renewable energy consumption is clustered under this hypothetical variable, the name of the observational variable was directly used in naming the hypothetical variable. However, it was found that the renewable energy consumption hypothetical variable has a negligible effect on the female labour force participation rate, which is the dependent variable). Given that the MSA values for all variables are above 0.50, it is appropriate to include each variable in the factor analysis (Kim, 1978). Furthermore, the low values of the off-diagonal elements of the anti-image matrix indicate that there is no multicollinearity problem among the variables, and factor analysis can be reliably applied.

The communalities table, which is an important output of the factor analysis, shows how well each variable is explained by the extracted factors. The communality value represents the proportion of a variable's variance accounted for by the factors and ranges from 0 to 1. High communality values indicate that the variable is well represented by the factors, while low values suggest that the variable is not sufficiently explained by them (Hair et al., 1998).

Table 8

Communalities

	CORRU	BURQU	INPRO	MAMOR	HUCPC	TOWPC	UMOIN	UINON	HATST	ADOFE	AGDER	AGVAL	EMAGF	FERRA	GDPPC	INVAL	OILRE	RECON	NACPC
Initial	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Extraction	0.841	0.798	0.666	0.896	0.924	0.920	0.713	0.893	0.690	0.830	0.875	0.759	0.782	0.936	0.864	0.690	0.824	0.937	0.740

Source: Calculated by the authors. Extraction method: Principal Component Analysis

According to the communalities values presented in Table 8, the majority of the variables have high communality values. The variables with the highest communality values were RECON (0.937), FERRA (0.936), HUCPC (0.924), and TOWPC (0.920). This indicates that a large proportion of the variance in these variables is explained by the factors and that these variables represent the factor structure well. On the other hand, the variables with the lowest communality values were INPRO (0.666), HATST (0.690), and INVAL (0.690). Although the communality values of these variables are lower compared to the others, they are still at an acceptable level (above 0.60). This suggests that these variables are substantially explained by the factors but are not represented as well as the other variables.

The residual matrix obtained from the factor analysis was examined to assess the extent to which the model could reproduce the original correlation matrix. Each cell in the residual matrix represents the difference between the original correlation and the correlation estimated by the model. The magnitude of these differences is considered an indicator of the model's fit to the data (Kline, 2016).

Table 9

Residual Matrix

	1 CORRU	2 BURQU	3 INPRO	4 MAMOR	5 HUCPC	6 TOWPC	7 UMOIN	8 UINON	9 HATST	10 ADOFE	11 AGDER	12 AGVAL	13 EMAGF	14 FERRA	15 GDPPC	16 INVAL	17 OILRE	18 RECON	19 NACPC
1		0.02	0.04	-0.00	-0.02	-0.01	-0.04	-0.03	-0.08	-0.01	-0.01	0.00	0.01	0.00	-0.02	0.04	-0.03	-0.00	0.01
2	0.02		-0.00	-0.00	-0.02	-0.02	-0.05	-0.03	-0.04	-0.02	0.02	0.00	0.00	0.01	-0.00	0.03	0.02	-0.01	-0.03
3	0.04	-0.00		-0.00	-0.02	-0.03	-0.13	-0.04	-0.06	0.03	-0.00	0.04	-0.04	0.01	-0.02	0.04	-0.03	0.05	0.01
4	-0.00	-0.00	-0.00		-0.01	-0.01	0.03	-0.00	0.02	-0.00	-0.02	-0.04	-0.03	-0.01	-0.00	0.02	-0.01	-0.00	-0.00
5	-0.02	-0.02	-0.02	-0.01		0.05	-0.04	-0.01	-0.05	0.04	-0.02	-0.00	-0.01	-0.00	0.04	-0.01	0.00	0.00	-0.01
6	-0.01	-0.02	-0.03	-0.01	0.05		-0.05	-0.02	-0.05	0.02	-0.02	0.01	0.00	-0.01	0.06	-0.02	-3.304E-5	-0.00	0.01
7	-0.04	-0.05	-0.13	0.03	-0.04	-0.05		0.05	0.12	-0.02	-0.01	-0.02	0.02	-0.02	-0.08	0.04	-0.01	-0.04	-0.03
8	-0.03	-0.03	-0.04	-0.00	-0.01	-0.02	0.05		0.08	-0.00	0.02	0.01	0.00	0.00	-0.03	0.02	0.01	-0.01	-0.03
9	-0.08	-0.04	-0.06	0.02	-0.05	-0.05	0.12	0.08		-0.04	0.05	0.01	0.07	-0.01	-0.06	0.03	0.02	-0.03	-0.03
10	-0.01	-0.02	0.03	-0.00	0.04	0.02	-0.02	-0.00	-0.04		-0.02	-0.07	-0.07	-0.01	0.02	0.02	-0.02	0.04	-0.01
11	-0.01	0.02	-0.00	-0.02	-0.02	-0.02	-0.01	0.02	0.05	-0.02		-0.07	-0.03	0.02	-0.04	0.00	0.03	0.04	-0.04
12	0.00	0.00	0.04	-0.04	-0.00	0.01	-0.02	0.01	0.01	-0.07	-0.07		0.05	-0.02	0.00	-0.04	0.01	-0.05	0.07
13	0.01	0.00	-0.04	-0.03	-0.01	0.00	0.02	0.00	0.07	-0.07	-0.03	0.05		-0.05	0.01	0.02	0.00	-0.08	0.01
14	0.00	0.01	0.01	-0.01	-0.00	-0.01	-0.02	0.00	-0.01	-0.01	0.02	-0.02	-0.05		0.00	0.02	-0.00	0.02	-0.02
15	-0.02	-0.00	-0.02	-0.00	0.04	0.06	-0.08	-0.03	-0.06	0.02	-0.04	0.00	0.01	0.00		-0.00	0.01	-0.00	-0.02
16	0.04	0.03	0.04	0.02	-0.01	-0.02	0.04	0.02	0.03	0.02	0.00	-0.04	0.02	0.02	-0.00		-0.10	-0.05	-0.16
17	-0.03	0.02	-0.03	-0.01	0.00	-3.304E-5	-0.01	0.01	0.02	-0.02	0.03	0.01	0.00	-0.00	0.01	-0.10		0.01	-0.08

	1 CORRU	2 BURQU	3 INPRO	4 MAMOR	5 HUCPC	6 TOWPC	7 UMOIN	8 UINON	9 HATST	10 ADOFE	11 AGDER	12 AGVAL	13 EMAGF	14 FERRA	15 GDPPC	16 INVAL	17 OILRE	18 RECON	19 NACPC
18	−0.00	−0.01	0.05	−0.00	0.00	−0.00	−0.04	−0.01	−0.03	0.04	0.04	−0.05	−0.08	0.02	−0.00	−0.05	0.01		0.01
19	0.01	−0.03	0.01	−0.00	−0.01	0.01	−0.03	−0.03	−0.03	−0.01	−0.04	0.07	0.01	−0.02	−0.02	−0.16	−0.08	0.01	

Source: Calculated by the authors. Extraction Method: Principal Component Analysis. Residuals are computed between the observed and reproduced correlations. **There were 29 (16.0%) nonredundant residuals with absolute values greater than 0.05.**

Upon examination of the residual matrix in Table 9, most the residual values are below 0.10 in absolute value. Notably, most residual correlations between variables were below 0.05. This suggests that the factor model largely explains the relationships between the variables successfully. However, some cells (e.g., −0.13 between UMOIN and INPRO; −0.16 between INVAL and NACPC) showed residuals exceeding 0.10 in absolute value. These higher residual values indicate that the model does not adequately explain the relationships between these specific variable pairs. Overall, considering the distribution and magnitude of the residual values, the model's explanatory power can be deemed adequate for general validity.

Table 10 displays the eigenvalues and variance explanation percentages of the factors, which are determined by Kaiser's eigenvalue criterion. According to Table 6, the variance explanation percentages of the first four principal components with eigenvalues greater than 1 are 50.54, 14.89, 10.65 and 5.89, respectively. The cumulative variance explanation percentages of the 4 principal components are 81.98%. In other words, all 4 principal components could explain 81.98% of the total variance. This is also indicative of the scale's validity. Considering that the fictional variables are the standardised forms of the principal components, 4 fictional variables were obtained according to Kaiser's eigenvalue criterion.

Table 10

Eigenvalues and Variance Explanation Percentages of Factors

Principal component	Eigenvalues	Percentage	Cumulative percentage	Loading squares sum after rotation	Percentage	Cumulative percentage
1	9.60	50.54	50.54	8.13	42.79	42.79
2	2.82	14.89	65.43	4.19	22.07	64.87
3	2.02	10.65	76.08	2.12	11.17	76.04
4	1.12	5.89	**81.98**	1.12	5.93	81.98
5	0.67	3.53	85.51			
6	0.51	2.71	88.23			
7	0.41	2.18	90.42			
8	0.35	1.88	92.30			
9	0.32	1.73	94.03			
10	0.26	1.37	95.41			
11	0.18	0.96	96.37			
12	0.15	0.81	97.18			
13	0.13	0.72	97.90			
14	0.11	0.62	98.53			
15	0.09	0.50	99.03			
16	0.06	0.35	99.39			

Principal component	Eigenvalues	Percentage	Cumulative percentage	Loading squares sum after rotation	Percentage	Cumulative percentage
17	0.05	0.30	99.69			
18	0.04	0.21	99.91			
19	0.01	0.08	100.00			

Source: Calculated by the authors.

Once the fictional variables have been obtained, they can be named meaningfully to complete the factor analysis. However, in this case, due to the PCA, one variable was clustered into two fictional variables simultaneously, which made it difficult to interpret and name the fictional variables. To ensure a consistent and meaningful interpretation of the fictive variables, we applied the quartile rotation method, which is an orthogonal rotation method, to these variables.

Because of the factor analysis conducted on the data obtained in the study, four main factors were identified. In order to assess the internal consistency of the factors and the overall scale, Cronbach's alpha coefficients were calculated. The Cronbach's alpha coefficient for the entire scale, which encompasses all variables, was found to be [0.416]. This value indicates that the scale, in general, possesses a high level of internal consistency. Additionally, the Cronbach's alpha coefficients calculated separately for each factor were determined as [0.418] for Factor 1, [0.618] for Factor 2, and [0.734] for Factor 3. These results demonstrate that each factor also exhibits an acceptable level of reliability. The Cronbach's alpha coefficients obtained for both the overall scale and the identified factors indicate that the scale and its subdimensions are reliable. To evaluate the discriminant validity of the scale, an independent samples t-test was conducted between the top 27% and bottom 27% groups based on the total scores. The analysis revealed a significant difference in the total scores between the top group (N=23, M=2,444,624.81, SD=2,307,920.15) and the bottom group (N=23, M=125,714.25, SD=48,006.70) ($t(44) = 4.818$, $p<0.001$). The mean difference between the groups was 2,318,910.56, with a 95% confidence interval ranging from 1,348,836.12 to 3,288,984.99. Levene's test indicated unequal variances ($F=20.181$, $p<0.001$); however, the significance level remained consistent under both the assumption of equal variances and the assumption of unequal variances. In both cases, a statistically significant difference between the top and bottom groups was observed. These findings suggest that the scale has a high ability to discriminate between individuals with high and low scores, indicating adequate discriminant validity.

The matrix of the loads obtained after the rotation process is shown in Table 11. Loads that are below an absolute value of 0.65 are not shown in Table 11. This is because the loads that show a correlation can only be considered statistically significant at a confidence level of 95% when this value is exceeded (Işık et al., 2004).

Table 11

Post-rotation Loadings Matrix

Variables	Factor 1	Factor 2	Factor 3	Factor 4
HUCPC	0.957			
TOWPC	0.953			
GDPPC	0.923			
UINON	0.912			
CORRU	0.895			
BURQU	0.862			
UMOIN	0.831			
INPRO	0.803			
HATST	0.714			
AGDER		0.912		
MAMOR		0.882		
FERRA		0.879		
ADOFE		0.735		
EMAGF		0.699		
AGVAL		0.660		
OILRE			0.894	
NACPC			0.813	
INVAL			0.756	
RECON				0.966

Source: Calculated by the authors.

Table 11 shows the results of the exploratory factor analysis method, which yielded four fictitious variables. The first of the fictitious variables obtained by the exploratory factor analysis method was named "Indicator of the Level of Development of Countries," the second as "Indicator of Reliance on Agriculture as a Traditional Mode of Production," the third as "Indicator of Reliance on Strategic Natural Resources," and the last as "Renewable Energy Consumption Indicator".

The fit of the model obtained from the confirmatory factor analysis to the data was comprehensively evaluated using various fit indices and comparative model tests. The analysis results are summarised and interpreted below.

Table 12

Model -data Fit

Model Tests				
Label	X^2	df		*p*
User Model	750	147		<0.001
Baseline Model	13207	171		<0.001
Fit Indices				
		95% Confidence Intervals		
SRMR	RMSEA	Lower	Upper	RMSEA *p*
0.216	0.217	0.202	0.233	<0.001

Model Tests	
User Model and Baseline Model	Model
Comparative Fit Index (CFI)	0.954
Tucker-Lewis Index (TLI)	0.946
Bentler-Bonett Non-normed Fit Index (NNFI)	0.946
Relative Noncentrality Index (RNI)	0.954
Bentler-Bonett Normed Fit Index (NFI)	0.943
Bollen's Relative Fit Index (RFI)	0.934
Bollen's Incremental Fit Index (IFI)	0.954
Parsimony-normed Fit Index (PNFI)	0.811

Source: Calculated by the authors.

As presented in Table 12, the model appears to have room for improvement in terms of the absolute fit indices (SRMR and RMSEA), whereas it demonstrates a notably strong performance with respect to the comparative fit indices (such as CFI, TLI, IFI, etc.). Although the significance of the chi-square test suggests that there may be certain deficiencies in the model's absolute fit, the high values of the comparative fit indices indicate that the model achieves a substantial improvement over the baseline model. Therefore, it can be concluded that the model generally exhibits an acceptable and robust fit although some additional modifications may be required to enhance its absolute fit.

After confirming that the factor structure and reliability are acceptable, it is necessary to calculate the Average Variance Extracted (AVE) value for each factor. Based on the post-rotation loading matrix presented in Table 11, the AVE values for each factor are provided in Table 13. According to Table 13, since the AVE values are above 0.50, it can be stated that the factors have an acceptable level of internal consistency (Fornell & Larcker, 1981). The AVE value for Factor 4 is quite high (0.933). This is because there is only one observed variable clustered under this factor.

Table 13

Average Variance Extracted Value for each Factor

Factor	AVE
Factor 1	0.731
Factor 2	0.611
Factor 3	0.681
Factor 4	0.933

Source: Calculated by the authors.

The naming of these 4 independent fictitious variables (factors) has been done for now, but the reasons for the naming will be discussed together with the main purpose of this study, which is to obtain the quantitative values of the 4 independent factors affecting the female labour force participation rate by the regression method. To determine the significant independent variable(s), we analyse the quantitative values of the independent variables presented in Table 14 from the regression analysis. Upon analysing Table 11, it is evident that factor F1 has a significant and positive effect on LFPRF at a 95% confidence level. Similarly, factor F2 has a significant and positive effect on LFPRF at a 90% confidence level. On the other hand, factor F3 had a significant and negative effect on LFPRF at a 95% confidence level, while factor F4 did not have any statistically significant effect on LFPRF. Equation 2 for prediction can be derived from Table 14.

$$(\widehat{LFPRF}) = 58.865 + 8.649F_{1i} + 2.706F_{2i} - 5.136F_{3i} - 0.716F_{4i} \quad (2)$$

Table 14

Regression Model Results

	Beta Forecaster	Standard Error	Standardise Beta Forecaster	t	p	Confidence Interval Lower Bound	Confidence Interval Upper Bound	Collinearity Statistics	
								Tolerance	VIF
Constant	58.865	1.441		40.847	0.000**	55.998	61.732	1.000	1.000
F1	8.649	1.449	0.516	5.967	0.000**	5.766	11.533	1.000	1.000
F2	2.706	1.449	0.161	1.867	0.066*	−0.178	5.589	1.000	1.000
F3	−5.136	1.449	−0.306	−3.543	0.001**	−8.019	−2.252	1.000	1.000
F4	−0.716	1.449	−0.043	−0.494	0.623	−3.600	2.167	1.000	1.000
Dependent Variable: LFPRF								1.000	1.000

Notes: **significant at 0.95 confidence level; *significant at 0.90 confidence level

Source: Calculated by the authors.

According to the prediction equation, an increase of 1 point in Factor 1 is expected to increase the LFPRF score by 8.649 points. The interpretation of the prediction equation in terms of standard deviation is that a 1 standard deviation increase in Factor 1 will increase the LFPRF by 0.516 standard deviations. In the next section of the study, the factors will be interpreted and named, and the findings of the established regression model will be evaluated. Exploratory factor analysis aims to summarise the relationships between variables by revealing a smaller number of independent factors. In this process, it minimises the multicollinearity problem by ensuring that the factors are unrelated to each other (Costello & Osborne, 2005; Fabrigar & Wegener, 2012). The presented analysis results support this characteristic of the exploratory factor analysis and demonstrate that there is no multicollinearity problem among the factors.

Discussion

The first fictitious variable (Factor 1) obtained through the exploratory factor analysis method has been named the indicator of the Level of Development of Countries. Institutional development is measured by the level of corruption (CORRU), bureaucratic quality (BURQU), and investment profile (INPRO); economic development by per capita wealth (TOWPC) and GDP per capita (GDPPC); technological development by the number of women using mobile money, financial accounts (UMOIN), and the internet (UINON); and human capital by the present value of women's lifetime earnings (HUCPC), and the increase in student test scores (HATST). These indicators are considered reflections of economic development in the economics literature. In other words, a country's level of development can be seen as a reflection of female's labour force participation decisions. As seen in Equation 2, the level of development of countries is designed as a quantity that changes in the same direction as the female labour force participation rate. Accordingly, a 1 unit change in the level of development of countries results in an 8.649 unit change in the same direction in the female labour force participation rate. In economically developed countries, there is a strong correlation between the increase in income, wealth, and wages per woman and the rise in female's labour force participation. Increases in income, wealth, and wages increase female's labour supply through the substitution effect. These countries not only foster economic development but also prevent discrimination in the labour market through institutional infrastructure and legal regulations, implementing policies that promote gender

equality and increase labour force participation. Additionally, social networks and the widespread use of advanced technology are other important factors that support females' participation in the labour force.

The subsequent ranking of countries is typically determined by the weighting of factor scores, a process that is commonly conducted through the use of factor analysis. The factor scores calculated for each country were determined according to the effect of factor loadings on the observational variables. Equation 3 is the one that is used for obtaining factor scores.

$$F_i = w_1X_1 + w_2X_2 + \cdots + w_jX_j \quad (3)$$

Here, F_i denotes the score of country i for the specified factor, and w_j is the weight of the j-th observational variable. The rank function constructed according to the quantitative values (factor scores) of the first factor shows that the top five countries are: Norway (2.74), Switzerland (2.37), the USA (2.22), Sweden (2.22), and Australia (2.14); the last five countries are: Nicaragua (-1.08), Moldova (-1.05), Armenia (-0.99), Egypt (-0.97), and El Salvador (-0.92). The findings indicate that the Factor 1 variable obtained through factor analysis can serve as an indicator of a country's level of development.

When table 11 is analysed, changes in observational variables such as age dependency ratio (AGDER), which is demographic in nature; maternal mortality rate (MAMOR), total fertility rate (FERRA), and adolescent fertility rate (ADOFE), which are related to health; female employment in the agricultural sector (EMAGF) and the share of the agricultural sector in GDP (AGVAL), which are economic in nature, affect the traditional agriculture-based mode of production of countries in the same direction, and increases or decreases in these observational variables shape the perceptions in the economics literature on whether countries are agriculture-based economies or not. Therefore, the second of the fictitious variables (Factor 2) obtained through the exploratory factor analysis method is named the Indicator of Reliance on Agriculture as a Traditional Mode of Production. The indicator of dependence on agriculture as a traditional mode of production, similar to the indicator of the level of development of countries, is designed as a quantity that varies in parallel with the labour force participation rate of women. According to the quantitative value of this factor in Equation 2, a 1 unit change in the indicator of dependence on agriculture as a traditional mode of production results in a 2.706 unit change in the same direction in the female labour force participation rate. When ranking countries based on the quantitative values of factor 2, the top five were Niger (4.09), Tanzania (3.04), Uganda (2.84), Mozambique (2.66), and Cameroon (2.38). The bottom five are Bahrain (-1.24), Ukraine (-0.96), Russia (-0.94), Croatia (-0.82), and Thailand (-0.82). The findings suggest that factor 2 can be considered an indicator of reliance on agriculture as a traditional mode of production. Among these countries, common characteristics include a patriarchal social structure, low levels of education, high unemployment rates, low industrial development, low use of contraceptive methods, early marriages, high maternal mortality rates, and the employment of women in the agricultural sector as unpaid family workers or for low wages. The underdeveloped industrial and service sectors in these countries have resulted in agriculture becoming the dominant sector, with a higher share in GDP than any other sector. The limited education opportunities available to women in these societies restricts their employment options to agricultural work. This phenomenon is commonly referred to as the 'feminisation of agriculture" in economic literature (Tamang et al., 2014). As such, even though the agricultural sector is a sector with low marginal product productivity in countries based on agriculture as a traditional mode of production, it has a bidirectional effect on determining the female labour force participation rate in traditional societies.

The third fictitious variable (Factor 3) obtained through the factor analysis method is named the Indicator of Reliance on Strategic Natural Resources. The strategic natural resource dependence indicator was named considering its strong relationship with the observational variables presented in Table 11. According to Table 11, the changes and magnitudes in the per capita natural capital (NACPC), obtained by dividing the rents from all natural resources (such as oil, natural gas, minerals, coal, and forests) by the population, including the share of oil rents in GDP (OILRE), provide information on the extent to which a country relies on strategic natural resources when analysing and evaluating its economy. The information provided by this table helps to evaluate the extent to which a country relies on strategic natural resources when considering its economy. The interaction between changes in the first two observational variables in Table 11 and the strategic natural resource dependence in a country's economy creates the perception, in economic literature, that the country's economic structure is based on strategic natural resources to the extent of the magnitude of these variables. As can be seen from Equation 2, the quantitative value of the third factor has a negative sign. A one unit change in the strategic dependence on natural resources indicator causes a change of 5.136 units in the opposite direction in the female labour force participation rate, in absolute value. Based on the quantitative values of the third factor, the top five countries were Saudi Arabia (5.52), Iraq (4.70), Gabon (2.51), Iran (1.94), and Norway (1.86). Meanwhile, the bottom five countries are Greece (-0.94), Luxembourg (-0.81), Pakistan (-0.79), Portugal (-0.75), and Kenya (-0.73). countries with strategic natural resources, other than Norway, tend to have a traditional patriarchal social structure. Religious and cultural factors often play a dominant role in preventing women from participating in the labour market in these countries. In these countries, women have been excluded not only from working life but also from many areas of the public sphere. The similarity between developed countries such as Norway and the other countries mentioned above, in terms of having strategic natural resources, has been effective in establishing strong relationships with the indicator of strategic natural resource dependence, which affects the share of the industrial sector in the GDP variable.

The fourth and final fictional variable (Factor 4) obtained through factor analysis was designated the Renewable Energy Consumption Indicator. Given that only the observational variable of renewable energy consumption was clustered under this construct variable, the name of the observational variable was directly used in the naming of the construct variable. A renewed examination of Equation 2 reveals that the fictitious variable of renewable energy consumption exerts negligible influence on the dependent variable of female labour force participation rate (given that the statistical confidence level (p) of 0.377 is exceedingly low).

Conclusion

Technological advances have reduced the time between structural transformations in production and labour markets. Consequently, it has become imperative for the labour force and working life to adapt to these changes. In this context, it is imperative to expeditiously implement policies that enhance the labour force participation of women, a demographic that faces numerous disadvantages. In this study, the factors affecting the female labour force participation rate, as well as the direction and magnitude of their impact, were statistically analysed. Through factor analysis, abstract variables were made meaningful using concrete data, and quantitative values related to the female labour force participation rate were subsequently calculated using regression analysis. In analysing the factors determining female labour force participation rates, variables from not only economic and demographic categories but also health, education, energy, technology, human capital, political, and institutional categories were considered. This comprehensive

approach enabled multidimensional findings and facilitated a holistic perspective on the issue. Therefore, the policy recommendations presented below should be seen as complementary rather than substitutive.

As the first factor, the level of development of countries is a determining factor in female's labour force participation. Low wage and income levels as indicators of underdevelopment emphasise the importance of wage improvements and supportive policies. For sustainable female employment, job-oriented, technology-based, and continuous learning training programs need to be expanded. These programs will increase women's access to skilled jobs, reduce gender-based occupational segregation, and contribute to economic development. In the long term, effective education policies will support political and economic stability by strengthening the institutional infrastructure. The second factor determining the female labour force participation rate is the indicator of a country's traditional mode of production based on agriculture. Although this factor contributes positively to the increase in the said rate, the level of development of countries based on agriculture as a traditional mode of production remains low, as the name of the factor suggests. The low level of development and patriarchal structure result in women being exposed to low-paid, precarious, and intensive working conditions in agriculture. With migration from agriculture, these problems persist in urban areas, and females' participation in the labour force is constrained. It is imperative to register women in agricultural employment, ensure their social security rights, and enhance occupational health and safety measures. The implementation of age-specific policy designs, the initiation of birth control awareness-raising programs, and the effective execution of gender-balanced development policies in rural areas have been identified as additional measures that could contribute to the resolution of these issues. The third factor determining the female labour force participation rate is the indicator of strategic natural resource dependence. In economies where natural resources are of strategic importance, it is noteworthy that the share of natural resource rents in GDP is high and that there is a presence of capital-intensive industry. While the adoption of old technologies transferred from industrialised countries has increased the marginal productivity of labour in these economies, the service sector has not developed, and the agricultural sector has lagged behind due to geographical and technological limitations. The reinforcement of a patriarchal structure by religious and cultural values has further limited females' participation in the labour force. These structural impediments have culminated in the under-representation of women, even within the agricultural and industrial sectors. Economies dependent on strategic natural resources are at risk of sustainability with the propagation of renewable energy sources. Measures to address this problem should be taken without delay. A contemporary interpretation of patriarchal cultural and religious norms, coupled with the elimination of discriminatory practices, is imperative to enhance female participation in the labour force. Achieving these objectives necessitates a transformation of social attitudes to align with the outlined goals.

The absence of a holistic theory in the literature for determining the female labour force participation rate highlights certain limitations of this study. First, although the observational variables exhibited structural significance, the quantitative values obtained from the regression analysis caused omitted variable bias, leading to the establishment of only correlation relationships. Second, the restriction of panel data analysis to the EU and OECD countries, along with the inherent characteristics of the independent variables in the factor analysis, prevented the use of this method. The application of factor analysis was instrumental in addressing concerns regarding the independence of the variables in the context of panel data analysis. This approach helped avoid erroneous findings and provided valuable insights for future theoretical frameworks. However, due to the absence of variables representing religious and cultural factors and the exclusion of country-specific unit effects, the quantitative values of the factors were calculated with bias.

In subsequent studies, the factors determining the female labour force participation rate can be examined in different dimensions by using the factor analysis method. This will increase the amount of preliminary information required for the formation of a theory at this rate. The method is advantageous in that it allows the researcher to engage in creativity and the ability to make philosophical interpretations, which will be very useful in formulating a theory about what can increase female's labour force participation. Furthermore, if religious and cultural values are concretised as observational variables and rendered measurable, causal relationships related to the female labour force participation rate can be examined using panel data analysis, a sophisticated technique. Given the macro-level approach of this study, it is imperative to cross-reference its findings with those of the micro-level studies. Consequently, micro-level studies to be conducted in the future can examine the micro-foundations of the findings.

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Unveiling the Pricing Anomaly: A Detailed Examination of Initial Public Offerings in Borsa Istanbul in 2023

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Abstract This study investigates the short-term pricing anomalies observed in the initial public offerings in Borsa Istanbul during 2023. The raw returns of 39 newly listed firms were initially calculated and benchmarked against the Borsa Istanbul-100 index. To determine abnormal returns, these raw returns were adjusted for market performance over periods of one, three, and seven days post-offering. The statistical significance of these abnormal returns was evaluated using t-statistics at a 5% significance level. The results demonstrate statistically significant pricing anomalies, thereby challenging the market efficiency hypothesis. The presence of these anomalies shows that market participants do not immediately incorporate all available information into IPO pricing. This research contributes to the literature by highlighting the unique dynamics of an emerging market and provides empirical evidence of persistent short-term anomalies in initial public offering pricing in Borsa Istanbul. It underscores the need for enhanced regulatory frameworks to improve market efficiency and offers strategic insights for investors navigating the Turkish IPO market.

Keywords IPO · Pricing anomalies · Short-term analysis · Borsa Istanbul Stock Exchange · Abnormal returns

Jel Codes G12, G14, G32

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Unveiling the Pricing Anomaly: A Detailed Examination of Initial Public Offerings in Borsa Istanbul in 2023

The efficient market hypothesis posits that stock prices fully reflect all available information, making it impossible for investors to consistently achieve returns that outperform the market (Fama, 1970). However, empirical evidence often demonstrates deviations from this theoretical model, particularly in the context of initial public offerings (IPOs). This study focuses on the Borsa Istanbul, where recent IPOs have presented opportunities to evaluate market efficiency in short-term price behaviours.

In 2023, a comprehensive analysis was conducted on 39 firms that were publicly listed for the first time. These firms' performance was meticulously tracked from their IPOs, providing a unique dataset for examining potential short-term pricing anomalies. The methodology involved calculating raw returns and adjusting these figures to isolate abnormal returns over subsequent days, which were then statistically analysed.

Previous research has frequently highlighted that IPOs tend to exhibit significant abnormal returns shortly after the market debut, showing a temporary market inefficiency (Ritter, 1991; Loughran & Ritter, 2004). This phenomenon is often attributed to factors such as investor sentiment, underpricing by underwriters, and informational asymmetries between insiders and the general investor population.

Additionally, studies focusing on emerging markets, such as Borsa Istanbul, indicate that these anomalies can be more pronounced due to less stringent regulatory environments and varying levels of investor sophistication (Akyol et al., 2005). Therefore, the analysis of the Istanbul market not only contributes to the broader discourse on IPOs but also highlights specific regional dynamics that may influence pricing behaviours.

As the study progresses, the flow of the paper will explore the hypothesis that short-term pricing anomalies exist within the IPOs conducted in Borsa Istanbul. The subsequent sections will detail the methodology, present the empirical findings, and discuss the implications of these results on our understanding of market dynamics and IPO strategies. This introduction sets the stage for a rigorous examination of IPO performance, challenging prevailing financial theories with empirical data from a unique market setting.

Contribution to the Literature

This study contributes to the existing literature by providing an in-depth analysis of IPO pricing anomalies within an emerging market context, specifically focusing on the Borsa Istanbul during the year 2023. The inclusion of data from this particular market adds to the comprehensiveness of global IPO studies, which are often dominated by data from more developed markets. By employing a rigorous methodological framework that adjusts raw returns for market performance, a nuanced understanding of the extent and nature of pricing anomalies in IPOs is offered. Furthermore, the implications of these findings are discussed, highlighting the potential for regulatory improvements and strategic adjustments by market participants. Thus, this research not only enhances our understanding of IPO dynamics in emerging markets but also indicates practical implications for policymakers and investors aiming to mitigate the risks associated with IPO investments.

Literature Review

The Efficient Market Hypothesis (EMH), first articulated by Fama (1970), posits that financial markets are "informationally efficient," meaning that stock prices at any given time reflect all available information. This foundational theory has been a central theme in financial economics, influencing how researchers and practitioners view market behaviour and pricing mechanisms. However, the presence of anomalies, particularly around Initial Public Offerings (IPOs), has spurred a significant body of research questioning the universal applicability of the EMH.

Initial Public Offerings have been a rich area of study due to the frequent occurrence of underpricing, where IPOs are often priced below their market value at launch, leading to significant first-day returns for investors. Ritter (1991) and Loughran and Ritter (2004) have extensively documented these phenomena in developed markets, suggesting that underpricing serves as an incentive mechanism to mitigate investor uncertainty about the value of newly listed companies.

Further extending the discussion, Ibbotson and Jaffe (1975) and Rock (1986) examined the role of information asymmetry in IPO pricing. They argue that underpricing compensates investors for the risk of investing in new issues without adequate information. This perspective is particularly relevant in emerging markets, where information asymmetries are more pronounced due to less stringent disclosure requirements and regulatory oversight.

Research specific to emerging markets like Akyol et al. (2005) and Aggarwal, Leal, and Hernandez (1993) emphasises how local economic conditions, investor sentiment, and institutional frameworks play critical roles in shaping IPO outcomes. These studies highlight that emerging markets often display greater volatility and pricing anomalies compared to their developed counterparts, which can be attributed to the evolving nature of their financial and regulatory environments.

In addition to underpricing, scholars have explored the long-term performance of IPOs. Ritter (1991) and subsequent studies by Jegadeesh, Weinstein, and Welch (1993) found that while IPOs may initially outperform, their long-term market performance often fails to sustain the early momentum. This observation raises questions about the long-term value of IPOs and the rationality of investors during the IPO process.

McDonald and Fisher (1972) conducted a study examining 142 initial public offerings (IPOs) from the first quarter of 1969, each involving the sale of a minimum of 150,000 shares and exceeding $1 million in total. Their research aimed to provide insights into IPO underpricing, in line with the efficient market hypothesis. In addition, they explored pricing disparities among investment banks, attributing these differences to variations in investment bank behaviour during the pricing process. This study contributes to the literature by shedding light on the phenomenon of IPO underpricing and its relationship with investment bank practices. The dataset used likely comprises IPO data, including pricing details and investment bank involvement, allowing for a comprehensive analysis. The methodology employed may involve statistical analyses to assess the extent of underpricing and compare pricing strategies across investment banks. The findings support the efficient market hypothesis and show that differences in investment bank behaviour influence IPO pricing outcomes.

Logue (1973) examines the behaviour of investment banks in the pricing process of initial public offerings (IPOs), highlighting the implications of underpricing on both the investment bank and the issuing firm. The study finds that when an investment bank underprices an IPO, it minimises its own costs and risks while providing short-term gains to investors. However, this also signifies a loss in IPO proceeds for the issuing

firm. Conversely, pricing the IPO at or above its true value results in losses for investors and increases the investment bank's costs and the risk of IPO failure. Consequently, other firms considering IPOs may hesitate to choose the investment bank associated with a failed offering. The literature review aims to investigate the impact of investment bank behaviour on IPO pricing dynamics. The dataset used in this study likely includes IPO data and investment bank actions, enabling a comprehensive analysis of their interactions. The methodology may involve statistical modelling or case studies to assess the relationship between investment bank behaviour and IPO outcomes. The findings underscore the importance of investment bank pricing decisions in determining IPO success and subsequent market reputation.

Rock (1986) proposed the adverse selection model as a prominent explanation for the low pricing anomaly observed in initial public offerings (IPOs). This model categorises investors into two groups: informed investors who seek to purchase shares when the IPO is underpriced and uninformed investors who are willing to purchase shares regardless of pricing. The model suggests that in instances of underpricing, even if there is demand from both informed and uninformed investors, the distribution to uninformed investors will be minimal. Conversely, in cases of overpricing, uninformed investors will end up acquiring all issued shares, leading to the winner's curse phenomenon. The purpose of this literature is to investigate the implications of the adverse selection model on IPO pricing dynamics. The dataset used in this study comprises IPO data from various markets, allowing for a comprehensive analysis of pricing patterns. The methodology involves examining the distribution of shares to different investor groups under various pricing scenarios. The findings indicate that the adverse selection model provides valuable insights into understanding IPO underpricing phenomena, highlighting the importance of considering information asymmetry in IPO pricing mechanisms.

Muscarella and Vetsuypens (1989), in their study, rigorously tested the validity of Baron's 1982 model on IPO underpricing, which attributes lower offer prices to information asymmetries between issuers and underwriters. The research specifically focuses on a unique dataset comprising 38 investment banks that went public between 1970 and 1987 and undertook the distribution of their own securities, representing an unusual case of self-marketing during IPOs. The methodology involves a comparative analysis of these self-marketed IPOs against traditionally underwritten IPOs, assessing the levels of underpricing in both scenarios. Contrary to the predictions of Baron's model, the findings reveal that even when investment banks market their own IPOs—presumably reducing information asymmetries—the level of underpricing does not significantly differ from that observed in IPOs involving external underwriters.

Loughran and Ritter (2004), in their study investigation of IPO first-day returns, a longitudinal dataset spanning the 1980s to the early 2000s is scrutinised to elucidate the dynamic nature of underpricing trends. It is observed that a stark escalation in average first-day returns occurred, with an initial 7% in the 1980s, a rise to nearly 15% in the 1990s, a surge to 65% during the dot-com bubble, and a reversion to 12% post-bubble. The methodology applied likely encompasses a comparative statistical analysis across different time periods, aiming to uncover underlying patterns. The findings indicate that shifts in issuer objectives were significantly impacted by the market milieu, with less emphasis on maximising proceeds and a greater focus on obtaining research coverage in the later periods. Allocations of high-demand IPOs to executives' brokerage accounts are postulated to have incentivized a preference for underwriters known for pronounced underpricing.

Ellul and Pagano (2006), the purpose of their study is to expand upon traditional explanations for the underpricing of initial public offerings (IPOs) by introducing a novel theory that incorporates investor

concerns regarding after-market illiquidity resulting from asymmetric information post-IPO. The researchers use a dataset comprising 337 British IPOs conducted between 1998 and 2000 to investigate this phenomenon. Employing various measures of liquidity, the study finds empirical support for their model's predictions, indicating that expected after-market liquidity and liquidity risk significantly influences IPO underpricing. The methodology involves blending liquidity concerns with adverse selection and risk as motives for underpricing, offering a more comprehensive understanding of IPO pricing dynamics.

Ljungqvist (2007) examined the extensive phenomenon of IPO underpricing in his chapter, which seeks to elucidate the reasons behind the significant first-day price jumps observed in the U.S. markets during the 1990s, where the average discount exceeded 20%. The study is grounded in a review of diverse theoretical frameworks categorised under asymmetric information, institutional, control, and behavioural headings. Data encompassing various IPOs over a decade serve as the basis for the analysis, with a methodology that likely involves both qualitative and quantitative assessment of the empirical evidence related to these theories. Asymmetric information models are posited as having a primary influence on underpricing due to the information disparities among the issuing firms, underwriting banks, and new investors. However, the substantial variance in underpricing rates, particularly during peak periods such as the late 1990s dot-com bubble, shows that no single information-based explanation fully accounts for the observed outcomes. Consequently, the chapter also explores behavioural theories, institutional differences across countries, potential conflicts of interest within investment banks, and the implications of using auction methods for IPO pricing.

Chambers and Dimson (2009) delves into the historical underpricing of Initial Public Offerings (IPOs) in the UK, presenting an extensive analysis of IPO market efficiency from the post-World War I era to the modern deregulated market environment. The study encompasses a comprehensive dataset of British IPOs spanning from 1917 through 1986, with a subsequent examination of the period following the 1986 deregulation of the UK stock market. The methodology likely includes historical data analysis, comparing underpricing across different regulatory and economic contexts. The results indicate a distinct increase in the average underpricing from 3.80% during the interwar and World War II periods (1917-1945) to 9.15% in the post-war period up to 1986, with even higher rates subsequent to market deregulation. These findings are significant as they demonstrate that the increase in underpricing occurred despite advancements in regulatory and disclosure standards and irrespective of the changing composition of firms or the prestige of IPO underwriters.

Zou et al. (2020) conducted a study focusing on 10-year IPO initial returns in China's small and medium-sized enterprise (SME) board from 2006 to 2016, analysing a sample of 755 IPOs. The aim of their research was to examine the impact of policy changes in IPO pricing and trading mechanisms on first-day initial returns. Employing the stochastic frontier approach, the authors estimate the fair value of IPOs and decompose the components of deliberate underpricing and mis-valuation factors. They then use linear regressions to investigate the correlation between first-day initial returns and deliberate underpricing or misvaluation factors. The study finds that misvaluation factors, particularly the irrational behaviour of individual investors, primarily contribute to IPO underpricing in China's SME market, rather than deliberate underpricing. Additionally, the characteristics of IPO pricing vary across different periods, influenced by changes in IPO pricing policies.

Duong et al. (2021) investigated the impact of trading rules on market manipulation on initial public offering (IPO) underpricing using a large sample of 13,459 IPOs from 37 countries. Their study aims to assess

how exchange regulations affect IPO underpricing and subsequent market outcomes. The authors find that stringent trading rules on market manipulation decrease IPO underpricing. This effect is moderated by factors such as the certification of IPOs by reputable intermediaries, the level of shareholder rights protection in the country, the quality of financial reporting, and the adoption of International Financial Reporting Standards (IFRS). Additionally, better trading rules on market manipulation are associated with higher IPO proceeds, subscription levels, and trading volume, as well as lower IPO listing fees and better long-term post-IPO performance.

Mehmood, Mohd Rashid, and Tajuddin (2021) conducted a comprehensive review of underpricing research in initial public offerings (IPOs) across developed, developing, and emerging markets over the past three decades. The study aims to explore the extent of underpricing in different market segments and identify the key factors influencing initial returns. Through a thorough examination of existing literature, the authors find that underpricing tends to be higher in emerging markets compared to developing and developed markets, with issuers in emerging markets often perceiving underpricing as a signal of quality IPOs due to significant information asymmetry. The review identifies several significant factors that influence the level of underpricing, including country-specific environments, micro- and macroeconomic conditions, the quality of legal frameworks governing listing regulations, socio-political factors, and IPO marketing strategies. In addition, the authors discuss various theories and propositions developed to explain underpricing phenomena across the three market segments. They indicate that these factors could serve as primary determinants of IPO underpricing in future research, highlighting the importance of considering the diverse contextual factors influencing underpricing dynamics in different markets.

Gupta, Singh, and Yadav (2022) conducted a study focusing on the impact of media coverage on initial public offering (IPO) underpricing in the Indian market. Recognising the pivotal role of the media in disseminating information to investors, particularly those lacking the expertise to interpret prospectus information, the authors aim to disaggregate traditional IPO underpricing into three categories: voluntary, pre-market, and post-market, and assess the comparative influence of media sentiments on each category. Employing sentiment analysis on 2,891 media articles and using robust regression techniques, the study analyzes a sample of 222 Indian IPOs from 2009 to 2018. The findings indicate a positive relationship between media sentiment and traditional underpricing, with a particularly significant association observed between sentiment and pre-market underpricing. Surprisingly, the study reveals that the number of media articles does not significantly impact IPO underpricing. The research contributes to the literature by shedding light on the role of the media in IPO performance in the context of a developing market like India, where IPO laws and transparency levels differ from those in developed countries. By disaggregating IPO underpricing and evaluating media influence on primary and secondary markets separately, the study offers insights to investors for making effective investment strategies based on media sentiments.

Salerno, Sampagnaro, and Verdoliva (2022) conducted a study examining the relationship between FinTech IPOs (venture capital and equity crowdfunding-backed) and short-run performance, focusing on the level of underpricing. Utilising an international sample, the authors aim to assess whether FinTech IPOs exhibit higher levels of underpricing compared to non-FinTech IPOs and to provide insights into the implications of the FinTech industry on stock underpricing for managers and entrepreneurs. After correcting for selection bias, the study finds that FinTech IPOs are indeed more underpriced than similar non-FinTech IPOs. This result remains robust after addressing issues related to unobserved factors, confirming a positive relationship between being a FinTech IPO and a higher level of underpricing. The analysis contributes

to a better understanding of the impact of the FinTech industry on IPO underpricing dynamics, offering implications for stakeholders in the FinTech sector.

Liu et al. (2023) present a study focusing on the relationship between investor attention and initial public offering (IPO) underpricing, aiming to provide insights into how firms attract attention and its subsequent impact on IPO outcomes. Building on earlier research indicating the long-term benefits of pre-offering investor attention, the authors propose a model wherein firms utilise underpricing as a strategy to attract investor attention and encourage participation in the IPO process. The model generates predictions regarding the relationship between initial returns and attention, retention, expansion, and the benefits of attention, considering the asymmetry of this relationship. Empirical findings support the model's predictions, indicating a positive relationship between investor attention and both initial returns and the magnitude of price revision. Furthermore, the study reveals an asymmetric relationship between attention and underpricing, which is stronger under conditions of greater ex ante uncertainty. The implications of these findings extend to direct listings, public information adjustment, the popularity of grey market/when-issued trading, and the potential impact of the JOBS Act on pre-IPO trading. Overall, the research contributes to our understanding of IPO underpricing dynamics and sheds light on the mechanisms through which firms attract investor attention in the pre-offer phase.

Katsafados et al. (2023) explored the predictive power of textual information extracted from S-1 filings in explaining initial public offering (IPO) underpricing, employing a novel approach by integrating machine learning algorithms into their analysis. Using a dataset comprising 2,481 US IPOs, the authors demonstrate that textual information complements financial variables in predicting both the likelihood and magnitude of underpricing, resulting in improved prediction accuracy compared to models utilising financial data alone. Their findings reveal that models incorporating both textual and financial data outperform those relying solely on financial variables, with the best-performing model achieving a substantial improvement in accuracy. Moreover, the authors highlight the superiority of sophisticated machine learning models over traditional logistic regression in predicting IPO underpricing. They attribute the enhanced predictive power of textual information to its ability to mitigate the ex ante valuation uncertainty of IPO firms. Additionally, the authors construct a portfolio based on out-of-sample machine learning predictions, which yields remarkable average returns and outperforms the benchmark in various time dimensions, underscoring the practical relevance of their findings for investors in IPO markets.

Ranganathan and Veeraraghavan (2023) investigated the impact of the specific use of proceeds disclosure on initial public offering (IPO) underpricing in India, leveraging a unique regulatory framework that allows for the estimation of voluntary and aftermarket underpricing. Their study aims to ascertain whether disclosure of the specific use of proceeds influences underpricing in the pre- and aftermarket phases. Analysing data from Indian IPOs, the authors find that disclosure of specific use of proceeds increases voluntary underpricing during the premarket phase while reducing aftermarket underpricing. Moreover, they observed that the effect of disclosure varies depending on the level of information asymmetry and investor sentiment, with a greater impact observed for firms facing higher information asymmetry in the premarket and those with higher investor sentiment in the aftermarket. These core findings remain robust even after addressing endogeneity concerns through various tests. Overall, the study highlights the differential impact of disclosure on underpricing in different stages of the IPO process, shedding light on the role of the specific use of proceeds disclosure in shaping investor perceptions and market outcomes.

Gao, Wang, and Liu (2024) investigated the relationship between board chair gender and IPO underpricing in China, examining the phenomenon through the lens of the glass ceiling theory. Utilising a large sample of Chinese IPOs, the study reveals that firms with female board chairs (FBCs) experience lower levels of underpricing compared to those led by male board chairs (MBCs), suggesting that investors interpret FBCs as a positive signal for IPO success. The authors employed instrumental variable regressions and propensity score matched sample tests to address potential endogeneity concerns, confirming the robustness of their findings. Further analyses indicate that this relationship is more pronounced in firms characterised by greater internal gender discrimination, higher risk-taking propensity, and CEO-chair duality. Moreover, firms led by FBC exhibit better operating performance post-IPO although there is no evidence indicating that they adopt more conservative financial reporting or risk-taking behaviours. This study extends existing research on IPO underpricing determinants and the influence of gender discrimination on corporate leadership, offering implications for optimising gender diversity in top management and enhancing IPO pricing efficiency.

Underpricing Anomaly in IPOs Performed in 2023 in Borsa İstanbul Stock Exchange

Dataset and Sample Structure

The dataset for this study comprises the initial public offerings (IPOs) of 39 firms that were first listed on Borsa Istanbul in 2023. Extensive data, including IPO prices, the revenue collected from the IPOs, and the dates of the offerings, were gathered from Borsa Istanbul. Post-IPO stock price information was obtained from the trading platform TradingView. This sample provides a comprehensive base for analysing the short-term pricing anomalies in the IPO market of an emerging financial market such as Turkey.

The following tables contain summarised statistics (frequency analysis) of IPOs on Borsa Istanbul in 2023. Table 1 shows the number of IPOs by type of sale and Table 2 shows the number of IPOs by market.

Table 1

Distribution of initial public offerings based on the sales type

Sale Method in an IPO	# of IPOs
Sales in the Exchange– Book Building at Fixed Price	5
Book Building at a Fixed Price	34
TOTAL	**39**

Source: https://spk.gov.tr/ihrac-verileri/ilk-halka-arz-verileri

The table presents two of the methods used for share allocation in Initial Public Offerings (IPOs) in 2023: book building at a fixed price and sales conducted within the exchange. While Borsa Istanbul (BIST) offers three methods for share allocation—book building, sales within the exchange, and sales without book building—only two of these methods were utilised in the IPOs examined for 2023. Specifically, five IPOs were executed on the exchange, showing that these entities might have sought the transparency and liquidity provided by the exchange environment. In contrast, the majority, 34 IPOs, were conducted using book building, reflecting a preference for a more controlled sale environment where issuers may negotiate directly with investors. This disparity could be attributed to several factors, such as cost considerations, speed of execution, and the desire for a more selective investor base. The table highlights a predominant trend of companies opting for IPOs through book building, possibly due to the perceived advantages this method offers over other available options.

Table 2

Distribution of initial public offerings based on the market

Market Type	# of IPOs
BIST–Main	3
BIST-Stars	36
TOTAL	**39**

Source: https://spk.gov.tr/ihrac-verileri/ilk-halka-arz-verileri

The table displays a division of Initial Public Offerings (IPOs) across two Borsa İstanbul (BIST) market segments, with only three IPOs listed on the Main market and a significant majority, thirty-six, opting for the Stars market. The inclination towards the BIST Stars segment may be due to its appeal to companies seeking enhanced visibility and credibility through stringent listing criteria related to financial transparency and corporate governance. This distribution suggests that during the period under review, the market conditions or strategic objectives favoured the Stars market, perhaps because of its potential to attract more discerning investors and possibly offer better trading liquidity for newly listed companies.

The amount of funds raised from the public offering for each company, the ratio of demand to the public offering, and the number of investors allocated are shown in Table 3 as follows:

Table 3

Amount of Funds Raised from Public Offering by Company, Demand Ratio to Public Offering, and Number of Investors Allocated

Firm Title	Amount of Funds Raised (USD)	Subscription Ratio in IPO	# of Investors Allocated
Akfen Renewable Energy Inc.	176.139.961	23	419.123
CW Energy Engineering Trade and Industry Inc.	167.577.938	4	2.243.594
Bien Building Products Industry Tourism and Trade Inc.	158.219.970	1	1.446.140
Astor Energy Inc.	139.864.984	34	690.734
Enerya Energy Inc.	127.886.331	3	2.637.008
Europower Energy and Automation Technologies Industry Trade Inc.	125.980.668	4	2.118.379
Kaleseramik Çanakkale Kalebodur Ceramics Industry	101.677.986	3	1.919.116
İzdemir Energy Electricity Production Inc.	97.203.476	4	2.648.584
Kayseri Sugar Factory Inc.	88.148.674	1	1.619.459
ASCE Real Estate Investment Partnership Inc.	77.173.211	2	1.320.135
Reeder Technology Industry and Trade Inc.	74.248.051	4	4.208.278
Ebebek Retail Inc.	69.719.585	8	3.804.835
Adra Real Estate Investment Partnership Inc.	62.014.185	1	2.536.304
Tatlıpınar Energy Production Inc.	58.487.219	4	2.233.460
Koza Polyester Industry and Trade Inc.	56.545.713	5	1.729.153
Eksun Food Agriculture Industry and Trade Inc.	51.538.314	15	1.210.861
Göknur Foodstuffs Energy Manufacturing Import Export Trade and Industry Inc.	46.225.350	8	862.805
CVK Mining Enterprises Industry and Trade Inc.	45.858.204	5	1.452.252

Firm Title	Amount of Funds Raised (USD)	Subscription Ratio in IPO	# of Investors Allocated
Great Chefs Food Tourism Textile Consulting Organisation Education Industry and Trade Inc.	42.747.770	5	1.800.881
Atakey Potato Food Industry and Trade Inc.	41.452.793	5	1.665.576
Kuzugrup Real Estate Investment Partnership Inc.	38.198.699	6	2.085.695
A1 Capital Investment Securities Inc.	37.343.052	2	753.645
Hat-San Ship Repair Maintenance Marine Transportation Industry and Trade Inc.	37.177.126	6	3.735.529
Pasifik Eurasia Logistics Foreign Trade Inc.	36.922.810	3	903.205
Katılımevim Savings Financing Inc.	35.002.824	1	474.210
Gıpta Office Stationery and Promotional Products Manufacturing Industry Inc.	31.183.907	7	3.364.933
Söke Milling Industry and Trade Inc.	31.000.331	118	787.164
Fuzul Real Estate Investment Partnership Inc.	30.396.523	3	1.326.874
DMR Bakery Products Production Food Wholesale Retail Export Inc.	28.335.406	7	2.974.287
Office Yem Food Industry Trade Inc.	22.913.511	3	1.425.001
Graınturk Agriculture Inc.	22.703.115	6	1.248.019
SDT Space and Defence Technologies Inc.	20.966.603	20	838.560
Tarkim Plant Protection Industry and Trade Inc.	20.078.371	4	2.675.408
Bülbüloğlu Crane Industry and Trade Inc.	18.975.282	131	373.600
Mackolik Internet Services Trade Inc.	17.201.804	31	678.726
Tapdi Oxygen Special Health and Education Services Industry Trade Inc.	15.247.096	2	743.501
Baydöner Restaurants	13.986.842	3	1.264.215
Forte Information Communication Technologies and Defence Industry Inc.	11.379.602	3	660.379
Oncosem Oncological Systems Industry and Trade Inc.	5.569.194	18	36.044
Grand Total	**2.283.292.481**	**13**	**64.915.672**

Source: https://spk.gov.tr/ihrac-verileri/ilk-halka-arz-verileri

In the table presented, a summary of IPOs is provided, delineating funds raised by various firms, the subscription ratios attained, and the number of investors allocated. Akfen Renewable Energy Inc. is observed to have raised the highest amount of funds, amounting to $176,139,961, with a subscription ratio of 23 and attracting 419,123 investors. In contrast, CW Energy Engineering Trade and Industry Inc. and Bien Building Products Industry Tourism and Trade Inc. also raised substantial funds but with lower subscription ratios and a higher number of investors, suggesting a broader distribution of their shares. A diversity in the level of investor interest is depicted, with the subscription ratios ranging widely, from as high as 118 for Söke Milling Industry and Trade Inc., indicating a possibly oversubscribed offering, to as low as 1 for several companies, which might reflect a targeted or more exclusive investor outreach. The total of approximately $2.28 billion raised across these IPOs, coupled with an average subscription ratio of 13 and a considerable aggregate of over 64.9 million investors, underscores a robust participation and capital acquisition in these market

entries, which may be attributed to the prevailing economic sentiment and the strategic positioning of these firms within their respective sectors.

The number of initial public offerings by brokerage firms is shown below in Table 4.

Table 4

Number of Initial Public Offerings by the Brokerage Firm

Firm Title	# of IPOs
Garanti Investment Securities Inc.	4
Information Investment Securities Inc.	3
Halk Investment Securities Inc.	3
Information Investment MD	2
Tera Investment Securities Inc.	2
Yapı Kredi Investment Securities Inc.	2
Pyramid Securities Inc.	1
Consortium led by information Investment MD-Vakıf Investment	1
Consortium led by Deniz Investment - T. Development and Investment Bank	1
Deniz Investment MD	1
Information Investment Securities Inc.	1
A1 Capital Investment Securities Inc.	1
TEB Investment Securities Inc.	1
Garanti Investment Securities Inc.	1
Ak Investment MD	1
Consortium led by Gedik Investment MD	1
Ahlatcı Investment, Vakıf Investment Securities Inc.	1
Consortium led by Halk Investment MD	1
Consortium led by İş Investment MD and Ara Investment	1
Halk Investment MD.	1
QNB Finance Investment Securities Inc.	1
Tera Investment Securities Inc.	1
Ak Investment Securities Inc.	1
TSKB, Investment Financing and Ziraat Investment Securities Inc.	1
Consortium led by Ak Investment-Garanti Investment and Yapı Kredi Investment	1
Ünlü Securities Inc.	1
Consortium led by A1 Capital Investment MD	1
Information Investment MD	1
Consortium led by Halk Investment and Integral Investment MD	1
TOTAL	**39**

Source: https://spk.gov.tr/ihrac-verileri/ilk-halka-arz-verileri

The table provided enumerates the entities that have orchestrated IPOs, highlighting a range of investment security companies and various consortia that have facilitated these offerings. It is observed that Garanti Investment Securities Inc. took the lead in underwriting four IPOs, while information Investment Securities Inc. and Halk Investment Securities Inc. were each responsible for three. A consortium led by

information Investment MD-Vakıf Investment and others engaged in singular IPOs, reflecting a strategy that perhaps leveraged combined expertise for specific market entries. This distribution across entities may indicate market perceptions of their respective proficiency and reputations. The cumulative number of 39 IPOs underscores a diverse and competitive field within the securities sector, with the involvement of consortia indicating collaborative approaches in some market debuts, possibly to mitigate risks or to capitalise on shared resources and networks. The varied participation of different firms and consortia in this process reflects the dynamic nature of the investment landscape, where strategic alliances and expertise specialisation play pivotal roles in the orchestration of IPOs.

Methodology

The methodology of this study centres around the calculation of raw and abnormal returns to identify short-term pricing anomalies following IPOs. Raw returns (R) for each firm were calculated for specific days post-IPO using the following formula:

R= (Price on day t – IPO price) / IPO price (1)

The market return (MR) is also calculated as follows:

MR = (BIST-100 Price on day t – BIST-100 Price on day t-1) / BIST-100 Price on day t-1) (2)

Abnormal returns were then calculated by adjusting these raw returns against the Borsa Istanbul-100 national equity index's percentage change, serving as the market return benchmark. The abnormal return, average abnormal return, cumulative abnormal return and average cumulative abnormal return are the focal points of the analysis, calculated as follows (Asquith and Mullins,1986):

Adjusted Return= Raw Return – Market Return (3)

$$\overline{\mathbf{AR_t}} = \frac{1}{N}\sum_{i=1}^{n} AR_{it}(4) \tag{1}$$

$$\mathbf{CAR_{t_1}^{t_2}} = \sum_{t=t_1}^{t_2} AR_t(5) \tag{2}$$

$$\overline{CAR_t} = \frac{1}{N}\sum_{i=1}^{N} CAR_{it}(6) \tag{3}$$

The hypothesis statements are as follows:

H_0: $\overline{AR_t}$, $\overline{CAR_t}$≤0 (No pricing anomaly is present)

H_1: $\overline{AR_t}$, $\overline{CAR_t}$≤0 (A pricing anomaly is present)

The statistical significance of the observed returns was assessed using t-statistics compared against critical values at a 5% significance level.

3. **Test Results**

The statistical analysis revealed that the abnormal returns post-IPO were significant, especially within the first three days following the offerings. The results for the one-day, three-day, and seven-day periods post-IPO are as follows:

The first-day price performances of stocks offered to the public for the first time in 2023 are shown in Table 5 below:

Table 5

First Daily Price Performances of Stocks Offered to the Public for the First Time in 2023

N	R	t-statistic	AR	t-statistic
39	0,08	1,58*	0,08	1,50*

Note: n is the number of observations. * indicates significance at the 5% significance level. The critical values required for the t-test were taken from Tarı (2012: 500) and is 1.645 for 5%.

Table 5 presents the first-day price performance of 39 IPOs listed on Borsa Istanbul in 2023. The table reports the raw return (R), abnormal return (AR), and corresponding t-statistics for each measure. The findings reveal that the first-day raw return and abnormal return are both positive, each registering a value of 0.08. The respective t-statistics for these returns are 1.58 and 1.50, with the abnormal return's t-statistic approaching the critical threshold for significance at the 5% level (t-critical = 1.645). These results indicate the presence of short-term underpricing, a phenomenon frequently observed in IPOs, where the offer price is set below the subsequent market price on the first trading day. This underpricing is often attributed to information asymmetry, issuer strategies to stimulate demand, or efforts to reduce the risk of listing failure. The marginal significance of the t-statistics implies that, while a clear positive return is observed, the anomaly is not overwhelmingly significant. Nonetheless, the positive first-day abnormal returns show that early investors may achieve excess profits. This finding supports previous literature on IPO underpricing and highlights the potential for short-term gains in the Turkish IPO market.

The first-3 days price performances of stocks offered to the public for the first time in 2023 are shown in Table 6 below:

Table 6

First 3 Days Price Performances of Stocks Offered to the Public for the First Time in 2023

Day	n	R	t-statistic	AR	t-statistic	CAR	t-statistic
1	39	0,08	1,58	0,08	1,50	0,27	2,48
2	39	0,08	1,47	0,08	1,35	0,16	1,66
3	39	0,06	0,06*	0,07	0,07*	0,15	0,14*

Note: n is the number of observations. * indicates significance at the 5% significance level. The critical values required for the t-test were taken from Tarı (2012: 500) and is 1.645 for 5%.

Table 6 extends the analysis of IPO performance to a 3-day period following the public offering. The raw returns (R), abnormal returns (AR), and cumulative abnormal returns (CAR) are reported for each of the three days, along with their corresponding t-statistics. The results reveal that positive returns persist beyond the initial trading day, with cumulative abnormal returns (CAR) reaching 0.27 by the end of Day 3. The t-statistic for the CAR (2.48) is statistically significant at the 5% level, indicating sustained abnormal returns over this period. While the abnormal returns for the first two days remain positive and significant, a decline is observed on the third day, where the abnormal returns are lower (0.07) and the associated t-statistic (0.07) is notably weak. The pattern observed in this table reflects a typical post-IPO trend where high initial investor enthusiasm and speculative activity drive returns upwards, only for the momentum to wane in subsequent days. This tapering effect may be due to profit-taking by early investors or the market's gradual incorporation of new information. The statistical significance of cumulative returns over the 3-day period highlights the persistence of IPO underpricing and indicates that market adjustments are not immediate. These results challenge the efficient market hypothesis, which assumes that prices fully and instantaneously reflect available information. For investors and policymakers, these findings underscore the importance of

understanding the short-term dynamics of IPO pricing as well as the role of behavioural factors, such as investor sentiment and speculative trading.

The first-7 days price performances of stocks offered to the public for the first time in 2023 are shown in Table 7 below:

Table 7

First 7 Days Price Performances of Stocks Offered to the Public for the First Time in 2023

Day	n	R	t-statistic	AR	t-statistic	CAR	t-statistic
1	39	0,08	1,58	0,08	1,50	0,27	2,48
2	39	0,08	1,47	0,08	1,35	0,16	1,66
3	39	0,06	0,06*	0,07	0,07*	0,15	0,14*
4	39	0,05	0,79	0,06	0,75	0,12	0,97
5	39	0,06	0,85*	0,05	0,69*	0,10	0,85*
6	39	0,05	0,75	0,04	0,55	0,09	0,70
7	39	• 0,12	• 0,13*	• 0,10	• 0,10*	• 0,06	• 0,06*

Note: n is the number of observations. * indicates significance at the 5% significance level. The critical values required for the t-test were taken from Tarı (2012: 500) and is 1.645 for 5%.

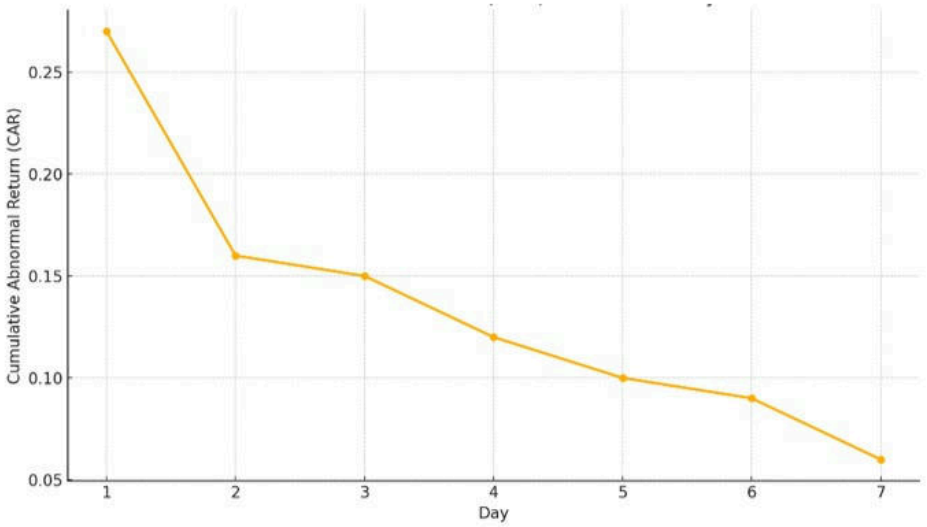
Table 7 provides a comprehensive view of the performance of IPOs on Borsa Istanbul over a 7-day period, highlighting daily raw returns (R), abnormal returns (AR), and cumulative abnormal returns (CAR), alongside their respective t-statistics. The data reveal that positive abnormal returns persist for the first five days, with the fifth day exhibiting a notable level of significance (t-statistic = 0.85*), suggesting that short-term gains remain achievable for investors. However, a shift in trend was observed on the sixth and seventh days, with abnormal returns turning negative. By the seventh day, the abnormal return declines to 0.10, with a corresponding t-statistic of 0.10*, indicating a potential correction in the market valuation of these newly listed shares.

The evolution of the cumulative abnormal returns (CAR) over this 7-day period is particularly noteworthy. The CAR steadily increased from 0.27 on Day 1 to a peak of 0.15 on Day 3, after which it began to taper off. By the end of Day 7, the CAR stood at 0.06, signaling a gradual convergence of IPO prices towards their fundamental values. This trend aligns with the "reversion to the mean" theory often discussed in the IPO literature, where the inflated initial returns are gradually corrected as market participants reassess the true value of the newly listed stocks. One possible explanation for this reversal in returns be early profit-taking by speculative investors who capitalise on the initial market euphoria. Additionally, as new information becomes available to the broader market, the initial price deviations caused by information asymmetry may diminish, leading to more rational pricing. This pattern is consistent with prior research on IPOs in emerging markets, where early price volatility is often more pronounced due to the higher degree of investor sentiment and limited market transparency.

A visual interpretation of short-term pricing dynamics following initial public offerings is presented through the cumulative abnormal returns (CAR) plotted over the first seven trading days, offering empirical insight into the temporal trajectory of market adjustments.

Figure 1

Cumulative Abnormal Returns over First 7 Days Post-IPO



The evolution of cumulative abnormal returns (CAR) within the first seven trading days stands out as illustrative of short-term market dynamics in Borsa Istanbul's 2023 IPOs. A notable upward progression occurs during the initial three days with CAR reaching a zenith of 0.27—showing signs of heightened investor excitement and speculation characteristic to underpriced IPOs. Following Day 3, this figure drops and stabilizes at 0.06 by Day 7. This drop further signals a market correction where previously frothy valuations are rationalized as fresh information gets integrated into the system. The pattern illustrates the fleeting nature of such inefficiencies in emerging markets which are dominated by hype due to speculative trading and minimal disclosure policies. All in all, the pattern is a challenge to instantaneous market efficiency hypotheses as some gains from trades can still be captured by precocious investors even though prices swiftly revert to underlying asset values just restore equilibrium post-adjustments. In any case these findings highlight for regulators the need for enhancing post-IPO transparency policies aimed at increasing confidence and reducing volatility surrounding newly listed companies.

These results underscore the presence of pricing anomalies in the short term, challenging the efficiency of market responses to new listings on Borsa Istanbul.

Discussion

This study's examination of short-term pricing anomalies in IPOs at Borsa Istanbul in 2023 has revealed significant insights that both align with and diverge from findings in the existing literature. Consistent with studies such as Ritter (1991) and Loughran & Ritter (2004), which report that IPOs frequently experience short-term abnormal returns due to factors like investor optimism and underpricing by underwriters, this study also identified similar anomalies within the first week of IPO listings.

However, where this study distinguishes itself is in its focus on an emerging market context. Unlike many studies that concentrated on developed markets, such as those in the United States or Western Europe, the findings here emphasise the unique dynamics of the Turkish financial market. For instance, while the literature often points to regulatory and institutional factors as critical determinants of IPO performance, this study suggests that in emerging markets like Turkey, other variables such as market sentiment and local

economic conditions might play a more significant role. This agrees with Akyol et al. (2005), who show that emerging markets exhibit distinct behaviours due to their developmental stage and regulatory environment.

Moreover, this study extends the discourse by highlighting the persistence of anomalies beyond the immediate aftermath of IPOs, suggesting that market inefficiencies in Borsa Istanbul may be more pronounced and longer-lasting than those documented in more mature markets. This finding challenges the assumption commonly held in much of the existing literature that markets swiftly correct any mispricings, as posited by the efficient market hypothesis (Fama, 1970). The significant contribution of this research lies in its detailed analysis of an underexplored market, providing empirical evidence that extends our understanding of financial markets' geographical nuances. By focusing on a single emerging market with a limited sample size within a specific timeframe, this study offers a focused narrative that underscores the variability of IPO behaviours across different economic contexts.

In summary, while this study corroborates some established findings in the broader IPO literature, it also illuminates new aspects of market behaviour in emerging markets, providing a foundation for further inquiry into global financial market dynamics. This research, therefore, not only enriches the existing academic discourse by challenging some conventional norms but also opens new avenues for future investigations into the complexities of IPO markets worldwide.

In light of the t-statistical evaluations conducted for different post-IPO periods, the following table synthesizes the hypothesis test outcomes, summarizing the presence and significance of pricing anomalies across one-day, three-day, and seven-day intervals.

Table 8

Summary of Hypothesis Test Results on IPO Pricing Anomalies in Borsa Istanbul (2023)

Period	Observed AR	t-statistic (AR)	Observed CAR	t-statistic (CAR)	Critical t-value (5%)	Hypothesis Decision	Interpretation
Day 1	0.08	1.50	0.27	2.48	1.645	Fail to Reject H_0	Marginal anomaly; not statistically significant at 5%
Days 1–3 (Cumulative)	–	–	0.27	2.48	1.645	Reject H_0	Statistically significant anomaly observed
Days 1–7 (Cumulative)	–	–	0.06	0.06	1.645	Fail to Reject H_0	Anomaly dissipates; returns converge to normal

As per the test results, it was observed that significant statistically abnormal returns were detected within a window of three days post IPO listings on Borsa Istanbul during 2023. The cumulative abnormal return (CAR) for this period generated a t-statistic of 2.48 which is above the 5% critical value of 1.645. Hence, the null hypothesis claiming no pricing anomalies to be present (H_0: AR, CAR ≤ 0) is rejected for the three day window supporting the claim of short-term underpricing. On the contrary, first day abnormal return although positive (AR = 0.08), yielded a t-statistic of 1.50 which does not surpass the critical value. This indicates the anomaly may exist but is not strongly supported on just the first trading day only. In addition, in analyzing over a period of seven days, there clearly emerged a dissipation of abnormal returns such that CAR equaled to 0.06 and its t-statistic standing at (0.06) demonstrated no evidence towards persistent mispricing. These observations are in support with other literature revolving around IPO underpricing in emerging markets where it is observed to be strong but then quickly reverts back toward equilibrium as information flow

increases and new data gets incorporated into markets mechanism over time demonstrating temporal irrational behavior or inefficiency within Turkish IPO market .

Conclusion

The phenomenon of initial public offerings (IPOs) has been a critical topic of investigation within the realm of financial markets, particularly in relation to market efficiency, information asymmetry, and investor behaviour. The Efficient Market Hypothesis (EMH) posits that all available information is fully reflected in stock prices, leaving no room for investors to achieve abnormal returns. However, empirical evidence has frequently contradicted this theoretical model, especially in IPO contexts, where short-term pricing anomalies have been well-documented. Such anomalies are often linked to investor sentiment, asymmetric information, and underwriter strategies, making IPOs a fertile ground for exploring deviations from market efficiency.

Emerging markets, unlike their developed counterparts, tend to display unique market characteristics that influence the pricing behaviour of IPOs. The relative immaturity of these markets, coupled with weaker regulatory oversight and heightened information asymmetry, amplifies the likelihood of pricing inefficiencies. Studies have demonstrated that IPOs in emerging markets such as those in Turkey are prone to higher levels of volatility and stronger underpricing effects. These characteristics present a unique opportunity to assess market efficiency within a non-traditional financial landscape. Accordingly, the Borsa Istanbul serves as an ideal setting for examining these phenomena, as it reflects the characteristics of an emerging market while providing access to sufficient data for empirical analysis.

This study investigates the short-term pricing anomalies observed in 39 IPOs conducted on Borsa Istanbul during 2023. The analysis focuses on the raw returns (R), abnormal returns (AR), and cumulative abnormal returns (CAR) within the one-day, three-day, and seven-day periods post-IPO. Through the use of t-statistics, the statistical significance of these returns is examined, providing insight into whether abnormal returns are sustained beyond the initial trading day. The findings reveal the existence of significant pricing anomalies, particularly within the first three days following an IPO. While raw returns are consistently positive across the one-day, three-day, and seven-day windows, abnormal returns begin to wane after the third day, suggesting a gradual alignment of market prices with fundamental values.

Moreover, the study highlights notable fluctuations in the cumulative abnormal returns (CAR) during the seven-day observation period. On the first day, CAR exhibited a significant positive increase, reaching a peak on the third day. However, in the days that follow, a decline in CAR is observed, with returns eventually approaching zero. This pattern is consistent with the "reversion to the mean" hypothesis, whereby inflated returns generated by market enthusiasm are progressively corrected as investor sentiment stabilises. The downward shift in CAR towards the end of the seven-day period may also reflect profit-taking behaviour by speculative investors, as well as the market's effort to integrate new information about the IPO's intrinsic value. These results support the argument that while short-term pricing anomalies exist, they are not persistent, as prices gradually adjust to reflect available information.

The overall findings of this study contribute to the existing literature on IPO pricing behaviour in emerging markets. Evidence of short-term pricing anomalies challenges the EMH's premise that markets operate with complete informational efficiency. The persistent underpricing effect seen in the first three days indicates that newly listed firms on Borsa Istanbul are subject to speculative trading and investor overreaction. However, the eventual convergence of prices towards fundamental values aligns with theoretical expecta-

tions, underscoring the self-correcting nature of financial markets. From a regulatory perspective, these findings highlight the importance of enhancing disclosure requirements and transparency during the IPO process to improve market efficiency. For investors, the presence of short-term pricing anomalies may signal lucrative trading opportunities, but it also underscores the need for caution, as profits from IPO speculation are not guaranteed to persist. Overall, the study sheds light on the dynamic nature of IPO pricing in emerging markets, offering valuable insights for policymakers, investors, and academics alike.

Implications

The implications of this study are manifold. For policymakers and regulatory bodies, the evidence of short-term pricing anomalies shows a need for more stringent disclosure requirements and possibly a review of the IPO processes to enhance market transparency and efficiency. For investors, the findings highlight the potential for gains from short-term investments in IPOs, although such strategies require careful analysis of market conditions and individual IPO characteristics. For academics, this study enriches the existing literature on market efficiency and provides a basis for further scholarly discussion on the unique aspects of emerging markets. Ultimately, these insights could guide the development of more sophisticated financial models and investment strategies that better reflect the realities of the IPO market.

Limitations

This study, while providing valuable insights into IPO pricing anomalies in Borsa Istanbul, is not without its limitations. First, the analysis was confined to a single year and a specific emerging market, which may limit the generalizability of the findings. Additionally, the sample size of 39 firms, although sufficient for initial observations, is relatively small and might not capture the full spectrum of market behaviours. Furthermore, the reliance on public data limits the ability to account for private negotiations and insider information that could significantly impact IPO pricing. These factors should be considered when interpreting the results of this study.

Further Research

Given the limitations noted, further research is essential to deepen and broaden the understanding of IPO pricing anomalies. Future studies could expand the timeframe of the analysis to include multiple years and different market conditions to test the consistency of the observed anomalies. Additionally, increasing the sample size and including different markets would enhance the robustness and applicability of the findings. Investigating the role of regulatory frameworks and their impact on IPO performance across various jurisdictions could also provide significant insights. Moreover, qualitative studies focusing on the decision-making processes of investors and underwriters during IPOs could complement the quantitative data, offering a more holistic view of the market dynamics.

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Technological Endogeneity and Growth Trajectories: A Comparative Analysis of Türkiye and South Korea's Economic Journeys

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Abstract The sources of differences in the growth and welfare of countries in the globalising world have been a long-standing topic of debate. In the economic growth literature, numerous studies have explored these sources, yet there is still no clear consensus. One of the most prominent fields regarding the sources of growth and the welfare of nations is the endogenous growth theory introduced in the 1990s. The effects of technological development, a standout achievement of the modern era, on economic growth have led to the discovery of many substantial sources related to the growth and welfare of countries, integrated into popular culture via endogenous growth theories. This study aims to enhance the understanding of the endogenous growth theory by exploring the interplay between technology and economic development across various countries and variables. The primary motivation is to examine potential technology-driven disparities in nations' growth and welfare levels. The main research question is whether countries pursuing endogenous growth policies experience more sustainable and higher-quality growth compared to others. To answer this question, the study examines the effects of technology endogenization on Türkiye and South Korea, two countries that had similar economic conditions in the past but now show significant differences. Using ARDL Cointegration Analysis and covering the period from 1990 to 2020, the evidence demonstrates that South Korea achieved more stable and higher-quality growth due to its policy of endogenizing technology. In contrast, Türkiye has not succeeded in this area and needs improvements.

Keywords Endogenous growth · Technology · ARDL analysis

Jel Codes C32, O30

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Technological Endogeneity and Growth Trajectories: A Comparative Analysis of Türkiye and South Korea's Economic Journeys

The concept of economic growth has been one of the most extensively contemplated subjects in economic thought from its inception to this day. Historically, this concept, which has been attributed to various sources, is considered the fundamental determinant for nations to reach a certain level of prosperity. In this context, identifying the primary sources of economic growth and implementing policies to strengthen these sources is of great importance.

Even more crucial than achieving economic growth is, as Acemoğlu and Üçer (2015) state, the establishment of a stable, high-quality, and equitably shared growth infrastructure across the nation. It is predicted that only when such a growth structure is achieved can national welfare reach optimal levels. The key to attaining these desired conditions is, as one of the most significant problems in the field of economics, the efficient utilisation of all available resources. The effective use of economic resources, in other words, total factor productivity growth, is directly related to one of the most significant achievements of the age: technological advancements and innovations.

Although the importance of new production techniques in the economical growth area has been explored in economic literature since the era of classical economists, the direct relationship between growth and technology was not explicitly established until the Solow (1956) model. According to the Solow model, which laid the foundations for this relationship, technology was an external factor representing the segment of growth that could not be explained by variations in labour and capital. This significant relationship gained a substantial dimension in the early 1990s with Paul Romer's article. Romer (1990) argued that technology is as influential on growth as capital and labour and incorporated technology into the centre of the production function by endogenizing it. The process of endogenizing technology initiated by Romer has been expanded or differentiated through various studies with different perspectives.

Considering all this, the aspects of how technology and growth interact, as well as potential differences among countries, constitute the fundamental motivation of this study. In the process of investigating this relationship, two prominent examples emerge: South Korea, which has successfully integrated technology, and Türkiye, which has struggled to incorporate technological development into its growth policies. In the 1960s, Türkiye and South Korea emerged on the international stage as two countries with similar economic growth rates and socio-economic characteristics. However, the gap between these two nations, which had been growing at a comparable pace for nearly twenty years, began to widen in South Korea's favour during the 1980s. Since then, this gap has continued to expand rapidly. Under current conditions, South Korea has achieved the status of a developed country and ranks among the world's largest economies, whereas Türkiye remains a developing country struggling with unresolved structural problems. Although the two countries experienced similar economic conditions until the 1980s, the significant differences that have emerged since then, and the underlying reasons for these differences, have drawn considerable interest. This research attributes South Korea's success—often referred to as a "miracle" in the literature—to its robust economic structure, underpinned by production and exports.

The primary aim of this study is to provide policy recommendations for Türkiye by empirically demonstrating that South Korea's most critical strategy for achieving this economic structure lies in the export of

high value-added technologies. It also explores how weaknesses in this area have affected Türkiye's growth trajectory.

In the context of all these explanations, the original contribution of this study lies in its comparative analysis of Türkiye and South Korea, nations that have adopted distinct approaches to technological endogeneity and economic growth policies, using multiple growth-based variables. The models in which the mentioned variables are structured are Romer (1990)-based endogenous growth models. The empirical analysis applied constitutes another pillar of this study's contribution by addressing the empirical gap in previous studies, which have primarily focused on R&D activities but have fallen short in examining high value-added technology production, their exports, and the structural dynamics of labour and comprehensive capital variables in relation to these factors.

With this perspective, the research question of the study revolves around whether countries that endogenize technological advancements and pursue growth policies in alignment with technology achieve a more stable and high-quality growth structure. Furthermore, potential outcomes that may arise when labour and capital variables, traditionally considered the main determinants of growth, are examined in conjunction with technology integration are also central to the research focus.

This research seeks to offer a deeper understanding of how varying strategies of integrating technology with economic policies can impact overall economic stability and growth quality. In addition, this research seeks to bridge existing knowledge gaps by highlighting the interplay between traditional growth determinants and modern technological integration, offering a nuanced understanding of how technology-driven growth can be optimised in varying national contexts.

In the course of investigating the aforementioned relationships, the study is structured into four sections. Following the introduction, which outlines the general framework of the study, the second section briefly touches upon a literature review that highlights the overall trends in similar studies. When we reach the third section, the methodology to be employed will be explained. In this step, data sets and variables are introduced, followed by an explanation of the derivation of the econometric model, which forms the basis of the analysis. The fourth section of the study will encompass the econometric analysis comparing Türkiye and South Korea. Within this section, unit root tests, serving as the foundational steps of the time series analysis, will be conducted initially, followed by the presentation of the empirical findings. Subsequently, the quantitative results obtained from the simultaneous analysis of the two selected countries will be qualitatively compared. Finally, the study will be concluded in the discussion and conclusion sections, providing an overall assessment.

Literature

The endogenization of technology is a prominent subject concerning nations' ability to achieve high-quality economic growth. The achievements of countries such as Germany, China, and South Korea, which have successfully endogenized technology within their growth policies, are economically enlightening examples. In the empirical analysis, different perspectives and approaches are used to demonstrate the positive impact of technology on total factor productivity and growth.

When reviewing the studies in the existing literature, the empirical comparison of the growth structures of Türkiye and South Korea, which began with significant similarities in their growth patterns, has largely been overlooked. Moreover, nearly all studies have focused on R&D activities as a measure of technological development. While R&D activities are undeniably one of the most important indicators for measuring tech-

nological progress, the emphasis on countries achieving strong growth through the volume of technology exports—especially South Korea—has not been sufficiently addressed, representing a notable gap in the literature.

Furthermore, the integration of the two models by combining Romer's (1990) theoretical framework, which underpins endogenous growth theories and highlights the importance of large-scale capital and technological development, with Okun's law, which examines the negative relationship between unemployment and growth, introduces a significant new dimension to this study.

Table 1 presents a summary of related studies within the field of economics that focus on the endogenization of technology, aligning with the approach taken in the current research. It provides an overview of the methodologies employed and the findings achieved in studies examining the effects of technology on total factor productivity and economic growth through various variables.

Table 1

Literature Review

Authors	Period	Countries	Method	Variables	Effect
Coe and Helpman (1995)	1971 1990	22 OECD Countries	Panel Cointegration Analysis	Domestic and Foreign R&D Investments	Positive
Jones (1995)	1880 1987	USA and 14 OECD Countries	Time Series	R&D Investments	Varies*
Nonneman and Vanhoudt (1996)	1960 1985	22 OECD Countries	Panel Data	R&D Investments, Physical Capital, Labour	Positive
Chiang, Kao & Chen (1997)	1971 1990	15 OECD Countries and G7 Countries	Panel Cointegration Analysis	Domestic and Foreign R&D Investments	Positive
Segerstrom (1998)	1965 1990	5 Developed Countries	Quantitative Data Analysis	R&D Investments and Patents	Negative
Eaton and Kortum (1999)	1980 1990	5 Developed Countries	Quantitative Data Analysis	Participants in R&D Activities and Patents	Positive
Howitt (2000)	1998	Selected Countries	Cross-Sectional Data	R&D Investments and Technology Transfers	Positive
Griffith, Redding & Reenen (2001)	1974 1990	12 OECD Countries	Panel Data	R&D Investments, Human Capital, Import	Positive
Cuaresma & Wörz (2005)	1981 1997	45 OECD Countries	Panel Data	Low-Tech and High-Tech Product Exports	Positive
Rodrik (2006)	1992 2003	China	Linear Regression Analysis	Tech Product Exports	Positive
Falk (2007)	1970 2004	22 OECD Countries	Panel GMM	R&D Investments and High-Tech Product Exports	Positive
Ha and Howitt (2007)	1950 2000	USA	Cointegration Analysis	R&D Investments	Varies*
Coe, Helpman & Hoffmaister (2009)	1971 2004	24 OECD Countries	Panel Cointegration Analysis	R&D and Human Capital Investments	Positive
Jarreau and Poncet (2011)	1997 2009	China	Time Series	Foreign Direct Investments (FDI), Human Capital, Foreign Trade, and High-Tech Product Exports	Positive

Authors	Period	Countries	Method	Variables	Effect
Göçer (2013)	1996 2012	11 Asian Countries	Panel Data	R&D, High-Tech Exports, ICT	Positive
Wu, Ma & Zhuo (2016)	1981 2010	Selected 80 Countries	Panel Data	FDI, High-Tech Product Exports, Scientific Articles, Human and Physical Capital	Positive
Ekananda and Parlinggoman (2017)	1992 2014	Selected 50 Countries	Panel Data	FDI, High-Tech and Other Technological Products Export	Positive
Kim (2020)	1996 2013	14 OECD Countries	Panel Data	R&D in the High-Tech Industry Sector	Positive
Daysi et al. (2021)	2000 2020	Colombia, Ecuador, and Peru	Panel Data	High-Technology Product Exports and Carbon Dioxide Emissions	Positive
Ahmad and Zheng (2022)	1990 2019	36 OECD Countries	Panel GMM	GDP, R&D Expenditure, Patents, Saving Rate, Household Consumption, Labour Force, Gross Fixed Capital, Real Interest Rate	Positive
Hamia (2022)	1990 2019	Developing 18 Countries-Developed 22 Countries	Panel Causality Analysis	Technology Transfers in Low, Medium, and High-Tech Industries	Positive
Lam et al. (2022)	1990 2015	Malaysia	ARDL	FDI, High-Tech Product Exports	Positive
Behera, Haldar & Sethi (2023)	2000 2020	Emerging 13 Countries	Panel Data	GDP Per Capita, ICT Usage (Mobile Cellular Subscription & Individual Using Internet), Spending on Technological Innovation, R&D Expenditures, FDI, Institutional Quality, Financial Development, Trade Openness	Positive
Nihal et al. (2023)	1996 2020	G8 Countries	Panel VAR and Causality Analyses	GDP, R&D Expenditures, Technological Human Capital, Scientific Articles, Patent Applications	Positive
Akcigit, Pearce & Prato (2024)	2001 2013	Denmark	Calibration-Simulated Method of Moments (SMM)	R&D Subsidies, Education Subsidies, Total Factor Productivity (GDP Growth), Patents, R&D Project Numbers, Individual Indicators	Positive
Islam, Rahaman & Chen (2024)	1996 2021	25 Middle-income countries	Panel ARDL Analysis	GDP, R&D Expenditure, Foreign Remittances, FDI, Labour Force, TFP, Capital Stock	Positive
Li et al. (2024)	2008 2021	30 Provinces of China	Spatial Panel Data	GDP, R&D Personnel Flow, R&D Capital Flow, and Regional Absorptive Capacity	Positive
Sojoodi and Baghbanpour (2024)	2007 2020	Developing 30 Countries–Developed 30 Countries	Panel Causality Analysis	GDP Growth and High-Tech Industry Exports	Varies*
Tung and Hoang (2024)	1996 2019	Emerging 29 Countries	Panel ARDL Analysis	Gross National Output, National Gross Capital, Labour, R&D Expenditure and Education Development, Corruption Index	Positive

Note: * Different effects have been observed in the short and long term.

Methodology

The impact of technology endogenization on economic growth is examined through a comparison of Türkiye and South Korea, following models such as Romer's (1990) endogenous growth model and R&D-based models like Grossman & Helpman's (1991). Based on preliminary tests, it has been determined that the most suitable method for the analysis is the method of Autoregressive Distributed Lag (ARDL). Here, the dataset and variables are introduced, followed by an explanation of the establishment and derivation of the econometric model.

Data and Variables

The common variables and data sets for the analyses to be conducted for Türkiye and South Korea are presented in Table 2.

Table 2
Variables

Variables	Indicators	Sources
GDP (Y)	Real GDP Per Capita (Base Year 2015, Million $)	World Bank
Unemployment (UNL)[1]	Number of Unemployed Individuals Aged 15 and Over	ILO
Human Capital (HC)	Number of Individuals Enrolled in Higher Education	UNESCO
Physical Capital (K)	Real Gross Fixed Capital Formation (Base Year 2015, Million $)	World Bank
High-Tech Product Exports (HTX)	Export of Computer, Electronic, Optical, Pharmaceutical, Aerospace, and Space Industry Products (Base Year 2015, Million $)	OECD

Due to the data limitations in the high-technology product export data, the analyses for both countries cover the period from 1990 to 2020. The data for all monetary variables used in the analyses are real data adjusted to the base year 2015 by data sources. This is because nominal data may not reflect real values as they are not adjusted for inflation effects. Additionally, the data are selected annually and included in the analysis after taking natural logarithms. Time series analyses were conducted using the EViews 13 software package, which is one of the most useful econometric programs.

Modelling

While establishing the main model for analysing the impact of technology on growth, starting from a Cobb-Douglas (1928) type production function will enhance the understanding of the model's endogenous growth foundations. In technology-based growth models, due to the productivity increase generated by technology, the marginal productivities of production factors do not decrease over time. In other words, the assumption of increasing returns to scale holds. Therefore, the basic model of the production function, the Cobb-Douglas type for endogenous growth models, where $\alpha+\beta > 1$, can be expressed as follows:

$$Y = A.K^{\alpha}.L^{\beta} \quad (1)$$

[1] The variable coded as UNL represents the population aged 15 and over who are not in the labour force. Consistent with the fundamental equation, Total Labour Force = Employment + Unemployment, as in various studies in the literature, the representative variable for labour is based on unemployment data. This enables the investigation of the relationship between unemployment and economic growth in the empirical section.

In the equation, Y denotes the growth indicator represented by per capita GDP, while A signifies the total factor productivity. Additionally, K stands for physical capital and L represents labour. In the fundamental Cobb-Douglas production function, capital encompasses both physical capital (K) and human capital (HC), similar to the AR&D-based growth literature. Human capital plays a crucial role in these models of technology-based growth. Accordingly, the production function used in the model is the Extended Cobb-Douglas production function, reflecting the comprehensive treatment of capital.

$$Y = A.UNL^{\alpha}.HC^{\beta}.K^{\theta}.HTX^{\delta} \tag{2}$$

In the common model established for the comparative analysis of Türkiye and South Korea, total factor productivity (A) is considered as an indicator that represents how much of the growth is attributable to technological advancement and the efficient utilisation of production factors (Acemoğlu & Üçer, 2019: 6). High-technology product exports, denoted as HTX, symbolise the technology variable that enhances total factor productivity and growth.

The econometric model will be developed from the Extended Cobb-Douglas production function by applying Log-Linearisation, owing to the characteristic exponential form of the Cobb-Douglas production functions. The Log-Linearisation method is defined as the process of linearising non-linear models by using the Taylor series. In this context, non-linear models go through a series of mathematical steps until they reach stationary conditions. Within this scope, the principles of the First-Order Taylor Series Approximation, based on the theorem of the famous mathematician Brook Taylor, are followed through the following steps (Zietz, 2006). According to the Taylor Series Approximation (First Order), for any function f(x), at the initial spot to represent the stationary value of the x variable, it is expressed as follows:

$$x = x^{*} \tag{3}$$

$$f(x) = f(x^{*}) + f'(x^{*}).(x - x^{*}) \tag{4}$$

In the equation, where f'(x*) represents the derivative of the stationary value of the function f(x), and (x-x*) represents the change in x, the logarithmic representation of any exponential function is as follows:

$$y = a.x^{b} \tag{5}$$

$$\log(y) = b.\log(x) + \log(a) \tag{6}$$

In adapting this fundamental approach to the model, the natural logarithm of the variables is taken first:

$$Y = A.UNL^{\alpha}.HC^{\beta}.K^{\theta}.HTX^{\delta} \tag{7}$$

$$lnY = lnA + \alpha.lnUNL + \beta.lnHC + \theta.lnK + \delta.lnHTX \tag{8}$$

Taking into account the necessity of linearising variables in the stationary equilibrium and using the initial condition x = x*:

$$lnY^{*} = lnA^{*} + \alpha.lnUNL^{*} + \beta.lnHC^{*} + \theta.lnK^{*} + \delta.lnHTX^{*} \tag{9}$$

Then, the stationary values of each variable are substituted into equation (4), with f(x) = lnY:

$$\begin{aligned} lnY^{*} + \frac{1}{Y^{*}_{.}}(Y - Y^{*}) = lnA^{*} + \frac{1}{A^{*}_{.}}(A - A^{*}) + \alpha.lnUNL^{*} + \frac{a}{UNL^{*}_{.}}(UNL - UNL^{*}) + \\ \beta.lnHC^{*} + \frac{\beta}{HC^{*}_{.}}(HC - HC^{*}) + \theta.lnK^{*} + \frac{\theta}{K^{*}_{.}}(K - K^{*}) + \delta.lnHTX^{*} + \frac{\delta}{HTX^{*}_{.}}(HTX\text{-}HTX^{*}) \end{aligned} \tag{10}$$

Given that the equality in equation (9) is known, when the variables are substituted in their place:

$$lnY^* = lnA^* + \alpha.lnUNL^* + \beta.lnHC^* + \theta.lnK^* + \delta.lnHTX^* + \frac{1}{Y^*_{.}}(Y - Y^*) = lnA^* + \frac{1}{A^*_{.}}(A\text{-}A^*) + \alpha.lnL^* + \frac{\alpha}{UNL^*_{.}}(UNL\text{-}UNL^*) + \beta.lnHC^* + \frac{\beta}{HC^*_{.}}(HC\text{-}HC^*) + \theta.lnK^* + \frac{\theta}{K^*_{.}}(K\text{-}K^*) + \delta.lnHTX^* + \frac{\delta}{HTX^*_{.}}(HTX\text{-}HTX^*) \quad (11)$$

When the necessary simplifications are performed, the equation transforms into the following form:

$$\frac{1}{Y^*_{.}}(Y - Y^*) = \frac{1}{A^*_{.}}(A - A^*) + \frac{\alpha}{UNL^*_{.}}(UNL\text{-}UNL^*) + \frac{\beta}{HC^*_{.}}(HC\text{-}HC^*) + \frac{\theta}{K^*_{.}}(K\text{-}K^*) + \frac{\delta}{HTX^*_{.}}(HTX\text{-}HTX^*) \quad (12)$$

$$\frac{(Y - Y^*)}{Y^*} = \frac{(A - A^*)}{A^*} + \alpha.\frac{(UNL\text{-}UNL^*)}{UNL^*} + \beta.\frac{(HC\text{-}HC^*)}{HC^*} + \theta.\frac{(KK\text{-}KK^*)}{K^*} + \delta.\frac{(HTX\text{-}HTX^*)}{HTX^*} \quad (13)$$

and:

$$\frac{(Y - Y^*)}{Y^*} = \tilde{Y} \quad (14)$$

$$\frac{(A - A^*)}{A^*} = \tilde{A} \quad (15)$$

$$\frac{(UNL\text{-}UNL^*)}{UNL^*} = \widetilde{UNL} \quad (16)$$

$$\frac{(HC\text{-}HC^*)}{HC^*} = \widetilde{HC} \quad (17)$$

$$\frac{(KK\text{-}KK^*)}{K^*} = \tilde{K} \quad (18)$$

$$\frac{(HTX\text{-}HTX^*)}{HTX^*} = \widetilde{HTX} \quad (19)$$

Thus, when the deterministic format, showing the estimated values of the main population for the variables and including the residuals (ũ), is transformed into a stochastic format, it appears as follows:

$$\tilde{Y} = \tilde{A} + \alpha.\widetilde{UNL} + \beta.\widetilde{HC} + \theta.\tilde{K} + \delta.\widetilde{HTX} + \tilde{u} \quad (20)$$

Analysis

In this subsection of the study, a roadmap is aimed to be created for the stages of the applied analyses, and a theoretical framework regarding the tests used will be outlined. Then, the results of the application for Türkiye and South Korea will be presented sequentially. In the final stage, the obtained analysis results will be interpreted comparatively. Within the scope of the ARDL analysis to be applied in the study, the basic equation for Türkiye and South Korea is as follows:

$$Y_t = A_0 + \sum_{i=1}^{p} \psi_i.Y_{t\text{-}i} + \sum_{j=0}^{q_1} .\alpha_j.UNL_{t\text{-}j} + \sum_{j=0}^{q_2} .\beta_j.HC_{t\text{-}j} + \sum_{j=0}^{q_3} .\theta_j.K_{t\text{-}j} + \sum_{j=0}^{q_4} .\delta_j.HTX_{t\text{-}j} + u_t \quad (21)$$

In addition to the basic ARDL model, the most suitable ECM model as described in the Pesaran, Shin, & Smith (2001) article has been selected and adapted to the variables of the main model. The representation of the common, unrestricted intercept, and trendless equation for the ECM model is as follows:

$$\Delta Y_t = A_0 + \gamma.Y_{t-1} + \alpha.UNL_{t-1} + \beta.HC_{t-1} + \theta.K_{t-1} + \delta.HTX_{t-1} + \sum_{i=1}^{p-1} C_{0,i}.\Delta Y_{t-1} + \sum_{j=1}^{qj-1} C_j.\Delta UNL_{t-j} + \sum_{j=1}^{qj-1} C_j.\Delta HC_{t-j} + \sum_{j=1}^{qj-1} C_j.\Delta K_{t-j} + \sum_{j=1}^{qj-1} C_j.\Delta HTX_{t-j} + d_1.\Delta UNL_t + d_2.\Delta HC_t + d_3.\Delta K_t + d_4.\Delta HTX_t + u_t \quad (22)$$

Unit Root Tests

In the first stage of the ARDL analysis, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were sequentially applied for Türkiye and South Korea, and stationarity checks of the series were performed. On the basis of the preliminary tests conducted before this stage, no structural breaks were detected for both countries, and these tests were deemed sufficient.

Table 3

Unit Root Tests for Variables Related to Türkiye

	ADF			PP		
	H_0 : The series has unit roots.			H_0 : The series has unit roots.		
Variables	**Test Statistics**	**%5 Critical Value**	**Probabilities***	**Test Statistics**	**%5 Critical Value**	**Probabilities***
Y	−2.56		0.30	−2.60		0.28
UNL	−2.63		0.27	−2.10		0.52
HC	−3.04	−3.57	0.14	−1.84	−3.57	0.66
K	−2.62		0.28	−2.69		0.25
HTX	−0.50		0.98	−0.76		0.96

Note: *MacKinnon (1996) one-sided p-values

According to the findings, it can be said that the null hypothesis H_0 cannot be rejected for any variable related to Türkiye, and all variables contain unit roots.

Table 4

Unit Root Tests for the First Differences of Variables Related to Türkiye

	ADF			PP		
	H_0 : The series has unit roots.			H_0 : The series has unit roots.		
Variables	**Test Statistics**	**%5 Critical Value**	**Probabilities***	**Test Statistics**	**%5 Critical Value**	**Probabilities***
ΔY	−5.38		0.00	−5.95		0.00
ΔUNL	−5.07		0.00	−9.41		0.00
ΔHC	−3.99	−3.57	0.02	−4.14	−3.57	0.01
ΔK	−5.75		0.00	−5.77		0.00
ΔHTX	−3.86		0.03	−3.70		0.04

Note: *MacKinnon (1996) one-sided p-values

Table 4 demonstrates that all series are stationary in their first differences for both unit root tests. In this case, none of the variables is integrated of order 2. Thus, the condition of no variable being I(2) is satisfied for the ARDL analysis.

Table 5

Unit Root Tests for Variables Related to South Korea

	ADF			PP		
	H_0 : The series has unit roots.			H_0 : The series has unit roots.		
Variables	**Test Statistics**	**%5 Critical Value**	**Variables**	**Test Statistics**	**%5 Critical Value**	**Variables**
Y	−0.84		0.95	−0.90		0.94
UNL	−3.61		0.04	−2.01		0.57
HC	−1.17	−3.57	0.90	−0.94	−3.57	0.94
K	−3.53		0.05	−5.40		0.00
HTX	−4.65		0.00	−4.60		0.01

As a result of the unit root tests applied, it is concluded that the Y, HC, and K variables related to South Korea contain unit roots, while the UNL and HTX variables are non-stationary and exhibit stationary properties in levels. At this stage, for the applicability of the ARDL analysis, it is necessary for the non-stationary Y, HC, and K variables to become stationary in their first differences. Thus, the ADF and PP tests were applied to the first differences in the non-stationary series:

Table 6

Unit Root Tests for the First Differences of Variables Related to South Korea

	ADF			PP		
	H_0 : The series has unit roots.			H_0 : The series has unit roots.		
Variables	**Test Statistics**	**%5 Critical Value**	**Variables**	**Test Statistics**	**%5 Critical Value**	**Variables**
ΔY	−4.75		0.00	−16.80		0.00
ΔUNL	-		-	−6.18		0.00
ΔHC	−6.81	−3.57	0.00	−6.85	−3.57	0.00
ΔK	−4.65		0.00	-		-
ΔHTX	-		-	-		-

Note: *MacKinnon (1996) one-sided p-values

According to the ADF test, the non-stationary Y, HC, and K variables become stationary in their first differences. According to the PP test, the non-stationary Y, UNL, and HC variables also become stationary in their first differences. In this case, the null hypothesis H_0 is rejected for all series containing unit roots based on both the probability and test statistic values. Thus, it is concluded that the ARDL analysis can be applied to South Korea as well, as none of the series exceeds the I(2) level.

Empirical Findings

As a result of the preliminary tests applied, the most suitable models were determined as ARDL(3, 4, 4, 3, 3) for Türkiye and ARDL(4, 3, 4, 2, 4) for South Korea. In the next stage, the applicability of ARDL analysis was confirmed for both countries based on the results of all diagnostic tests.

Table 7

F Bound Test Results

H_0 : No cointegration		n = 30*	
Test Statistics	**α**	**I(0)***	**I(1)***
F_{TR} = 21.04	10%	2.752	3.994
F_{KR} = 7.47	5%	3.354	4.774
k = 4	1%	4.768	6.67

Source: *Narayan (2005)

When examining the F bound test results, the critical values from the table published in Narayan's (2005) article are used, considering the sample size is 30. According to the boundary test results, in order to speak of the presence of a cointegration relationship, it is necessary to consider I(0) and I(1) critical values proposed by Peseran, Shin, & Smith (2001):

- If the F-stat is less than I(0), there is no cointegration relationship.
- If I(0) < F-stat < I(1), no conclusion can be made about the presence of a cointegration relationship.
- If the F-statistic is greater than I(1), the series are cointegrated.

In this context, the findings of the F bound test provide proof of a cointegration relationship for both countries. However, the validity of the cointegration relationship may not always be accurately determined based on the F-test values. In some cases, the cointegration relationship that emerges may be spurious or insignificant. Therefore, for the most reliable results, it is necessary to also examine the t-statistic value and make the final decision (Mert & Çağlar, 2019).

Table 8

t Bound Test Results

H_0 : No cointegration			
Test Statistics	**α**	**I(0)**	**I(1)**
t_{TR}= −8.27	10%	-2.57	-3.66
t_{KR}= −3.85	5%	-2.86	-3.99
	2.5%	-3.13	-4.26
	1%	-3.43	-4.6

For Türkiye, the test statistic value t_{TR} = |-8.27| was calculated, which is greater than the critical value |-4.6|, leading to the rejection of the null hypothesis (H_0). Thus, it is observed that the series has a valid cointegration relationship at a 99% confidence level. In the case of South Korea, at a 90% confidence level, t_{KR} = |-3.85|, which is greater than the critical value |-3.66|, indicating that a cointegration relationship is valid.

Concluding that the cointegration relationship is valid, the models must pass the diagnostic tests for the analysis to work. The diagnostic tests of the analyses for both models are shown in Tables 9 and 10:

Table 9

Diagnostics for Türkiye

Tests	Test Statistics	Probabilities
Normality (Jarque-Bera)	JB= 1.87	0.39
Serial Correlation (Breusch-Godfrey LM)	F = 1.45	0.36
Heteroskedasticity (Breusch-Pagan-Godfrey)	F = 0.36	0.96
Specification (Ramsey-RESET)	t = 0.08	0.94
R^2 = 0.99, Adj. R^2 = 0.99, F = 5598.66, Prob. = 0.00		

Table 10

Diagnostics for South Korea

Tests	Test Statistics	Probabilities
Normality (Jarque-Bera)	JB = 0.02	0.99
Serial Correlation (Breusch-Godfrey LM)	F = 8.93	0.05
Heteroskedasticity (Breusch-Pagan-Godfrey)	F = 0.25	0.99
Specification (Ramsey-RESET)	t = 0.65	0.55
R^2 = 0.99, Adj. R^2 = 0.99, F = 2376.93, Prob. = 0.00		

The probability value of the Jarque-Bera test, which examines whether the error terms are distributed around the mean value of 0, is 0.39 > 0.01 for Türkiye and 0.99 > 0.01 for South Korea. This indicates that the error terms are normally distributed in both cases. Similarly, the probability value of the Breusch-Godfrey LM test was calculated as 0.36 > 0.01 for Türkiye and 0.05 > 0.01 for South Korea. From these results, it can be concluded that there is no serial correlation in the models up to 2 lags. According to the Breusch-Pagan-Godfrey test results, which assess heteroscedasticity, the probability values are 0.96 > 0.01 for Türkiye and 0.99 > 0.01 for South Korea. This suggests that the variance of the error terms remains constant in both models. Finally, Ramsey's RESET test, which checks for measurement and specification errors in the models, yields probability values of 0.94 > 0.01 for Türkiye and 0.55 > 0.01 for South Korea. This confirms that there are no measurement or specification errors in either model. At this stage, conducting the CUSUM and CUSUM2 tests to assess the stability of the parameters is crucial for ensuring accurate analysis results. The diagrams for Türkiye and South Korea are presented below:

Figure 1

CUSUM and CUSUM of Squares Tests for Türkiye

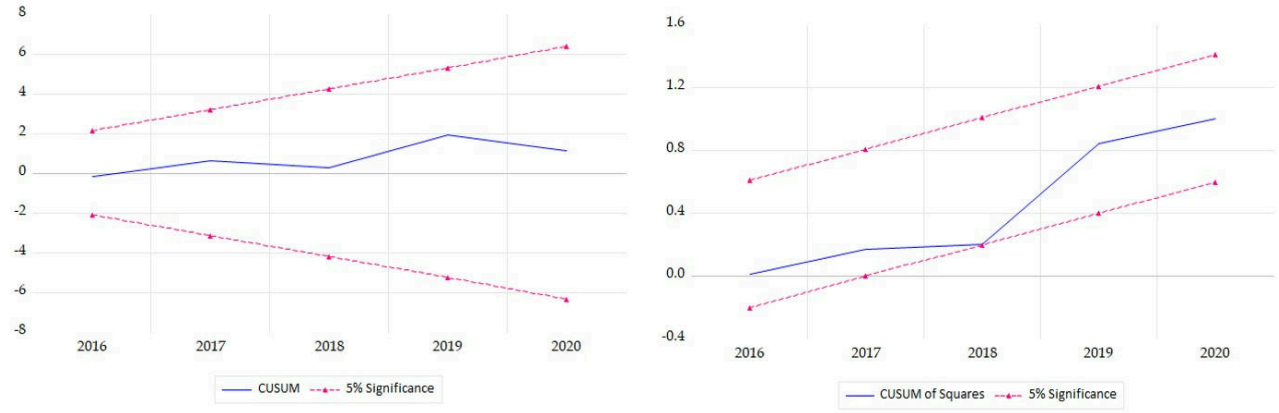
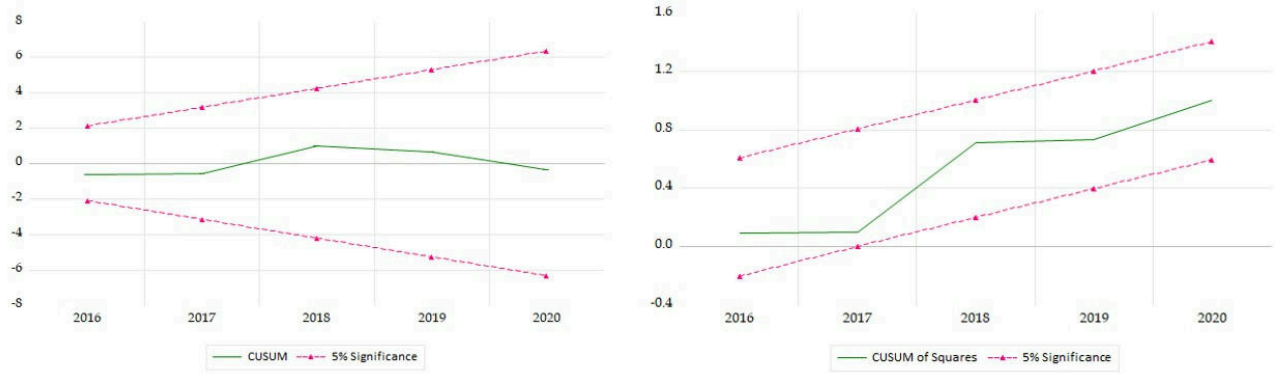


Figure 2

CUSUM and CUSUM of Squares Tests for South Korea



The CUSUM and the CUSUM of squares tests indicate whether the model parameters are stable in the long run. Analysis of the figures shows that none of the parameters for the two countries exceed the critical limits of the 95% confidence level. Therefore, the assumption that the parameters are stable is met and the results are robust. Thus, the last assumption of the ARDL analysis is also met and the conclusions of the long- and short-term results can be analysed.

Table 11

Long-Term Results and Error Correction Coefficient of ARDL(3, 4, 4, 3, 3) Model:

Y	Coefficients	Standart Error	Test Statistics	Prob.
UNL	0.027935	0.010710	2.608421	0.0478
HC	0.180998	0.008693	20.82059	0.0000
K	0.271056	0.017367	15.60743	0.0000
HTX	-0.009818	0.002155	-4.555130	0.0061
ECM_{t-1}*	−1.414397	0.102779	−13.76160	0.0000

Note: *The probability value does not conform to a standard distribution.

The findings of the long-term tests for Türkiye show that all parameters are economically and statistically significant, and their standard errors are reasonable. The coefficient of the UNL variable being 0.028 implies that a 1% change in unemployment increases growth by 0.028%. This result suggests that in Türkiye, the Okun's Law, which typically shows a negative correlation between unemployment and growth, is not applicable. The main reason for this is that growth in Türkiye does not create employment opportunities, indicating Schumpeterian creative destruction. In other words, the effects of Schumpeterian creative destruction lead to increased growth in the long term, accompanied by rising unemployment.

In a developing country like Türkiye, the coexistence of qualitative endogeneous growth and imperfect labour market matching implies that the effects of Schumpeterian creative destruction lead to increased growth in the long term, along with rising unemployment (Cerisier, & Postel-Vinay, 1998). Additionally, the low flexibility of Türkiye's labour market and the absence of effective wages result in technology-driven economic growth moving in tandem with increased unemployment (Nagel, 2015). Such unemployment, where technology-driven economic growth and increased unemployment coexist, points to the presence of a dual economy with a labour market that features a high-wage primary sector and a secondary sector characterised by lower wages. When viewed from the perspective of human capital, a 1% change in the enrolment rate in higher education yields 0.18% expand in growth, indicating a positive relationship between

an increase in educated workforce skills and growth. The impact of changes in physical capital accumulation on growth is also confirmed, with a coefficient of 0.27 for the K variable. As expected, a 1% rise in physical capital accumulation expands growth by 0.27%.

In this context, the findings demonstrate that the only variable with a negligible impact on growth is HTX, with a coefficient of −0.098. This suggests that Türkiye lacks the necessary conditions for the manufacturing and export of value-added technologies and that the effectiveness of high-technology production is insufficient.

Table 12

Long-Term Results and Error Correction Coefficient of ARDL (4, 3, 4, 2, 4) Model:

Y	Coefficients	Standart Error	Test Statistics	Prob.
UNL	−0.218771	0.039429	−5.548524	0.0026
HC	0.349047	0.029549	11.81240	0.0001
K	0.458207	0.087696	5.224954	0.0034
HTX	0.104066	0.025372	4.101589	0.0093
ECM_{t-1}*	−0.778944	0.095013	−8.198312	0.0004

Note: *The probability value does not conform to a standard distribution.

For South Korea, the long-term results of the model show that all parameters are statistically significant at a 99% confidence level and their standard errors are acceptable. In addition, all parameter coefficients are consistent with economic theory.

As an indicator of unemployment in the economy, the coefficient of the UNL variable is calculated as −0.22. This result suggests that a 1% change in unemployment decreases growth by 0.22%. This finding validates Okun's Law in South Korea, indicating that changes in unemployment have a significant negative impact on economic growth. This outcome also underscores the quality of growth in South Korea, where an increase in economic growth corresponds to a rise in employment.

When considering the human capital denoted by the HC variable, the coefficient is 0.35. This coefficient's interpretation indicates that a 1% change in human capital results in a 0.35% increase in economic growth, underscoring the substantial role of human capital in fostering economic growth in South Korea. The coefficient for physical capital stands at 0.46, signifying that a 1% alteration in physical capital accumulation leads to a 0.46% boost in economic growth. This highlights the essentiality of accumulating physical capital as a crucial component of South Korea's economic growth.

Focusing on the main objective of this study to explore the connection between technology and economic growth—the coefficient of the HTX variable included in the model holds critical significance.The HTX variable represents data on high-technology exports. The coefficient for this variable is computed as 0.10, indicating that a 1% shift in high-tech product exports results in a 0.10% uptick in economic growth. This discovery holds particular significance for countries like South Korea, which prioritise growth policies centred on exports. It highlights the crucial role of generating and exporting advanced technologies in fuelling the country's economic growth. Furthermore, it introduces an additional dimension to the well-established positive nexus between R&D and high-technology export within the context of the endogenous growth literature.

To determine whether the error correction models (ECM) are working, the most crucial factor is the significance of the error correction coefficient, as presented in Table 12 and Table 13 In both countries, this

coefficient is significant. However, its deviation from a standard t-distribution indicates that this result may not be reliable. Therefore, the t-statistic values for the ECM model should be examined for the conclusions.

Table 13

t-Test Results for Error Correction Models

H_0 : No cointegration			
Test Statistics	**α**	**I(0)**	**I(1)**
t_{TR} = −13.76	10%	−2.57	−3.66
t_{KR} = −8.20	5%	-2.86	-3.99
	2.5%	-3.13	-4.26
	1%	-3.43	-4.6

The t-statistic value for the ECM coefficient is −13.76 for Türkiye and −8.20 for South Korea. These values are significant at the 99% confidence level as they are greater than |-4.6|. This indicates that the coefficients are both statistically and economically significant, confirming the validity and robustness of the ECM models. Furthermore, these results provide strong evidence for the presence of cointegration relationships between the series at the highest level of significance, 99%.

The error correction coefficients also reveal how rapidly adjustments are made to return to the long-term equilibrium. For Türkiye, the error correction coefficient is 0.71, meaning that any short-term fluctuations will be corrected within 0.71 years. For South Korea, the coefficient is 1.28, indicating that deviations from the long-term equilibrium will be corrected within 1.28 years. This implies that both countries' economic variables are Granger-causing long-term economic growth.

Upon examining the outcomes of the ARDL analysis between Türkiye and South Korea, it is observed that high technology exports have different effects on growth. In Türkiye, the coefficient for high-tech exports is −0.01, whereas in South Korea, it stands at 0.10. This discrepancy suggests that Türkiye has not attained a significant concentration of high-value technology, a fact reinforced by research and development (R&D) activity indicators.

When we examine the capital accumulation coefficients, South Korea scores 0.45, whereas Türkiye lags behind with a coefficient of 0.27, indicating an investment and savings gap. On another note, the coefficients for human capital were 0.18 in Türkiye and 0.35 in South Korea, emphasising the need for productivity improvements in both physical and human capital accumulation.

To conclude, this comparative econometric analysis underscores the inadequacies in the efficient utilisation of economic resources in Türkiye, spanning physical and human capital. This deficiency adversely affects the country's capacity to achieve a high-quality growth model. In contrast, South Korea has successfully harnessed its limited natural resources by prioritising technological innovations. These findings elucidate the substantial disparities in income levels, income distribution, and overall well-being between the two countries, despite their initially similar economic structures.

Conclusion

The technological revolutions, from the Industrial Revolution in 18th-century England to the approaching Industry 5.0 era, have been among the most remarkable periods the world has faced. The swift progress in information technologies, AI and robotics, integrated swiftly into daily life, necessitated adaptation from all countries worldwide.

From an economic growth perspective, the rapid innovations in this technological age made the potential impacts of these changes on growth and prosperity a significant area of research. Particularly in the 1990s, the effects of technological activities that accelerated worldwide on growth became the subject of various studies. In this context, studies that constructed endogenous growth theories, such as Romer (1986; 1990), Grossman and Helpman (1991; 1997), and Aghion and Howitt (1992), generally suggested that the primary source of technological development was the R&D activities carried out by profit-seeking firms and governments.

In line with this common view, knowledge obtained through R&D activities enabled the implementation of new production techniques in sectors such as agriculture and industry, allowing for the creation of a more efficient production chain in a shorter period. Furthermore, with the continuous development of machinery, equipment, and devices, the productivity of both capital and labour increased, resulting in an increase in production volume. On the other hand, the demand for products, especially those of countries that exported high-tech products, increased rapidly due to product differentiations and innovations. As understood from this general framework, innovations were expected to lead to an increase in the total output produced within the country, the level of total factor productivity, and the income to be obtained, or, in other words, the economy was expected to grow further.

Alongside R&D activities, various significant variables can be examined for their impact on growth within the context of technological effects. The variables included patents, scientific research and publications, and the manufacturing or export of high technology. Given the current conditions, one of the leading areas of the technological age was the assembly and trade of high technology such as computers, robots, electronic devices, advanced medical equipment, aerospace, and space industry vehicles. Especially for countries with booming industrial and technology sectors such as Germany, China, and South Korea, high-tech products were among the areas where innovative activities were concentrated the most.

When reviewing the previous studies on the nexus between technology and growth in the context of endogenous growth, most studies evaluated technology solely through R&D activities. However, very few studies have focused on the export of high technology within the context of this innovation. In particular, there were almost negligible studies that simultaneously analysed high-tech product exports, labour, and extensive capital. Therefore, this study aimed to contribute to this limited field in the literature by selecting high-tech product exports as the main technology variable and shedding light on this subject with current data.

In line with this goal, a comparative econometric analysis framework was drawn for the selected countries, Türkiye and South Korea, by following Romer's model. The most crucial step in this process was determining the variables. In this study, to align with economic theory, high-tech product exports, representing the main technology indicator, were included in the model along with a comprehensive set of capital, both human and physical. Additionally, unemployment data were chosen to represent labour to examine the relevance of Okun's Law, allowing for the challenge of deficiencies in the employment-intensive quality of growth in Türkiye and South Korea.

The findings of the ARDL analysis revealed that while the findings for South Korea aligned directly with R&D-based endogenous growth theories, there were some inconsistencies on the Turkish side. The results for South Korea indicated that the effect of both physical and human capital, as well as high-tech product exports on growth, were positive and significant. Furthermore, the results for the unemployment variable were consistent with Okun's Law, showing a negative relationship between growth and unemployment.

These findings suggested that the endogenization of technology had been a policy success for South Korea. Thanks to the technology-intensive growth policies implemented since the 1980s, South Korea has followed a path of high-quality growth as an advanced country today. Furthermore, areas such as income distribution and the increase in welfare were improving every day. South Korea's results also supported Lucas' theory, which highlighted the positive effect of educated human capital on growth. In terms of human capital, Türkiye's results also supported the same theory, providing positive and statistically significant results. As expected, physical capital was positively related to growth in both countries.

The results of the analysis revealed a fundamental disparity in the findings of the two countries concerning technology and labour representative variables. For Türkiye, the effect of high technolgy exports on economic growth was calculated to be very low and negative. As seen from this effect, Türkiye did not seem to prioritise R&D activities and the manufacturing and export of high technologies. Based on Türkiye's findings regarding the labour variable, the positive coefficient of unemployment indicated that although the country's growth path was positive, it did not create employment.

The research conducted throughout this study highlighted that the necessity for Türkiye to emphasise technology-related activities was an important economic policy recommendation. In this regard, it was anticipated that growth policies should be made more technology-intensive, enabling the country to greatly enhance the productivity of its abundant natural resources, workforce, human and physical capital. Thus, the currently positive accumulation of human and physical capital could reach even higher levels, and the structure of growth could shift towards job creation. Specifically, this transformation would depend on the increase in R&D and the workforce's skills in these areas, the establishment or enhancement of new and quality R&D centres and technology zones, and the provision of more comprehensive tax incentives and support in technology-related areas. With these policies, it was expected that the production and export of information technology could be increased, and economic growth could take a much more structurally sound path. In the current circumstances, it seemed that the increase in national prosperity was largely contingent on such radical changes and developments.

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Research Article

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Youth Poverty in the Framework of Amartya Sen's Capability Approach

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Abstract In its most basic sense, poverty is the lack of income to meet the basic needs of individuals. Today, the economic approach may not be considered sufficient to define and explain poverty. Amartya Sen's Capability Approach is an approach that explains poverty multidimensional beyond income inadequacy. Youth are among the groups most affected by poverty, which is a multidimensional concept beyond income inadequacy. Studies on youth poverty are new and insufficient in terms of quality and quantity. In this context, the aim of this study is to try to explain youth poverty within the framework of Amartya Sen's Capability Approach and to reveal the situation of young people in EU countries and Turkey. In the data on youth poverty in the EU and Turkey, indicators affecting the capabilities of young people such as participation, employment and unemployment, education and training, health and well-being, the digital world and social exclusion were used. Most of the data on these indicators are taken from EUROSTAT and TURKSTAT data. As a result, it is seen that young people in Turkey are more deprived than young people in the EU in almost all indicators and lag behind in terms of capabilities.

Keywords Youth poverty · Capability approach · Social exclusion

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Youth Poverty in the Framework of Amartya Sen's Capability Approach

The phenomenon of poverty has been one of the world's most important social problems both in the past and today. Different disciplines have evaluated the phenomenon of poverty from their own perspectives and put forward various definitions and criteria. Different disciplines such as economics, sociology, anthropology, social policy and political science define and analyse poverty with their own unique approaches. Traditional definitions of poverty, in which the economic dimension is predominant, define poverty as the inability of an individual's total income to meet the minimum level of food, clothing and other items necessary for his/her biological survival. Modern definitions are more inclusive, considering factors such as social exclusion, access to education and health services, quality of life and human rights. Therefore, new definitions now include deprivation, inadequate use of public services and social exclusion in addition to income inadequacy. Research and analysis of poverty and inequality are based on approaches that consider these dimensions into account. The most widely used of these approaches is Amartya Sen's "Capability Approach". Within the framework of this approach, which sees poverty not only as a lack of income but also as a lack of the capability to lead a decent life, young people are among the segments most affected by this deprivation.

Due to structural and economic problems, neo-liberal policies, discrimination and uncertainties surrounding the transition from childhood to adulthood, young people are vulnerable and disadvantaged despite poverty. In this context, youth poverty prevents young people from accessing the best conditions and causes individuals to face certain problems as they step into adulthood, and this process occurs under unfavourable conditions. Especially in developing countries, several young people living in absolute poverty intensify the problem, making youth poverty a global problem. In addition, youth poverty should be considered a permanent problem throughout the world, including in developed economies.

When studies and research on poverty are considered, it is seen that studies on youth poverty are insufficient and started especially in the mid-20th century. Considering the importance of the subject, these studies are insufficient in terms of quality and quantity. In this context, the aim of this study is to explain youth poverty in the context of Amartya Sen's Capability Approach and to present data on youth poverty in the European Union and Turkey. For this purpose, first, Amartya Sen's capability approach will be explained and the relationship between youth and poverty will be emphasised. Then, with the help of EUROSTAT and TURKSTAT data, data on the indicators that are determined within the framework of the capability approach will be presented.

Amartya Sen's Capability Approach

There are different approaches to explaining and measuring poverty in the literature. These approaches include monetary poverty, capability poverty, social exclusion poverty, and participatory poverty. The monetary approach is a goods- or utility-based approach. This approach uses an absolute income threshold calculated by placing a monetary value on the minimum amount of goods that a family or individual needs to survive. Thus, monetary poverty is defined as a family or individual income below the poverty line. In the social exclusion approach, poverty is a person's relative deprivation or lack of access to certain goods or services that others in society have. In the capability approach, poverty is defined as when a person lacks or is unable to develop the capabilities needed to achieve a certain level of functioning. Last, the participatory

approach emphasises that the poor themselves should be involved in defining what it means to be poor (Laderchi et al., 2003).

Amartya Sen, one of the economists who has made significant contributions to the literature on poverty and development, has approached the problem of poverty from a different perspective in the context of capacity deprivation in his studies since the 1980s. Amartya Sen's approach to the problem of development and poverty also forms the theoretical basis of the concept of human development defined in the Human Development Report published by the United Nations Development Program in 1990. Amartya Sen put forward the capability approach by stating that approach that address poverty only in its economic dimension are not sufficient to explain poverty. Poverty with its economic dimension is generally defined as not having enough income to provide the minimum needs necessary for survival. The capability approach defines poverty as being deprived of the basic capabilities necessary to live a life worth human dignity. Approach emphasises the freedom of the individual instead of income and utility and focuses on what people can really do or be. The basic claim of the capability approach is that in order to understand how well a person is doing, it is necessary to look at the kind of life they lead and what they have achieved in terms of beings and doings (Sen, 1999; Sen, 2000; Sen, 2001; Sen, 2004).

The capability approach is based on two concepts: capabilities and functioning. According to Sen, functionings are actions and situations that individuals value in their lives, such as adequate nutrition, being healthy, being happy, self-respect, participating in social life, etc. (Sen, 1993; Sen, 2001). The approach emphasises that certain functionings such as being happy, acting freely, making choices, respecting oneself, being healthy, having adequate nutrition, and going out in public without embarrassment are intrinsically important. According to Sen, functionings are the constituent elements of a person's being and are characteristics of both doings and beings. (Sen, 1985). Capability, in its most basic sense, is an individual's ability to do a thing. The existence of the limits of an individual's capabilities are skills such as being able to read, speak, ride a bicycle or walk. According to Sen, capability is "the ability to achieve valued functionings" (Sen, 1993: 49). Therefore, capability refers to the different combinations of functionings that an individual can achieve, and an individual's capability expresses the freedom of the individual. Capabilities show how an individual transforms his/her resources into functionings. For example, an individual who voluntarily fasts or goes on a hunger strike has the ability not to be peckish but chooses to be peckish (Sen, 1985; Sen, 2001).

Sen explains the differences between functionings and capabilities as follows: Functionings are an achievement,,capabilities are the ability to achieve. While functionings are directly related to living conditions, capabilities are the freedom to achieve different combinations of functionings. Sen (1987) stated that individuals must have these freedoms in order to survive and not fall into poverty. Although capability and functioning are two independent concepts, they are closely related to each other. Capability gains meaning as the sum of the functionings that an individual can achieve, and although it is evaluated within the framework of functionings, functionings are also components of capabilities. When evaluated in terms of freedom, the concept of capability comes to the fore. For example, while a wealthy but dieting individual and a starving individual in Africa are in the same functional situation in terms of eating and nutrition, the situations of these two individuals differ in terms of capabilities. While it is the wealthy individual's own choice to be malnourished, the malnutrition of the individual in Africa is compulsory due to lack of access to food. Another important aspect to be considered in the approach is the distinction between goods and services and their functioning. What is important for the welfare and happiness of individuals is the transformation of goods and services into functionings. According to Sen, the real benefits and welfare of

goods and services can be calculated through the capabilities one possesses. Different capabilities can lead to different benefits, and the lack of capabilities is a serious obstacle to the transformation of what one has into benefits. Sen tries to explain this with the bicycle example. Accordingly, owning a bicycle may not necessarily mean deriving utility from it. The main feature of a bicycle that contributes to human life is not the materials it is made of or its shape, but the fact that it provides faster and less tiring transportation than walking (Sen, 2001).

At this point, Sen mentions five factors that are important in transforming resources into capabilities. in terms of utility: personal characteristics, social characteristics, environmental characteristics, differences in relational perspectives and intra-family distribution. Personal characteristics are related to physical condition (disability, illness, etc.), age, gender, intelligence, skills, etc. Individuals' personal characteristics are decisive in the transformation of goods and services into functionings and they differ. Income cannot compensate some of them. For example, if an individual has a physical disability or does not know how to ride a bicycle, the benefit that a bicycle provides to the individual, i.e., its transformation into a function, will be limited. Or a sick individual may need more money to reach the same level of well-being as a healthy individual and may not enjoy the same quality of life even if they have the necessary income and medical treatment. Again, two individuals may have the money to buy books, but if one of them is visually impaired, they will not be able to function in the same way. The second factor is social characteristics such as public policies, educational arrangements, prevalence of crime, social norms, discrimination, and hierarchical structure. There may be social or even legal norms that prohibit or make it difficult for a woman to ride a bicycle alone. Therefore, in such a situation, the functionalization of the bicycle for a woman living in that society will be either limited or impossible. Environmental factors include climate, diseases, pollution, and geographical structure. This will affect the relationship between income and well-being. For example, the heating and clothing needs of poor individuals in cold climates will not be the same as those in warm climates, or the prevalence of certain diseases such as AIDS in certain parts of the world will significantly alter the quality of life of individuals living there. Differences in relational perspectives include differences in being poor in a developed and developing country. As Adam Smith noted, the utility of goods and services may vary across communities according to customs and traditions. Accordingly, if individuals with the same income level have different social environments and different networks of relationships, the benefits they receive from goods and services will differ. Finally, intrafamily income is earned by one or more individuals in the household, and the distribution of this income within the family varies. There may be disproportionate use of income within the family in favour of some family members and to the detriment of others. This may be related to the different needs of individuals, but may also be related to gender or age. Many studies have shown that women in particular receive a smaller share of family income. For example, the family may emphasise the male child and this may result in high rates of disease, malnutrition, low educational attainment, etc. in girls (Sen, 1985; Sen, 1992; Sen, 1999; Sen, 2001).

According to Sen, although it is important to provide utilities, the main goal is not to increase utilities, but to increase capabilities. In other words, it is important whether the ends (a long and healthy life, a humane life, etc.) can be achieved through the means rather than the means (incomes, resources, etc.). Within this perspective, Sen defines five different types of freedom: political freedom, economic freedom, social freedom/social opportunities, transparency and protective security (Sen, 1999: 58-60). These freedoms contribute to the ability to live free. Political freedoms refer to civil rights, freedom of political expression, freedom of control, an uncensored press, and freedom of choice. Economic freedoms refer to opportunities for individuals to engage freely in economic activities (production, consumption, exchange). The exercise of

these freedoms depends on the resources available, prices and the way markets work. Social freedoms are the freedom and capacity to enjoy social opportunities and public services. Enjoying these freedoms allows individuals to live better and participate in economic and political activities. For example, lack of education can be a significant barrier to participation in the labour market and can lead to a lack of capabilities. Or, despite free state education services, the inability of girls to study indicates a lack of capabilities as a lack of freedom of education. Transparency safeguards are the existence of a transparent social structure in terms of information and access to information. These safeguards play an instrumental role in preventing corruption, fiscal irresponsibility, and underhanded dealings. Protective security means creating a social safety net to prevent vulnerable individuals from falling into irreversible misery, starvation and death. Despite a well-functioning economic system, some individuals may face severe deprivation due to material changes that adversely affect their lives. Protective security includes arrangements such as unemployment benefits for the unemployed and income support and social assistance for the poor. According to Sen, these instrumental freedoms can further strengthen individuals' capabilities by directly increasing them (Sen, 1999).

In the framework of the approach, poverty is not only an economic problem and a matter of inequality (Sen, 1983), but also the inability to maintain a minimum capability to participate in society (Sen, 1981). Therefore, the capability approach defines poverty as "capability deprivation". In this context, according to Sen, poverty does not refer to "deprivation in meeting basic needs" but rather to "lack of basic capabilities necessary to achieve an acceptable level of living" (Sen, 1993: 109). Accordingly, as an individual's alternative gains diversify, his/her capabilities increase, which protects the individual from falling into poverty. When the opportunity to make free choices that will increase one's capabilities disappears, individuals become vulnerable to poverty. On the other hand, individuals' acquiring new acquisitions and increasing their capabilities raise their standard of living, increase their income level and productivity, and have significant effects in lifting individuals out of poverty. In this context, especially women, youth, the disabled, and minority groups are more disadvantaged to capability acquisition and enhancement. Even if these disadvantaged groups have the capabilities, they may face obstacles in having functionings such as equal opportunities in education, access to health services, and inclusion in work life.

Youth and Poverty

Youth, which is a critical transition period in the lives of individuals, is the period of stepping from childhood to adulthood and is a development process that is completed with the realisation or reaching a certain level of identification, autonomy and responsibility. In this framework, having economic independence, adopting a system of values in accordance with social values, acting in accordance with social roles, starting a family, being responsible, and having a job that generates income and can meet the needs of both oneself and one's family are important elements of this development process (Gökçe, 1971: 20). In this period of development and transition, which is an important period for both the individual and the society that plays an important role in the process of participating in social life, individuals should be prepared for adulthood in the best possible conditions.

During adolescence, the individual goes through a process in which there is uncertainty about the future and he/she cannot be fully independent while trying to find his/her place in society. In this process, young people may face some obstacles and problems both socially and economically. While social problems are adaptation, discrimination, social exclusion, inadequate access to health and education, inequality of opportunity, nutrition and housing; economic problems are unemployment, poverty, lack of knowledge and

skills required by the labour market, etc. (Gökçe, 1971: 20). In this context, poverty is a source of all these problems and a problem that negatively affects the transition period.

Although there is no generally accepted definition of youth poverty in the literature, youth poverty is defined by considering the concepts of youth and poverty together. When looking at the concept of "youth," there is no international consensus on the definition, and the definitions in the literature generally limit the period biologically to a certain age range, and the limitation varies from society to society. Internationally, the age group 15-24 is used as the standard definition of youth. In some countries, this age group has been expanded to include 15-29 and sometimes 15-34 age groups. The education process and socio-economic conditions of countries are determinative in determining the age range (Yeşil & Orhan, 2023). However, today, only biological age is no longer a sufficient criterion in definitions; social and psychological criteria are also valid (Murat, 1995). In this sense, even if the beginning of the youth period is accepted as biological age, the process is also supported by social and psychological factors such as completing education, entering a job/profession, gaining economic independence, independent residence, living as a couple or starting a family (Galland, 2001), spiritual development, and reaching the status of being an adult. The Turkish Ministry of Youth and Sports (2018) has also stated that not only biological factors but also sociological factors should be taken into consideration in the definition of youth, and has recognised individuals between the ages of "14 and 29" as youth.

The concept of poverty, like the concept of youth, does not have a generally accepted definition. Poverty is handled in different ways in terms of its economic, social, cultural and political dimensions; therefore, different approaches emerge in poverty definitions. According to the first definition made in 1901 by Rowntree, poverty is the situation where an individual's total income is insufficient to meet even the lowest level of food and clothing, which are the minimum requirements for a healthy and productive life (Rowntree, 1901 cited in Şenkal, 2021: 17). According to Şenses (2006), poverty is a situation in which individuals do not have sufficient and regular income to meet their basic needs. Şenses sees poverty as a situation in which individuals do not have sufficient resources for their needs, remain below the absolute minimum welfare level and are unable to purchase the goods and services necessary to live (Şenses, 2006: 61). The World Bank (WB) defines poverty as the deprivation of individuals in meeting vital needs such as food, shelter, education and health (World Bank Development Report, 2000: 1).

Although definitions generally emphasise income, it is not a sufficient approach to address poverty only from an economic perspective. As mentioned earlier, in recent years, Amartya Sen's capability approach has become one of the most widely used approaches to explain and understand poverty and inequality. Amartya Sen has put forward the theory of the deprivation of capabilities by stating that approach that address poverty only with its economic dimension are not sufficient to understand poverty. According to Sen, poverty is being deprived of the basic capabilities necessary to live a life worth human dignity. Accordingly, poverty is the inadequacy of capabilities including health, education and freedom, democracy, etc., which are indicators of the freedom to lead a life worthy of human dignity (Sen, 2000; Sen, 2001).

The capability approach, which is at the basis of the human development paradigm, emphasises extent to which individuals are able to achieve the capabilities they value, such as working, being productive, having an income, being educated, engaging in politics, living in love and respect, expressing their thoughts freely, being able to travel, and living a healthy, safe and dignified life free from violence as a basic human development criterion. It defines individuals who cannot have these capabilities as poor. In this approach, income level is one of the factors affecting real poverty, that is, the lack of capabilities. A low and insufficient

income is a reason for a poor life. According to the capability approach, the relationship between income and capabilities is affected by factors such as age, gender and social roles, illness or disability, and place of residence. These factors reduce the individual's ability to earn income and make it difficult to transform income into capabilities. In particular, older, younger, disabled or disadvantaged groups may need more income to gain the same functions (Sen, 1999: 127-128, Sen, 2000).

In this context, it is possible to state that young people are disadvantaged when family, education, health, employment, social relations, etc. are considered. If young people cannot obtain basic 'capabilities' such as education, health and income, which are important for their development as individuals, they face obstacles in accessing other capabilities and development/welfare inputs cannot be used effectively by young people. For example, a young girl who cannot go out at night does not have the opportunity to realise her right to "live freely" or a young woman who cannot work without the permission of her father/husband cannot exercise her freedom to work. Laws or legal regulations do not always provide to the same extent the capabilities that young people are interested in and find valuable, such as education, being healthy, living an independent life, gaining economic independence, participating in sports, artistic and intellectual activities and travelling. Deprived of these capabilities, young people must continue their lives in a more unfavourable position compared to adults (Aydınlıgil, 2006).

In this context, youth poverty can be defined as the situation where young people do not have sufficient income to meet their basic needs and are deprived of the basic capabilities necessary to live a life worthy of human dignity.

It is important to analyse youth poverty within the framework of Amartya Sen's capabilities approach, which emphasises the importance of individuals having the freedom and capability to live a fulfilling life and participate fully in society. Sen's capability approach addresses poverty in the context of a lack of basic human capacities and thus takes a broader view of poverty. Sen, who opposes definitions that describe poverty in terms of the amount of income, has dealt with poverty in the context of "capability" and sees the concept of capability as the ability to avoid situations that no one would want, such as hunger, illness, lack of education, and poor living conditions. In addition, Sen does not accept that development is only realised through concepts such as the development of industry, growth of the economy, increase in employment, development of technology and increase in per capita income, and states that what is important is to expand people's freedom. Therefore the approach recognises that youth poverty is not only caused by limited financial resources but also by a lack of access to quality education, health services, employment opportunities, social participation, and other basic capabilities necessary for individual development. It also emphasises the importance of addressing the structural barriers and inequalities that limit young people's ability to escape poverty.

Youth Poverty in the European Union (EU) and Turkey

The study revealed the dimensions of youth poverty in the EU and Turkey within the framework of Amartya Sen's capability approach. Youth poverty is not only about income deprivation but also about the limitations on young people's capabilities to fulfil their potential. In this context, Sen's approach provides a tool to examine and suggest solutions to the constraints young people face in key areas. Although Sen mentions the importance of capabilities, he argues that they cannot be subject to a predetermined list. Therefore, the indicators have been identified in line with the basic explanations of the capability approach. These indicators ane participation in society, employment and unemployment, education, digital life, health and well-being, and social exclusion.

In line with this purpose and indicators, although the data on the youth population in the EU and Turkey generally include data on individuals between the ages of 15-24, in some indicators data on young people between the ages of 15 - 29 and 18 - 24 in others could be reached. While it is more possible to access these data on youth in the EU, it is not possible to access some data in Turkey because statistics are based on households. Therefore, most of the data will be taken from EUROSTAT, OECD, TURKSTAT and TURKSTAT's "Youth in Statistics 2021 and 2022" Report. In addition, Habitat's Youth Wellbeing Report will also be used. However, in both the EU and Turkey, it is not possible to access up-to-date data on youth statistics on some indicators.

General Overview

An analysis of the change over the years shows that the youth population has been declining in both the EU and Turkey since 1990. TURKSTAT's population forecasts predict that this decline will continue. Nevertheless, Turkey has a younger population than the EU. In fact, this advantage of Turkey's young population is defined as a "demographic window of opportunity". According to EUROSTAT data, the number of young people between the ages of 15 and 29 in the EU is approximately 73 million, while in Turkey this number is approximately 20 million. According to OECD 2022 data, the youth population rate in Turkey is 22.2%, while this rate is 15% in the EU.

In terms of poverty, EUROSTAT calculates youth poverty by taking into account the share of young people living in households with an equivalent disposable income below 60% of the national median equivalent disposable income compared to the total population (EU Youth Report, 2012: 277). In Turkey, data on youth poverty are determined by the Turkish Statistical Institute by calculating the income per individual based on the number of individuals living in the household. In other words, family income is taken as the basis for measuring youth poverty. TURKSTAT uses the "60% criterion of equivalent household disposable median income" to calculate youth poverty (Statistics on Youth, 2021). In this context, when general data on youth poverty are analysed, the poverty rate among young people in Turkey is higher than that in the EU. According to EUROSTAT 2022 data, while the poverty rate of young people (18-24) is 21.7% in the EU, this rate is 23.9% in Turkey. When analysed by gender, the poverty rate for young women in Turkey in 2021 is 29.7%, while this rate is 25.1% for young men. The average for the EU is 23.1% for young women and 21.5% for young men. Poverty rates are higher for women in both Turkey and the EU.

According to the TURKSTAT Statistics on Youth 2021 report, while the poverty rate among young people aged 15-24 is 26.7%, this rate is 23.3% among young people aged 15-29. In addition, according to the Habitat Youth Wellbeing Survey (2023: 10 - 11), although the average income of young people is in the range of 3000 TL-9000 TL, the income range that young people state that they need is 9000 TL –18000 TL. Accordingly, 80% of young people experience relative deprivation, that is, they try to live on less than the income they need. In the research, young people drew attention to the low wages and stated that they live with debt. Accordingly, while 61% of young people defined themselves as middle class in 2017, this rate decreased to 4% in 2023. Furthermore, 17% of the youth interviewed had credit card debt, 15% had installment debt and 14% had personal loan debt. This deterioration in the economic situation of young people increases the sense of relative deprivation among them (Habitat Youth Wellbeing Survey, 2023: 10 - 11).

Participation in the Society

Participation in society is the relationship established with society members who come together and work for creating a more livable society (Gottlieb, 2006: 2). From a societal perspective, participation is

defined as partnership, shared values and activities, while from an individual perspective, it is defined as the individual's ability to participate in society (Beckley, 2006: 130). Social participation activities include relationships and interactions with family members, relatives, friends or coworkers, interactions that span the social sphere, and contributions to society (Herzog et al., 2002: 593; Glass & Balfour, 2003: 313). The most prominent forms of social participation include occupational and social roles, social activities such as seeing/meeting friends, participating in social/artistic activities, and group/team work (Berkman et al., 2000: 849).

What is noteworthy here is that social participation is expressed as a skill that needs to be developed. In the context of Amartya Sen's Capability Approach, the inability to maintain a minimum capability/skill to participate in society, i.e., the inability to participate in social activities, is a cause of poverty. Therefore, the prevention or inadequacy of youth participation in society is a cause of youth poverty.

Youth Participation is defined by the UN as economic participation (work and development), political participation (decision-making processes), social participation (taking part in society and environmental activities) and cultural participation (artistic and cultural activities) (UNDP, 2008). Impeded or inadequate participation in these processes implies a deprivation of capabilities and leads to youth poverty.

According to EUROSTAT 2022 data, the participation rate of young people (15 - 29) in society in the EU is 22.4%, while this rate is 23.4% for women and 21.4% for men. Participation in cultural and sports activities among young people is 85.2%, while the proportion of young people who see family and friends every week is 3.9%. In addition, 58.3% of young people have not participated in artistic activities and events in the last 12 months. Of course, the difficulty of returning to normal life after the pandemic may be a factor in this.

In Turkey, there is no clear data on these variables. However, the participation of young people in these processes in Turkey is quite problematic. The patriarchal structure that continues to influence lifestyles in general and the economic difficulties experienced in recent years have limited the life and wealth opportunities of young people in particular, narrowing their access to capabilities. Therefore, the capabilities of young people in Turkey for individual and social transformation are restricted, and they have difficulties in accessing many of the things they value and care about (Aydınlıgil, 2006).

According to the Habitat Youth Wellbeing Survey (2023: 14), only 9% of young people (18 - 24) in Turkey are engaged in any voluntary activity. The most important problems faced by young people who volunteer are cost and time issues, i.e., they have difficulty in covering their expenses and cannot find the time to volunteer. For the majority who do not volunteer, the most important reason for this is lack of time. In addition, 60% of young people said that they were not interested in volunteering activities, which is a very high rate. Again, 7% of young people are members of an association, sports club or political party.

Employment and Unemployment

In addition to providing young people with an identity and status in social life, employment is an important factor for young people to take responsibility and gain independence. Young people who are not employed cannot gain social identity and status and are also deprived of income (Gündoğan, 1999). Factors such as prolonged education periods, lack of experience, the education received not meeting the requirements of the labour market, and the economic and cyclical situation of the countries affect young people's transition to employment (Calderon, 2004: 65; Işık, 2016: 136) and prevent young people from earning income and participating in consumption. It increases their deprivation and causes social exclusion.

When we look at the employment data of young people (Table 1), the employment rate, which is 49.3% in the EU, is 46.3% in Turkey. While the employment rate of young women is close to that of men in the EU, it is almost half of that of men in Turkey. The fact that young women and men do not have the same capabilities to be employed can be evaluated on the basis of gender. Especially in Turkey, gender stereotypes constitute an obstacle to women's participation in employment.

Table 1

Youth Laborforce in EU and Turkey

15–29 (2023)	EU		Turkey	
Employment	49,7		46,3	
	Female	Male	Female	Male
	46,7	52,5	32,1	60
Unemployment	14,2		14,2	
	Female	Male	Female	Male
	15,4	13,2	22	11,3
Long-term Unemployment	2,4		2,6	
	Female	Male	Female	Male
	2,3	2,5	4,8	1,5
NEET	11,2		25,8	
	Female	Male	Female	Male
	12,5	10,1	36,3	15,6

Based on data from EUROSTAT and TÜİK.

Today, regardless of the level of development, unemployment is one of the most serious problems of all countries. Unemployment not only affects the unemployed individual but also the dependents of the unemployed. Disadvantaged groups are among the groups most affected by unemployment, and it can be said that young people are at the top of these groups. ILO's Global Employment Trends Reports also state that unemployment affects young people the most (Işık, 2016). According to the ILO and the UN, the youth labour force is defined as the population between the ages of 15 and 24 years, employed or unemployed and not in education. In this context, youth unemployment is defined as the young population between the ages of 15 and 24 who are ready to work but cannot find a job at the current wage level and are actively looking for a job (Karabıyık, 2009). The economic and social consequences and problems caused by the unemployment of the youth, which is considered a very important advantage for countries, are of great importance. Whether the cause is structural, economic or individual, the problem of youth unemployment is not only an economic but also a social problem.

In terms of the capability approach, unemployment prevents young people from assuming responsibility and independence in the transition to adulthood and affects their capabilities and thus their freedoms, especially by causing educated young people to remain out of the labour market or out of employment. An analysis of the unemployment data (Table 1) shows that the youth unemployment rate in the EU and Turkey is 14.2%. As in the employment data, while female and male youth unemployment rates are close to each other in the EU, female youth unemployment in Turkey is almost twice as high as male youth unemployment. While long-term unemployment is 2.4% in the EU, it is 2.6% in Turkey. Again, this rate is quite high (4.8%) for young women in Turkey. Marriage, gender roles that impose more unpaid labour on young women, limited

access to productive resources and gender-based discrimination are among the most important reasons that disadvantage young women in labour markets and lead to increased unemployment of young women.

The concept of NEET, which is used to define young people who are neither in education nor in employment, has become an important problem for countries. According to the standard definition established by the European Employment Commission (EMCO) and the International Labour Organisation (ILO) in 2020, NEET is defined as young people aged 15-24 who are unemployed and inactive in education. Although the age classification of young people with NEET status differs from country to country, NEET status is generally considered as the active labour force potential in the 15-24 and 15-29 age range (OECD, 2019 cited in Coşkun & Çelik, 2021: 1). These young people, also defined as "Home Youth" in recent years, do not take part in education and active labour market. These young people are at risk as individuals with incomes below the poverty line and lacking the capabilities and freedoms to improve their economic situation.

Despite having a young and dynamic population potential, Turkey has the highest NEET rate among the EU. In 2023 (Table 1), while the average NEET rate in the EU is 11.2%, this rate is 25.8% in Turkey. While female and male NEET rates are close to each other in the EU, the NEET rate for young women in Turkey is quite high at 36.3%. The fact that a significant portion of the young population in Turkey is neither in education nor in employment indicates that the youth potential has not been sufficiently used. When this opportunity/potential is not used enough, youth poverty will deepen and the welfare level of the society will decrease.

Education

Education as a source of human capital is important for both economic and social development. The purpose of education is to serve in every social, economic, and societal field. The aims of education include raising individuals who will benefit the society, guiding and informing individuals, shaping the behaviour of individuals, making individuals ready to join the labour force by providing them with qualifications, reducing inequalities, ensuring development, etc. In today's information society, education, which facilitates the participation of individuals in the labour market and leads them to prosperity, has gained great importance (Çokgezen & Erdene, 2015). In this context, the quality of education affects the employment conditions of young people and may lead to their impoverishment.

A reciprocal relationship between poverty and education. As the level of poverty increases, access to educational opportunities decreases. As the level of education decreases, the level of poverty increases and a vicious circle is entered. Poverty, limited resources, malnutrition, high school fees and inadequate parental education make it difficult to access education and the quality of education decreases (Çokgezen & Erdene, 2015). The UN and the WB also emphasise the importance of education in their efforts to combat poverty.

The capability approach attaches importance to education in the fight against poverty. Accordingly, individuals' freedoms should be increased through education. From this perspective, young people can get the education they need, and they will gain the freedom to realise and take the actions they desire. The capability approach focuses on the fact that the most important goal of education is to increase the capabilities of individuals to live the life they want. At this point, education has two aspects: improving the skills of young people and increasing the opportunities in front of young people, thus increasing their capabilities. In addition to providing individuals with new capabilities, education teaches them values that will enable them to make the right choices about the use of these capabilities. While the individual learns new skills that will increase his/her capabilities through education, he/she also learns values that will enable him/her to use these skills for a good purpose (Saito, 2003).

In this context, according to the EUROSTAT 2023 data for the EU and Turkey, the educational attainment of young people in Turkey is at a lower level compared to Europe. While the rate of young people (15 - 29 year olds) attending secondary education and above is 64.2% in the EU, this rate is 57.9% in Turkey. According to OECD 2022 data, while the rate of youth aged 17-18 attending secondary and higher education is above 80% in the EU, in Turkey this rate is above 80% for 17-year-olds, but falls below 40% by the age of 18. While the increase in this rate in Turkey over the years is a welcome development in terms of raising the educational level of young people and increasing their capabilities, the exclusion of these young people from the labour market is a situation that needs to be considered. EUROSTAT 2023 data shows that the rate of young people (15 - 19 years old) below the primary education level is also higher in Turkey (42.1%) than in the EU (35.8%). The rate of young people (18 - 24 years old) who leave education early in 2023 is 19.5% in Turkey and 9.6% in the EU. While this rate is 11.3% for young men in the EU and 20.1% in Turkey, it is 7.7% for young women in the EU and 19% in Turkey. Although this rate is higher in Turkey than in the EU, it is encouraging to see that this rate has halved in 10 years, i.e., the number of early school leavers has decreased. Education is the reason why young women do not participate in all levels of society at the same rate as men. In 21st-century Turkey, even though women's level of education has increased, it still lags behind men's. Both the patriarchal structure that supports gender stereotypes and regional inequalities can be considered as reasons for this backwardness. It is not easy to access education in every region of the country, especially in rural areas. For young women, this situation is more challenging.

Health and Well-being

One of the most important issues of human life is health. Today, health is not only a subject of medicine but also of social sciences. The World Health Organisation (WHO) defines health not only as the absence of disease or infirmity but also as a state of complete physical, social and mental well-being. Well-being is a positive state experienced by individuals and societies, including quality of life and the ability to contribute to the world. The well-being of a society can be observed through the psychological resilience of individuals, how much they have the capacity to take action and how ready they are to overcome challenges (WHO, 2021: 3, 10). Therefore, in order for a society to build its future, it needs healthy and well-being individuals, young people. Given today's changing and evolving conditions, the chances for young people to improve their health and well-being are higher than ever, yet many lack access to the basic information, quality services and protective environments they need to stay healthy and well.

According to the WHO (2011), the main health and well-being risks for young people are traffic accidents, drowning, violence, alcohol, drug and tobacco use, depression and anxiety, HIV/Aids, HPV, other infectious diseases, early pregnancy and childbirth, obesity, lack of nutrition and physical activity.

Like the WHO, UNICEF considers environmental risks such as unhealthy diets, sedentary lifestyles, mental health disorders, alcohol and tobacco use and air pollution to be the most important problems facing young people today. In addition, infectious diseases such as malaria and cholera kill young people, especially in low- and middle-income countries where health services, water, sanitation, and hygiene facilities are inadequate. The fact that young people in low- and middle-income countries, where the majority of today's youth live, are among the groups most at risk of contracting infectious diseases such as HIV and have the least access to treatment shows how great the risk is. UNICEF also draws attention to the risks faced by young girls such as puberty, early pregnancy and teenage births (UNICEF, 2016). All in all, the deprivation of health and well-being affects the lives of young people and excludes them from education, social and economic opportunities, and deprives them of their capabilities.

Table 2

Indicators of Health and Well-being

(2019)	EU			Turkey		
Daily smoking	17,1			24,3		
Those who do not consume alcohol	27,9			85,3		
Those who do not consume fruits and vegetables	41,2			42,8		
Disability level (moderate and severe)	9,5			7,5		
Those who never participate in sports activities	30,8			80		
Suicide or self-harm	6			6		
Body Mass Index	**Skinny**	**Normal**	**Obese**	**Skinny**	**Normal**	**Obese**
	2,9	45,8	16	3,8	40,1	21,2

Based on data from EUROSTAT.

EUROSTAT measures the health and well-being of young people (aged 15 - 29) through indicators of smoking and alcohol use, body mass index, fruit and vegetable consumption, level of disability, level of sports activity and suicide or self-harm (Table 2). Accordingly, while smoking is higher among young people in Turkey compared to young people in the EU, alcohol consumption is higher among young people in the EU. Although the consumption of fruits and vegetables is similar, 80% of young people in Turkey do not engage in any sport. The risk of obesity is also relatively higher among young people in Turkey (21.2%).

Digital World

Digitalisation, conceptualised by the Turkish Language Institution as "digitisation" (TDK, 2023), refers to the process of digitising accessible information and existing resources in a way that can be read by a computer (DinamikCrm, 2023). Today, digitalisation has accelerated with the rapid development of information technologies. Thanks to the rapid development of information technologies and especially the internet, individuals all over the world are getting closer to each other, changing the meaning of time and space in the traditional sense and creating a virtual world that can be seen as an almost more effective space. In today's world, where everything changes and transforms at every moment, perceptions and habits change and transform in parallel with technological advances. In the digital world, billions of people living in the world can transmit any information to each other in a very short period of time, express their own opinions, receive the education they want, react to an event or development, carry out joint projects, trade anywhere in the world and follow many developments in the world simultaneously (Şentürk, 2013: 32).

Young people are more directly affected by this situation and adapt more easily to new trends and current practices. As an important part of the digital world, it is important for young people to have the opportunity to use this technology. With this opportunity, young people can increase their own capabilities and freedoms by realising a quick interaction between cultures and societies and by accessing information easily.

According to EUROSTAT 2023 data, the frequency of internet use by young people (16 - 29 years old) in the EU is 96.93%, while this rate is 95.14% in Turkey. In both the EU (82.82%) and Turkey (91.92%), most young people use the internet for social media and messaging. As can be seen in Table 3, in both the EU and Turkey, young people prefer to use the internet for social media, while the proportion of young people who prefer

to use the internet for education is quite low. TURKSTAT's Statistics on Youth Report (2021 and 2022) also contains similar data.

Table 3

Reasons for Internet Use

	EU	Turkey
Social Media	83,01	91,92
E-mail and texting	88,94	60,68
Finding information about goods and services	71,27	81,79
Reading a magazine newspaper	65,60	69,24
Internet banking	67,08	68,31
Purchasing goods and services	24,21	1377
Online education	23,20	13

Based on data from EUROSTAT.

The increasing digitalisation both in the economy and society is affecting the world of work, and this situation is expected to continue rapidly in the coming years. Digitalisation can transform large areas of working life and affect occupations at all skill levels. Digitalisation has significant potential to stimulate youth employment, but to turn this potential into real decent work opportunities, young people need to acquire new skills to keep pace with the digital world (ILO, 2022). In this context, EUROSTAT 2021 data shows that 71% of young people in the EU have digital skills above the basic level, while 50.98% of young people in Turkey have these skills. Considering that we are in the digital age, the digital skills of young people in Turkey need to be increased.

Social Exclusion

It was mentioned that an approach to explaining poverty is the social exclusion approach. Although social exclusion is a phenomenon with a comprehensive and broad explanations in the literature, it was considered as one of the indicators of the capability approach within the scope and aim of the article and was examined in terms of youth poverty within the framework of this approach.

The concept of social exclusion was first used in France in the 1970s for the disadvantaged and those who could not benefit from the social protection opportunities of the state. The use of the concept that emerged in France became widespread both in the European Union and international organisations in the following years and played an important role in social policy studies.

The broad scope of the concept has led to different definitions. While Silver (1994) defines social exclusion as the breaking of social ties, Levitas (2005: 26) defines social exclusion as a phenomenon resulting from poverty and the erosion of civil rights, participation in labour markets, and moral and cultural reasons. Sen (2000) defines social exclusion as inequality and relative poverty, exclusion from the labour market, exclusion from the credit market, and gender-based exclusion. Social exclusion is not only about the absence of material wealth but also about symbolic exclusion, deprivation and lack of participation in basic formal and social institutions. Social exclusion is therefore a phenomenon that emphasises the relationship between the individual and society and the quality of that relationship (Silver, 1994). Young people are among the groups most affected by social exclusion. In EUROSTAT statistics, social exclusion is measured through poverty risk, material and social deprivation, working poverty and housing deprivation. The same

measurements are used in the youth statistics. In this article, social exclusion will be examined through these indicators.

The poverty risk refers to individuals who are at risk of poverty, experiencing severe material deprivation and living in households where the number of employees or jobs is very low (Eurostat Statistics Explained, 2024). The median value of income is usually used in poverty risk measurements. Both the EU and Turkey use 60% of the median income as the poverty risk threshold. Individuals below this threshold have lower incomes compared to other individuals living in the society and fall behind the average welfare level of the society (Aydın, 2019). The proportion of young people (aged 16 - 29) at risk of poverty in the EU is 24.5% in 2022, while in Turkey it is 36.6% in 2021. For men, this rate is 23.9% in the EU and 35% in Turkey. For women, this rate is 25.1% in the EU and 35.8% in Turkey.

Table 4

Vital Needs

Household Level Items	Individual Level Items
Ability to cover unexpected expenses	Have an internet connection
Ability to pay for one week of holiday per year	Worn clothes can be replaced with new ones
Facing payment delays (rent payments, utility bills, other loan payments, etc.)	Be able to have two pairs of suitable footwear (including one pair of all-weather shoes)
Receiving a meal of meat, chicken, fish or a vegetarian equivalent every second day	To be able to spend a small amount of money for himself or herself each week
Keeping the house warm enough	Having regular leisure time activities
Be able to have a car for personal use	Being able to get together with friends/family for a drink/ dinner at least once a month
Ability to replace worn-out furniture	

Eurostat Statistics Explained, 2024

Material and social deprivation is the inability of individuals to meet at least seven of the thirteen items (Table 4) considered as vital needs (Eurostat Statistics Explained, 2024). The OECD defines material and social deprivation as the inability of individuals or households to afford consumption goods and behaviours that are considered normal in a given time and society, regardless of individual preferences (OECD, 2007). The proportion of young people experiencing material and social deprivation is 12% in the EU in 2022 and 32% in Turkey in 2021. While this rate for women is 12.5% in the EU and 33.1% in Turkey, this rate for men is 11.7% in the EU and 30.9% in Turkey. As can be seen, almost one in three young people in Turkey is experiencing material and social deprivation.

One indicator of social exclusion is working poverty. The concept, which is generally defined as the situation where working individuals are poor in terms of disposable net income, tries to explain why individuals are poor despite working. Although there is no consensus on the type of poverty to be taken as a basis for definition, the WB's absolute poverty criteria are used in developing countries and relative poverty criteria are used in EU countries (Erdoğdu & Kutlu, 2014). According to the International Labour Organisation (ILO), all employees living in a poor family are considered as the working poor, but this scope has been widened in different studies. Accordingly, all employees living in a poor family, all full-time employees working in a poor family, all family members living in a poor family where at least one person works, and all individuals living in a poor family with at least one full-time employee can be considered as working poor (Gündoğan, 2007).

In the context of youth poverty, working poverty is an important issue. Young workers are twice as likely as adult workers to live in extreme poverty; namely, young workers live or work on less than US$ 1.90 per day

(ILO, 2022). In particular, young people working in precarious and low-paid jobs experience poverty more. According to EUROSTAT data, while the rate of working poverty among young people in the EU is 8.8% in 2022, this rate in Turkey is 10.9% in 2021.

Housing deprivation is another indicator of social exclusion. Housing, which provides shelter against natural phenomena and health hazards arising from the environment, is important for all stages of human life. According to the 1948 Universal Declaration of Human Rights, "Everyone has the right to food, clothing, housing and medical care for the health and well-being of himself and his family." The Declaration considers the right to housing together with fundamental human rights and states that the right to housing combines with other rights to provide the individual with the necessary standard of living (Yeşil & Orhan, 2023).

The concept of housing deprivation refers to inadequate housing. Housing deprivation can be defined as homelessness where an individual does not have access to a minimally adequate dwelling (Busch-Geertsema et al., 2016: 125; homelessness and living on the street or in temporary shelters (Amore, 2016) or living in the homes of friends (Brousse, 2004: 6) because they do not have a home of their own (Hick & Srephens, 2022).

The traditional definition of housing deprivation used by EUROSTAT is that housing-deprived individuals are those who live in a dwelling that is considered overcrowded and who also suffer from at least one of the other conditions of housing deprivation. Other conditions include a leaky roof or rotting window frames or floors, lack of a bathroom or shower and flush toilet for the sole use of the household, or lack of electricity/darkness. Accordingly, while the rate of housing deprivation among young people in the EU is 6.9% according to 2020 data, this rate in Turkey is quite high at 28.2%. This shows that about one-third of the young people in Turkey live in overcrowded households and in housing with poor conditions. Considering the youth unemployment rates, poverty rates and high rents in Turkey, it is likely that young people have problems accessing housing. While it has become largely impossible for a young person who does not have any income other than financial support from the family or wage income to own a house by saving from the wages he/she earns by working (Yeşil & Orhan, 2023), it also becomes difficult for him/her to live in a house with good conditions.

Conclusion

In the world and in Turkey, the share of the young population in the total population is considerable. Countries with a high youth population have a demographic advantage because the well-educated young population ensures development and progress. In addition, it is essential for societies that want to develop and prosper that young people live in a healthy environment, develop freely in the fields they want and are predisposed to, take initiative, and participate in society and the economy. At the same time, young people have expectations from the societies in which they live, such as a good education, a good job and a decent life.

The youth period, which is the transition period of an individual to adulthood, is a period in which individuals' energy and willingness to spend are intense, and at the same time, the desire to receive education and work is high. However, in this period of low income, youth poverty is a prominent problem.

This study attempts to explain youth poverty in the context of Amartya Sen's capability approach and to present the general situation of youth poverty in the EU and Turkey with data. In the context of the capability approach, it is revealed that youth poverty is an important problem in both the EU and Turkey. EUROSTAT statistics also show that young people in the EU and Turkey are deprived compared to adults in terms

of participation in society, participation in employment, education, health and well-being, digital life and social inclusion. Young women in particular are more disadvantaged than men in all these indicators. While the data for young women and men are closer in the EU, they are quite different in Turkey. This situation shows that gender roles and stereotypes are still valid for young women and inequalities have not been overcome. Therefore, women and men do not have the same capabilities. In all indicators analysed in the study, Turkey's data are quite unfavourable compared to the EU.

When evaluated in the context of the capabilities approach, it is seen that young people in Turkey are more disadvantaged and deprived of capabilities and therefore poorer than young people in EU member states in terms of social participation, employment, education, health and well-being, digital life and social exclusion. In this process of deprivation, the deprivation of young people from capabilities such as education, employment, social participation, health, and digital life reduces their functionality and thus deepens their poverty. At this point, societies that set out with the goal of development and growth should aim to increase the capabilities of young people while combating youth poverty.

Limitations

The lack of a standardised definition and measurement of youth poverty is one of the limitations of the study. Therefore, the lack of consensus on who should be included in the scope of youth poverty and which indicators other than income should be included limits the collection of and access to data on the situation of young people in the world and in Turkey. Another limitation of the study is the lack of up-to-date data on some indicators, especially in Turkey.

Ethics Committee Approval: Publicly available data from the websites of EUROSTAT, TURKSTAT and OECD were used. Therefore, ethics committee permission was not obtained.

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Examining the Impact of Financial Development on Carbon Emissions: Insights from Emerging Economies

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Abstract This study investigates the impact of financial market development on the environmental quality of emerging countries through an analysis of panel data from 21 Emerging Countries covering the period from 2001 to 2023. To accomplish this objective, we constructed stock market-based and banking sector-based indices to measure the level of financial market development using principal component analysis. We then identified the cross-sectional dependence and employed unit root testing to ensure accurate estimation. By employing a panel ARDL bound test, we demonstrate that financial development positively impacts environmental quality in emerging countries. The findings provide new insights for researchers and policymakers who seek to develop comprehensive energy supply and economic policies to alleviate the adverse effects of pollution.

Keywords Financial development · Environmental quality · CO2 Emissions · Panel ARDL bound test · Emerging countries

Jel Codes O1, O13, F6, F64

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Examining the Impact of Financial Development on Carbon Emissions: Insights from Emerging Economies

Environmental risks resulting from economic models and policies that prioritise economic growth—EG—have become a global concern. This issue is highly contentious, as it lies at the connection of sustainable development and environmental economics, affecting both developed and developing countries. A developed financial sector that facilitates access to financial resources and eliminates investment barriers has increasingly become a vital component of economic growth and development. However, it should be noted that financial development—FD—also has related costs. An increase in CO2 emissions has been linked to economic growth accelerated by financial development, resulting in global warming and its wide-ranging effects.

According to Khan and Ozturk (2021), the prioritisation of EG in economic models has generated global concerns regarding environmental risks. This matter is highly debated and at the convergence of sustainable development and environmental economics, impacting all countries. The establishment of a well-developed financial sector is pivotal in facilitating access to financial resources and eliminating obstacles to investment, thus contributing significantly to economic development (ED) and economic growth. However, it is important to acknowledge that FD also entails associated costs. The acceleration of economic growth through FD has been determined to be connected to an rise in CO2 emissions, leading to global warming and its far-reaching effects.

Grossman and Krueger (1991) made the first attempt to discover the potential link between economic development and CO2 emissions. They introduced the Environmental Kuznets Curve–EKC hypothesis, which holds that environmental contamination initially rises along the early phases of economic expansion, as identified by Kuznets (1955). However, as higher income levels are attained, the environmental quality improves, indicating an inverted-U relationship between environmental contamination and ED. Similarly, Zilibotti (1994) conducted a study using FD on technology as a proxy for economic development. His research discovered that FD, which fosters the progress of technology, diminishes the concentration of carbon emissions. Studies conducted with countries or country groups with different levels of economic development display that FD has both positive and negative impacts on CO2 emissions (Charfeddine & Khediri,2016; Hao et al., 2016; Anwar et al., 2021). In particular, different FD indicators used in studies may lead to different results on similar subjects. This creates a discord in the literature and necessitates “more detailed studies.”

This study executes a panel autoregressive distributed lag–ARDL model examining the association between FD and CO2 emissions in emerging economies. However, no single indicator of financial institutions and markets can capture all aspects of a financial system. Given the multifaceted nature of financial systems, no single indicator of financial sectors and capital markets can fully encompass all aspects of FD. For this reason, we formed a financial development index, the FDX, which comprises the banking sector and stock market sector components. One of the contributions of this study is the creation of a comprehensive financial development index that will fill the literature gap and emphasise the index's fundamental role in a heterogeneous group of different countries. The second contribution of this paper is about the country group. The second contribution lies in the focus on emerging countries, which face a range of challenges and transitions in their rapidly growing economies, including increasing financial activities. In this context, financial markets play a crucial role in economic activities and, consequently, CO2 emissions. In this context,

financial markets significantly impact economic activities and, thus, CO2 emissions. Thus, this study investigates the nexus between FD and CO2 emissions in fast-growing emerging countries.

The remaining sections of the study are designed as follows: Section 2 explains the theoretical framework, and Section 3 provides information about the data and measures of FD and explains the construction of the composite FDX. The methodological approach is discussed in Section 4. The estimation findings are displayed in Section 5. Finally, the paper is concluded in Section 6.

Theoretical Background

The theoretical background of this study demonstrates a growing interest in understanding the link between FD and environmental quality (EQ), particularly concerning CO2 emissions. The EKC hypothesis offers a possible link between environmental enhancement and ED, and this link can be extended by applying it to FD, one of the indicators of ED. Since the worldwide financial crisis in 2009, FD's critical significance in economic development has got attention, according to scholars and policymakers. Previous empirical studies have provided mixed findings regarding the effect of FD on EQ. Accordingly, Shafik and Bandyopadhyay (1992) claim that the EKC helps explain the relationship between EQ and FD based on its hypothesis. The dynamic link between FD and environmental improvement is a vital concept favoring academic fields and policy networks.

The relationship between FD and CO2 emissions is complex and multifaceted. Although there is no definitive consensus, several studies have explored this relationship and identified various patterns. Many researchers have contended that FD follows an inverted U-shaped pattern with CO2 emissions, similar to the Environmental Kuznets Curve hypothesis. In the initial stages of financial development, CO2 emissions tend to increase as economic activities expand, energy consumption rises, and industrialization occurs. However, as financial development progresses, economies tend to shift towards cleaner and more efficient technologies, leading to a decrease in CO2 emissions (Paramati et al., 2017; Phong, 2019; Jiang & Ma, 2019; Setiawati & Salsabila, 2023; Ofori et al., 2023).

Moreover, another recent study, Yiadom et al. (2023) examined the interaction between finance, ED, and carbon emissions in 97 countries, including 50 with low-income and 47with high-incomes, over the period from 1991 to 2019. Their results revealed that low-income economies need an FD threshold of 0.354, while high-income countries need a higher threshold of 0.662 to reduce carbon emissions, confirming the existence of a finance-led EKC. The authors also highlighted that a per capita GDP of at least US$ 10,067 is needed for ED to reduce emissions, with a subsequent increase in ED leading to a 0.96% reduction in carbon emissions across all income levels.

FD, mainly through increased access to capital and investment, can facilitate technological innovation. This may result in the shift to cleaner energy sources, improved energy efficiency, and the development of eco-friendly technologies, thereby reducing CO2 emissions. Yu et al. (2024) studied the effect of FD and FDI on CO_2 emissions in 57 developed and developing countries over the period of 2000 to 2017, focusing on carbon pricing. The authors found that financial depth in institutions reduces CO_2 intensity in advanced economies but raises it in emerging ones. Access to financial institutions has an adverse effect in both economies. Inward FDI quality raises CO_2 intensity in developing economies but lowers it in advanced ones. They also showed that carbon pricing in advanced countries can lessen the negative impact of FDI on CO2 intensity, boosting climate-friendly investment. Moreover, FD often correlates with improved governance structures and institutions, including environmental regulations. As countries develop financially, they

may introduce stricter regulations and policies to mitigate environmental impacts and enforce emission standards, resulting in reduced CO2 emissions. Moreover, a positive effect of FD through information and communication technology on carbon emission was supported by Tao et al. (2023), who examined the impacts of FD on carbon emission in OECD countries. Their results showed that three FD proxies, namely, deepening, efficiency and size, significantly alleviate carbon emission concentration. They concluded that there is a non-linear nexus between FD and carbon emission intensity. Ahmad et al. (2025) examined the association between FD, EG, and CO2 emissions in 46 Sub-Saharan countries from 2000 to 2020. The authors applied many statistical tests to ensure robustness, including the Pesaran test. Co-integration tests confirmed the long-term relationships. Moreover, they also used four methods (Quantile Methods through the Method of Moments (MMQR), FMOLS, DOLS and Canonical Correlation Regression) to analyse the long-term effect of FD on CO2 emissions. Their results showed that energy use, trade openness, natural resources, and GDP positively impact emissions, while FDI reduces them. These findings provide further evidence that FD can reduce emissions in the long run, particularly through investments that promote cleaner technologies and energy efficiency, complementing the outcomes of other studies such as those by Yu et al. (2024) and Tao et al. (2023).

Additionally, Solaymani and Montes (2024) argued that New Zealand's environmental policies and political situation might influence several factors affecting both EG and CO2 emissions. Their findings indicated that renewable and non-renewable energy consumption, FDI, and effective governance promote EG, while resource wealth income negatively impacts growth because of their high costs. Furthermore, renewable energy use, FD, and effective governance notably lower CO2 emissions. The exchange rate also facilitates the reduction of carbon emissions by negatively affecting EG and trade. Lastly, the burning of fossil fuels remains the major driver of higher CO2 emissions. According to their findings, renewable energy use, FD, and effective governance significantly reduce CO2 emissions.

Financial development can also influence energy consumption patterns. As economies grow financially, there is probably an increase in the energy demand. If fossil fuel-based energy sources primarily meet this demand, it could result in higher CO2 emissions. However, financial development can also encourage the transition to sustainable energy sources and promote energy efficiency by mitigating CO2 emissions.

The development effect in finance has emerged as a disputable question within the domain of natural economics and ED, particularly regarding CO2 emissions. The related literature has different empirical findings for the FD effect on environmental quality with several measures. Some studies report a positive link between FD and EQ, while others have found a negative relationship. The differences in the findings may be attributed to the various measures and proxies used to capture FD and EQ, as well as the level differences for FD in the research.

Prempeh (2024) analysed the role of FD, globalisation, clean energy, EG, and manufacturing expansion in lessening environmental damage in the ECOWAS region, within the framework of the N-shaped EKC between the years 1990 to 2019. The author used second-generation econometric methods, such as the Driscoll-Kraay panel regression and panel quantile estimation. The findings confirmed the N-shaped EKC for the region, revealing that increased FD and green energy usage are linked to lower environmental damage, while globalisation and industrialisation negatively affect environmental quality. The outcomes also showed that the structure of the EKC is determined by the particular characteristics of each country. For countries with low and medium emissions, the N-shaped EKC holds, but this is not the case for high emitters. FD reduces environmental damage in both low and high emitters, with no significant impact on medium emitters.

Some researchers support the EKC hypothesis, while others claim the opposite. For the sake of the study, we just analysed the studies involving country groups. According to some researchers, FD is a negative link between environmental factors (Abbasi & Riaz, 2016; Paramati et al., 2017; Park et al.,2018; Zaidi et al.,2019). For example, Ehigiamusoe and Lean (2019) used FMOLS and DOLS for 122 nations between 1990 and 2014, finding a negative relationship in the whole sample. Moreover, in countries with high income, improvement in finance lowered CO2 emissions, but in others, carbon emissions increased. Khan and Ozturk (2021) used 88 emerging nations between 2000 and 2014. Their findings confirm that FD plays a vital role in reducing pollution. Their outcomes also indicate that FD lessens the negative impacts of income and trade openness|-TO. Al-Mulali et al. (2015c) used ecological footprints with the environmental degradation indicator by using 93 countries that are categorised by income. The authors provided a negative association between FD and environmental degradation. Lee et al. (2015) used 25 OECD countries in their study. According to their findings, there is no EKC for OECD countries. However, they found that the FD coefficient for the eight countries was statistically significant and negative.

According to the study of Lv and Li (2021), 97 countries from 2000 and 2014 were used in the analysis, and their results suggest that FD is crucial to the lessening of CO2 emissions and that a country's environmental performance may be enhanced by its proximity to regions with a high level of FD. Bayar et al. (2020) employed long-term estimation to reveal that primary energy consumption and the growth of the financial sector had a beneficial effect on CO2 emissions in 11 post-transition European economies. Their findings are meant to catch the attention of decision-makers so that they may develop country-specific policies that strike a balance between EG and CO2 emissions.

Kırıkkaleli et al. (2022) studied the effect of FD and green energy consumption on consumption-based CO2 emissions in Chile using ARDL bounds with Kripfganz & Schneider's (2018) estimations, FMOLS, DOLS, and gradual shift causality tests. Their results show that while FD and renewable energy use decrease the consumption-based CO2 emissions in Chile, EG and electricity consumption increase the consumption-based carbon emissions. Rahman et al. (2022) investigated the impact of agricultural and industrial output on carbon emissions by employing the novel FARDL method to obtain quarterly data. They showed that FD and inflation increase carbon emissions, with inflation affecting only the agriculture-CO2 relationship. The authors also demonstrated that agriculture and forestry influence CO2 emissions over the short, medium, and long term. Based on their results, the authors recommended that Pakistan's government focus on sustainable agriculture and introduce a carbon tax on industries to support green energy initiatives and tree planting projects.

On the other hand, in another group of studies, environmental degradation and FD are positively correlated (Hafeez et al., 2018; Phong, 2019; Sheraz et al., 2022; Latif et al., 2023). Dangers arising from financial measures are causing global environmental problems, and improvements in the financial sector and CO2 emissions are positively correlated. (Shahbaz et al., 2020).

Charfeddine and Kahia (2019) analyses were done for 24 MENA countries spanning from 1980 to 2015. Their outcomes imply that FD has a marginal impact and can only marginally account for EG and CO2 emissions. These results show that there has been little progress in the financial sector's ability to promote both economic expansion and the enhancement of environmental conditions. Furthermore, Jamel et al. (2017) used OLS and causality estimation for 40 European countries and showed that energy consumption, FDI, inflation, capital stock, and urban population growth had no impact on CO2 emissions.

Another group of studies found contradictory results about FD on CO2 emissions, and the reason for that is level differences for FD have not existed in their study (Al-Mulali & Sab, 2012; Saidi & Mbarek, 2017; Jiang & Ma, 2019; Cetin & Bakirtas, 2020). Another reason for the contradictory findings is that different intermediaries for the improvement in finance have been used in some research, as Zhang (2011) exhibited that using various intermediaries has several effects on CO2 emissions. Acheampong (2019) used 46 nations of Sub-Saharan Africa between the years 2000 and 2005. The results are somewhat confusing. There are positive and negative associations between FD and environmental quality. Recently, Adebayo et al. (2023) found mixed results. They analysed the impacts of FD of the MINT nations (Indonesia, Mexico, Turkey and Nigeria) on their CO2 emissions by applying historical data covering the years 1969 and 2019. The full-sample bootstrap non-Granger causality results for Turkey and Mexico show that there is a one-way causal relation between FD and CO2 emissions. However, their empirical findings from the rolling-window bootstrap estimation display that the nexus between FD and carbon emissions is date-stamped; these imply important causal feedback links between FD and CO2 emissions in sub-sampled periods in the MINT states.

Most of the above-mentioned research is applied in OECD, European countries, MENA countries, etc. Consequently, more practical proof is required to define the possible link between FD and CO_2 emissions in a heterogeneous group consisting of different countries. In addition, this study proposes a new inclusive financial development index, which incorporates selected variables to offer a more detailed measurement of FD. The contribution of this FD measure to the literature lies in the fact that, while existing studies often rely on limited measures of FD, this study integrates a broader range of FD indicators, empowering a more detailed and comprehensive analysis of the environmental impacts of FD. In this context, the application of this FD index and the use of a broader data set compared to previous studies address the existing gaps in the literature. This study aims to investigate the link between FD and CO2 emissions, with the outcomes suggesting a negative relationship. Moreover, this study analyzes the effect of FD on CO2 emissions using a range of FD indicators. Therefore, these findings have important implications for policymakers, suggesting that emerging countries can alter their CO2 emissions with the aid of FD.

Data and Measurement of FD

This study uses annual data for 21 emerging countries[1] spanning 23 years from 2001 to 2023. The study period ends in 2023 owing to the lack of more recent data, especially energy usage and CO2 emissions indices. Our sample consists of only 21 emerging countries for two reasons. First, by narrowing the focus to a specific country group, it is possible to reduce variability and sample heterogeneity. Second, emerging countries may allow for consistent measurements of financial development since they have less mature financial systems.

CO_2 emission is the dependent variable and is gauged by the metric tons per capita, whereas the indicator of FD constructed by the authors is an independent variable. The control variables are energy consumption and per capita GDP (in 2010 constant US dollars). The energy consumption and CO2 emissions data were acquired from the Statista online database. The remaining data were taken from the World Development Indicators Database (WDI). (Table 1) displays the basic statistics for the indices of FDX and the variables used in the analysis.

[1] Brazil, Chile,China,Colombia, Egypt, Greece, Hungary, India, Indonesia, the Korean Republic, Malaysia, Mexico, Morocco, Pakistan, Peru, the Philippines, Poland, Russia, SouthAfrica, Thailand and Turkey

Table 1
Basic Statistics

Variable	Observation	Mean	Std. Dev.	Min	Max
$lnCO_2$	483	0.51	0.35	−0.20	1.09
lnENG	483	1.77	0.13	1.45	1.94
lnGDP	483	3.77	0.35	2.89	4.51
SMTV	483	65.81	76.57	.84	556.91
SMCAP	483	55.73	46.93	7.47	328.36
SMTR	483	29.85	34.80	.22	249.17
BM	483	69.37	38.90	14.35	211.82
PC	483	58.43	35.38	11.60	182.86
FSD	483	51.68	25.99	12.44	128.84
DMB	483	65.29	34.49	2.02	174.53
BCBD	483	104.49	51.49	35.409	365.99

describing an indication of FD is a difficult task because of the complexity of the financial services that financial systems provide. Although different measures have been used in the empirical literature to determine financial depth, there is no direct extent of financial system development. Given the complexity and diversity of financial systems in emerging economies, this study aims to obtain a more comprehensive picture of FD. Instead of relying solely on the bank-based indicator, we used both bank-based and market-based proxies to evaluate FD in these countries. This approach ensures a fuller understanding of the financial landscape, considering both traditional banking and more advanced market mechanisms. Following Ang and McKibbin(2007), we employ principal component analysis (PCA) to construct a composite FDX. The ratio of stock market turnover (SMTV), stock market capitalisation – SMCAP, and stock market total value traded (SMTR) are used as indices of stock market development. Additionally, we used private credits —PC, broad money—BM, financial system deposits—FSD, deposit money bank assets—DMB, and bank credits to bank deposits – BCBDto measure bank development. All FD indicators are in the form of a percentage of GDP. PCA was used to overcome the multicollinearity problems that may occur due to the standard information present in the financial development indicators. This method converts correlated variables into uncorrelated variables, and the purpose of using PCA was to obtain a composite FDX that captures the most important variations in FD indicators. The outcomes of PCA for FDX are presented below (Table nr. 2).

Table 2
PCA Outcomes

	Comp-1	Comp-2	Comp-3	Comp-4	Comp-5	Comp-6	Comp-7	Comp-8
Eigenvalues	3.981	1.462	1.138	.706	.493	.159	.043	.015
% of the variance	0.497	0.183	0.142	0.088	0.061	0.019	0.005	0.001
Cumulative %	0.497	0.680	0.822	0.911	0.972	0.992	0.998	1.000
Eigenvectors								
VARIABLE	**Vc-1**	**Vc-2**	**Vc-3**	**Vc-4**	**Vc-5**	**Vc-6**	**Vc-7**	**Vc-8**
SMTV	0.220	0.396	0.203	0.865	0.093	0.006	−0.046	0.032
SMCAP	0.264	0.450	0.656	−0.338	−0.085	−0.478	0.048	0.021
SMTR	0.220	0.532	0.334	−0.313	0.650	0.313	−0.039	−0.056

	Comp-1	Comp-2	Comp-3	Comp-4	Comp-5	Comp-6	Comp-7	Comp-8
PC	0.464	0.196	−0.214	0.063	−0.386	−0.422	−0.039	−0.723
BM	0.475	0.310	−0.415	0.157	−0.324	0.160	0.166	−0.078
FSD	0.397	0.465	0.516	0.024	0.327	−0.015	0.258	0.166
DMB	0.488	0.101	0.433	0.079	0.054	−0.347	−0.847	0.484
BCBD	0.218	0.105	−0.578	−0.052	−0.297	−0.154	0.254	0.450

As shown in (Table 2), The first component accounts for 49% of the total variance, while Component 2 and Component 3 explain 18% and 14% of the total variance, respectively. Following Kaiser's rule (Kaiser,1960), we choose the first, second, and third principal components as these components have eigenvalues greater than one.

Methodology

This paper explores the relationship between FD and CO_2 emissions in emerging countries while also addressing potential endogeneity and country-specific effects problems. To accomplish this, following Baltagi (2013), we used panel data analysis, specifically the panel autoregressive distributed lag (ARDL) technique, which can account for variables with different orders of integration and varying lags on each variable (Pesaran et al., 2001) to determine the short-term and long-term dynamics simultaneously.

Expressing our model in the general panel data framework, we get:

$$CO_{2\text{it}} = \alpha_0 + \alpha_1 ENG_{\text{it}} + \alpha_2 GDP_{\text{it}} + \alpha_3 FDX_{\text{it}} + \in_{\text{it}} \quad (1)$$

To reduce the heteroscedasticity problem, we take the logarithm of both sides. As a result, the estimating model can now be written as

$$lnCO_{2\text{it}} = \alpha_0 + \alpha_1 lnENGit + \alpha_2 lnGDPit + \alpha_3 lnFDXit + \in_{\text{it}} \quad (2)$$

The unrestricted specification of the panel ARDL model representation above is given by;

$$Y_{\text{it}} = \sum_{j=1}^{p} \gamma ij Yi, t-j \sum_{j=0}^{q} \delta ij Xi, t-j + \mu i + \varepsilon it \quad (3)$$

Where:

$CO2_{it}$ – Carbon Emission

ENG_{it} – EnergyConsumption

GDP_{it} – per capita GDP

FDX_{it} – Financial Development Index

Xit–set of explanatory variables;

γij – the coefficients ofthe laggedd explanatory variables;

δij – the coefficient ofthe laggedd explained variable in the short run;

i–each cross-section;

t – the estimation period.

To explore the short-term and long-term dynamics simultaneously, we used the mean group estimator MG or the pooled mean group estimator PMG. The MG estimator averages the long-term coefficients of each cross-section to estimate the parameters for the long term, while the PMG approach involves pooling

separate regression coefficients. The PMG approach keeps long-run coefficients constant and homogeneous, while short-run coefficients (such as intercepts, slopes, and adjustment speed coefficients) are permitted to vary across cross-sections.

The validity of the PMG approach relies on the existence of a long-run association between the variables, and the Hausman test can be used to decide the appropriate estimator for the panel ARDL. Overall, this paper utilises a rigorous methodology to observe the link between FD and CO_2 emissions in emerging countries while also addressing potential issues with endogeneity and country-specific effects.

We selected the ARDL method because it is well-suited for examining both short- and long-run relationships in the framework of emerging countries. This model allows us to gauge the effect of FD on CO2 emissions while considering potential endogeneity and controlling for heterogeneity across countries. Given its ability to address these complexities effectively, The ARDL framework itself provides a robust estimation of the relationship, detecting the nuances of the data without the need for supplementary tests.

Estimation Results

According to the panel data literature, the significant cross-sectional dependence – CD is likely shown because of the common shocks and unobserved factors in the panel data models. Thus, the initial stage of the empirical panel time series analysis is detecting the cross-sectional dependence. The null hypothesis of the CD statistic testing assumes zero dependence, while the acceptance of the alternate hypothesis demonstrates cross-sectional dependence between the panel units. We conducted the Friedman, Frees, and Pesaran CD tests on the data to determine whether cross-sectional dependency occurred or not. (Table 3) displays the test outcomes.

Tablo veya Table 3

CD Test Outcomes

CD Tests		
	Test stat.	**Prob.**
Friedman	34.382	0.023
Frees	2.139	0.000
Pesaran CD	4.221	0.000

According to the results, the null hypothesis of zero dependence is strongly rejected, concluding that the variables are not cross-sectionally independent. This result indicates that the rest of the sample could experience a shock that originates in one of the emerging countries.

Panel Unit-Root Tests

Since the co-integration tests require the integration of all the variables into order one, the integration order of the variables must be defined before applying the panel ARDL approach. In the existing panel data literature, Maddala & Wu, Levin-Lin-Chu, and Im-Pesaran-Shin's Unit Root (UR) tests are applied to define the variables' integration order. These tests are mentioned as "first-generation panel *UR* tests." Because these tests assume zero cross-sectional dependence, they cannot be applied in the presence of CD (O'Connell, 1998). In this case, Pesaran (2004) gives the cross-sectional augmented IPS–CIPS unit root testssecond-generation *UR* teststo detect the variables' *UR* properties. (Table 4) shows the CIPS test results both at the level and the 1st difference form. The findings indicate that FDX is stationary at the level whereas the other variables are stationary at 1st difference.

Table 4
CIPS UR Test

Variables	Level (constant&trend)	1st difference (constant)
Emissions	-2.323*	-4.280**
ENG	-2.392**	-4.386**
GDP per capita	-2.386**	-3.782**
FDX	-1.468	-2.982**

Note: ** and * signifies significance at the 1% and 5% level, respectively.

Results of the Panel ARDL Estimation Method

In this paper, we estimate three regression models using the PMG estimation approach. We first empirically test the effect of the index of the total FD. For the robustness check, we regress the logarithm of the carbon emissions on the PC and SMTV, which are the indicators of the financial market and stock market generally used in the literature. The outcomes of the PMG technique for the panel ARDL estimation are displayed in (Table 5), which presents the long-run effects of the dependent variables on the CO2 emissions.

Table 5
Panel ARDL PMG Estimation Results

Variables	(I)	(II)	(III)
Long-Run PMG Estimation			
FDX_{it}	−0.011*		
PC_{it}		−0.005***	
$SMTV_{it}$			−0.004*
ENG_{it}	0.712	0.643	0.559
$GDPC_{it}$	0.176***	0.138***	0.061**
ECT_{it-1}	−0.436***	−0.428***	−0.523***
Short-Run PMG Estimation			
$\Delta CO2_{it}$	0.302***	−0.218	0.334
FDX_{it}	0.083		
PC_{it}		0.052	
$SMTV_{it}$			0.023
ENG_{it}	0.478***	0.224**	0.152**
$GDPC_{it}$	0.147**	0.095***	0.078***
Hausman Test	0.929	0.994	0.91

Note: *,**,*** show levels of significance at 1%, 5% & %10 respectively.

According to the Hausman test results, we accept the null hypothesis of the homogeneity restriction, providing evidence that the PMG approach is consistent and efficient in all models. As mentioned before, the estimator of the PMG permits the short-run coefficients to vary from country to country while it imposes a homogeneity constraint on the long-run coefficients.

The long-run estimation outcomes show a significantly negative long-run association between CO2 emissions and FD. Specifically, a 1% increase in FD leads to a 0.011% decrease in CO2 emissions in the long term. This finding is consistent with those of Tamazian et al. (2009), Al-Mulali et al. (2015b), and Nasreen et

al. (2017), who have demonstrated that rising financial development results in lower CO2 emissions. It is not surprising that financial markets have helped emerging countries reduce their pollution levels, given the recent developments in their financial systems. (Cole & Elliot, 2005). While the short-run results demonstrate that there is no statistically significant relationship between CO2 emissions and FD, it is vital to note that financial markets in emerging countries may still be in their early phases of development. Therefore, the full impact of FD on emissions may not be immediately observable in the short term.

Furthermore, during FD, countries may adopt new energy technologies, reducing CO2 emissions and environmental pollution (Frankel & Romer, 1999). We further tested the effects of PC and SMTV on CO2 emissions (Column II and Column III). The coefficients of FM and FI also support the identical results (with coefficients of −0.05 and −0.04, respectively). This robustness check confirms the results obtained using the index of FD. However, the effect of both variables on carbon emissions was found to be statistically insignificant in the short term.

We control all models for the logarithm of energy use and real GDPC. The significant positive coefficients of energy usage reveal that a higher level of energy usage will increase CO2 emissions. The coefficients for GPPC are positively significant for all three models in the short and long run, which infers that economies with a higher level of GDPPC experience a higher level of CO2 emissions in emerging countries. This result is consistent with the related literature on the GDP-CO2 emission relationship.

Furthermore, the estimated coefficients for *ECT* in all models are negative and significant, varying between −0.428 and −0.523. In the case of FD, where ECT is −0.436, the CO2 emissions of the preceding year's shocks and deviations from the long-run path are done in the current year.

Conclusion

This paper aimed to examine the association between FD and CO2 emissions in selected emerging economies. For this purpose, first, PCA is applied to conduct the index of FD with three stock market development indices and five banking sector development indices. In the second step, cross-sectional dependence tests were conducted. The estimation results of these tests provided evidence of the cross-sectional dependence between the emerging countries. Under the cross-sectional dependency, we employed the second-generation unit root test to identify the correct integration order. Finally, we used the PMG approach to discover the determinants' long-term cointegration correlations.

The PMG long-run estimation findings demonstrate that FD has a negative impact on CO2 emission. This finding also indicates that FD contributes to improving the EQ in the selected emerging countries. According to the results, a 1% increase in FD will result in a 0.011% reduction in CO2 emission. However, a 1% rise in GDP and ENG will increase CO2 emissions by 0.176% and 0.712%, respectively. The results also demonstrate the validity of the EKC hypothesis in selected emerging countries where the requirement for a high-quality environment increases as economies expand.

Emerging countries account for a noteworthy portion of the global population and contribute significantly to global carbon emissions, GDP, CO2 emissions, and FD. The current trend of rising CO2 emissions is an important issue for emerging countries. To address this issue, several economic and financial policies should be implemented that encourage GDP while protecting the environment. Overall, our findings show that GDP and ENG positively contribute to CO2 emissions in emerging countries. These findings emphasise the importance of enacting clean and environmental policies to minimise the effects of energy usage and economic expansion on CO2 emissions.

To sum up, our findings indicate that policies aimed at improving FD could also improve EQ in these countries. However, GDP and ENG have a positive impact on CO2 emissions, highlighting the importance of implementing clean and environmental policies to mitigate the impacts of economic expansion and energy use. Overall, the findings of this paper provide essential insights for policymakers and researchers interested in understanding the relationship between FD and EQ in emerging economies.

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The Relationship between Health Expenditures and Foreign Direct Investment: Analysis of the ARDL Cointegration Approach and Toda-Yamamoto Causality

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Abstract The health sector comprises lots of themes which are health expenditures, health investments, the pharmaceutical and medical equipment industries, and health tourism. Health investments are often closely related to foreign direct investments. The priority motivation of foreign direct investments in field of health is humanistic development in other words, promoting human health. Investing in the health sector is difficult and carries inherent risks, despite the various contributions of FDI to a country's economy. The conneciton between health expenditures in GDP, FDI in GDP, service trade volume in GDP and the number of doctors has been examined for Turkey with ARDL analysis between 1975 and 2019. Obtaining results show a long-term correlation among the variables for analysis period.

Keywords Health expenditure · Foreign Direct Investments · Cointegration and Causality Approach

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The Relationship between Health Expenditures and Foreign Direct Investment: Analysis of the ARDL Cointegration Approach and Toda-Yamamoto Causality

The World Health Organisation (WHO) defines health as: "health is not only the absence of disease and infirmity but a state of complete physical, mental and social well-being" (WHO, 2020). The elements that reflect economic aspect of health are health expenditures, health service financing, budget provision for health, regulation of health services, resource allocation, function of the public in health, supervision of all these and health-related situations (Dilek & Konak, 2023, p.19-21). The health services sector can be stated as a service market, where consumers and producers interact as a part of of goods and services, and where the continuous control of these interactions is ensured (Kocasoy, 2014, p. 5- 11). In the health service market, demand is generally uncertain and supply exceeds demand (Boutsioli, 2010). On the other hand, life expectancy of human is a main determinant of their health expenditures. Health expenditure is a the health indicators and it reveals the quality of health services in countries. All of these are features that attract the attention of countries and lead them to revise their policies accordingly (Abdullah Siddiqua & Huque, 2017, p. 5-7). In essence, health expenditures refers to “the expenses incurred during the provision of health services." (there are three main types of health services: preventive, curative and rehabilitative. Preventive healthcare (health services) is health services for the individual and the environment. Curative health care consists of outpatient treatment, inpatient treatment, which is an advanced stage, and advanced technology supported treatments. Rehabilitative health services are medical and social rehabilitation). In more detail, health expenditures can be defined as follows: "Expenditures on buildings and infrastructure of health institutions, expenditures on health labor force and equipment, investment expenditures to improve physical and mental health conditions of citizens, investment expenditures on environmental health, investment expenditures on the production of drugs-medical equipment and diagnostic-imaging devices, investment expenditures on health education, investment expenditures on monitoring and research for optimum stock of health goods, personnel and organisation planning, investment expenditures on disease-drug side effects-distribution, etc.". R&D (research and development) expenditures, standardisation-quality-device calibration-monitoring expenditures." (Zorkun & Bülbül, 2022, p. 253-254). Among these, pharmaceutical expenditure represents a significant proportion of health expenditure (Eren, 2015, p. 149-150). In summary, health expenditure refers to all expenditure on health services provided in line with the needs of society and all expenditure made to restore health when it has been lost (Karababa, 2017, p. 60).

In the last period, particularly in developed countries, the aging of the population by an average of 5% has stimulated to significant inrease in health expenditures for therapeutic purposes (Karababa, 2017, p. 60). It has been observed that health expenditures increase day by day in OECD countries. In this direction, patients also look for alternative ways to receive more cost-effective health services. Especially the healthcare of developing countries attracts the attention of developed countries in this regard. Therefore, health services are becoming increasingly internationalised (Timmermans, 2004, p. 454).

In developed countries, the rise in the senescent population and the consequent rise in health expenditures, high-cost treatments, long waiting times, the development of communication technologies, the relative cheapening of international flights, the relative favourability of exchange rates, the strain on social security institutions as a result of the increase in cost burdens in social security and the strain on the state

in financing health services have opened the door to new searches for international patients and investors (Binler, 2015, p. 6).

In recent years, the international healthcare sector has experienced a period of accelerated growth, driven by increasing trade, developing media and a globalised world. The World Trade Organisation (WTO), in its "The General Agreement on Trade in Services (GATS)" signed in 1995, included many service sectors, especially health services, in international trade regulations (Mortensen, 2008, p. 5). Thus, international healthcare has become open to development as a new commercial field. The sector enables patients to undergo health-care services from outside, to put it another way from abroad or branches in other countries (Jackson & Barber, 2015, p. 20-21). However, for a country to realize international trade in health service, its health infrastructure must be good. The number of medical doctors or specialist (including the number of all health-care providers), the good condition of health expenditures, the number of hospital beds and hospitals will provide an advantage to countries for the provision of health services internationally (Sakala, Kolster & Fundani, 2013, p. 8).

International healthcare can generally be implemented in the ways specified by GATS (Smith, Chanda & Tangcharoensathien, 2009, p.594). These forms of implementation are as follows (UN et al., 2012, p.112-113; Chanda and Richard, 2006, p. 247):

- Cross-border supply: here, no one travels across the border, so It is exactly like trading goods. Telemedicine services and diagnosing patients via internet are related to this service.
- Consumption abroad: It is where a patient in a country travels to other countries to get medical support and services.
- Commercial presence: It implies when a service provider in a country provides the service in the territory of another country. In this context, commercial assets are held to establish close contact between the consumer and the producer. It refers to foreign direct investments in service areas such as health, education, finance, insurance, etc. The service provided by a hospital with foreign capital can be given as an example.
- Presence of natural persons: The application is in the form of a non-permanent presence of real people; the temporary presence of a person in a country other than his/her own country to provide a commercial service is within the scope of this type of service.

Health is a crucial component of human capital. The development of the health system is an essential factor in the decision-making process for foreign direct investment and investors. In this context, it is important to investigate how the developments and advancements on health in Turkey affect the foreign direct investments flow to the country. This study makes a difference in the literature with its analysis period and analysis method. Also, in this study, number of doctors and trade openness rate data are used different from others.

Until this point, health expenditures have been mentioned and it has been emphasized that the WTO states that international health service provision can be made. In the subsequent sections of the work, firstly, the connection between international health services, foreign direct investment and health expenditures has explained theoretically and the characteristics of FDI in health have mentioned. After that, there are some examples from around the world to illustrate this topic. Finally, the relationship between health expenditures and FDI has been analysed empirically.

International Health Services and Foreign Direct Investment

In last decades, healthcare has become one of the favorite sectors that can be actively offered in the international market, like manufacturing and many other service sectors. The globalisation of the sector is reinforced by increasing in trade and foreign direct investment (FDI) (Shenkar Liang & Shenkar, 2021, p.1). The most important determinants of FDI are; openness to foreign trade (foreign trade volume/gross national product), infrastructure systems, market size, labor costs and labor productivity, geographical proximity, trade deficit, technological competitiveness, quality of life, political risk, incentives and operating conditions (Kurtaran, 2007, p. 374-376). These determinants are also valid for health services. On the other hand, there are reasons to allow FDI in healthcare. These are the reduction of costs, the reduction of health pressure on the public, the possibility of access to better quality services and the potential for increasing health tourism (Zimny, 2011, p. 3-4). FDI can help state intervention in the health sector in terms of compulsory production, export bans and facilitating imports. In addition, implementing and potentially strengthening FDI in pandemic-related industries may be beneficial for national security and public health. However, contracts are signed to support public health policies and minimize investor and host country disputes (UNCTAD, 2020, p. 89).

Health expenditures can be financed from domestic sources (tax, insurance, etc.) or foreign direct investment, portfolio flows or commercial loans. In other respects, the provision of medical and health-care services through FDI may sometimes be allowed to improve the health of poor people (Smith, 2004, p. 2314-2315). Additionaly, FDI in health services both offers opportunities and poses some risks to countries. Table 1 presents these risks and opportunities. Accordingly, international investment from outside in health services enables the development of services in areas such as infrastructure, technology and quality. In addition, FDI increases the exports of health services by decreasing the imports of health services, thus it helps the internationalisation of services. However, the risks of FDI in health services must be taken into consideration by all market actors. These risks are issues such as inequality among patients, increased burden in health services, imbalance in resource distribution and internal brain drain. In addition to this, the role of the government in healthcare is to provide a fair distribution of medical support and care. Therefore, the government establishes a balance between all citizens of the country and health tourists in international healthcare (Batbaylı, 2021b, p.125-126). Therefore, FDI inflow in health services should be carried out under the supervision of the government, taking into account the possible risks.

Table 1

Risks and Opportunities of FDI in Healthcare

	Threats	**Opportunities**
Capacity	Occurence or acceleration of internal brain drain by attracting more qualified medical doctors and workers.	Elimination of supply shortages Prevention or inversion of brain drain
	Insufficiency of medical rescurces in public institutions	To put into practice newly attainable services, equipments and treatments
Quality	Deterioration of the quality of public services because of the scarcity of high-quality resources.	Know-how and technology and knowledge boosts and transfers
	More than adequate investment in advanced private sector technology by government at the cost of other social and public health needs.	Competition between suppliers increases standards and quality and also decreases prices
	Aggravation of two-fer healthcare market	Minimization of financial respnsibility of government

	Threats	Opportunities
Equity	Crowding out of poorer patients Cream-skimming of weather patients	Re-distrubution of government expenses to the public health care

Source: Mantovani, 2020.

In a report published by the United Nations in 2021, basic (key) investment policies are given when investors invest in health. The purpose of this is to protect the sector. According to these policies in Tablo 2, investments can be made in the areas of administration, health infrastructure and health services. FDI inflows to these areas are accepted within certain limits and various incentives and facilities are provided for investments.

Table 2

Essential Investment Practices in the Health Sector

Industry	Entry and acceptance	Investment promotions and enabling	Investment incentives	International practices
Manufacturing	• FDI limits	• Investor targeting	• Specific to healthcare sector	• Preversation of IP rights
	• Provisory entry	• SEZs		• Investment preversation
	• FDI screening	• Health or Medical Sector Clusters • Further assistance	• As a part of general manufacturing systems	• Access to ISDS
Health Infrastructure	• FDI limits	• Investor targeting	• Specific to healthcare sector	• Investment preservation
	• Approval procedures			• Access to ISDS
	• Provisory entry		• As a part of general investment systems	
	• FDI screening			
Health Services	• FDI prohibition	• Further assistance	• Specific to healthcare sector	• Market access and national treatment
	• FDI limits	• Health and medical expositions		
	• Provisory entry	• SEZs	• As a part of general innovation support systems	• Investment preservation
	• FDI screening	• Health or Medical Sector Clusters		• Access to ISDS

Note: IIA = International investment agreement, IP = Intellectual property, ISDS = Investor-State dispute settlement, SEZ = Special economic zone, TRIPS = Agreement on Trade-Related Aspects of Intellectual Property Rights. a Applies primarily in developing countries, b Applies primarily in developed countries.
Source: UNCTAD 2021: 134.

Foreign patients (health tourists) who receive health services for consumption abroad can receive the service relatively easily as in their own countries. However, an investor who wants to hold commercial assets

in terms of healthcare faces many obstacles. More specifically, foreign firms that establish subsidiaries or branches that provide services in another country are often subject to economic restrictions. To decide whether a foreign firm's market entry is guaranteed on economic grounds, it is crucial to conduct a comprehensive review of the economic criteria and to be aware of the limitations on foreign capital participation (WTO, 2022).

Restrictions on foreign investment in healthcare have been introduced by "the Organisation for Economic Development and Cooperation (OECD)". Some of these are given below (Blouin, 2006, p. 172-173):

• All ownership, which is foreign, is not allowed, joint venture with local facility is obligatory.

• It is given to foreign ownership confirmation depending on policy directives and issues of general national interest.

• According to economic need or "net national benefit" condition, foreign investment is approved.

• Confirmation is given to foreign investment conditional on recognition of certain performance (for example, export achievements, contribution of local personnel, technology transfer, use of local goods and services).

• Acquisition of existing firms may be allowed with foreign capital limited to minority shares only.

• Some activities or sectors can only be reserved for investment by citizens.

• There are restrictions on land acquisition and "the composition of the board of management".

• Investors should focus on economically disadvantaged groups or regions.

Similarly, there may be restrictions on foreign investment in the healthcare sector:

• The right to limit the commercial establishment of foreign healthcare suppliers to natural (real) people,

• The right to demand that foreign-owned facilities ensure education to citizens,

• Limitations on foreign capital participation and types of legal entities allowed,

• There are restrictions on foreign investment in insurance services.

• Additionally, an economic need test can be applied for foreign investment in hospital services.

"Health" contributes to the development of countries and it is considered an indicator of the development of a country. For this reason, health expenditures have a significant share in the budget for both individual and public purposes. However, due to the unpredictable, non-substitutable and indispensable nature of health, sometimes there are sudden changes in private and public health expenditures. In addition, health care, which is the responsibility of the government, has a significant share in the gross domestic product (GDP) (Batbaylı, 2021a, p. 50; Batbaylı, 2021b). A higher share of the public than the private sector in total health expenditures and a good health infrastructure are desirable conditions for increased welfare. On the other side, health expenditures are beneficial to individuals and concern the whole society with their externality effect (Zorkun & Bülbül, 2022, p. 253). However, the expectation that the portion of health expenditures in GDP will increase, puts pressure on public and private health expenditures. Therefore, health expenditures made through foreign direct investment also confer a benefit the country where the investment is made. However, the potential for private health expenditures in the country can go to the health facility that comes with FDI. In this context, while foreign investors and the accompanying foreign human capital benefit, the health expenditure pressure on the public may not change. However, if local goods and services are used in the health facility in question, the public burden can be alleviated and it

can contribute to the country's economy. On the other side, since the risks and restrictions arising from the investment are determined to protect the country's health service, these must be taken into consideration. Thus, ensuring that the national health service is not damaged will be prioritized.

Examples of FDI in Health

Foreign direct investments, which are one of the ways to make health services international, manifest themselves as quality service and developed infrastructure in host countries. For this reason, countries such as Thailand, Nepal, India, Sri Lanka and Indonesia have become increasingly open to FDIs in health. For instance, it was planned to establish a big hospital in Delhi. Consequently, India has granted approval for a German company to participate in this scheme with 90% foreign capital. Several private corporate hospitals have been established between Canada, Australia and India. One of them is a heart center that is US$40 million (United States). Besides, It is clear that corporate medical centers like hospitals in developing countries establish a commercial presence overseas. For example, “Apollo Hospitals” in India has built a hospital in another country and it plans to invest around US$4 billion to establish 15 new hospitals in Malaysia, Sri Lanka, and Nepal.

Healthcare firms in some developing and industrialised countries are increasingly engaged in alliances and joint ventures, resulting in different regional healthcare chains and networks. For example, “Singapore-based Parkway Group” has acquired hospitals in Asia and the United Kingdom. Joint ventures have been established with partners in the United Kingdom, India, Sri Lanka, Malaysia and Indonesia to form Gleneagles International, an international hospital chain. In these particular, other examples are as follows: Raffles Medical Group in Singapore has established global strategic alliances with healthcare organisations from industrialised countries. These partnerships are being used to develop an integrated network of healthcare firms providing high-quality and cost-effective health services (Chanda, 2002, p. 159). "Cleveland Clinic" in the US manages a facility in Abu Dhabi. It has constructed a new hospital there. "Hospital Punta Pacifica" in Panama City is a subsidiary of US-based "Johns Hopkins International". Dallas-based "International Hospital Corporation" manages several hospitals in Mexico. It has established new hospitals according to American standards. The services in Mexico are advertised as "offering quality healthcare at relatively low Mexican prices" in the United States. "Wockhardt" in India, is affiliated with "Harvard Medical School" (Zimny, 2011, p. 11). Spain has changed its FDI screening procedure through several decrees to address concerns triggered by the COVID-19 pandemic. The new regime clearly states that acquisitions of more than 10% of capital exceeding €1 million in various sectors, including healthcare and biotechnology, must be reported. Besides, the new regime applies to European Union (EU) investors where at least 25% is owned by a third-country investor. Although the changes were initially temporary, they appear to have been made permanent (Burnside et al., 2020).

Literature

A review of the existing literature reveals a paucity of studies that have investigated the connection between foreign direct investments in health and health expenditures. For this reason, studies on national and international health services that are closest to the subject are included (Table 3).

Table 3

Literature Search

Author	Year	Subject	Method	Result
Barro	2003	The impact of social variables and economic variables on economic growth were examined.	Panel data analysis	The international trade openness rate affects economic growth positively, while health indicators negatively affect economic growth.
Alsan Bloom & Canning	2006	The impact of public health on FDI inflow has been investigated.	Panel data analysis	FDI in low, middle income countries is strongly influenced by public health.
Outreville	2007	The relation between health and FDI was examined.	Spearman rank correlation	FDI has been found to have a significant impact on primary healthcare infrastructure and many healthcare systems.
Erdoğan & Bozkurt	2008	The relationship between life expectancy and economic growth was examined.	ARDL analysis	A positive relationship has been seen between economic growth and life expectancy.
Korkmaz et al.	2014	The relationship between health tourism revenues, health expenditures and number of tourists was investigated.	Regression, Frequency analysis	The number of tourists affects health tourism revenues and health expenditures.
Unver & Erdoğan	2015	The impact of FDI on health expenditures, education expenditures and social security expenditures was examined .	Dynamic panel method	The impact of FDI inflows on health expenditure, educaiton expenditure is negative.
Göçer & Aydın	2016	The relationship between health expenditures, the number of doctors and tourism service revenues was examined.	Kapetanios unit root test, Maki cointegration and Toda-Yamamoto causality analysis	There is cointegration and causality relation between variables.
Magombeyi & Odhiambo	2017	The relationship between poverty decline and FDI has been examined.	ARDL analysis	Poverty reduction has a positive effect on FDI in the short term.
Burns et al.	2017	The health effect of foreign direct investments in low-middle-income countries has been examined.	Panel data analysis	FDI provides a general benefit to public health in low-middle-income countries.
Giammanco & Gitto	2019	The different national institutional factors in FDI has been investigated.	Panel Data Analysis	Public health are positively related to FDI.
Shahid Siddique & Liaqat	2019	It aims to examine the relationship between health, FDI and income.	Panel Data Analysis	Income, FDI and health are related each other strongly.
Esener & Karadağ	2020	The relationship between the life expectancy, one of the health indicators and economic growth was examined.	ARDL analysis	There is a positive relationship between the variables.
Tokmak & Sönmez	2021	The relation between GDP per capita, FDI, external openness rate, health expenditures,	Panel Data Analysis	As aresult; GDP, health, public, education expenditures, exports, FDI, life expectancy, inflation and trade openness are positive;

Author	Year	Subject	Method	Result
		education expenditures, public expenditures, birth rate, life expectancy and inflation rate was examined.		Fertility rate and imports have a negative impact.
Biri	2021	It aims to determine which factors are more effective in health tourism and investments for health tourism.	Engle-Granger Cointegration Analysis	Private health investments and exchange rates affect health tourism income in the short and long term.
Verma	2021	The impact of increasing FDI inflows on healthcare capacity has been examined.	Regression Analysis	FDI has been found to affect a country's health expenditure capacity in the short and long term.

The connection between health indicators and various economic indicators has been frequently examined in the literature. What makes this study different from others is to investigate the long-term relationship between foreign direct investments and health indicators that contribute to health expenditures in Turkey. The combination of health indicators and indicators that lead to international trade is important in terms of its contribution to the development of the sector and health tourism.

Data Set and Methodology

This work is aimed to analyze the connection between international trade and health services, taking into account health expenditures, foreign direct investment, the trade openness rate in the service sector and the number of doctors in Turkey. In this context, Autoregressive Distributed Lag (ARDL) analysis will be applied using 1975-2019 annual data. The variables and their sites are given in Table 4.

Table 4
Data Set

Health expenditure in GDP **(sh)**	OECD Health Data
Number of doctors (per 1000 people **(ds)**)	OECD Health Data
FDI in GDP **(dyy)**	Worldbank
Trade openness rate* **(da)**	Worldbank

Note: This formula expresses the foreign trade volume in GDP. Service trade is taken into account as foreign trade volume. It is calculated as follows: External openness ratio (index): (Export+Import/GDP)*100

It has been stated in the previous parts of the study that the selected variables are theoretically related to each other. “Sh” and “ds” variables are among the most used health indicators in the literature. FDI facilitates the internationalisation of the healthcare sector. The increase in the share of “Dyy in GDP” shows whether the country in question can easily accept foreign capital and paves the way for internationalisation. Furthermore, considering that health services operate in coordination with many other sectors, FDI in the context of both goods and services is linked to the expenditures made for optimal health, which is an essential component of human life. Because of healthcare is a service industry, while the "da" variable has been calculated, only international service trade is considered.

Methodology

In this research, the connection between health expenditures and foreign direct investments will be tested with cointegration analysis. However, before the cointegration test, it is necessary to ensure that the

series are stationary or in what order they are stationary. In addition, the stationarity of the series prevents the emergence of spurious regression problems in the analysis we will apply (Kaya & Belke, 2017, p. 34). For this reason, primarily Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests, which are basic unit root detection model, will be used. In economies that are frequently affected by the economic conjuncture, the time series variables are likely to contain unit roots with structural breaks. Because of the length of the series and a dynamic economic environment, it is most likely that the economic time series data can show more than one break. For this reason, Lee and Strazicich (LS) unit root test can give more reliable and robust results (Yardımcı, 2024, p.30). And also, the Lee and Strazicich (LS) test, which consider stuctural breaks and change in regime, will be used in the work. The test results indicates that the time of the structural break should be included in the alternative and null hypothesis (Şen & Şit, 2015, p. 6756). In the LS test, if the alternative to the null hypothesis is "there is a structural break", the series contains a unit root with a structural break. This situation is explained by Lee and Strazicich (2003, 2004) as "non-stationary alternative hypothesis with structural breaks" (Yıldırım, 2009, p. 329).

Variables in time series are often not stationary. Therefore, stationary properties of the series are detected by applying various unit root tests. However, variables may not always be equally stationary. If this situation is valid, it is recommended to use the ARDL method. In addition, this feature of the ARDL approach, which provides safe results for small samples, makes it much more useful than other cointegration approaches (Chandio et al, 2020, p. 5). While we apply the cointegration test, we should detect and determine the cointegration order of each variable. Nevertheless, depending on the strength of the unit root models, various models give different results. In the light of this situation, Pesaran and Shin (1995) and Perasan, Shin and Smith (2001) offer a different model for cointegration. This procedure, known as the ARDL Model, is not to need the classification of variables as I(1) or I(0) and this situation is advantageous. Unlike standard cointegration tests, does not detect a unit root preliminary test (Sharifi-Renani, 2008, p. 4). Nevertheless, if the variables are integrated to the second or greater degree, the analysis in question cannot be applied. In the model, the difference of the explained variable is used. Independent variables can happen in two ways. The difference of the explained variable can start from the first order lag, other variables can start from the zeroth lag or the first order lag of all independent variables is included in the model. The ARDL analysis equation (1) and hypothesis are as follows (Esen, Yıldırım & Kostakoğlu, 2012, p. 257):

$\Delta sh_t = \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta sh_{t-p} + \sum_{i=1}^{p} \beta_2 \Delta ds_{t-p} + \sum_{i=1}^{p} \beta_3 \Delta da_{t-p} + \sum_{i=1}^{p} \beta_4 \Delta dyy_{t-p} + \gamma_1 sh_{t-p} + \gamma_2 ds_{t-p} + \gamma_3 da_{t-p} + \gamma_4 dyy_{t-p} + ?t$ (1)

$H_0 : \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$ There is no cointegration (null hypothesis).

$H_1: \gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq 0$ There is cointegration (alternative hypothesis).

t sybolizes time, β_0 is the constant term, β_x and γ_x is the regression coefficient and u is the error term of the model. Hypotheses are tested with the Wald test and F statistics. If the computed F statistic is above the upper level of the band, the null hypothesis is not accepted, and then we can say there is cointegration. If the computed F statistic is under the lower level of the band, it implies that there is no cointegration and the null hypothesis can be accepted. If the result is between the lower and upper bound, it is in the area of uncertainty (Sharifi-Renani, 2008, p. 4; Esen, Yıldırım & Kostakoğlu, 2012, p. 257).

In this study, after the ARDL analysis, the Toda and Yamamoto (1995) Causality test, which emerged with the development of the Granger Causality test will be applied. Granger causality test is found by adding the lagged value of a series to the equation for another series in the regression (Kutlar, 2017, p. 10). However, the

fact that the variables have different degrees of integration assumes that the results of the Granger (1969) test may be biased. The difference between the Toda and Yamamoto (TY) test and the Granger test is that loss of information is prevented by including the level values of non-stationary variables in the analysis. In order to apply the TY approach, first the unit root test is performed. Accordingly, the stationarity level of the highest degree stationary series is the maximum degree of integration ($d_{\max}$). Then, the appropriate lag length (p) determined by the unconstrained Vector Autoregression (VAR) model is used in the TY test ($d_{\max}$ + p). TY causality analysis is performed with the VAR model, which is re-estimated by taking into account the highest degree of integration and delays (Özaydın &Apaydın, 2019, p. 670). There is separate results emerge for both variables in the TY (Doğan, 2017, p. 24). The equation (2) is as follows (Meçik & Koyuncu, 2020, p. 2626):

$$Y_t = \alpha + \sum_{i=1}^{p+d_{\max}} \alpha_{1i} Y_{t-1} + \sum_{i=1}^{p+d_{\max}} \alpha_{2i} X_{t-1} + \mu_{1t} \quad (2)$$

$$X_t = \alpha + \sum_{i=1}^{p+d_{\max}} \beta_{1i} X_{t-1} + \sum_{i=1}^{p+d_{\max}} \beta_{2i} Y_{t-1} + \mu_{1t}$$

H_0 : There is no Granger causality relationship from Y to X. H_1, there is an alternative.

H_0 : There is no Granger causality relationship from X to Y. H_1, there is an alternative.

Results

In this part of the study, the results of the analysis applied according to econometric methodology are included. When Table 5 is examined, in line with both ADF and PP test results, except for the foreign direct investment variable, all others are stationary to the first degree. While the variables of health expenditures, number of doctors, and external openness rate are I(1), the foreign direct investment variable is I(0).

Table 5

Result of Basic Unit Roots Tests

Variable	ADF*				PP*			
	Level		1st		Level		1st	
	t-stat	prob	t-stat	prob	t-stat	Prob	t-stat	prob
da_t	-2.76	0.21	-4.85	0.001	-2.76	0.21	-4.51	0.004
ds_t	-1.18	0.9	-4.32	0.007	-0.29	0.98	-4.37	0.006
dyy_t	-4.72	0.002	-	-	-4.99	0.001	-	-
sh_t	-2.38	0.38	-7.18	0	-1.9	0.63	-7.08	0

For the ADF test, a model with constant and trend was selected with the SIC information criterion. Bartlett kernel and Newey-West Bandwidth criteria were chosen for the PP test.

Table 6 shows the result of the Lee and Strazicich unit root test with structural breaks, which allows two breaks. Obtaining test statistic values are interpreted by comparing them with the critical values of Lee and Strazicich (1999). Accordingly, da_t , ds_t, sh_t test statistics values are less than the critical values in model A. Results for Model C differ. The test statistic value of dyy_t is less than the critical values in both models. We interpret these resutls as follow; the basic hypothesis is accepted, the series contain unit roots with structural breaks and are not stationary.

Table 6

Result of Unit Roots Tests with Structural Breaks (L-S)

Variable	Model	Lag	Break Date	Test Stat.	Critical Values*		
					1%	5%	10%
da_t	A	0	1990, 2005	-2.42	-4.54	-3.84	-3.5
	C	1	1988, 2015	-8.91	-5.82	-5.28	-4.98
ds_t	A	1	1982, 1984	-2.05	-4.54	-3.84	-3.5
	C	3	1988, 2005	-5.6	-5.82	-5.28	-4.98
dyy_t	A	4	1982, 2005	-3.12	-4.54	-3.84	-3.5
	C	4	1986, 2000	-3.59	-5.82	-5.28	-4.98
sh_t	A	3	1990, 1995	-2.33	-4.54	-3.84	-3.5
	C	3	1983, 2001	-6.81	-5.82	-5.28	-4.98

Note: Critical values are taken from Lee and Strazicich (1999).

When the break dates are analysed, it is observed that after the 1980s, the externalisation policies of the Turkish economy have affected the trade openness index (ratio) and foreign direct investments. In particular, between 1980 and 2000, it had been adopted political and legal regulations concerning financial markets. Increasing foreign capital inflows in the 1990s had a significant impact on the national economy. The share of foreign direct investments in GDP showed a break in 1982, 1986, 2000 and 2005. On the other hand, the globalisation of the service sector all over the world since the 1970s has pushed countries to work in this field. In Turkey, the share of the service sector in GDP increased significantly in 1990. The volume of the service sector, which has an important economic-political value in the country's international trade, mainly includes tourism, health tourism, transport and communication sectors (TUIK, 2022). Similarly, after the 1980s, investments and expenditures in the field of health in Turkey had increased, with the health infrastructure had targeted for improvement and legal arrangements had made in this direction (T.C. Ministry of Health, 2012, p. 45-57).

It has been observed that the stationarity levels of time series reveal different results according to unit root tests with and without breaks. However, it was observed that the variables were not cointegrated into the I(2) order. Therefore, ARDL analysis can be applied. The structural break dates revealed in the LS test were taken into account in the cointegration analysis.

In the ARDL analysis, a constant model was selected and the appropriate lag length was determined as 4 according to Akaike Bilgi Kriteri (AIC), Schwart Bilgi Kriteri (SIC), Hannan Quin (HQ) values. It has been observed that there is no problem in the ARDL (4, 3, 4, 1) model created in this context and that it satisfies all assumptions (Table 5). When the bounds test results in Table 7 are examined, the F-statistic of 6.396 value is greater than the significance level of 10% and 5% critical upper limit value (3.983 and 4.733, respectively). Accordingly, the H_0 hypothesis cannot be rejected and there is a cointegration relationship between the variables at 10% and 5% significance levels.

Table 7

ARDL Model Boundary Test Results

k	F-stat**	Importance Level	Critical Values	
			Lower Limit	Upper Limit
3	6.396	10%	2.893	3.983
		5%	3.535	4.733
		1%	4.983	6.423
		Assumptions of the model		
		R-squared	0.98	
		Adjusted R-squared	0.96	
		F-statistic	62.01	
		Prob(F-statistic)	0.00	
		Durbin-Watson stat	1.82	

Notes: Breusch-Godfrey Serial Correlation LM Test; F-statistic (Prob): 0.8068, ObsR-squared (Prob): 0.6469. Heteroskedasticity Test: Breusch-Pagan-Godfrey; F-statistic (Prob): 0.1607, ObsR-squared (Prob): 0.1917, Scaled explained (Prob): 0.9947. Normality Test; Jarque-Bera: 0.0184 (Prob: 0.9908). According to the results here, there is no autocorrelation and heteroscedasticity problem in the model. In addition, the model is normally distributed. ** is significant at 5% and 10% level.

Table 8 presents the long-run variable coefficients according to the ARDL model. Probability values of the variables are not significant. Accordingly, the change in the share of foreign direct investments in GDP positively affects health expenditures in GDP. However, an increase in the number of doctors per 1000 people decreases the share of health expenditures in GDP by affecting it negatively. Turkey's openness to foreign trade in the service sector has a positive effect on the share of health expenditures in GDP.

Table 8

ARDL Long Term Period Results

Variable	Coefficient	t-Statistic	Prob
dyy_t	0.072	0.509	0.615
ds_t	−0.010	−0.017	0.986
da_t	0.125	1.475	0.154

Table 9 presents the findings of the short-run error correction model calculated over the ARDL model. The error correction term (ecm) is less than 1 and the probability value is significant. Moreover, since the coefficient of ECM has a negative sign as expected, it can be said that the model works. Accordingly, the deviation between the variables in the long run converges by 27% in the next period and the equilibrium is restored. In the short term period, a change in foreign direct investments in GDP positively affects the health expenditures in GDP. A change in the number of doctors affects health expenditures negatively. 1% change in the number of doctors reduces the health expenditures in GDP by −1.41% in the short run. However, the increase in Turkey's openness to foreign trade in the service sector has a negative effect on health expenditures in the short term period.

Table 9

ARDL Short Term Period Results

Variable	Coefficient	t-Statistic	Prob.
d(sh(-1))	0.275	2.041	0.0534***
d(sh(-2))	0.515	3.786	0.001*
d(sh(-3))	0.549	4.263	0.0003*
d(dyy)	0.038	1.61	0.1216
d(dyy(-1))	0.0058	0.236	0.8153
d(dyy(-2))	0.05	2.285	0.0323**
d(ds)	−1.414	−1.78	0.0887***
d(ds(-1))	−2.621	−3.151	0.0046*
d(ds(-2))	−0.105	−0.145	0.8856
d(ds(-3))	−1.757	−2.781	0.0109**
d(da)	−0.002	−0.323	0.7496
c	0.843	5.85	0*
Ecm(-1)*	−0.273	−5.392	0*

Note: It is significant at *1%, ** 5%, ***10% levels.

Figure 1 and Figure 2 presents The CUSUM test (Cumulative Sum of Recursive Residuals) and the CUSUM-squared test (Cumulative Sum of Squares of Recursive Residuals) are depend on the cumulative sum of recursive residuals depended on the first set of n observations. It is upgraded recursively and is plotted against the break points (Baharumshah Mohd & Mansur Masih, 2009, p. 239). If the plot of the test statistics are within the 5% significance level, namely, if the test statistic lies within the boundary lines, then the model has not stability problem.

Figure 1

Cumulative Sum of Recursive Residuals

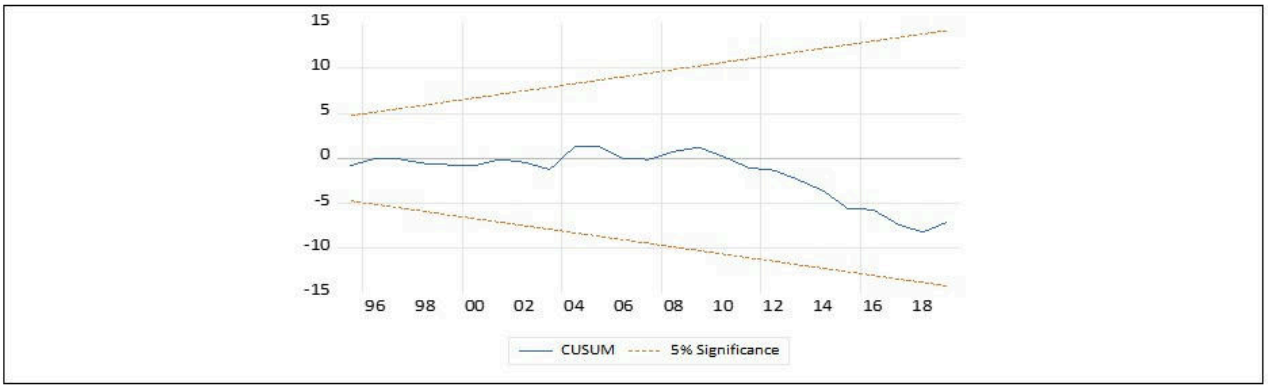
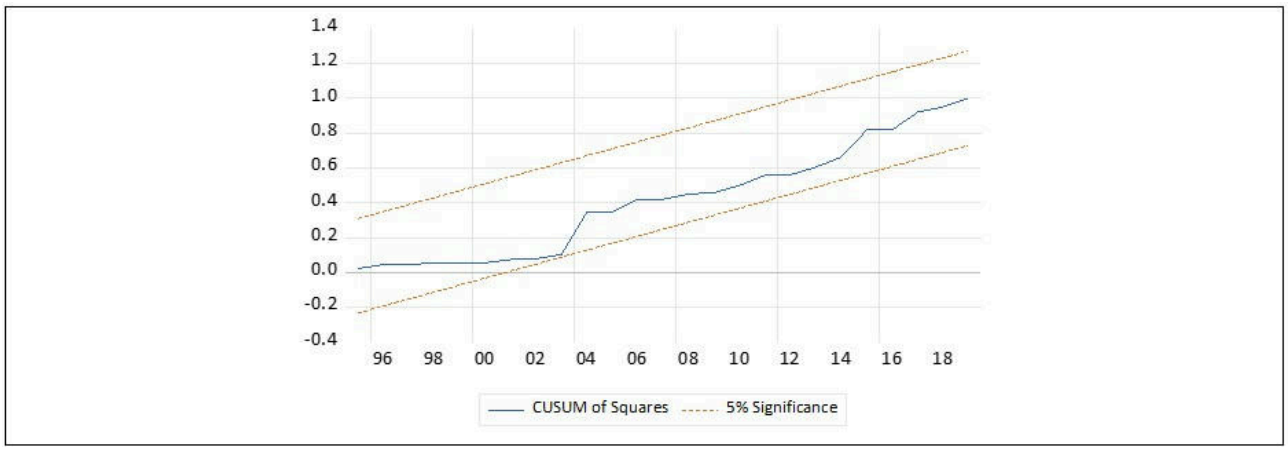


Figure 2

Cumulative Sum of Squares of Recursive Residuals



Causality test, which is developed as Toda-Yamamoto, are given in Table 10. With respect to the findings obtained, there is unidirectional causality from FDI in GDP to health expenditures in GDP. There is causality from health expenditures to the number of doctors and from the number of doctors to external openness. In the other causality test results indicated by X, it is concluded that it hasn't causality in the Granger sense.

Table 10

*Toda-Yamamoto Causality Test**

FDI in GDP **	→	Health expenditure in GDP
Health expenditure in GDP ***	→	Number of doctors
Trade openness rate	X	Health expenditure in GDP
Number of doctors	X	FDI in GDP
Trade openness rate	X	FDI in GDP
Trade openness rate ****	←	Number of doctors

Notes: *d_max +s = 1+1=2. →, ← indicates unidirectional causality. X indicates no causality. ** X^2 test stat: 5.5742, Prob: 0.0616. *** X^2 test stat: 10.535, Prob: 0.0052. **** X^2 test stat: 5.3699, Prob: 0.0682.

Conclusion

Foreign direct investment helps to obtain clear information about the current economic outlook of countries. It also indicates countries' economic openness. In addition; the infrastructure of the country, high quality of life, quality human capital, technological competitiveness, geographical location, political situation, incentives and investment capacity are important factors for inflows of FDI. The status and qualities of these factors affect FDI inflow. Therefore, it contributes to the health, education, social development and welfare of the investing country. Apart from this, foreign direct investments are closely related to human health and income.

If the foreign capital investments in the country are in a field related to health, it helps to spread health at the disadvantage group and areas. Therefore, the burden of health expenditures on the public sector will be reduced and public resources can be transferred to other areas. On the other side, the arrival of human capital with FDI may increase the quality of health services. The supply-demand imbalance at the core of health economics can be partially eliminated by FDI. An increase in the supply of health services, which is under the responsibility of the public sector, will ease the burden of the government. Consequently, the

development and improvement of health contribute to the development of the country both individually and socially. However, FDIs carry some risks but these can be eliminated by measures such as restrictions, regulations, incentives and policies in foreign capital inflows. Health care and expenditure are mostly the responsibility of the government. Because of that situation, countries allocate substantial amount of GDP to health expenditures. However, foreign direct investments in health care are important for reasons such as the number of doctors, hospital beds, hospitals, life expectancy at birth and increasing health expenditures in other countries, increasing in the elderly population. On the other hand, the motivation to reverse the international brain drain, the desire to reduce healthcare imports and increase exports, and the incentive to increase health tourism revenues encourage direct foreign investments.

In this work, the connection between health expenditures and foreign direct investments have been tested with ARDL cointegration and Toda- Yamamoto Causality analysis. Firstly, stationarity properties of the series have been investigated with unit root and obtaining findings indicate that series are not equally stationary. As a result of this, it has been used the ARDL method in line with the literature. In the long term period, there is a correlation between foreign direct investments and health indicators. It has found that there is a long term period connection between health expenditures in GDP, the volume of services trade in GDP, FDI in GDP and number of doctors variables in Turkey. In addition, while the increase in the share of health expenditures in GDP is positively affected by the increase in the portion of FDI in GDP and the increase in the rate of openness in the services sector, the increase in the number of doctors is negatively affected. Similar results is valid in the short run. However, openness to foreign trade in the service sector has negative effects on health expenditures in the short term period. Moreover, according to the Toda-Yamamoto test, foreign direct investments have found to be the cause of health expenditures. The results obtained at end of the study support Alsan Bloom and Canning (2006) and Verma (2021). In addition, while health expenditures are the cause of the number of doctors, the number of doctors is the cause of the country's openness to foreign trade in the service sector.

Ultimately, health expenditures are affected by FDI. Since the health sector is a stakeholder sector with transport, tourism, construction, insurance, communication services, pharmaceutical sector, medical devices and equipment production sector, FDI creates added value in this field and thus affects both health expenditures and national welfare. In this context, FDI inflows should be beneficial for the investor and the investee country. In particular, if FDI is to be made in the field of health, it should increase economic welfare in that country and protect the investor. It should provide net national benefits such as technology transfer, allowing the use of local goods and services. In addition, transferring the income obtained from the sector through foreign capital to health expenditures within the country will benefit human health and economic development.

We suggest that the distinction between the impact of FDI from europe and the impact of FDI from overseas countries on health expenditure should be investigated in further research.

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Wearing the Shirt of Fire: Guardians Managing the Orphan Estate in the 16th Century Ottoman Empire

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Abstract In Ottoman history, the task of protecting the orphaned minor's inheritance was not left to the relatives alone; it was instead an institutionalised practice monitored under the supervision of the sharia court. The guardian (*vasi*) was the person in this situation responsible for protecting the orphan's estate and providing for the orphan's maintenance until the orphan reached maturity. This institutional practice continued to exist for centuries in the Ottoman Empire. The richness of the Ottoman primary sources enables us to trace this practice in detail. This paper analyses the economic activities in which the guardians were involved whilst protecting the orphan estate. It uses sharia court registers (the *sharia sicills*) as the primary archival source. Different records regarding guardian activities were compiled for a century-long period in the 16th century. This study mainly employs records from İstanbul, the imperial capital, and other regions of the empire like Bursa, Konya, Trabzon, Cyprus, and Sarajevo. The first impression is that the credit relations have the most significant share in this compilation of economic activities. Other activities include selling estates and sustaining alimony to the orphans. As a general rule, orphans' money was extended as loans with rate of return to cover expenses and protect the money from diminishing. In cases of need, orphans' shares in real estate were sold with the permission of the sharia court. In most cases, when the orphan reaches maturity and settles accounts with the guardian, both sides appear to leave the court satisfied. Such records provide valuable insights into the Ottoman socio-economic history of the era. For instance, changes in alimony payments and fluctuations in the rate of return of credits throughout the 16th century are significant and will be evaluated in this paper. Along with these analyses, this paper will highlight the possible differences between İstanbul and other regions in the Ottoman Empire.

Keywords Orphan estate · Ottoman history · credit

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Wearing the Shirt of Fire: Guardians Managing the Orphan Estate in the 16th Century Ottoman Empire

Orphan estate is a shirt of fire.[1]

It is commanded in Islam that when a child is orphaned, his/her share of the estate should be approached to protect and meet the needs of the orphan. This sensitivity gained a classical order with the development of the sharia court in Islamic history (McKibbin Metzger, 2023).

As an important part of Islamic history, this institutionalised application enjoyed a long lifetime in Ottoman history (from 14th century to the 20th century) as well. Fortunately, there are rich sources from which one can trace the practice of protecting orphan estates in the Ottoman Empire, which makes it unique in Islamic history. In this respect, protecting the orphans' estate (property and money) was not only left as a family matter but was also recorded and supervised by the qādi/sharia court. This application found its place in the Ottoman code of law (*kanunnāme*) by stating that the sharia court official (qassām) is to intervene in estate division if there was orphaned minor(s) left (Akgündüz, 1992a, pp. 394–395). In line with this code, sharia court records illustrate the whole process of protecting an orphan's estate, which starts with appointing a guardian and ends with the orphan reaching maturity and receiving his/her estate whilst settling accounts.

Moreover, a guardian (*vasi*)[2] is responsible for an orphan's estate (*yetim malı*, pl. *emval-i eytam*). Guardianship was of two types. In the first one, the person who left an inheritance appoints a guardian before their death. The second and more common one is the guardian appointed by the sharia court, i.e., the *qādi*. The responsibilities of these two groups of guardians regarding the orphan estate are the same. After accepting guardianship, they were responsible for the orphan's share of the estate. While the estate was being divided, according to Islamic law, the deceased's receivable and payable accounts were also settled. The accounts that were not settled during the division of the estate were followed up later by the guardian. In order to control the activities of these guardians, the *qādi* would sometimes appoint supervisors called *nāzırs*. In principle, most of the guardians' economic endeavours were registered since they had to get the approval of the *qādi*. The guardian's responsibility had two sharp ends: the first was to protect the orphan's property and money, and the second was to provide for the orphan's maintenance. Hence, the guardian is not expected to leave idle the orphan's estate, specifically his/her money. Guardians enter economic and financial endeavours with orphan money, such as lending or entering into commercial partnerships. On the other side, the *qādi* authorised the guardian to spend a sum, enabling the orphan to live without reducing his/her previous standard of living. This unsurprisingly meant the loss of orphan money. In cases of insufficient money, selling the property for these maintenance expenditures was also possible.

The guardians responsible for orphan estates were usually surviving parents or relatives, and in some cases, trustworthy people from the neighbourhood. In Islamic jurisprudence, caring for infants up to seven requires a special upbringing (Bardakoğlu, 1998), which was also considered in the appointment of guardians. When the orphan reached physical and mental maturity, the guardian would hand over his or

[1] Original: Yetim malı ateşten gömlektir. (Şinasi, 1302, p. 488, nr. 3870)

[2] As a term, "*vasi*" is a person appointed by the court to people who do not have the capacity to perform due to limitations such as age and mental health, and is responsible for protecting their property. (Devellioğlu, 1980) (Pakalın, 1993)

her share of the estate to the orphan, and the court would approve this. If there were any disputes during this process, the sharia court would decide how to settle the matter.

The practice of protecting orphans' estates, described in the outline so far, remained a classical institution in the Ottoman Empire until its transformation in the late 19th century. In this period, in line with the centralist policies of the state during the *Tanzimat* (1839), the "*Emval-i Eytam Nezareti*" was established in 1851 (Çanlı, 2002; Özcan, 2006). In this study, I will focus on the sixteenth century Ottoman Empire to illustrate and analyse the above-mentioned institution, which gained its classical form in that era.

Literature Review

The number of studies dealing with protecting the estate left to orphans in the Ottoman Empire and their fate is relatively limited. Cafer Çiftçi's article titled "Bursa'da Eytam Keseleri" is one of the first of these few examples (Çiftçi, 2003). In this study, Çiftçi presents examples from the Bursa sharia court. Çiftçi's study is in the nature of an introduction and includes various examples from the 16th century to the 20th century. Fatih Bozkurt, who conducted a doctoral research on the probate registers, also published an article on orphans' estates (Bozkurt, 2011, 2012). In this study, Bozkurt analysed 18th-century probate records. He writes a special chapter on orphans and the management of orphan estates in these records and then discusses the process of registering and dividing the estate under the supervision of a guardian. Yahya Araz's book is another work that directly references the property left to orphans. Araz evaluated the relationship between orphans and guardians through some examples (Araz, 2013).

Aslı Deliktaş used Trabzon's sharia court records as a historical source and presented the general situations regarding guardian appointments in the registers for the seventeenth century. She prepared a list of guardian appointments and classified the content according to gender and proximity. Of the 103 guardians listed, 35 are the orphans' mothers, 39 are unrelated persons with unspecified ties, and the rest are relatives such as grandfather, brother, uncle, and grandmother. (Deliktaş, 2016; Muşmal & Gürbüz, 2018)

The issue of orphanhood and the protection of their inherited rights has naturally been studied in family history and women's and gender studies. Literature on this subject has developed, especially in English. (Cohen, 1984; Meriwether, 1996, pp. 219–235; Tucker, 1998; Yazbak, 2001; Alsabagh, 2018, p. 272)

Çiğdem Gürsoy has made an essential contribution to the literature on the protection and management of orphan estates in the Ottoman Empire (Gürsoy, 2020). In her article, Gürsoy scanned the documents containing the keywords orphan and guardian from the İstanbul sharia court *sicill*s published by the Islamic Research Centre of the Religious Foundation of Turkey (ISAM) and conducted a discussion on the sustainability of orphan estates. Ayşe Şimşek's article is one of the recent studies on the protection of orphans' estate as well as (Şimşek, 2021).

Mehmet Çanlı (Çanlı, 2002) and Tahsin Özcan's (Özcan, 2006) studies analysed the *Emval-i Eytam Nezareti*, which was established in the second half of the nineteenth century and is the leading example of the literature on orphans and their funds in that era. There is a growing number of research and analyses regarding the *Emval-i Eytam Nezareti* and the funds administered by these institutions (Ünal, 2010; Şahin, 2017; Taşar, 2019; Çanlı, 2020; Kızıldağ, Kayahan & Görkaş, 2023). A most recent study is Mestyan and Nori's article that focuses on sub-Ottoman khedivate Egypt and the capital of orphans (in their words/terminology) in the second half of the nineteenth century. They named the institution "probate regime" (Mestyan & Nori, 2022) and traced changes in this institution through Ottoman rule to the Egyptian khedives.

In addition to those mentioned here, various studies on probate books/*tereke* (Barkan, 1966; Özdeğer, 1988; Öztürk, 1995) and sharia *sicill*s also touch upon the orphan estate and guardian relations (Jennings, 1973, 1990; Cezar, 1998, pp. 15–32; İstekli, 2005; Yıldız, 2005).

In sum, the literature on orphan estates in the classical period of the Ottoman Empire is scarce. A few studies mentioned above limit themselves to a shorter period or a specific region. There is also a lack of economic analysis of guardian activities, especially in the earlier periods of the institution. In addition, there is a misconception that the protection of orphan estates was modernised by the *Emval-i Eytam Nezareti* in the later period of the Ottoman Empire. This article proposes that in the earlier period, the protection of orphan properties was institutionalised as well.

Sources and Method

To understand and analyse this institution in detail, various sources have been collected from different cities of the Ottoman Empire for a century-long period that covers the sixteenth-century Ottoman world. This will enhance our understanding of protecting orphan estates, especially orphan money, trace possible economic changes in the long term, and observe differences through regions, such as the centre and periphery.

Following the practices regarding protecting the properties of orphaned minors in the Ottoman Empire is possible thanks to multiple archival sources. The most important sources are the records kept in sharia courts, namely the *qādi sicill*s. In the Ottoman Empire, if there was an orphaned minor left, the registration of the assets of deceased persons and inheritance and the division of shares according to fiqh was under the supervision of the state (Berber, 2023, pp. 69–71). Furthermore, the *qādi*s were the supervisors of this process. Therefore, such records were included in the sharia *sicill*s kept by the *qādi*. When both the transcribed and unpublished registers are analysed, it is easy to see that many issues related to inheritance and orphans are dealt with within these sources. In summary, the sharia court records tell us about the appointment of guardians for orphans' estates, their activities such as the sales, and the loans and credits they distributed. It provides information about their relations; the accounts kept, the dismissals of guardians, and many other situations regarding the orphan estate.

Most of the sharia court *sicill*s used in this study are transcribed as theses and projects, making them easier to scan for relevant records. The Üsküdar sharia *sicill* nr. 98, and Sarajevo *sicill* nr. 2[3] was read and used for the first time. Sharia *sicill*s of İstanbul constitute the majority of the dataset. Along with İstanbul, *sicill*s from Bursa (Yılmaz, 2002; Canlı, 2006; Yediyıldız, 2010; Habib, 2019), Konya (Yörük, 2013; Özpolat & Sak, 2018), Manisa (Çamlı, 1993; Uzun, 2002), Trabzon (Korkmaz, 2014; Turan, 2014; Gedikli, 2020), Mardin (Günay, 2002), Kayseri (Ertürk, 1994), Antep (Çam, 2008; Ünlü, 2017; Altundaş, 2017; Nohutlu, 2019; Ekin & Karagöz, 2023), Halep (Ajghif, 2013; Said, 2015; Alnhayer, 2017; Bathish, 2019), Avlonya (Yılmaz, 2021), Kıbrıs (Tamçelik & Kasapoğlu, 2021) and Göynük (Soydemir & Gündoğdu, 2015) were scanned and relevant records were compiled.

Üsküdar *sicill* nr. 98[4] and Manisa *sicill* nr. 6 stands out with its high density of records on the transactions of guardians. The majority of the content of these two registers is related to guardians and orphan estates.

[3] Gazi Husrev-Begova Biblioteka, Sdz-2 (Sarajevo Sharia Sicill nr. 2.), 1564-1566.

[4] This *sicill* is devoted exclusively to orphan records and titled as "*sicill-i eytâm*" (orphan sicill). State Archives of Türkiye (BOA), Üsküdar Sicills under the directory of İstanbul Sharia *Sicill*s (İSTM.ŞSC.06.d) nr. 98, 1577-1601. Although another such record appears in the archival registry classifications for the Muğla registry numbered 188, an examination of the relevant registry reveals that this is not the case. See: (Akgündüz, 1988)

Especially Manisa Register nr. 6 contains the debts and receivables of the deceased and pledges made to fulfil the debt. It includes transactions such as the sale of property, and thus, it is almost as if it reveals the stages of probate registration (Uzun, 2002). Most *sicill*s of İstanbul used in this study are from the "Kadı Sicilleri" project along with a few master's theses (Akman, Gedikli & Aydın, 2011; Akman, Gedikli, & Aydın, 2012; Akman et al., 2012; *Balat Mahkemesi 1 Numaralı Sicil (H. 964-965/ M. 1557-1558)*, 2019; *Balat Mahkemesi - 2 Numaralı Sicil (H. 970 - 971/M. 1563)*, 2011; *Beşiktaş Mahkemesi 2 Numaralı Sicil (H. 966-968 / M. 1558-1561)*, 2019; *Tophane Mahkemesi 2 Numaralı Sicil (H. 966-967 / M. 1558-1559)*, 2019; Aydın & Tak, 2008; Çakır & Yılmaz, 2011; Çamlı, 2020; Dağdaş, 2010; Erol & Kılıç, 2011; Güler, 2010; Gültekin, 2010; Günalan, 2010a, 2010b, 2010c, 2010d; Günalan et al., 2012; Karaca & Yılmaz, 2010; Kazan, 2010; Kurt, 2019; Yıldız, 2010; Yılmaz, Akman & Aydın, 2011). In addition to these fully scanned sharia *sicill*s, the registers involving loans granted on orphan estates in the Sarajevo sicill nr. 2 were added to the dataset. Particular records from Ankara *sicill* nr. 1 and 2 (Ongan, 1958, 2014), from Jerusalem *sicill* nr. 67 from the PhD of Alsabagh (Alsabagh, 2018), Lârende from the first half of the 16th century (Aköz, 2006) and Edirne (Yiğit, 1993) have been used as well.

As a result of this scan, a dataset containing more than 3000 records related to the guardians of the orphan estate was compiled. In this way, a survey that can provide insight into orphans in a large part of the Ottoman territory in the 16th century has come to life. A general scan of the *sicill*s reveals that the average intensity of court proceedings concerning orphans in Ottoman society was 5%. This rate proves that orphans have an unignorable place in the duties and the registers and the court. Of all these records, 1023 were directly related to the economic transactions of the guardians. These transactions included money lending, sale and leasing of orphan property, and sustainment of alimony of the orphans, which were the guardians' responsibility with the orphan estate.

Map 1

Weighed map of activities regarding orphan estates. (Made with Palladio web app)

As the map illustrates the intensity, İstanbul is the centre with the number of transactions (599 records). Other important regions that provide several transactions are Bursa (96 records), Trabzon (75 records), Antep

(68 records), and Konya (65 records). Cyprus (43 records) and Sarajevo (35 records) followed these cities with other regions.

A rough two-third of the İstanbul records are from Üsküdar *sicill*s (380). A little less than a quarter is from Galata (137). Other regions, such as Beşiktaş, Balat and Eyüp, constitute a relatively small portion of the İstanbul dataset.

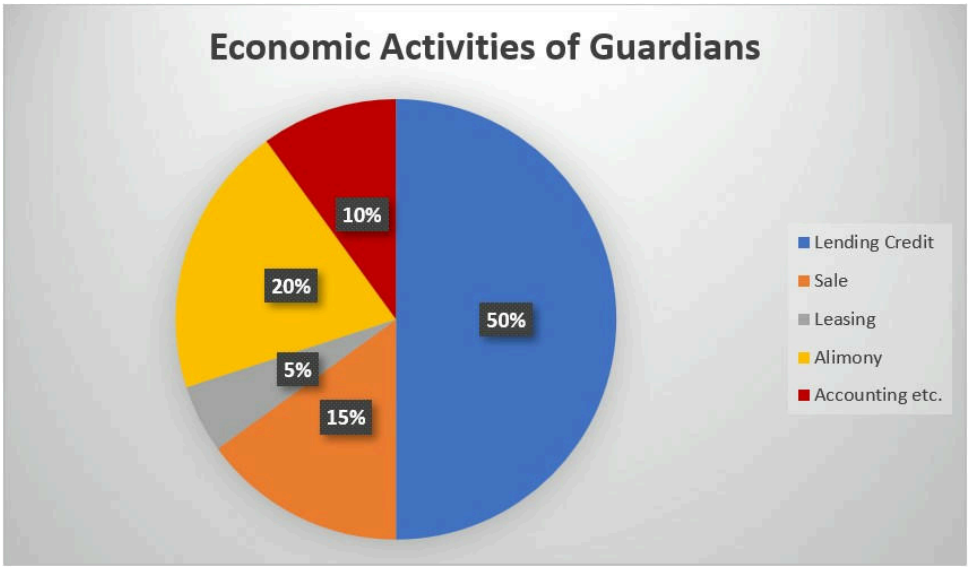
These records enable us to analyse the protection of orphan estates and the economic activities of guardians in different periods and regions of the 16th century Ottoman Empire. Since the abundance of the records is from the second half and especially the last quarter of the century, the analyses tend to be stronger in such periods.

Another point is that since the *qādi* court records are the primary source for this research, Muslim orphans constitute the majority of this study. With this in mind, the protection process of non-Muslim orphan estates, which were also recorded in the *sicill*s are used in the analyses of this study.

According to the dataset, approximately half of the total economic transactions are related to money lending. Orphan money was lent as loans by the guardians in return for specific maturity. The ratio of various sales transactions made by the guardians to total economic transactions is 15%. Again, 10% of the guardians' economic transactions can be traced from their provided accounts. Leasing transactions account for 5%, while alimony transactions, which can be recorded under expenses, account for 20%.

Graph 1

Rate of Economic Transactions of the Guardian



Economic Transactions of the Guardian

Sale and Leasing

Sale and leasing combined constitute a fifth of the total transactions of the guardian. As for leasing, it was rare for the guardian to enter new leases. Records are related to the fact that the guardians keep receiving payments from existing rent agreements and record this income. Furthermore, in one case, it was seen that the guardian increased the rent. This was done for the benefit of the orphans. Other than this, leasing was encountered in more than one type. These are classified as property rent and arable land rent. In addition

to these transactions, we came across provisions regarding taxable property or goods. There are insufficient data on leasing transactions to analyse by time or place. The rent of arable land, vineyards, gardens, etc., belonging to orphans was sometimes transferred to the guardian as part of the maintenance expenditure. Other rental income, especially shop rents, continued as a legacy of the deceased parent.

Second, sales are, by nature, considered a loss of the orphan's estate, so it is a transaction that the guardian cannot do without approval of the sharia court. In the sources examined, there are many rulings in which the sale was authorised. In most of these, the property sold is the house. One can also see the sale of various properties such as vineyards, orchards and goods. It is stated in the registers that almost all of the sales occurred for the orphan's expenses (alimony). In more general terms, these sales were permitted mostly because there was no other way to sustain the expenditures of the orphans. In some rare cases, they are sold so that keeping the house is not for the orphan's benefit. For example, if the property sold is a house, it is already unusable and ruined, and its sale would be beneficial. Another essential feature of the sales is that they are realised through auctions to the highest payer. In this way, the orphan's property is sold at the highest price.

Graph 2

Types of Sales

It is not possible to standardise and compare the sale prices of properties as the values are listed over a period of a century and are in different regions. Nevertheless, it can be said that the highest sales prices are for houses. House sale records from different regions such as Halep, Galata, Kıbrıs, Bursa were taken into account. The cost of houses varies between 500 piasters (*akçe*) and 72,000 piasters, with an average of over 9000 piasters. Ship sales that can be traced from Galata are also over 20,000 piasters.

As mentioned, although it may be misleading to construct a standard index due to the variability in the structure and location of properties, the general upward trend of prices from 1521 to 1600 is evident. The registry sources that provide data on the peaks are generally records from the Galata *sicill*s.[5] Comparing these data with the İstanbul real estate market study, a similar price increase is detected (Çiftçi, 2017).

[5]The Galata sharia court has a peculiar situation in Ottoman legal history. They kept the probate records that exceeded a certain amount and by demography they contained naval merchants and high officials.

General prices increased throughout the sixteenth century, affecting the sales in this category as well (Pamuk, 2000).

There are hardly any instances of guardians purchasing property on behalf of orphans, for investment or against debt. Most these transactions occurred to generate income to cover expenses.

Credit

In the pool of data on the economic transactions of guardians, loans constitute half of the transactions. Thus, it is undeniable that money lending is an essential item in guardians' financial transactions. There is at least one example of a loan from orphan money in every region that was analysed. Along with the abundance of records, this makes it easier to assert analyses and observe trends in the Ottoman credit market.

There are several reasons to deduce that the loans granted by the guardians were not ordinary debt. The first is that most of these loans were given at a certain interest rate, and the second is that the capital was usually distributed in particular shares, such as 500 and 1000 piasters each.[6]

In addition to these reasons, as a higher principle, it was explained in fatwas that the money lent by guardians could not be given without expecting anything in return (*karz-ı hasen*). This is because the guardian must conduct the economic transactions in favour of the orphan (Berber, 2023, pp. 75–79).

In the classical Ottoman society, lending money and debt relations were set under specific rules. These rules can be summarised as follows: the debt must be witnessed and registered, a surety or pledge must be provided against the debt and (if there is) the return must be limited according to legal ceilings. It is observed that these conditions are respected when the guardians lend the orphans' money to the credit market.

There are a few cases where the loans cannot be repaid. When the borrower died, a guarantor was contacted, and the court recognised and registered that the debt had embezzled him. In addition, if the loans cannot be paid, situations such as default and an increase in the rate do not occur. This is because these debts have maturity that do not exceed one year, and compound interest is not possible.

The identity of the parties to whom guardians lent orphans' money is too broad to be divided into a few groups. From this point of view, the Ottoman credit market was active during this period.

Forms of Credit

The primary lending method is *muʿāmele-i şerʿiyye*, an umbrella term for lending money with a return for a certain period. Another method of lending is *istiğlāl*. This commercial contract, referred to in fiqh as *beyʿ bil-istiğlāl*, appears 63 times. In short, *istiğlāl* is selling the house or other real estate and receiving cash yet continuing to live in the house and paying rent to the buyer, (Çizakça, n.d.). The rent price was the return on the total sale amount, the money lent. This nomenclature is not mentioned in some transactions that were estimated to be of the istiğlāl type. There are 21 records of this type, in which a house or property is sold and then leased back for a return of the sale amount, usually 10 %. However, the number of records in which it is stated in the record that it is *istiğlāl*, but the rate of return is not clear, is 5. Most properties sold and rented in istiğlāl contracts are houses. However, vineyards and other properties subject to istiğlāl can

[6] Yavuz Cezar claims that every debt record in the *sharia* court records should not be regarded as a loan. According to him, the maturity and rate of return make the debt a loan/credit (Cezar, 1998, p. 18). As per my findings, it is accurate to label the records as credit and loan. It is reasonable to recognise the lending of certain amounts as a loan as well. In addition to this condition, the guardian's lending with economic responsibility is sufficient to consider these loans as credit/loans.

be seen sporadically. In Trabzon and Antep, there is one record for each sale by *vefâ*. The sale by *vefâ*, or *bey' bi'l-vefâ*, is a sales contract that covers the sale of *istiğlāl*. It allows the debtor to recover his pledged property when he pays his debt after a certain maturity (Bayındır, 1992).

İstanbul is at the forefront in *istiğlāl* records. In most regions other than İstanbul, lending money using the *istiğlāl* method is not seen. In addition to the aforementioned records of sale in Trabzon and Antep, there are records in Konya that are assumed to be *istiğlāl*, as well as in Bursa and Avlonya. All of the aforementioned *istiğlāl* records appear after 1562. However, it is understood from the sharia court registers that *istiğlāl* was also seen in İstanbul before 1550, even if it was not called *istiğlāl*. Considering this information, it seems possible that *istiğlāl* was observed in centres where trade and credit were developed. However, this type is not observed in Halep as an exception to this situation. Situations such as the lack of money in the market to meet the demand for credit and the inability of creditors, i.e., those who demand a loan, to find a guarantor may also increase the number of *istiğlāl* records. For this reason, the absence of *istiğlāl* in a region does not indicate that the credit market is not developed there.

In 33% of the cases where loans were allocated and the rate of return was certain, the amount given was 1000 piasters. The frequency of 500 piasters is 23 %. The frequency of 2000 piasters was 10 % and that of 3000 piasters was 5 %. The overwhelming majority of the loan amounts are in multiples of 100 piasters. It is observed that in the last quarter of the century, there were no more transactions below 1000 piasters. It should be noted, however, that loans of the highest amounts were also granted at the beginning or the middle of the century.

Table 1

Amount and frequency of loans

Amount	Frequency of Occurrence
500 Piasters	105 times
1000 Piasters	150 times
2.000 Piasters	48 times
3.000 Piasters	24 times
4.000 Piasters	12 times
5.000 Piasters	10 times
6.000 Piasters	9 times
10.000 Piasters	5 times

The lowest amount of money lent for a return is 200 piasters. The highest amount given at one time is 120,000 piasters. Although the majority of these are in official currency piasters, there are also examples in other monetary units, especially in the far provinces of the Empire. The rate of other currency records such as *şâhî*, *kuruş*, and *filori* is 10%.

It is possible to draw some conclusions by following the parties to the loans. It is estimated that the loan records of the orphans of high-ranking officials were realised in high amounts. It is conceivable that these loans were allocated to the *sarraf*s, who in turn utilised these funds in various ways (Bölükbaşı, 2014). Yet, in the records the term *sarraf* has not been found except once. For further analyses, the movements of the actors of the credit market should be followed and examined in detail.

It was mentioned above that the total number of records is higher for İstanbul. Considering this, I have summed up the total amount of loans after converting other currencies such as gold, etc., into piasters for

comparison. Of the total amount, the share of İstanbul is 61 %, while the other regions account for 39 %. As a result, the total volume of transactions in İstanbul is 1.5 times higher than that of all other regions combined. These data indicate that İstanbul's credit activity was higher than that in other regions. This can be regarded as a natural consequence of İstanbul's position as the capital and centre.

Loan Yield Rates/Rates of Return

The rate of return is uncertain in 144 of the 589 loan records. It should not be assumed that all of these were given without any return (Jennings, 1973). Although some records indicate that these amounts were given in return as *muʿāmele* or *murabaha*[7], there is no information on how much these return amounts were. There is also no record of the loan rates being changed. The majority of the maturity of the loans are for 1 year. However, periodisation, such as 3 and 6 months, was rarely observed. An annualised standard was used when calculating the loan rates of return. The amount with a total three-year return is divided by three, and the six-month return is multiplied by two and added to the calculations.

In different periods of the 16th century, a ceiling of 15% was set for rates of return in loan relations. It is known that in exceptional cases, especially for those dealing with courtiers, *sarraf* could use loans with a rate of return of up to 25% (Şahiner, 1995, pp. 44–47). Tracing from the *kanunnames*, the one from the reign of Selim I (1512-1520) set an upper limit of 10% (Akgündüz, 1991, p. 93), the *kanunname* of the reign of Süleyman I (1520-1566), presumably promulgated in 1523, set an upper limit of 10% (Akgündüz, 1992b, p. 303), and the general *kanunname* of the reign of Murad III (1574-1595) similarly set an upper limit of 10% (Akgündüz, 1994, p. 115). However, there are also examples where the limit was 15% or 20 %. For example, the upper limit was set at 20% in the İstanbul *ihtisâb* (municipal) *kanunname* dated 1502 of the Bayezid II period (1481-1512) (Akgündüz, 1990, s. 295. Again, the rate in the Edirne ihtisâb kanunname dated 1502 is 20% (Akgündüz, 1990, p. 393). In a *fatwa* from 1536, transactions with a return above 15% were not permitted (Düzdağ, 1972, p. 161; Özcan, 2003, pp. 59–60). From this point of view, it can be said that there was a definite limit of 20 % in the early 16th century, and this upper limit was reduced to 10-15 % after the 1520s. These limits are not the actual values but the ceiling to the rate of return. It is possible to claim that the orphans' money was lent at the upper limit (without exceeding the ceiling) for the best interests of the orphan.

I have compiled a table that includes the loans from orphans' money. They are averaged if there is more than one value for a year. Data for İstanbul and other cities were processed together. In general, the rates do not fall below 10 %. In a few transactions, rates are set at 15% and 20%. Apart from the high and low points, the rates generally hover around 11%. In individual examples, the highest loan return rate is 20%. These loans, with 20%, appeared more than once in Cyprus, Avlonya, and once in Sarajevo. For the sake of comparison, note that the rates of return of waqf loans in Tahsin Özcan's study of Üsküdar cash waqfs are similar to the general picture of our findings. According to the list of rates of return prepared by Özcan, the frequency of rates of return above 10% was higher in the first half of the 16th century, while rates above 10% were not observed from 1550 until 1566 (the end year of his study) (Özcan, 2003, p. 383).

If İstanbul and other regions were to be compared, it becomes evident that their average rates of return also differ. As illustrated in the table below, while the average rate of return in İstanbul hardly exceeds 10%, the average rate in the provinces is 14%.

[7] *Muʿamele* is the shorter usage of *muʿāmele-i şerʿiyye* that was described above. *Murabaha* was the general term of the Ottomans that indicated the return of the loans. See: Berber, Interest or Usury.

Table 2

Centennial Average Rate of Return for İstanbul and Other Regions

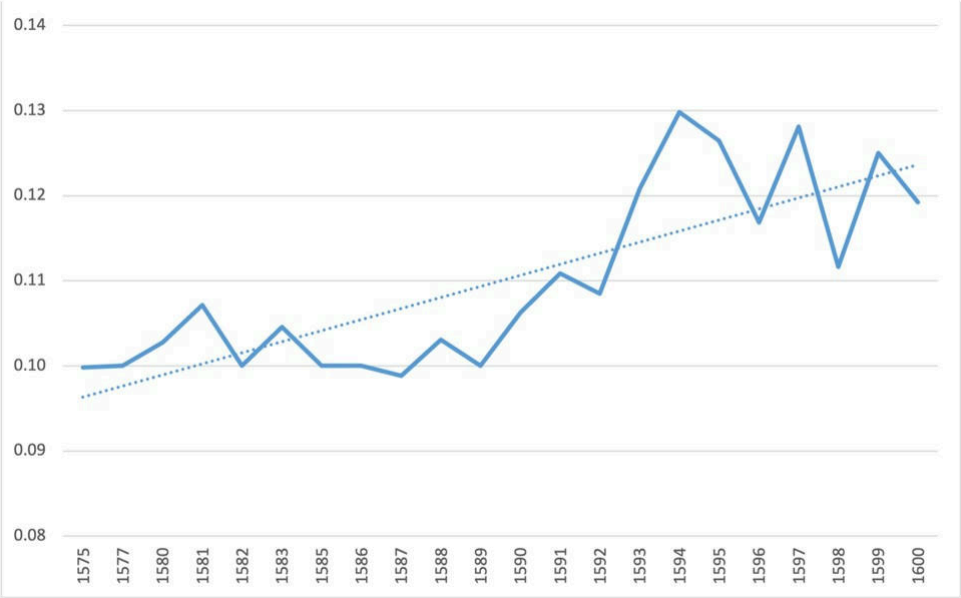
Average Rate of Return for İstanbul	Average Rate of Return for Other Regions
%10.23	%14.26

When orphan money was lent, was it given at a higher rate of return 'for the good of the orphan', or was it allocated at values within the regular credit market? From the sources I have analysed, the rates of return on orphans' money and other forms of debt appear similar. For example, if the credit market had an average rate of 10% in a sharia *sicill*, orphan money was not allocated at 15%. In regions such as Avlonya and Trabzon, where the rates were high, normal debt relations were treated at the same rate. In Manisa, the guardian's only loan transaction was at 10 %, while the general rate of other loans was 15%.

As for rates of return after 1575, the data is more concentrated, as shown in the graph below:

Figure 1

Loan Rate of Return after 1575



It can be seen that the rate of 10% was maintained in the 15 years between 1575 and 1590. However, after 1590, the rate of increase exceeded 10% and never fell below 11%. These rates did not increase from 10% to 15% but rose to 12%. During this period, any increase in the upper limit by any fatwa, regulation or *kanunname* was not detected. Even if such a thing existed, this rate would likely have been 15%. A reason behind the increase could be the reaction of the credit market to certain risks. In addition, the turmoil of the coin revision and the significant adulteration that took place at the end of the century may also have affected the credit market (Pamuk, 1999, pp. 143–161), (Tabakoğlu, 2015, pp. 549–550). This increase seems to align with the general upward trend mentioned above.

To conclude this section, it can be indicated that this institution had a structure that increased the credit supply. Orphans' money, like money waqfs, was allocated as loans. On the other hand, guardians could not demand loans for the needs of orphans, as this could be disadvantageous for the orphans. As a last resort, there were a few instances where loans were taken on behalf of the orphan, but these were not with returns, i.e. *muʿāmele-i şerʿiyye*. In conclusion, introducing orphans' money into the credit market expanded

the market and helped prevent unregistered usury. The rate of return increased after 1590 and continued to be above 10 per cent for a decade.

Alimony Expenses

Alimony (*nafaka*) is a word derived from the infinitive *infaq* (n-f-k), which means to spend to meet the needs of the orphan (Erbay, 2006). In his dictionary, Şemseddin Sami defines *vasi* as 'the one who provides for the maintenance of orphans' (Şemseddin Sami, 2019). The number of records containing alimony payments in our prepared dataset is 236. This large number allows us to track and analyse the amount of alimony throughout the 16th century.

In the alimony records, the total amount was stated if there was more than one orphan. There are also a few records in which the amount assigned to each orphan is stated separately. In the content of some alimony records, which are not many, it is observed that separate amounts are assigned to male and female orphans. The share of inheritance was considered here, or the age of the orphans may also have an effect.

In most cases, alimony was provided from the orphan's money, yet the guardian paid for the orphan's maintenance out of his/her pocket in eight registers. Again, the predetermined daily alimony amount was increased in four records by applying to the court. In two instances, the amount of alimony was reduced by appointing a guardian for a person who demanded less alimony, which meant that the amount of orphan money was reduced. In cases where the alimony was requested to be increased, the guardian had to present a valid excuse to the qādi court, and the qādi was not obliged to accept that excuse. However, in cases of decreasing alimony, if a relative of the orphan applies to the court and claims that he/she will provide the orphan with less alimony expense than the current amount or even without diminishing the orphan's money, the court has to evaluate this offer.

Only court-ordered alimony amounts are used in the following assessments and graphs for more accurate analyses. Unrequited alimony was also excluded. The quantities of alimony awarded in the Galata registers dramatically increase the overall average. This may be related to the population structure of Galata and the high amount of estate cases. This high level is not surprising given the presence of non-Muslim merchants and *sarraf*s in the region and the fact that the Galata court was also the venue for the proceedings of high-ranking court officials.

Even if the Galata records are excluded, the amount of alimony has increased, especially after 1590. Table below shows the averages of the annual alimony amounts according to the registry items:

Table 3

General Alimony Determination Averages per annum

Overall Average	1468 Piasters
İstanbul	1977 Piasters
Other Regions	866 Piasters

The average for İstanbul is much higher than the average for other regions. The general average value of 1468 piasters slightly exceeded the value of four piasters per day. The İstanbul average is slightly 5.5 piasters per day. The general average of all regions outside İstanbul is marginally less than 2.5 piasters daily. Let us evaluate the average of the individual centres that can form a series.

Table 4

Averages of Alimony Expenses in Some Centres (Annual)

Galata	2116 Piasters
Üsküdar	660 Piasters
Antep	1080 Piasters
Bursa	1260 Piasters
Cyprus	1569 Piasters

As mentioned, Galata stands out as being higher than the others. The average for Galata is a little higher than six piasters daily. Üsküdar data is highly representative throughout the century. Its average is lower than the general average for regions outside İstanbul, amounting to 1.83 piasters daily. Antep, which provides data for the 1530s and 1590s, averages three piasters daily. The average for the city of Bursa is 3.5 piasters per day, and the average for the Cyprus registry at the end of the century is 4.35 piasters per day. In addition, the averages of Manisa and Trabzon, which provide data from the mid-16th century, are close to each other and amount to 400 piasters per year (slightly more than one piaster per day). The average of Avlonya is two piasters per day.

As mentioned, most of the *sicill* records related to alimony are those in which the court authorises the guardian to spend and sets a limit on that expenditure. Furthermore, in many records, the guardian requested permission to sell property or other real estate from the estate for maintenance and other expenses. Undoubtedly, these expenditures and sales directly diminish the orphan's estate. Here again, the answer to the question of the sensitivity with which the amount required for the well-being and survival of the orphan is determined is the amount of the inheritance left to the orphan and the amount needed to maintain the standard of living.

Did the guardians receive payment from the amounts of maintenance determined for the orphans? Although it is not recommended in Islamic law that the guardian should receive a fee for his labour in protecting the orphan's estate, this is not entirely prohibited. On the other hand, there is no evidence of the guardian receiving payment in the records. The main priority in İslam was that the orphan's estate should not be diminished. Nevertheless, guardians may have benefited from the amount of maintenance assigned to the orphan. Yet, in guardian misconduct cases, such a mention was never encountered.

Conclusion

Studying Ottoman history enables us to illustrate an institution that has existed throughout Islamic history but was not known in detail regarding its application and procedures. In addition, although studies on maintaining and protecting orphan estates are increasing, it is with this study that we can observe the experience from both horizontal and vertical aspects. By scanning the sharia *sicill*s from different regions of the Ottoman Empire throughout the 16th century, I have examined various aspects of the guardians' activities related to orphan estates. From singular records such as alimony appointment registers, debt agreements/registers, accountings provided by the guardian, leasing agreements, sale registers, etc., a dataset containing guardian activities with orphan money was compiled. In this way, protecting and maintaining orphan properties/money will further be understood and observed. These relevant records provide sufficient data to analyse the economic transaction of the guardian with orphan money.

The analysis reveals that credit relationships dominate the economic activities of guardians. Orphans' capital was frequently lent to support their maintenance. In cases of financial necessity, the orphans' inher-

itance shares in real estate were sold with the qādi approval. In many instances, once the orphan reached maturity, accounts with the guardian were settled, with both parties often leaving the court satisfied.

The majority of these were loans granted through *muʿāmele-i şerʿiyye*. This can be interpreted as an attempt to increase the orphan's money through these risk-free methods in the 16th century, as the Ottoman credit market expanded. In addition, lending utilising the sale of *istiğlāl* is also increasingly encountered in the last quarter of the century. In the period and sources analysed, the number of records in which the guardian entered into a partnership relationship with the orphan's capital was almost non-existent. In partnership and maritime trade, which was the more common form of partnership in the Ottoman Empire, there was a risk of losing the orphan's money. To eliminate these risks, it is seen that the guardians did not enter into a partnership but resorted to the lending method.

By extending a loan from the orphan's estate, the guardian could increase the orphan's capital and, if necessary, cover the maintenance and other expenses for the orphan from the return of those loans. Thus, the orphan's estate (money) was not reduced. Throughout the 16th century, one of the essential points that can be said about orphans' capital utilised in the credit market is that their rates of return remained similar for a long time throughout the century. The increase observed towards the end of the century can be considered a risk-reducing move in the money market, clouded by the massive devaluation and coin revisions.

As for centre and periphery analyses, it is documented that the rate of return on loans in the capital İstanbul is lower than other regions by four percent. This might indicate that credit risk is lower in the centre than other cities. Another reason might be the abundance of money lending institutions and the relatively higher credit supply in İstanbul. In all regions, alimony expenses increased by the end of the century. However, if we pursue comparing, alimony payment differs from İstanbul than other regions as well. İstanbul is by far higher in alimony payments to orphans, yet if Galata data is excluded from İstanbul dataset, they became closer. The average of Üsküdar is even lower than that of some cities like Bursa and Antep.

All in all, protecting orphan estates was an important institution in Ottoman history for centuries, illustrating the relationship between religion and the economy. The history of such institutions provides insights into the socio-economic history of the Ottoman Empire along with legal and family history. Future researchers of the subject shall find important aspects of Islamic history and Islamic economics that were experienced for a long period in history.

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Portfolio Optimisation in the Cryptocurrency Market: Hybrid Integration of Markowitz and Ridge Methods

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Abstract Constructing an effective asset allocation strategy requires building well-diversified portfolios that maintain robust performance beyond the sample data. The classical Markowitz portfolio optimisation, while widely used, is known to suffer from issues such as estimation errors and sensitivity to multicollinearity, which can significantly distort the allocation process and reduce performance reliability. In order to surmount the aforementioned challenges, the incorporation of Machine Learning echniques, specifically Ridge regression, into the portfolio creation process has been effected. This has resulted in the provision of a hybrid model that combines the strengths of Markowitz optimisation and Ridge regression. The integration of these approaches within the hybrid model serves to mitigate the prediction risks while maintaining the diversification benefits inherent to the Markowitz framework. The model was trained using an 80/20 split and cross-validation was employed to prevent overfitting. The findings indicate that this integrated approach attains the maximum Sharpe ratio, thereby significantly enhancing risk-adjusted returns and portfolio stability when applied to cryptoasset returns. The findings emphasise the merits of integrating classical optimisation methodologies with machine learning to develop more robust and adaptive asset allocation strategies. By analysing the impact of high-volatility cryptoassets on portfolio performance, it makes important contributions to both the literature and practical portfolio strategies for investors.

Keywords Hybrid method · Crypto assets · Markowitz optimisation · Ridge method

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Portfolio Optimisation in the Cryptocurrency Market: Hybrid Integration of Markowitz and Ridge Methods

The relationship between risk and return in Harry Markowitz's article titled "Portfolio Selection" published in 1952, which is the basis of modern portfolio theory, is recognised as an important turning point in the investment world (Yiğiter, & Akkaynak, 2017). Markowitz (1952) explained the desire of investors to obtain maximum return with minimum risk in the modern finance literature by emphasising the importance of the balance between risk and return with the optimal portfolio. Modern Portfolio Theory mathematically assumes that the higher the risk, the greater the return potential of the investment on the basis of the risk-return balance (Abensur, & Carvalho, 2022). Investors may choose high-risk investment instruments when seeking higher returns, which may lead to higher losses. However, when two assets with different risk levels are preferred, the return from one asset is expected to compensate for the loss from the other asset. Therefore, it is possible to balance risk and return by investing in more than one asset (diversification) rather than investing in only one asset and assuming the risk.

Markowitz's portfolio theory not only emphasises the importance of diversifying investments in order to reduce overall portfolio risk but also specifies effective diversification methods (Kamil, et al. 2006). Diversification has become an increasingly important strategy at both the individual and macroeconomic levels. In order to mitigate the effects of economic shocks and instabilities, as well as to reduce vulnerabilities, investment diversification is supported by strategies that aim to optimise risk-return expectations for different asset classes (Sisay, 2024). Diversification is critical not only to optimise risk management but also to ensure sustainable investments as it increases the potential for expected returns (Asih et al., 2024). When choosing financial investment instruments, an investor who wants to build a good portfolio should also consider global assets. This is because including global investment instruments in the investment portfolio not only provides protection against country-specific risks but also contributes to increasing the long-term return potential due to the effects of macroeconomic variables such as economic growth, inflation or interest rates in different countries. In this context, diversification, which stands out as an important tool in achieving a risk-return balance, can only achieve its purpose when the right strategy is implemented. The right strategy is to form a portfolio by considering the risk and return performance of all assets in national and global financial markets. In recent years, crypto assets, which are accepted as a new asset class in financial markets because of technological development, have been frequently discussed by both investors and academics. It is observed that crypto assets are one of the main dynamics of economic, technological and social transformations beyond being just an investment instrument, as they have innovative infrastructure such as blockchain and are far from centralisation and authoritarian structure (Liu, & Tsyvinski, 2021; Yıldırım, 2019). These digital assets have high volatility as their value is determined by factors such as supply-demand balance, technological infrastructure, investor perception and speculative dynamics (Brauneis, & Mestel, 2019; Corbet et al., 2018). For this reason, crypto asset investments carry both potential gains and serious risks. In the literature, there are ongoing debates on the classification of cryptoassets as money, commodity, or a completely different financial instrument and their use for portfolio diversification or hedging (Bouri et al., 2017; Feng et al., 2018). Bitcoin has been intensively researched in the context of financial diversification and as a safe haven instrument, especially due to its leading position in the crypto market and its wide usage area (Konuşkan et al., 2019). Accordingly, the role of cryptocurrencies as an alternative investment instrument and its relationship with other asset classes offer a critical research area for future financial

innovations and market regulations (Saggu, A., Ante, L., & Kopiec, K., 2025). The aim of this study is to investigate the effect of cryptoassets on the risk and return of the investment portfolio. For this purpose, the risk and return of 15 crypto assets (BTC, ETH, USDT, BNB, USDC, XRP, DOGE, TRX, ADA, BCH, LITE, DAI, LTC, XMR, and XLM), which are included in the portfolio and have the highest trading volume, were analysed. In order to determine the portfolio performance measures of crypto assets, Markowitz optimisation was applied and then the Ridged regression method (Arı, & Önder, 2013), which is used when there is a high correlation between more than one explanatory variable and minimises the weight of variables and obtains parameter estimates with smaller variance compared to the least squares method in the presence of multiple linear connections. The data were analysed using a hybrid approach that combines Markowitz optimisation and Ridge regression method because the regulatory power of the Ridge method reduces the Markowitz over-sensitivity problem and the risk minimisation mechanism in the Markowitz method balances the tendency of the Ridge method to exclude low-importance assets from the portfolio.

In the second part of the study, the studies on the subject in the literature are included, the methodology and the analysis of the data obtained as a result of the methods used are mentioned in the third part and the findings are discussed in the last part.

Literature Review

Markowitz shows us how to use modern portfolio theory to de-risk all capitals/securities in an environment of high volatility (uncertainty) and to construct a theory of asset pricing. The Markowitz model and modern portfolio theory are concepts that have attracted attention in both national and international studies. In their study, Škrinjarić and Šostarić (2014) wanted to show how the Markov chains methodology and Markowitz portfolio optimisation model can lead to more effective results on investment decisions. They conclude that this integration leads to higher efficiency and lower risk for investors. Chambers, Hamzacebi, and Bayramoğlu (2016), who use grey system theory to support Markowitz portfolio optimisation during periods of high volatility, reveal that models developed with the modern approach can be optimised during periods of high volatility and offer effective strategies. They also argued that the grey system approach can improve portfolio performance and enables the development of new strategies to minimise investor risks. Another study that uses Markowitz's portfolio theory to obtain the best portfolio in the stock market is Chao, Tao and Zeng (2019). In the study, the risk returns of various stocks are analysed and the ways to form an optimal portfolio are shown. Similar to other studies, it is stated that the Markowitz theory is applicable for investors and effective results can be obtained. Janková (2019) compares the Markowitz theory and low-risk portfolio theories and finds that the downside risk approach in particular better serves the goal of minimising investors' losses. Raisa and Cristian (2021), aiming to determine the stock portfolio return and a minimum risk portfolio model, emphasised that Markowitz theory is an effective tool in financial portfolio management, that is, it will contribute to the development of strategies that can help investors adopt a more informed and systematic approach. Blay (2024) emphasised that Markowitz is not only an academic concept but also plays an important role in investors' portfolio construction processes. Finally, Savage and Ball (2024) developed a model called "Markowitzatron" to adapt the traditional Modern Portfolio Theory (MPT) to the oil industry. As a result, it is emphasised that integrating MPT into energy markets can provide significant advantages compared to traditional financial instruments.

Traditional currency is a store of value, a unit of account and, most importantly, a medium of exchange. Cryptocurrencies, especially Bitcoin accounts, are used as speculative investment instruments rather than as alternative currencies or a medium of exchange. Bitcoin also offers diversification advantages over

various other financial assets. Since cryptocurrencies are highly volatile, when portfolio theory is applied to cryptocurrency portfolios, it has been pointed out that the parameters that will cause problems have higher potential estimation errors. Platanakis and Urquhart (2019). In his study, Mazanec (2021) stated that the potential performance of portfolios using digital currencies together with traditional assets can be increased. Yermack (2015) compared the basic functions and features of Bitcoin and traditional currencies and argued that Bitcoin falls short of traditional currencies in many respects due to its volatility and limited acceptance. Kristoufek (2015) investigated Bitcoin price formation and price drivers. He argues that Bitcoin is not only a speculative asset; fundamental factors such as money supply, price level and trade use play a role in price formation. In contrast, Baek and Elbeck (2015), who argued that Bitcoin is a speculative asset, argued that the price of Bitcoin is driven by buyers and sellers. Dyhrberg (2016), who examines whether Bitcoin has the same capabilities as other hedging factors in the financial market, argues that, especially in times of uncertainty, Bircoin can function as a short-term hedge against the dollar like gold. And also by Dyhrberg (2016), he wanted to determine how Bitcon, US dollar and gold prices change and the existence of a relationship between them. As a result of the study, he stated that Bircoin has higher volatility than the dollar and gold and it behaves like gold during periods of uncertainty. Al-Yahyaee et al. (2019) found that for oil and S&P GSCI investors, Bitcoin and gold offer diversification benefits and there is evidence of hedging effectiveness and downside risk mitigation. Recently, the cryptocurrency market has attracted a lot of attention among investors. The main reasons why the cryptocurrency market is in the limelight are the diversification advantages and hedging capabilities that cryptocurrencies offer. The relationship between cryptocurrency and portfolio diversification emerges as investors combine cryptocurrencies with traditional asset classes to optimise returns and manage risk. High volatility and low correlation are the hallmarks of cryptocurrencies. Thanks to this feature, cryptocurrencies can reduce the overall risk profile of a portfolio or increase potential returns. Studies show that when digital assets such as Bitcoin, the most popular cryptocurrency, are used with traditional investment instruments, there is an increase in the overall performance of portfolios. Grujić and Šoja (2022) constructed 2 portfolios with and without Bitcoin to determine how desirable it is to invest in Bitcoin compared to other financial instruments. At the end of the study, it was found that the rational behaviour of institutional investors requires investing in Bitcoin using the Markowitz model and that Bitcoin is a good source of diversification in a portfolio of traditional financial instruments for both risk-averse investors and investors with a low risk appetite. Similarly, Šoja and Chamil (2019), who investigated whether Bitcoin is a useful diversification tool for investors, emphasised that Bitcoin can be a useful diversification tool for both risk-averse and risk-prone investors in a portfolio that includes traditional assets such as gold and stocks. Guesmi, Saadi, Abid, and Ftiti (2019), who argued that Bitcoin provides significant hedging advantages for portfolio diversification for investors, examined the conditional cross-effects and volatility between bitcoin and financial indicators (gold, oil, stocks). They emphasise that hedging strategies that include gold, oil, emerging equity markets and Bitcoin significantly reduce portfolio risk. Platanakis and Urquhart (2019) compared the performance of Markowitz diversification and the advanced Black-Litterman model with the VBC that controls the forecast errors in the cryptocurrency portfolio. They concluded that complex portfolio techniques that control for forecast errors are preferred when managing cryptocurrency portfolios.

Methodology

This section presents the methodology of the unit root tests and optimisation techniques used in the study to analyse the time series properties of the cryptocurrency assets.

Unit root test

In applied macroeconomic or financial time series research, the data under analysis often experience various shocks over the long term, such as economic recessions or financial crises. These shocks, if they exert a permanent influence on the time series, disrupt the stationarity of the series and result in a non-stationary process. Stationarity is a critical property as it determines whether the regression results reflect a valid relationship (Granger, & Newbold, 1974; Gujarati, 1995). Numerous unit root tests are available in the literature to examine the stationarity of the time series. This study utilises the Augmented Dickey-Fuller (ADF) unit root test as the reference method. The ADF test is frequently employed to assess the presence of a unit root in the time series data. Dickey and Fuller (1981) extended the Dickey-Fuller (DF) test, which is based on the AR(1) process, by accounting for higher-order autocorrelations. To address serial correlation issues, the ADF test relies on the AR(p) process and incorporates the lagged difference terms into the regression equation (Gujarati, 1995). The ADF test includes three model specifications, based on the inclusion of an intercept (μ) and deterministic trend (t), as detailed below:

$$\Delta y_t = \delta y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \varepsilon_i \tag{1}$$

$$\Delta y_t = \mu + \delta y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \varepsilon_i \tag{2}$$

$$\Delta y_t = \mu + \beta t + \delta y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \varepsilon_i \tag{3}$$

The null hypothesis for all three model strategies states the presence of a unit root, indicating a non-stationary process (Dickey, & Fuller, 1979; 1981).

Optimisation techniques

To develop an asset allocation strategy, the study begins with the global minimum variance portfolio optimisation framework. The problem is defined as follows:

$$\begin{aligned} w^* &= argmin_{w \in \mathbb{R}^K} \left\{ w' \hat{\Sigma} w \right\} \\ &\text{s.t.} \quad \mathbf{1}_K' w = 1 \end{aligned} \tag{4}$$

where w^* denotes the optimal weight vector, $\hat{\Sigma}$ is the estimated covariance matrix, and K is the number of assets. The analytical solution, assuming that the covariance matrix is non-singular, is expressed as

$$w^* = \left(\mathbf{1}_K' \hat{\Sigma}^{-1} \mathbf{1}_K \right)^{-1} \hat{\Sigma}^{-1} \mathbf{1}_K \tag{5}$$

However, the classic Markowitz model is prone to several issues, including sensitivity to estimation errors and the influence of multicollinearity among asset returns. These problems lead to unstable weights and, in turn, poor out-of-sample performance. To overcome these limitations, this study integrates Ridge regression into the portfolio optimisation process. Ridge regression introduces a regularisation penalty to shrink the weight estimates, reducing the adverse effects of multicollinearity while ensuring greater stability. In the Ridge regression, the coefficients are determined by minimising the sum of squared errors (SSE) while incorporating a penalty term applied to the coefficients (Hoerl, & Kennard, 1970). This approach represents the L2 regularisation, where λ corresponds a tuning parameter. The mathematical formulation of the Ridge regression is presented in Equation (6), (Tibshirani, 1996):

$$SSE_{L_2} = \sum_{i=1}^{n}(y_i - \grave{y}_i)^2 + \lambda \sum_{j=1}^{P}\beta_J^2 \tag{6}$$

The regularised problem is expressed as

$$w^* = argmin_{w\in\mathbb{R}^K}\left\{ w'\hat{\Sigma}w + \lambda \sum_{i=1}^{K}\rho(w_i) \right\} \quad \text{s.t.} \quad \mathbf{1}'_K w = 1 \tag{7}$$

Here, λ is the regularisation parameter, which determines the intensity of the shrinkage applied to the asset weights. Unlike classical Markowitz optimisation, the Ridge approach stabilises the solution without imposing sparsity, thereby producing more consistent weight vectors.

Finally, in order to compare portfolio optimisation and composition obtained with and without regularisation methods, the following metrics are used. To further enhance portfolio performance, this study develops a hybrid model that integrates the strengths of both Markowitz optimisation and Ridge regression. By leveraging Ridge's ability to handle multicollinearity and Markowitz's diversification benefits, the hybrid model provides improved stability and accuracy in asset weight estimation. This approach achieves the maximum sharpe ratio, outperforming each individual technique in terms of risk-adjusted returns. The regularisation parameter λ is selected through a 10-fold CV process, where λ is determined as the value that minimises out-of-sample variance. To systematically compare the performance and structure of portfolios constructed with and without regularisation techniques, a set of well-defined evaluation metrics is employed. To compare the performance and structure of portfolio optimisation with and without regularisation methods, the analysis uses the following evaluation metrics:

Out-of-sample variance:

$$\sigma^2 = \frac{1}{T-\tau-1}\sum_{t=\tau+1}^{T}(r_t - r^{\grave{}})^2 \tag{8}$$

Sharpe ratio:

$$SR = r^{\grave{}}\frac{)}{\sqrt{\sigma^2}} \tag{9}$$

Data, optimisation structures and empirical results

Table 1 provides an overview of the abbreviations, units of measurement, and database of the variables analysed in this paper. The variables are derived from the price series of 15 cryptocurrency assets, and to compute the return series, the price data were first transformed by taking their natural logarithms, followed by the application of first differencing.

Table 1
Data Information

Variables	Abbrevation	Unit	Data Transformation	Database
Bitcoin	BTC	Price (USD); return	Logarithmic difference	https://tr.investing.com/
Ethereum	ETH	Price (USD); return	Logarithmic difference	https://tr.investing.com/
Tether	USDT	Price (USD); return	Logarithmic difference	https://tr.investing.com/
Binance Coin	BNB	Price (USD); return	Logarithmic difference	https://tr.investing.com/
USD Coin	USDC	Price (USD); return	Logarithmic difference	https://tr.investing.com/
Ripple	XRP	Price (USD); return	Logarithmic difference	https://tr.investing.com/
Dogecoin	DOGE	Price (USD); return	Logarithmic difference	https://tr.investing.com/
Tron	TRX	Price (USD); return	Logarithmic difference	https://tr.investing.com/
Cardano	ADA	Price (USD); return	Logarithmic difference	https://tr.investing.com/
Bitcoincash	BCH	Price (USD); return	Logarithmic difference	https://tr.investing.com/
Chainlink	LINK	Price (USD); return	Logarithmic difference	https://tr.investing.com/
Dai	DAI	Price (USD); return	Logarithmic difference	https://tr.investing.com/
Litecoin	LTC	Price (USD); return	Logarithmic difference	https://tr.investing.com/
Monero	XMR	Price (USD); return	Logarithmic difference	https://tr.investing.com/
Stellar	XLM	Price (USD); return	Logarithmic difference	https://tr.investing.com/

In the first stage of the study, descriptive statistics are employed to provide an overview of the variables. Descriptive statistics serve as essential tools to summarise variables within a dataset and highlight their key characteristics. The descriptive statistics for cryptocurrency returns are presented in Table 2.

Table 2
Summary Statistics

Variables	Mean	Median	Std. Dev.	Maximum	Max. Date	Minimum	Min. Date	JB Stats.	p-Value
BTC	0.000897	0.000524	0.035766	0.177424	2021-02-08	−0.49728	2020-03-12	574.75***	0.0000
ETH	0.001539	0.001311	0.045026	0.230772	2020-10-19	−0.58964	2019-08-08	2441.61***	0.0000
USDT	0.000008	0.0	0.001466	0.019797	2018-09-24	−0.01514	2018-09-20	36817.57***	0.0000
BNB	0.002224	0.001508	0.047359	0.530574	2020-07-17	−0.58116	2019-08-08	14072.06***	0.0000
USDC	0.000007	0.0	0.007561	0.124631	2018-06-01	−0.22808	2018-05-31	14150431.30***	0.0000
XRP	0.000195	0.000437	0.0526	0.548118	2022-12-09	−0.54101	2020-05-21	30248.30***	0.0000
DOGE	0.001953	−0.000069	0.144433	4.141786	2019-06-12	−4.15589	2019-06-13	5816.47***	0.0000
TRX	0.001186	0.002167	0.045625	0.340529	2020-08-26	−0.57085	2019-08-08	19795.23***	0.0000
ADA	0.001117	0.000123	0.051216	0.286973	2020-07-08	−0.5372	2019-08-08	1002.86***	0.0000
BCH	0.000545	−0.000036	0.054757	0.459116	2023-07-29	−0.59772	2019-08-08	14102.52***	0.0000
LINK	0.001817	0.001286	0.059884	0.475424	2018-11-08	−0.63715	2019-08-08	3114.78***	0.0000
DAI	0.000002	0.0	0.005202	0.057088	2019-08-08	−0.05895	2019-08-09	3526449.81***	0.0000
LTC	0.000453	0.000932	0.048732	0.258175	2018-07-06	−0.48678	2019-08-08	7847.48***	0.0000
XMR	0.000583	0.002111	0.04636	0.342203	2020-10-15	−0.53539	2020-10-14	53940.69***	0.0000
XLM	−0.00011	0.000369	0.050151	0.553585	2020-06-03	−0.44031	2020-03-12	21052.73***	0.0000

Note: **** 1% significance level.*

Table 2 provides summary statistics for the returns of the selected cryptocurrency assets, offering valuable insights into their distribution and temporal characteristics. Among the cryptocurrencies analysed, DOGE exhibits the highest mean return aproximately 0.002, indicating a relatively strong average performance over the period studied. Conversely, XLM demonstrates the lowest mean return aproximately −0.0001, the only asset with a negative mean. When examining extreme values, the highest maximum return is observed for DOGE (approximately 4.1418 on 2019-06-12), while the lowest minimum return is recorded for the same cryptocurrency (aproximately −4.1559 on 2019-06-13), underscoring DOGE's extraordinary price fluctuations within a short period. The dates of maximum returns vary widely and are not clustered. Peak performance is asset-specific and not driven by a common market event. On the other hand, the dates of minimum returns frequently occur in 2019 or 2020, possibly reflecting market-wide downturns during these periods. Overall, most cryptocurrencies exhibit positive mean returns, with XLM as the exception, and the descriptive statistics indicate substantial heterogeneity in their risk and return profiles.

Table 3

Covariance analysis

Variables	BTC	ETH	USDT	BNB	USDC	XRP	DOGE	TRX	ADA	BCH	LINK	DAI	LITE	XMR	XLM
BTC	0.001279														
ETH	9.84E-06	0.002027													
USDT	−4.4E-07	−5.4E-07	2.1484E-06												
BNB	−3.6E-06	0.001524	−2.4521E-06	0.002243											
USDC	−6E-06	1.9E-05	−4.0659E-07	1.48E-05	5.72E-05										
XRP	2.98E-05	−0.0002	−1.8211E-06	−0.00017	−7.2E-06	0.002767									
DOGE	5.08E-05	0.001473	−4.1531E-07	0.001367	6.83E-06	8.85E-05	0.020861								
TRX	1.84E-05	0.00142	−1.9148E-06	0.001321	1.14E-05	−0.00024	0.001275	0.002082							
ADA	1.83E-05	0.001755	−5.6401E-07	0.001562	1.9E-05	−0.00022	0.001724	0.001524	0.002623						
BCH	−9.3E-06	0.001852	−6.4599E-07	0.00159	9.05E-06	−0.00015	0.001775	0.00159	0.0019	0.002998					
LINK	−6E-05	0.001868	−4.6367E-06	0.001684	−4.3E-06	−0.00021	0.001655	0.001513	0.001967	0.001998	0.003586				
DAI	1.38E-06	−2.4E-05	8.51689E-07	−1.8E-05	2.34E-06	1.93E-05	1.02E-05	−1.9E-05	−2.4E-05	−2.7E-05	−2.9E-05	2.71E-05			
LITE	−1.5E-05	0.001769	−6.741E-07	0.001562	1.78E-05	−0.00018	0.0016	0.001473	0.001831	0.002119	0.001884	−2.5E-05	0.002375		
XMR	−2.4E-05	0.001427	−4.0251E-07	0.001381	1.78E-05	−0.00024	0.001487	0.001298	0.001472	0.001599	0.001516	−2.2E-05	0.001512	0.002149	
XLM	1.63E-05	0.001586	1.59433E-08	0.001433	1.01E-05	−0.00021	0.001664	0.001488	0.001944	0.001831	0.001847	−2.2E-05	0.001704	0.001369	0.002515

At the core of Markowitz's portfolio theory lies the objective of minimising portfolio risk while maximising a given level of return. In this context, the covariance matrix is employed to calculate the total risk of a portfolio and assess the relationships between assets. The diagonal elements of the covariance matrix represent the variance of each asset and provide information about their individual levels of volatility. For instance, the variance of BTC is calculated as 0.00128, while the variance of ETH is 0.00203. This indicates that ETH is more volatile and therefore a riskier asset compared to BTC. Since volatility reflects the magnitude of fluctuations in an asset's returns, more volatile assets often have their portfolio weights reduced based on risk tolerance in Markowitz optimisation.

Additionally, the off-diagonal elements of the covariance matrix reflect the magnitude of the co-movement between the two assets. For example, the covariance between the BTC and ETH returns is calculated as approximately 0.0001. This positive value indicates that these two assets tend to produce similar returns. In contrast, the covariance between BTC and USDC is approximately −0.00001. This negative value indicates that the returns of these assets generally move in opposite directions.

Markowitz optimisation evaluates both individual risks (variance) and the relationships between assets (covariance) to determine the portfolio weights. The total risk of the portfolio is calculated as the interaction of the asset weights with the covariance matrix. In this framework, portfolio diversification allows the losses of one asset to be offset by the gains of another. The negative covariance between BTC and USDC demonstrate that including these two assets in the same portfolio could reduce the total risk (as is the case in the portfolio). In contrast, the positive covariance between BTC and ETH indicates that the diversification effect would be more limited.

Before proceeding to optimisation processes, we performed the ADF unit root test to evaluate the time series properties of the variables. The ADF unit root test determines whether the mean, variance, and covariance of the variables remain constant over time, indicating their stationarity. Stationarity in time series serves as a critical prerequisite in both theoretical and empirical analyses, as non-stationary variables reduce the predictive power of models and produce misleading results (Granger and Newbold, 1974). Accurate computation of the var-cov matrix, fundamental to optimisation models based on the Markowitz portfolio theory, depends on the stationarity of the variables. Non-stationary variables distort portfolio risk assessments, leading to erroneous calculations. Similarly, regularisation techniques such as Ridge regression require stationarity to ensure reliable parameter estimates and maintain the overall model accuracy.

Table 4

Results of the ADF unit root test

	Test strategies		
Variables	**Intercept (τ Stat.)**	**Intercept & trend (τ Stat.)**	**Results**
BTC	−49.7205***	−49.7248***	**I(0)**
ETH	−50.8747***	−50.8984***	**I(0)**
USDT	−19.2762***	−19.2716***	**I(0)**
BNB	−31.2256***	−31.2592***	**I(0)**
USDC	−19.3368***	−19.3327***	**I(0)**
XRP	−49.4755***	−49.4644***	**I(0)**
DOGE	−35.0646***	−35.0624***	**I(0)**
TRX	−51.5012***	−51.4896***	**I(0)**
ADA	−50.4248***	−50.4655***	**I(0)**
BCH	−49.6276***	−49.621***	**I(0)**
LINK	−50.6368***	−50.7221***	**I(0)**
DAI	−37.9376***	−37.9287***	**I(0)**
LTC	−49.9045***	−49.9171***	**I(0)**
XMR	−55.4164***	−55.4148***	**I(0)**
XLM	−49.5032***	−49.4932***	**I(0)**

Note: **,**,*** denote 10%, 5%, and 1% significance levels, respectively.*

Table 4 presents the results of the ADF unit root test conducted on the returns of fifteen cryptocurrencies. The test statistics indicate that the null hypothesis of a unit root is rejected for all return series at significance levels, indicate that the returns are stationary. This finding is inindicate line with our expectations, as the return series are essentially the first-diff. transformations of the price series, which are generally

stationary. This finding implies that cryptocurrency returns do not exhibit persistent trends or long-term memory, making them suitable for further econometric modelling and analysis. The stationarity of the return series is a crucial prerequisite for employing time series techniques that assume mean-reverting behaviour, such as volatility modelling or forecasting frameworks.

Table 5

Optimisation results

Performance criteria	**Markowitz**	**Ridge**	**Hibrit (Markowitz and ridge)**
Portfoy returns	0.2468	0.3664	**0.2609**
Portfoy volatility	0.3834	0.5989	**0.3158**
Sharpe ratio	0.5655	0.5618	**0.7311**
Weights			
Cryptoasset return; weights (%)	Btc: 13.93%	Btc: 9.85%	Btc: 21.01%
	Eth: 11.99%	Eth: 11.08%	Eth: 7.44%
	Usdt: 0.89%	Usdt: 0.07%	Usdt: 10.34%
	Bnb: 13.33%	Bnb: 19.24%	Bnb: 23.94%
	Usdc: 8.57%	Usdc: 0.02%	Usdc: 9.07%
	Xrp: 11.20%	Xrp: 4.51%	Xrp: 6.74%
	Doge: 5.70%	Doge: 8.41%	Doge: 1.59%
	Trx: 4.47%	Tron: 8.99%	Tron: 2.86%
	Ada: 6.48%	Ada: 7.71%	
	Bch: 2.05%	Bch: 2.46%	
	Link: 4.99%	Link: 18.34%	
	Dai: 11.99%	Dai: 0.04%	
	Ltc: 0.53%	Ltc: 4.66%	
	Xmr: 2.11%	Xmr: 5.66%	
	Xlm: 1.75%	Xlm: 0.78%	

Note: *The dataset was split into 80% for the training set and 20% for the test set for use in ML and ML-based techniques.*

Table 5 shows the portfolio performance measures obtained using Markowitz optimisation, Ridge regression and the Hybrid (Markowitz+Ridge) approach, which is a combination of both methods. Performance measures include portfolio return, volatility, and the Sharpe ratio. The annual portfolio return is calculated as 0.2468 with the Markowitz method, 0.3664 with the Ridge method, and 0.2609 with the Hybrid approach. While the Ridge method targets a higher return thanks to its regulatory power, the Hybrid model optimises this return and preserves the balanced structure of Markowitz. The hybrid model provides a more realistic structure by controlling Ridge's risk-taking tendency. Portfolio volatility was measured as 0.3834 in the Markowitz method, 0.5989 in the Ridge method and 0.3158 in the Hybrid model. In this context, Ridge accepts higher risk, but this leads to increased volatility. The hybrid model reduces Ridge's volatility and improves the risk-oriented structure of Markowitz. The Sharpe ratio shows the performance of a portfolio in optimising returns per unit of risk. It is calculated as 0.5655 for the Markowitz method, 0.5618 for the Ridge method and 0.7311 for the Hybrid (Markowitz+Ridge) approach. These results show that the Hybrid approach combines the strengths of both methods and optimises the risk-return trade-off of the portfolio

by significantly increasing the Sharpe ratio. Ridge's regularisation power and Markowitz's risk minimisation contributed to the higher performance of the Hybrid model.

Figure 1

Portfolio return and risk

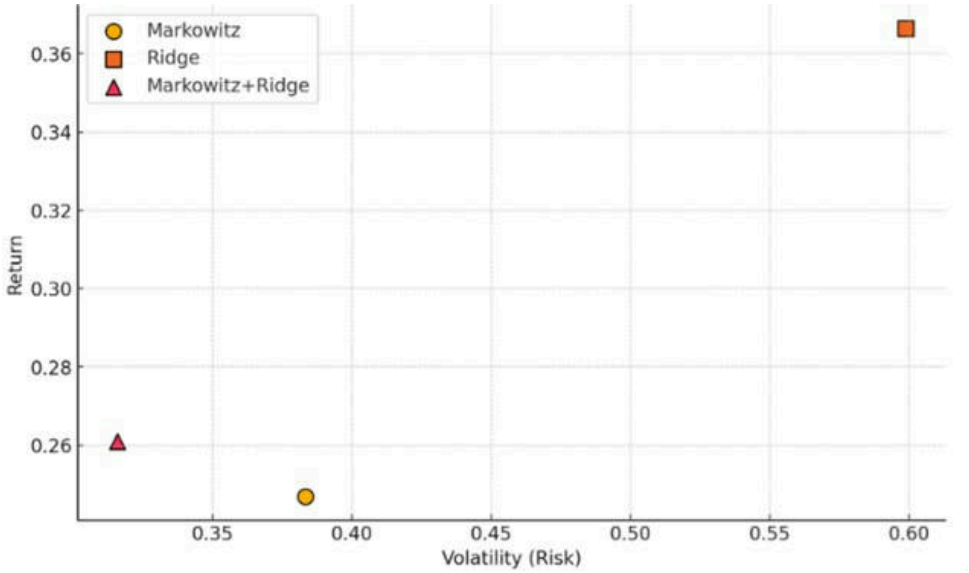
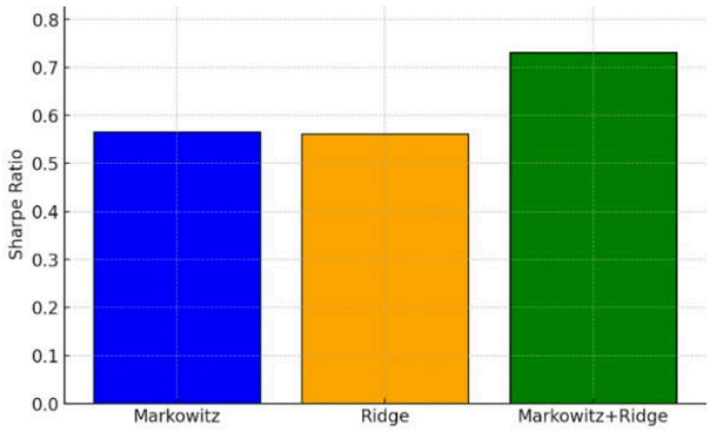


Figure 1 shows more clearly the balance achieved by the hybrid method. The combination of the Markowitz and Ridge methods provides a solution that improves the weaknesses of both algorithms. This is because Markowitz optimisation is overly dependent on the sensitivity of the data. This can lead to errors in predicting future returns based on historical data. However, the Hybrid approach reduces Markowitz's over-sensitivity problem by adding the regularisation power of Ridge. On the other hand, instead of excluding low-importance assets from the portfolio, the Ridge regression tries to artificially balance these assets. This may lead to unrealistic weights. The hybrid model balances this tendency of Ridge with Markowitz's risk minimisation mechanism.

Figure 2

Sharpe ratio comparison



As can be seen from Figures 1 and 2, the hybrid model has a higher sharpe ratio and lower volatility. Therefore, it shows that the portfolio obtained using the hybrid model provides higher risk-adjusted returns and manages volatility effectively.

Figure 3

Portfolio weight distribution

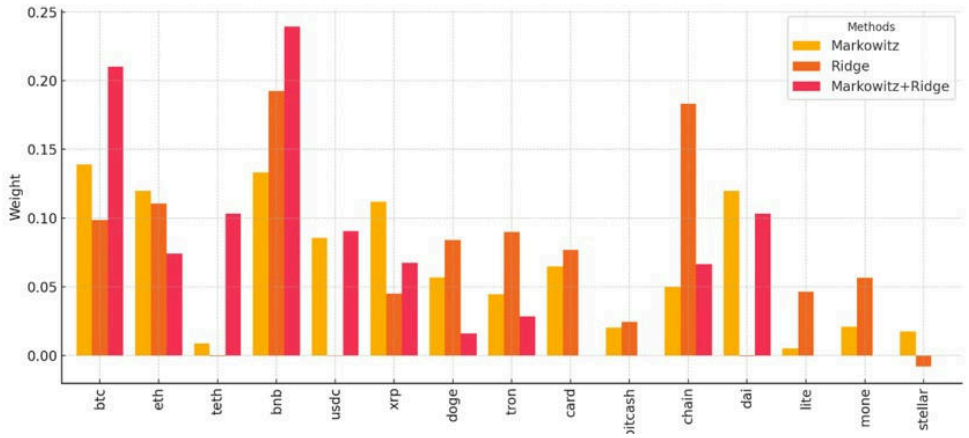


Table 6

Algorithm's parameters

Parameter	Markowitz	Ridge	Hybrid (Markowitz+Ridge)
Expected returns (R)	Historical returns	Returns predicted by Ridge regression	Returns predicted by Ridge regression
Covariance matrix (Σ)	Computed based on historical data	Computed based on Ridge-predicted returns	Computed based on Ridge-predicted returns
Risk (volatility)	Derived from the cov. matrix	Variance of the predicted returns	Hybrid approach (using covariance matrix)
Regularisation coefficient (λ)	Not used	Used in Ridge (λ > 0)	Used for Ridge-predicted returns
Cross validation (fold)	Not used	10 fold CV	10 fold CV
Sharpe ratio (SR)	Optimisation target	Optimisation target	Optimisation target

Conclusion

This study explores the integration of Markowitz optimisation and Ridge regression to address key limitations in traditional portfolio allocation, such as sensitivity to estimation errors and multicollinearity. Focusing on crypto asset returns, we implement a methodology where the dataset is split into 80% training and 20% testing subsets. To prevent overfitting and ensure model generalizability, CV is performed during the optimisation process. The results reveal that the standalone Markowitz and Ridge approaches yield lower sharpe ratios when applied individually. While Markowitz optimisation benefits from diversification, its sensitivity to estimation errors reduces its effectiveness. On the other hand, Ridge regression successfully mitigates multicollinearity but fails to achieve optimal risk-adjusted returns on its own. To handle these issues, by combining the strengths of both techniques into a hybrid model, we achieved the highest Sharpe ratio, significantly outperforming the individual methods. This integrated approach not only enhances portfolio stability but also improves risk-adjusted performance, demonstrating its practical utility in con-

structing robust cryptoasset portfolios. As a result, the findings we obtained underscore the importance of blending classical optimisation frameworks with ML techniques to address inherent weaknesses and improve portfolio efficiency.

The findings indicate that this integrated approach attains the maximum Sharpe ratio and substantially enhances risk-adjusted returns and portfolio stability when applied to cryptoasset returns. These findings underscore the merits of integrating classical optimisation methodologies with machine learning to develop more robust and adaptable asset allocation strategies. By analysing the impact of high-volatility cryptoassets on portfolio performance, significant contributions are made to both the existing literature and practical portfolio strategies for investors.

Features such as high volatility and low correlation of cryptoassets have increased the importance of the hybrid model. The ability of the hybrid model to produce consistent results under different market conditions shows that it is a powerful tool that can overcome the shortcomings of traditional methods. In this framework, the findings shows that this hybrid approach has several applications for both investors and academic researchers.

High volatility and low correlation are the hallmarks of the cryptoasset market. The performance of the hybrid model is evaluated on the basis of these characteristics. The applied model has provided effective results in the cryptomarket. However, the model's reliance on the Ridge penalty parameter, which is sensitive to data structure, may limit its robustness in low-volatility or highly correlated traditional markets. How the Ridge regression adjustment parameter, which is critical to the performance of the model, will adapt to different market dynamics is an important uncertainty. In addition, the fact that the data set of the study is limited to the crypto asset market relationship, which is the main subject of the study, may limit the generalizability of the Hybrid model for financial markets. In this framework, testing whether the model is applicable to different markets and asset classes may contribute to filling the gap in the literature.

For future studies, research areas such as the application of the hybrid model to other asset classes and the integration of macroeconomic variables into the model are recommended. This study concludes that combining traditional and modern approaches is a powerful and feasible method for portfolio optimisation in financial markets. The hybrid model may be especially beneficial for institutional investors managing high-volatility assets where traditional methods underperform.

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A Bibliometric Analysis of Social Entrepreneurship Research: Trends, Patterns, and Future Directions

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Abstract This study conducts a bibliometric analysis of social entrepreneurship academic literature from 1965 to 2024, using VOSviewer to understand and visualise publication trends and keyword co-occurrence patterns. The dataset, retrieved from Scopus, consists of 8,485 documents, categorised into academic articles, books, book chapters, and conference proceedings. The analysis focuses on identifying frequently used keywords, exploring their connections, and observing the development of key topics in the academic social entrepreneurship literature. Through co-occurrence analysis, this study visualises relationships between key concepts and shows trends. By examining the frequency and clusters of keywords, the study may provide a broader and deeper explanation of how the academic literature on social entrepreneurship research has evolved. The analysis of publication trends also shows how interest in social entrepreneurship has grown and how research focus and themes have changed over time. As Result, it can be said that social entrepreneurship as an academic field emerged in the early 2000s. Thus, from 1965 to 2010, research on social entrepreneurship mainly focused on defining key concepts and distinguishing the field from traditional- profit seeking entrepreneurship. In the years between 2011 and 2015, scholars began to explore social enterprises, social entrepreneurs, applications, systems, and their interactions. Between 2016 and 2020, the literature expanded to research interdisciplinary topics such as entrepreneurship education, gender(s), and hybrid organisations. In recent years, from 2021 to 2024, the focus of the social entrepreneurship literature has shifted towards themes like digitalisation, psychological motivations of social entrepreneurs and how they responded in times of crisis.

Keywords Bibliometric analysis · VOSviewer · co-occurrence analysis · Social entrepreneurship

Jel Codes L3, M1, M100

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A Bibliometric Analysis of Social Entrepreneurship Research: Trends, Patterns, and Future Directions

Social entrepreneurship has drawn growing interest from researchers in diverse fields such as business, management, economics, and the social sciences in general. Social entrepreneurship refers basically to using entrepreneurial approaches to overcome social problems or to reduce problems caused by social problems. As issues like poverty, inequality, and environmental damage affect people in more serious ways, social entrepreneurs have gained more attention for their role in creating new and innovative solutions. This growing interest has led to a large and still-growing body of research that explores what social entrepreneurship is, how it works, and what kind of impact it can- may have.

Although interest in social entrepreneurship has grown rapidly, the field is still seen as complex and there is little or no agreement on key concepts in the area. Researchers from different disciplines have studied it in diverse ways, which has added valuable perspectives but also caused confusion about creating a certain terminology and scope. Therefore, the literature on social entrepreneurship is rich but somewhat scattered. To better understand where the field stands and where it might be heading, a more organised and focused review of existing studies is needed.

This study uses bibliometric analysis to examine the academic social entrepreneurship literature from 1965 to 2024. Data from the Scopus database will be analysed with the VOSviewer software. The main goal is to identify key themes, trends, and connections in social entrepreneurship studies, providing a clear overview of how this research field has developed over time.

Social Entrepreneurship

Social entrepreneurship is a complex concept with different definitions and approaches from various disciplines, and its widespread use in different contexts reflects this complexity. Its complexity comes from its linkages to many scientific areas such as economics, sociology, and business, leading to different ways of understanding it. This review examines various definitions, highlighting the differences and similarities between various scientific perspectives.

One of the basic definitions of social entrepreneurship is its basic purpose or so-called social vision: social entrepreneurs are individuals, groups or organisations that seek to solve social problems or the effects of social problems through innovative activities, actions, practices, or systematic approaches. Bornstein and Davis define social entrepreneurship as the process of individuals or groups establishing or transforming organisations to overcome social problems such as poverty, environmental problems, lack of medical-financial support, or disabilities- chronic illnesses. In most cases, social entrepreneurship activities, methods, or approaches cannot completely solve the problem itself, but they can reduce its effects to a respectable extent. For example, while eradicating poverty is almost impossible through entrepreneurial activities, actions such as providing microcredit opportunities to the poor who wish to start their own businesses, even on a small scale, or offering education to enable them to create a steady income, although they may seem like very small, negligible steps, have significant importance in terms of their potential to permanently change people's lives for good. As a result, the quality of life of many people is improving directly or indirectly through social entrepreneurial activities (Ijiwole, 2019). This definition also emphasises the transformative potential of social entrepreneurship and labels the concept as a catalyst for social

change. Ghimire states that social entrepreneurship achieves financial sustainability through the income it generates, particularly operating under market conditions, while at the same time seeing the social benefits it strives to create and so draws strength from its stakeholders. (Ghimire, 2020a). This viewpoint highlights the 'dual purpose' of social benefit and financial sustainability, which is frequently emphasised in the social entrepreneurship literature.

The variety of definitions and the conceptual characteristics of social entrepreneurship, especially the lack of consensus on the key features of the social enterprises and their common characteristics, further complicate the clear understanding and make a clear definition of social entrepreneurship. According to Hojnik and Crnogaj (2020), the growing academic interest has intensified the discussions on how social entrepreneurship should be defined and studied. These authors emphasise that the nature and scope of social entrepreneurship activities vary significantly across European countries and cultures, reflecting the important influence of cultural and institutional environments. Although the social problems or their effects are very similar and most of the methods that are effective in one country can be reused in another country. As the authors have mentioned, in most cases country culture, the regulations or the approach of third parties to the social entrepreneurs may cause big differences. Not forgetting that the concept of social entrepreneurship not only exists in small portions of the world- in Europe, which is culturally more homogeneous than other parts of the world. Similarly, Toma (2022) highlights that the lack of clarity in concepts related to social entrepreneurship often leads to confusion, which limits the effective integration of social entrepreneurship into public policy frameworks and development initiatives. In most countries, the fact that social enterprises operate under the umbrella of foundations or NGOs or, since they are making profit, they are unable to benefit from tax exemptions despite their community-focused objectives. One of the reasons why social enterprises are not legally defined as a business or foundation class in most countries is that such enterprises cannot be clearly distinguished or defined, although their work for the social good has a very important nature.

Understanding social entrepreneurship and the motivations of social entrepreneurs is crucial to properly defining and understanding their activities. According to Boluk and Mottiar (2014), unlike conventional entrepreneurs who seek to generate financial profits, social entrepreneurs aim to create social benefits. This social benefit can differ across various areas and have different impacts, such as providing access to financial tools for the poor, solving a clean water problem in a region, or finding a way to conduct health checkups at an affordable cost. Miller et al. (2012) noted that social entrepreneurs are often motivated by internal factors such as empathy and compassion, which help them identify and solve social problems. Based on these definitions, social entrepreneurship prioritises social benefit over financial profit. However, it is also important to understand that no organisation can survive without financial resources. Therefore, social enterprises must generate financial income to be sustainable.

To understand social entrepreneurship correctly, it is necessary to pay attention to its operational models and fundamental motivations. Prabawanti (2023) argues that social entrepreneurship can be approached through different models that emphasise its motivations, types, and outcomes. These models help to understand the various strategies used by social entrepreneurs in different sectors. From microfinance tools, which are now globally recognised social entrepreneurship products, to providing a place for homeless people in a specific area to meet their food and hygiene needs; from solving the psychological problems of children who have been pushed into crime to raising the social profile of women fishermen, social entrepreneurs operate on a wide scale with a variety of objectives. Naturally, the tools used to solve different social problems,

the challenges encountered, and the support provided will also vary. Similarly, Urban and Kujinga (2017) emphasise the importance of the institutional environment in shaping entrepreneurial intentions and noted that local actors play a key role in defining and implementing social entrepreneurship.

Another pillar of social entrepreneurship is innovation. From a Schumpeterian perspective, an activity must involve innovation to be defined as entrepreneurship in the true sense of the word. Ghimire (2020b) defines social entrepreneurship as the process of using scarce resources as creatively as possible to solve social problems. This focus on innovation distinguishes social entrepreneurship from traditional charity work and charitable organisations, as the outcome of a social enterprise should prioritise long-term, sustainable solutions. Social capital is also one of the key factors in the success of a social enterprise. According to Coker et al. (2017), trust and cooperation among stakeholders are also necessary for the success of a social enterprise, as they help build strong networks and ensure relevant and sustained community participation. This aspect shows that social entrepreneurship is not only about solving problems but also about doing so through collaboration and shared responsibility. The literature also emphasises the empowering effect of social entrepreneurship on local communities. Suharto et al. (2021) argued that social entrepreneurship can support development in disadvantaged areas by addressing specific needs and creating economic opportunities. Similarly, Ijiwole (2019) notes that social entrepreneurship plays a vital role in reducing poverty and creating employment, which can lead to lasting improvements in people's lives.

In conclusion, social entrepreneurship is a broad and complex field shaped by various motivations, models, and outcomes. To provide a simple definition, social entrepreneurship is: A process in which an individual or group, referred to as a social entrepreneur, uses scarce resources in an innovative way to sustainably solve or reduce the impact of a social problem they have identified in society, while also generating their own financial returns. Its focus on innovation, sustainability, and social connections makes it a dynamic tool for addressing social problems. Unlike traditional charitable organisations, social entrepreneurship stands out for its sustainability, as it generates its own financial returns, thereby ensuring its long-term viability.

Literature Review

In recent years, academic interest in social entrepreneurship has grown significantly. Social entrepreneurship is increasingly recognised as structures and activities that create social change through innovation and provide both social and economic benefits. Since the early 2000s, the number of studies on social entrepreneurship conducted by academics from various disciplines has been steadily increasing (Granados et al., 2011; Ferreira et al., 2019; Dionisio, 2019). This growing interest stems from the nature of the field, which intersects with many academic disciplines such as business, economics, and sociology. Academics argue that more empirical studies using quantitative and mixed methods are needed to better understand the subject, going beyond qualitative and case-based research (Short et al., 2009; Saebi et al., 2019; Miah et al., 2024). Another point emphasised in the studies is the need for stronger interdisciplinary collaboration, as social entrepreneurship research is often spread across different academic fields and traditions (Rey-Martí et al., 2016; Sottini et al., 2024).

Many studies agree that the core components of social entrepreneurship are particularly social innovation and sustainable development (Farinha et al., 2020; Dunggio et al., 2024; Satar et al., 2023). These studies argue that social entrepreneurship not only creates economic value but also promotes social transformation through innovative solutions. Additionally, many studies acknowledge the importance of government

policies and institutional support in promoting social entrepreneurship (Trabskaia et al., 2023; Ahmad and Bajwa, 2023; Miah et al., 2024). The role of technology and digital platforms in scaling social impact is another common theme highlighted in studies examining the integration of artificial intelligence, digital finance mechanisms, and online collaboration tools in social entrepreneurship activities (De Bernardi et al., 2021; Kaushik et al., 2023).

Despite these similarities, differences emerge between the theoretical frameworks and regional approaches of various studies. For example, Kaneko (2013) offers a historical perspective and understanding specific to Japan, explaining how social entrepreneurship in the country differs from other social entrepreneurship models due to its strong community-based traditions. The differences between the Japanese and Western cultures highlighted in this study also influence the approaches to activities. Similarly, Teasdale et al. (2023) analyse historical changes in social entrepreneurship paradigms, noting that the field has shifted from an individualistic, heroic narrative to a more collective and systematic approach.

A very crucial difference between social entrepreneurship and traditional philanthropy is that social entrepreneurship values financial sustainability through organisational activities as much as achieving social goals. Yesmin (2021) and Kumuda et al. (2024) emphasise the importance of generating income and market-oriented approaches to ensure the longevity of social enterprises. Other researchers, such as Iskandar et al. (2021) and Sottini et al. (2024), prioritise a broader vision of social benefit and argue that financial models should not overshadow the core mission of social enterprises. Additionally, while some studies advocate for a more integrated collaboration between corporate social responsibility projects and social entrepreneurship (Ferreira et al., 2019; Trabskaia et al., 2023), other researchers view these two concepts as distinct fields with different objectives, applications, and outcomes (Saebi et al., 2019).

The relationship between social entrepreneurship and poverty alleviation is another area where the results of the studies differ. While Miah et al. (2024) and Ahmad and Bajwa (2023) consider social entrepreneurship as a crucial tool for poverty reduction and economic inclusion, De Bernardi et al. (2021) argue that this relationship should not be oversimplified and that structural inequalities and institutional barriers should be carefully considered in this context. Similarly, while some research focuses on the potential of social entrepreneurship in emerging markets and underdeveloped regions (Miah et al., 2024; Satar et al., 2023), other studies examine the work of social entrepreneurs in developed economies (Short et al., 2009; Granados et al., 2011).

There are also significant differences in the research methodologies applied in social entrepreneurship studies. While bibliometric analyses and systematic literature reviews stand out in the literature (Rey-Martí et al., 2016; Hota et al., 2020; Satar et al., 2023), other studies use historical-developmental analyses (Teasdale et al., 2023; Kaneko, 2013) or case study analyses (De Bernardi et al., 2021). This diversity reflects, to a great extent, the evolving nature of social entrepreneurship as an advancing academic field in both conceptual and empirical research. As a result, while there is a broad consensus on the importance of the innovativeness of social entrepreneurship in promoting sustainable development and social transformation, there are different perspectives on theoretical frameworks, financial sustainability, and methodological approaches. All these determining factors also help to understand the emerging differences and trends in the academic literature on social entrepreneurship. It can be predicted that future studies in this field can be conducted in fields such as science, medicine and engineering, where intensive collaborations have not been observed before, and the effects of organisations that have been operating as social enterprises for a relatively long time can be examined over time. In addition, studies on the role of social entrepreneurship in macroeco-

nomic indicators may inform future research, and exploring the effectiveness of various social enterprises in promoting economic development can also be a valuable area of investigation.

Methodology

The bibliometric pre-study conducted through Scopus involved a systematic search of the academic literature on social entrepreneurship. The search query included key terms "social entrepreneurship," "social entrepreneur," "social enterprise," and "social business," applied to the title, abstract, and keywords of the indexed documents. The retrieved dataset consists of 8,485 documents, spanning a variety of publication types including journal articles, book chapters, conference papers, and full books, all limited to the English language.

The study filtered the results by subject areas, focusing on Business, Management and Accounting, Social Sciences, Economics, Econometrics, and Finance, indicating a cross-disciplinary approach. The distribution of results by document type shows that journal articles make up the largest portion, followed by book chapters and conference papers, reflecting both theoretical and empirical contributions in the field.

The bibliometric analysis using VOSviewer was carried out to systematically examine the intellectual structure of the selected dataset. Co-occurrence analysis was used in the methodology. Co-occurrence analysis was performed by extracting and visualising frequently used keywords from the dataset. This method identifies the main themes and their interrelationships by matching terms that appear together in the same documents. The results are displayed as a network graph where the size of each node represents the frequency of a keyword and the proximity between nodes indicates the strength of co-occurrence. Cluster formation was observed, showing thematic groupings within the dataset. The VOSviewer tool was used for data processing and visualisation, and network diagrams and clustering maps were generated based on the co-occurrence matrices. The use of threshold settings allowed the selection of important nodes, ensuring that the most relevant keywords, references, and citations were included in the analysis.

Keyword co-occurrence analysis in bibliometric research plays a crucial role in identifying thematic structures and emerging trends within a given field. In VOSviewer, co-occurrence analysis examines how frequently two or more keywords appear together within the same body of academic literature, providing insights into conceptual linkages and dominant research themes (Van Eck & Waltman, 2010). The link strength in this analysis represents the frequency with which two keywords co-occur across the dataset, with a higher link strength indicating a strong thematic association between concepts and a lower link strength suggesting a weaker or more sporadic relationship (Chen et al., 2017). The size of nodes in a VOSviewer-generated network visualisation reflects the frequency of keyword appearances, while the distance between nodes signifies their relative association; keywords that frequently co-occur are positioned closer together, forming clusters that represent subfields or major research topics within the literature (Cobo et al., 2011).

Interpreting keyword co-occurrence networks enables researchers to map the intellectual landscape of a discipline and identify areas of interest, trends and potential research gaps (Donthu et al., 2021). Thicker connections between keywords indicate stronger thematic relationships, which can highlight well-established research areas, while isolated nodes or weakly connected keywords may indicate less-studied topics that could offer opportunities for further research (Zupic & Čater, 2015). Moreover, the visualisation of keyword networks facilitates interdisciplinary research by revealing connections between concepts in different fields, thereby promoting cross-domain knowledge integration (Aria & Cuccurullo, 2017). Therefore,

the systematic application of keyword co-occurrence analysis serves as a powerful tool for understanding the evolution, structure, and trajectory of interdisciplinary academic research.

In this study, the phases were determined based on the evolution of social entrepreneurship research and literature, considering significant developments in academic interest and thematic trends. Additionally, to increase comparability and maintain analytical integrity, a balanced segmentation was performed in terms of both time intervals and publication volume. This segmentation allows for a systematic examination of research trends while also capturing conceptual and methodological transformations in the field over time.

Findings

The findings table provides an overview of the publication trends in social entrepreneurship research between 1965 and 2024, categorised by academic papers, books, book chapters, and conference proceedings. The data reveal a clear trajectory of exponential growth in scholarly output, reflecting the increasing academic attention to social entrepreneurship over time.

Between 1965 and 2010, the total number of publications was relatively low (567), with 376 academic papers constituting most of the output. The number of books (26) and conference proceedings (51) suggest that the field was still emerging, with fewer dedicated research venues and limited interdisciplinary engagement. The relatively small number of book chapters (114) indicates that social entrepreneurship had not yet become a widely integrated topic within broader academic discussions.

The 2011-2015 period marks a significant increase in scholarly output, with 1,518 publications, nearly three times the total of the previous period. The sharp rise in academic papers (940) reflects the growing research interest and institutional recognition of social entrepreneurship as an academic discipline. The increase in books (80) and book chapters (401) suggests an expansion of conceptual frameworks and theoretical discourse. The rise in conference proceedings (97) indicates a growing number of academic conferences and workshops focused on social entrepreneurship, facilitating knowledge exchange and interdisciplinary collaboration.

During 2016-2020, the number of publications more than doubled, reaching 3,185. The strong increase in academic papers (2,066) highlights a shift towards empirical studies and methodological diversification. The rise in book chapters (821) suggests that social entrepreneurship has become a well-established research topic, frequently integrated into broader discussions on business, sustainability, and innovation. The increase in conference proceedings (179) indicates sustained academic engagement, with research findings being presented at specialised conferences. The 119 books published during this period suggest that more comprehensive theoretical frameworks and case studies were being developed.

The 2021-2024 period continues the upward trend, with 3,215 total publications, slightly exceeding the previous period. While the number of academic papers (2,282) continues to grow, the decrease in book chapters (693) and conference proceedings (131) suggests a stabilisation in interdisciplinary integration and conference activity. The decline in books (109) may indicate that major foundational theories have already been established, shifting research efforts towards journal publications, which are often more influential in academic rankings.

The cumulative total from 1965 to 2024 amounts to 8,485 publications, with academic papers (5,664) accounting for 66.8% of the total output. The substantial number of book chapters (2,029) indicates widespread interdisciplinary integration, while the relatively lower number of books (334) and conference

proceedings (458) suggest that journal publications remain the primary dissemination channel for research in this field.

Overall, the data illustrate an accelerating growth trend in social entrepreneurship research, particularly after 2010. The field has evolved from an emerging discipline with limited scholarly attention to a well-established area of study with diverse research outputs. The shift towards peer-reviewed journal articles and book chapters suggests increasing academic rigour and specialisation, while the steady volume of conference proceedings reflects continued scholarly engagement and collaboration.

Table 1

Social Entrepreneurship Publications between 1965 and 210

Years	Academic Papers	Books	Book Chapters	Proceedings	*Total Number of Publications*
1965-2010	376	26	114	51	*567*
2011-2015	940	80	401	97	*1518*
2016-2020	2066	119	821	179	*3185*
2021-2024	2282	109	693	131	*3215*
1965-2024	**5664**	**334**	**2029**	**458**	***8485***

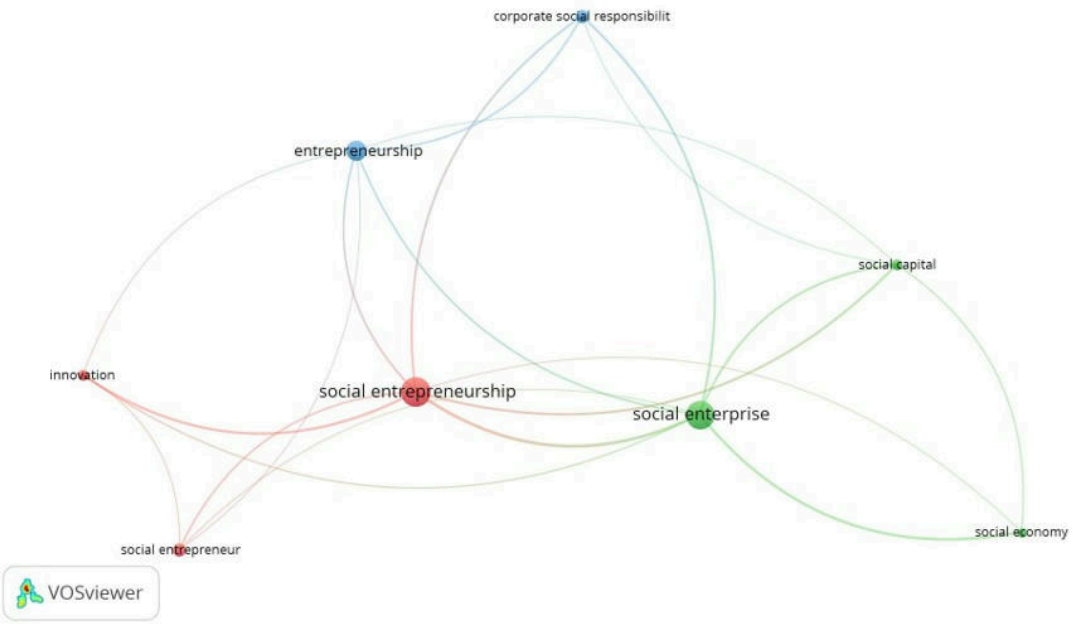
Social entrepreneurship research from 1965 to 2010 has focused on defining and conceptualising the field, emphasising its distinct characteristics compared to traditional entrepreneurship. As shown in Table 2 the dataset extracted from VOSviewer highlights key themes and their interconnections, providing insight into the evolution of academic discourse on the topic. Social entrepreneurship, as the most frequently mentioned term, signifies the central focus of the research domain. Its high total link strength indicates a strong interdisciplinary nature, suggesting that studies often discuss it in relation to various economic and organisational frameworks. The frequent occurrence of this term around analysing the mechanisms, challenges, and potential of social entrepreneurship in addressing societal issues.

Table 2

Publications between 1965 and 2010

KEYWORD	OCCURRENCES	TOTAL LINK STRENGTH
social entrepreneurship	85	37
social enterprise	77	37
entrepreneurship	39	15
social entrepreneur	18	6
corporate social responsibility	17	16
innovation	13	11
social capital	11	15
social economy	10	11

KEYWORD	OCCURRENCES	TOTAL LINK STRENGTH



Source: Scopus keyword co-occurrence data for 1965–2024 (analysed with VOSviewer by the author, 2025).

Closely associated with social entrepreneurship, the term social enterprise reflects the organisational structures through which social impact is generated. The similarity in link strength between social entrepreneurship and social enterprise indicates that these concepts are often explored together in academic discourse, particularly in discussions about models, operational strategies, and legal frameworks governing such entities. The presence of entrepreneurship as a distinct keyword suggests that social entrepreneurship is often examined in relation to broader entrepreneurial theories, albeit with a primary focus on the social rather than for-profit dimension. However, the relatively lower link strength of this term compared to social entrepreneurship highlights the differentiation that scholars make between these two domains.

The term “social entrepreneur” appears far less frequently in the dataset, with significantly lower occurrences and link strength, implying that while research acknowledges the role of individuals in driving social change, greater emphasis is placed on systemic, organisational, and policy-related aspects. This suggests that the academic community prioritises understanding social entrepreneurship as a structural phenomenon rather than focusing extensively on the personal attributes or leadership qualities of individual social entrepreneurs.

Several interconnected themes emerge in addition to the core keywords. Corporate social responsibility (CSR) features prominently, reflecting the intersection between social entrepreneurship and corporate initiatives aimed at generating social impact. The relatively high link strength of CSR suggests that scholars often explore it as a complementary or alternative approach to social entrepreneurship, particularly within the context of business ethics and sustainable development (Carroll, 1999). The presence of innovation as a key term highlights the extent to which social entrepreneurship research considers novel solutions to societal challenges. The strong link strength of innovation suggests that academic studies often discuss their

role in relation to both social entrepreneurship and social enterprises, reinforcing the idea that innovative approaches are crucial in addressing social problems (Phills et al, 2008).

Social capital appears as another significant concept, emphasising the role of networks, trust, and community engagement in the success of social enterprises. The relatively high link strength of social capital implies that scholars consider it a fundamental resource that enables social enterprises to mobilise support, secure funding, and scale their impact (Putnam, 2000). Research on social economy also reflects an ongoing effort to place social entrepreneurship within broader economic structures that prioritise social value creation over profit maximisation. While relevant, the moderate link strength of this theme suggests that, although social economy is acknowledged, it does not dominate discussions as much as CSR or innovation.

The structural and thematic implications of the VOSviewer-generated dataset indicate distinct patterns in the evolution of social entrepreneurship research. Terms with high occurrence and link strength, such as social entrepreneurship and social enterprise, form the backbone of the field, indicating a consistent focus on defining and categorising these concepts while exploring their theoretical underpinnings and operational models. Terms with moderate occurrence and link strength, including corporate social responsibility, innovation, and social capital, represent secondary but highly relevant themes. Their strong connectivity suggests that researchers frequently examine how social enterprises interact with corporate initiatives, leverage innovative solutions, and utilize social capital as key mechanisms for achieving success.

Conversely, terms with lower occurrences and weaker link strength, such as social entrepreneur and social economy, suggest that while these aspects are acknowledged, they do not constitute the primary focal points of the research during this period. The relative lack of emphasis on individual social entrepreneurs implies a research tendency towards systemic and structural approaches rather than case studies focusing on specific individuals. The limited discussion of social economy further suggests that, although alternative economic models are recognised, they have not yet become central themes within the literature of this time frame.

The analysis of academic studies on social entrepreneurship from 1965 to 2010 indicates a period of conceptualisation, with scholars working to define and differentiate the field. As research progressed, greater emphasis was placed on organisational structures, corporate partnerships, and the role of innovation in achieving social impact. The evolution of these themes set the stage for later research periods, where applied studies, governance mechanisms, and sustainability models would take on greater significance. Future research directions emerging from this period suggest a need for a deeper exploration of individual agencies within social entrepreneurship, the long-term sustainability of social enterprises, and the policy environments that shape their development. This period represents the foundation upon which the modern discourse on social entrepreneurship was built, transitioning from theoretical exploration to practical implementation in subsequent years.

Social Entrepreneurship Publications between 2011 and 2015

As shown in Table 3, the keyword analysis from VOSviewer for the period 2011-2015 provides a crucial perspective on the evolving landscape of social entrepreneurship research. Compared to the 1965-2010 period, there is a notable increase in the frequency and complexity of key terms, reflecting a maturing field with broader interdisciplinary engagement. Social entrepreneurship remains the dominant keyword, underscoring its central role in academic discourse. The substantial rise in occurrences from the previous period indicates exponential growth in research interest, with high link strength suggesting deep intercon-

nectedness with a wide range of topics, reinforcing the multidisciplinary nature of the field. The prominence of social enterprises reflects a growing emphasis on the structural and organisational aspects of social entrepreneurship. Compared to the earlier dataset, this term has seen significant growth, indicating increased scholarly focus on the operationalisation, management, and impact measurement of social enterprises. While traditional entrepreneurship remains a relevant framework, its proportionally lower frequency compared to social entrepreneurship suggests that researchers are increasingly differentiating social entrepreneurship as a distinct field with its own theories, challenges, and methodologies.

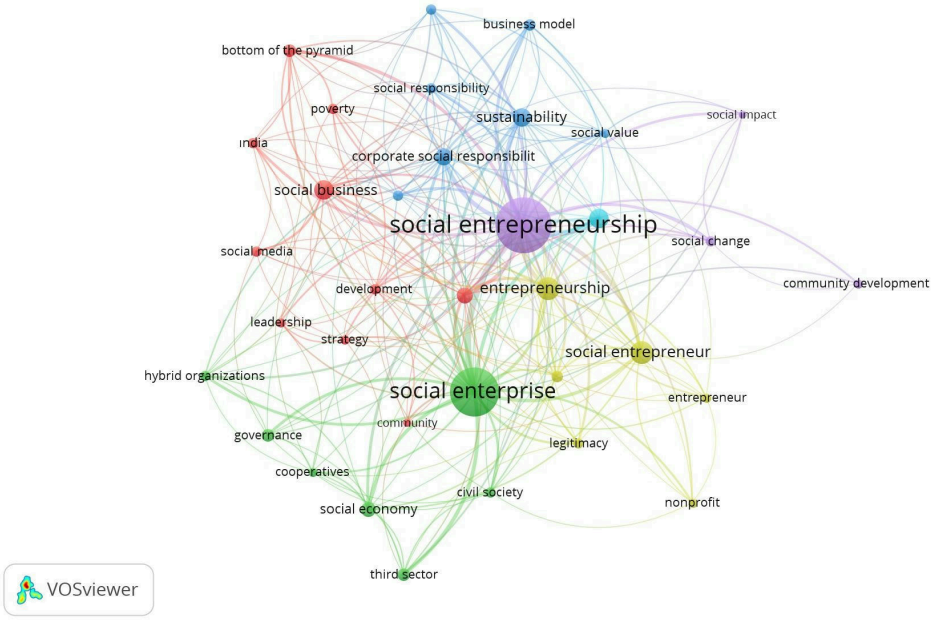
The increased frequency of the term "social entrepreneur" compared to the earlier period indicates a renewed academic interest in individual agency within social entrepreneurship. This could be attributed to case studies, biographical research, and psychological analyses exploring the motivations, leadership styles, and impact of social entrepreneurs. The expanded list of keywords reflects an evolving research landscape, integrating new perspectives and interdisciplinary linkages. The introduction of social innovation as a prominent keyword marks a conceptual evolution in the field. While innovation was previously acknowledged, its redefinition as social innovation underscores an increased focus on novel solutions to societal challenges. High link strength suggests that social innovation is now a key theoretical and practical framework within social entrepreneurship. The emergence of social business as a standalone keyword indicates an academic shift towards differentiating various models of social entrepreneurship. This term, popularised by figures like Muhammad Yunus, signifies enterprises that prioritise social impact while achieving financial sustainability (Yunus & Weber 2010).

Table 3

Publications between 2011 and 2015

KEYWORD	OCCURRENCES	TOTAL LINK STRENGTH
social entrepreneurship	392	359
social enterprise	301	251
entrepreneurship	68	89
social entrepreneur	68	71
social innovation	51	82
social business	50	54
sustainability	42	71
corporate social responsibility	40	82
innovation	36	61
social economy	31	42
third sector	22	32
bottom of the pyramid	21	38
governance	20	21
business model	19	30
social capital	19	37
development	16	25
sustainable development	16	26

KEYWORD	OCCURRENCES	TOTAL LINK STRENGTH



Source: Scopus keyword co-occurrence data for 1965–2024 (analysed with VOSviewer by the author, 2025).

The growing presence of sustainability-related terms reflects the strengthening link between social entrepreneurship and environmental concerns. This shows that researchers are now examining how social enterprises contribute to broader sustainability goals, including the United Nations Sustainable Development Goals (SDGs) (Sachs et al., 2019). The continuation of corporate social responsibility with greater frequency and a stronger connection compared to previous periods demonstrates that corporate social entrepreneurship is being studied more intensively in an academic context. This may indicate a trend towards hybrid business models emerging as conventional companies engage in social entrepreneurial activities through collaborations, impact investing, or intrapreneurship. Several new keywords indicate increased interest in the corporate and public policy dimensions. The inclusion of governance as a key term indicates that research is increasingly focusing on regulatory frameworks, accountability mechanisms, and the role of governments in supporting social entrepreneurship. The introduction of the term "business model" shows that academics are analysing how social enterprises creatively generate, deliver, and capture value in a financially sustainable manner.

The new keywords also highlight the intersection of social entrepreneurship with economic development. The growing focus on social economy suggests an academic effort to place social entrepreneurship within alternative economic paradigms that prioritise collective welfare over profit maximisation. The inclusion of the bottom of the pyramid, popularised by C.K. Prahalad, indicates a rising interest in how social enterprises serve low-income populations through innovative business models and inclusive market strategies (Prahalad, 2005). The broader term development further reinforces the field's expansion into policy-oriented discussions on poverty alleviation, economic empowerment, and capacity building. A comparison with the previous dataset highlights key trends, including significant growth in research output. The number of occurrences for core terms has dramatically increased, indicating a rapid expansion of the field. While

early research focused on defining social entrepreneurship, the 2011-2015 period reflects a transition towards applied research, including governance, business models, and economic impact. The presence of sustainability, corporate social responsibility, governance, and social innovation suggests that social entrepreneurship is now studied across disciplines including business, policy, economics, and environmental studies.

This period represents a shift from conceptual exploration to an applied research approach, focusing on impact measurement, governance mechanisms, and business models. Future research should continue to examine the role of social entrepreneurship in addressing global challenges, with particular attention to sustainability, hybrid business models, and the institutional frameworks that support their development. The evolution of social entrepreneurship research during this period reflects a deeper integration with broader economic and policy-oriented discussions, further cementing its status as a distinct field of study.

Social Entrepreneurship Publications between 2016 and 2020

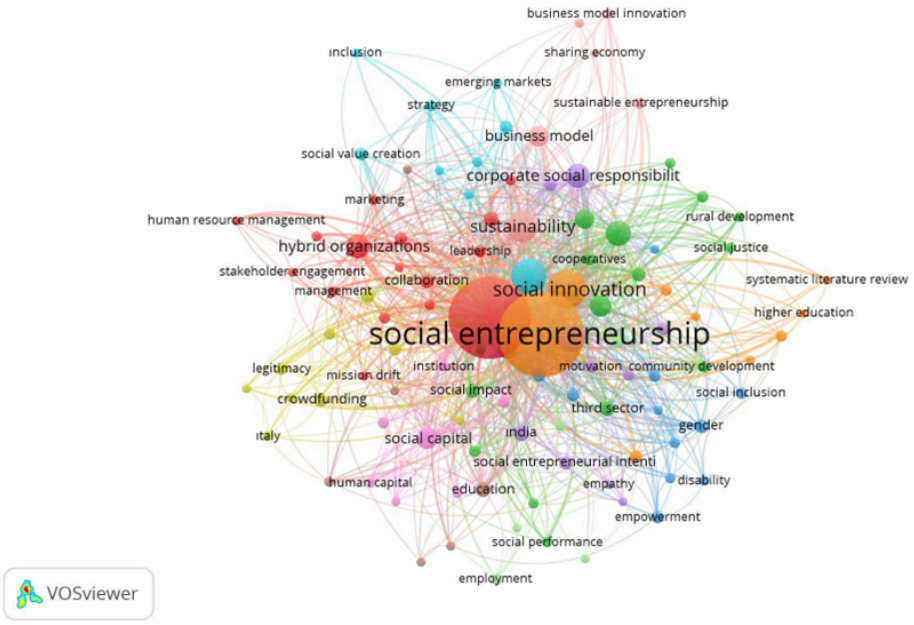
The keyword analysis for social entrepreneurship research from 2016 to 2020, generated by VOSviewer, reveals a continuation of the field's rapid expansion and increasing interdisciplinary focus, as shown in table 4. The significant rise in occurrences and link strengths across core and emerging themes suggests that social entrepreneurship has firmly established itself as a critical subject within academic discourse. Compared to previous periods, the landscape has evolved with greater emphasis on social innovation, sustainability, hybrid organisations, and new thematic areas such as gender, education, and collaboration. Social entrepreneurship has seen an exponential increase in frequency from 392 occurrences in the previous period to 881, highlighting its growing prominence. The deep interconnectedness of this term with various subthemes reflects the increasing complexity and breadth of the field. Social enterprise remains nearly as prevalent as social entrepreneurship, with a comparable link strength, suggesting that scholars are paying closer attention to organisational structures, business models, and governance strategies that define socially driven enterprises. The increased presence of social innovation signals a shift towards understanding how novel solutions drive social change. Its strong link strength indicates that it is highly integrated with broader social entrepreneurship discourse, underscoring its role in problem-solving and systemic change (Phills et al., 2008). While entrepreneurship remains a relevant framework, the continued predominance of social entrepreneurship and social enterprise suggests that research has fully distinguished social entrepreneurship as a separate domain with unique challenges, models, and success factors.

Table 4

Publications between 2016 and 2020

KEYWORD	OCCURRENCES	TOTAL LINK STRENGTH
social entrepreneurship	881	1090
social enterprise	822	1036
social innovation	183	307
Entrepreneurship	154	301
Sustainability	120	280
social entrepreneur	96	139
sustainable development	78	159
corporate social responsibility	74	155
hybrid organizations	73	135

KEYWORD	OCCURRENCES	TOTAL LINK STRENGTH
Innovation	67	147
social capital	59	112
social economy	57	96
social business	56	62
business model	52	87
social value	45	85
india	33	69
third sector	28	61
Education	27	54
Governance	27	52
Gender	26	55
Collaboration	25	49
social entrepreneurial intention	25	22



Source: Scopus keyword co-occurrence data for 1965–2024 (analysed with VOSviewer by the author, 2025).

The increased visibility of sustainability and sustainable development suggests that social entrepreneurship is now widely recognised as a tool for achieving long-term environmental, economic, and social goals. The strong link strengths of these terms indicate that sustainability is a deeply embedded theme in the social entrepreneurship literature. Although social entrepreneurs appear less frequently than broader organisational concepts, their steady increase in occurrences compared to previous periods reflects ongoing interest in the role of individuals in driving social change. Several newly prominent keywords indicate an evolving research agenda that integrates governance, business models, hybrid organisations, and social impact assessment. Corporate social responsibility continues to be a significant theme, maintaining its

relevance from previous periods. The steady increase in link strength suggests an ongoing exploration of how corporate initiatives intersect with social entrepreneurship (Carroll & Shabana, 2010). Hybrid organisations reflect the growing visibility of companies operating at the intersection of the for-profit and non-profit sectors. These organisations demonstrate an academic shift towards the analysis of innovative legislative structures, governance mechanisms, and financial sustainability by embedding social change within commercial strategies. In the context of social innovation, the sustainability of innovation highlights the growing focus on creativity, technology, and new approaches in addressing societal challenges.

The growing interest in social capital has led researchers to examine how networks, trust, and social engagement contribute to the effectiveness and measurability of social enterprises or social entrepreneurial activities (Putnam, 2000). The growing popularity of the social economy reflects continued interest in alternative economic models that prioritise social well-being over profit maximisation. This indicates that the concept of social entrepreneurship is expanding beyond individual initiatives to more systemic approaches. The inclusion of social work alongside social enterprises demonstrates ongoing efforts to distinguish between diverse types of social impact-oriented organisations. The presence of the keyword "business model" highlights the academic interest in understanding how social enterprises create, sustain, and scale their impact through innovative organisational structures. The emergence of the concept of "social value" as a separate keyword indicates a growing interest in measuring and defining the social benefits created by social enterprises. The specific mention of India suggests a growing geographical focus, likely due to the country's dynamic social entrepreneurship ecosystem. Research in this area may explore government policies, grassroots innovations, and scalable business models within developing economies.

The continued presence of the third sector reinforces the importance of non-profit organisations, cooperatives, and civil society groups in the broader landscape of social entrepreneurship. The emergence of education as a keyword indicates an increasing interest in how social entrepreneurship is integrated into academic curricula and training programs. The inclusion of governance suggests a focus on accountability, transparency, and institutional frameworks that support social enterprises. The introduction of gender as a keyword reflects a growing research agenda on gender dynamics in social entrepreneurship, including the role of women entrepreneurs and gender-inclusive business models. The presence of collaboration highlights an academic interest in partnerships among social enterprises, governments, corporations, and civil society organisations. A newly emerging term, social entrepreneurial intention, signifies an increasing focus on the psychological and motivational factors that drive individuals to engage in social entrepreneurship.

A comparison with previous data sets reveals several different trends. A significant increase in the use of basic terms indicates that social entrepreneurship is no longer an emerging and developing field of research but has become an established academic discipline. While previous studies focused on defining social entrepreneurship, the 2016-2020 period saw practical aspects such as business models, governance, and impact measurement come to the fore. The presence of terms such as hybrid organisations, collaboration, and the third sector indicates a shift towards examining complex, multi-stakeholder social entrepreneurship models. The inclusion of India and gender has also led to a diversification of research on the effects of geographical and demographic differences in social entrepreneurship and the unique challenges encountered in this regard.

This period represents a transition from theoretical exploration to applied research, focusing on social entrepreneurship's intersection with governance, sustainability, and economic models. The continued expansion into interdisciplinary studies suggests that future research should further explore the role of

digital transformation, financial mechanisms, and policy interventions in scaling social enterprises. With the growing focus on impact measurement and hybrid models, the field is likely to deepen its engagement with empirical methodologies to evaluate the long-term effectiveness of social entrepreneurship initiatives. This phase marks a pivotal moment in social entrepreneurship research, bridging foundational theories with real-world applications.

Social Entrepreneurship Publications between 2021 and 2024

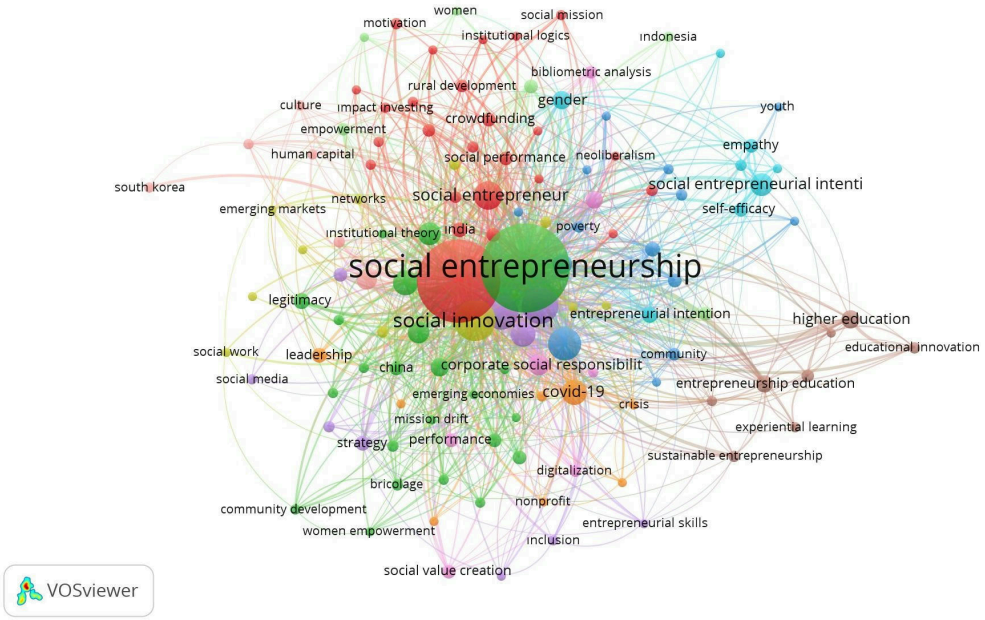
The VOSviewer-generated keyword analysis for social entrepreneurship research from 2021 to 2024 in table 5 presents a significant expansion in thematic depth and interdisciplinary integration. Compared to previous periods, this dataset reveals new conceptual frameworks, the growing role of digital and financial mechanisms, and an increased emphasis on global crises such as COVID-19. The rise in occurrences and total link strength of core terms such as social entrepreneurship and social enterprise indicate sustained scholarly interest, while emerging themes such as circular economy, crowdfunding, self-efficacy, and legitimacy suggest new directions for research. Social entrepreneurship remains the dominant keyword, with a sharp increase in occurrences from 881 in the previous period to 947. This increased strength suggests that social entrepreneurship continues to be a highly relevant research topic with expanding interdisciplinary connections, particularly in the context of addressing global challenges through socially driven entrepreneurial solutions. Social enterprises maintain a strong presence, emphasising the field's continued focus on organisational structures, business models, and sustainable operations. Its strong link strength indicates an ongoing exploration of governance mechanisms, financial viability, and impact measurement of social enterprises. The consistent growth of social innovation suggests that researchers are increasingly examining how innovative approaches drive systemic change. This term remains closely integrated with other key themes, highlighting its role in problem-solving and sustainability (Phills et al., 2008). The increase in occurrences and link strength of entrepreneurship indicates a continued emphasis on connecting social entrepreneurship with broader entrepreneurial theories, particularly in opportunity recognition, business development, and ecosystem interactions.

Table 5

Publications between 2021 and 2024

KEYWORD	OCCURRENCES	TOTAL LINK STRENGTH
social entrepreneurship	947	1288
social enterprise	817	1073
social innovation	202	359
entrepreneurship	164	325
sustainability	144	288
sustainable development	133	259
social entrepreneur	100	151
innovation	80	160
hybrid organizations	75	128
covid-19	74	123
social entrepreneurial intention	63	73
social impact	62	130
social business	58	93

KEYWORD	OCCURRENCES	TOTAL LINK STRENGTH
corporate social responsibility	53	92
social capital	53	96
social economy	44	66
higher education	43	81
business model	41	81
gender	41	68
entrepreneurship education	37	66
systematic literature review	35	74



Source: Scopus keyword co-occurrence data for 1965–2024 (analysed with VOSviewer by the author, 2025).

The increasing frequency of sustainability-related terms reflects the growing recognition of social entrepreneurship as a key driver of the United Nations Sustainable Development Goals (SDGs). This trend indicates that social enterprises are now widely viewed as critical factors contributing to economic, environmental, and social sustainability (Sachs et al., 2019). Although social entrepreneurs remain less frequent than broader organisational concepts, their steady presence suggests an ongoing interest in understanding the characteristics, motivations, and leadership styles of individuals who drive social change. New and reinforced keywords indicate the evolving research priorities in social entrepreneurship, highlighting governance, digital transformation, and financial mechanisms. The enduring presence of innovation suggests that technological and business model innovations are increasingly intertwined with social entrepreneurship research. The continued focus on hybrid organisations highlights their growing importance in balancing social and financial objectives. Research in this area likely explores how these organisations navigate legitimacy, governance, and sustainability challenges. The inclusion of COVID-19 as a keyword underscores the pandemic's profound impact on social entrepreneurship, ranging from resilience strategies to accelerated

digital transformation. Studies likely explore how social enterprises adapted to crises, developed innovative solutions, and contributed to public health responses.

Social entrepreneurial intention reflects an increasing focus on psychological and behavioural factors influencing individuals' motivations to engage in social entrepreneurship. Its intersection with self-efficacy and empathy suggests a deeper investigation into how individuals develop a social entrepreneurial mindset. The rise of social impact suggests an academic shift towards impact measurement and assessment frameworks, emphasising how social enterprises create value beyond financial returns. The consistent presence of social business highlights ongoing efforts to distinguish various models within the social entrepreneurship spectrum, particularly those prioritising financial sustainability (Yunus & Weber, 2010). Corporate social responsibility remains integral to discussions, reflecting the growing involvement of traditional businesses in social entrepreneurship through partnerships, impact investing, and sustainable business practices (Carroll & Shabana, 2010). Several keywords reveal newly emerging focus areas in social entrepreneurship research. The increasing presence of higher education and entrepreneurship education in keyword analyses suggests that more scholars are examining the integration of social entrepreneurship into university curricula and training programs designed to cultivate entrepreneurial skills for social impact. The presence of legitimacy suggests a growing interest in how social enterprises gain and maintain credibility within different institutional and regulatory environments. The emergence of the circular economy highlights an increasing focus on sustainable business models, particularly those that reduce waste, optimise resource use, and promote environmental sustainability.

The inclusion of the ecosystem points to a shift towards studying the interdependencies among social enterprises, governments, corporations, and non-profits. The increasing presence of crowdfunding signals the growing role of alternative financing mechanisms in supporting social enterprises, particularly in the context of digital platforms. The inclusion of empathy and self-efficacy as keywords reflects an increasing psychological focus, particularly on how these factors influence social entrepreneurial behaviour and decision-making. The presence of China and India in keyword analyses suggests a rise in regional comparative studies, likely examining how different socio-economic and regulatory environments shape social entrepreneurship. A comparison with earlier datasets reveals several key trends. The inclusion of COVID-19 suggests that research has expanded to include crisis management and resilience strategies within social enterprises. The rise of social impact, social value, and performance indicates a growing demand for measuring the effectiveness of social enterprises. The emergence of the circular economy and the continued prominence of sustainability indicate that environmental sustainability is becoming a central concern in social entrepreneurship. The increasing presence of social entrepreneurial intention, self-efficacy, and empathy suggests that research is increasingly exploring what motivates individuals to engage in social entrepreneurship. The inclusion of China and India suggests that social entrepreneurship research is expanding beyond Western-centric perspectives, highlighting the need for regional and comparative studies.

This period demonstrates a further shift from conceptual discussions to applied and impact-driven research, with a stronger focus on measuring and evaluating the effectiveness of social entrepreneurship initiatives. The increased focus on digital transformation, financial mechanisms, and psychological dimensions suggests that future research should further explore the role of technology, alternative financing, and human behaviour in shaping social enterprises. With the growing need for innovative solutions to global challenges, social entrepreneurship research is expected to expand further into interdisciplinary areas, integrating insights from technology, behavioural science, and policymaking. The field has matured into an

essential component of broader discussions on sustainable development, crisis adaptation, and financial inclusion, positioning social enterprises as key agents of systemic change. ÜstüFormun Altı

Conclusion and Discussion

Social entrepreneurship has evolved significantly over the last 50 years, reflecting changes in societal needs, economic structures, and technological advances. This comparative analysis examines VOSviewer-generated keyword data from four different periods (1965-2010, 2011-2015, 2016-2020 and 2021-2024), highlighting the commonalities, differences, and emerging research directions in the field of social entrepreneurship.

In all four periods, the terms 'social entrepreneurship' and 'social enterprise' consistently stand out as the most frequently used keywords. The steady increase in the frequency and relevance of these terms indicates that the field is increasingly recognised as an independent discipline distinct from traditional entrepreneurship. The predominant focus of the literature on social entrepreneurship has shifted from establishing the basic concepts of social entrepreneurship (1965-2010) to exploring its operational models, practices, and case studies (2011-2024). The role of innovation in social entrepreneurship has been a theme that initially emerged as 'innovation' (1965-2010) and then evolved into 'social innovation' (2011-2024). This shift reflects a growing emphasis on the role of creativity and innovative solutions in addressing social challenges. Social innovation became a particularly dominant research theme between 2016 and 2024, reflecting the role that social enterprises play in driving systemic change.

While "entrepreneurship" remains an important keyword in all analysed periods, its overall link strength is consistently lower than "social entrepreneurship" and "social enterprise". This indicates that while traditional theories of entrepreneurship form the foundations, the field of social entrepreneurship is increasingly differentiating towards its own distinct theoretical and practical terminology. Sustainability emerged as a key theme from the period 2011-2015 and becomes more prominent in the later years (2016-2024). This shift can also be considered in line with the global adoption of the United Nations Sustainable Development Goals (SDGs), which emphasise the role of social enterprises and entrepreneurs in promoting economic, social, and environmental sustainability. CSR has been a recurring theme since the first studies and demonstrates a continuing interest in how businesses integrate their social vision into their organisational structures. Similarly, business models emerged as a keyword in later periods (2011-2024), reflecting the growing interest in how social enterprises operate in a sustainable manner.

Research on social entrepreneurship began relatively recently during the period from 1965 to 2010, focusing on defining the field and distinguishing it from traditional entrepreneurship. Key terms included "social entrepreneurship," "social enterprise," "entrepreneurship," "corporate social responsibility," "social capital," and "social economy." The studies were primarily theoretical, exploring organisational structures, ethical issues, and the role of social capital. Between 2011 and 2015, there was a significant increase in the number of studies, with new themes such as "social innovation," "social enterprise," "the base of the pyramid," "the third sector," and "management" emerging. Research began to address how social enterprises interacted with broader economic and governance systems, leading to an increased focus on impact measurement and organisational sustainability.

Between 2016 and 2020, the literature on social entrepreneurship significantly expanded both qualitatively and quantitatively, and it has begun to include interdisciplinary themes such as "hybrid organisations," "education," "gender," "collaboration," and "social entrepreneurial intention." It can also be said that there

was an increase in geographical focus during this period; the emergence of "India" as a keyword particularly attracted academic interest due to the country being noticeable for its population and poverty. The inclusion of "social economy" and "third sector" in studies suggests that research has started to explore the systematic frameworks within which social enterprises operate.

The latest period (2021-2024) introduces new keywords such as "COVID-19," "higher education," "entrepreneurship education," "systematic literature review," "legitimacy," "China," "circular economy," "crowdfunding," "self-efficacy," and "empathy." These shifts indicate an increasing emphasis on technology, behavioural science, and the resilience of social enterprises in crises. The emergence and increasing importance of the “circular economy” has also highlighted sustainability, which is one of the crucial elements of social entrepreneurship. Along with this, it is also observed that “crowdfunding” has gained importance as an alternative financing mechanism. The emergence of “crowdfunding,” “entrepreneurship education,” and “digital transformation” indicates that social entrepreneurial activities are becoming progressively easier and that potential social entrepreneurs are being enabled to realise their visions. New key terms such as “self-sufficiency,” “empathy,” and “social entrepreneurship intention” show an increasing focus on the psychological factors that influence entrepreneurial behaviour. This indicates a shift from an institution-centred view of social entrepreneurship to an individual-centred perspective. The inclusion of COVID-19 marks a shift towards resilience strategies and adaptation measures in response to global crises, and it indicates that social entrepreneurs who will work against potential future global crises may be observed. Furthermore, future research could continue to explore how social enterprises and social businesses cope with potential pandemics, economic stagnations, and climate-related challenges. The presence of "India" (2016-2024) and "China" (2021-2024) indicates a growing interest in cross-country analyses that reflect the increasing globalisation of social entrepreneurship. The rising frequency of terms such as "social impact," "social value," and "performance" highlights a shift in the field towards developing standardised methods for evaluating the effectiveness of social enterprises. Assessing the value created by social entrepreneurs on both local and global scales has become increasingly important. One of the main reasons for this is the attitudes of both public institutions and the private sector in selecting the most efficient social enterprise to support for various reasons.

The evolution of social entrepreneurship research from 1965 to 2024 demonstrates a transition from theoretical foundations to applied, interdisciplinary, and impact-driven studies. Early research focused on defining the field, while later studies examined governance, sustainability, and business models. The most recent period (2021-2024) highlights an increased emphasis on digitalisation, behavioural science, regional studies, and resilience. Social entrepreneurship stands out as a field that is developing and is expected to continue to develop. Accordingly, the place of this issue in the academic literature is also increasing. When the studies conducted in the field of social entrepreneurship to date are examined within the scope of research, it has been observed that social entrepreneurship will be shaped particularly by the intensive use of technology, and that future research will evolve in this direction. Specifically, the use of topics such as artificial intelligence, the Internet of Things, NFTs, cryptocurrencies, and wearable health technologies in the field of social entrepreneurship will also draw interest. Moreover, it can be considered that social enterprises and consequently the literature on social entrepreneurship will focus on studies in this area, particularly due to the growing attention to concepts related to health, especially public health, such as malnutrition, child malnutrition, sedentary lifestyle, and their effects, not only in underdeveloped countries but also in developed countries.

Future research suggestions

Future research should address the methodological gaps and expand the scope of bibliometric analysis in social entrepreneurship studies. The current study relies primarily on co-occurrence analysis and publication trends, while co-citation analysis and bibliographic coupling remain unexplored. Future studies should apply co-citation analysis to identify the most influential works and theoretical foundations within the field, as well as bibliographic coupling to examine the evolution of contemporary research themes. These techniques would provide a deeper understanding of the intellectual structures and emerging scholarly trajectories.

Co-authorship analysis should be conducted to map collaborative networks among researchers, institutions, and countries. Identifying patterns of academic collaboration would reveal the geographical distribution of research output and highlight key research hubs in social entrepreneurship. Additionally, studying co-authorship networks could facilitate the identification of influential researchers and emerging scholars contributing to the field.

A methodological classification of the social entrepreneurship literature should be undertaken to determine the dominant research approaches. The increasing volume of publications necessitates an assessment of the balance between qualitative, quantitative, and mixed-methods studies. Understanding the methodological diversity in social entrepreneurship research would help identify trends in empirical approaches and inform future studies on the most effective methodologies for investigating social entrepreneurship phenomena.

Thematic analysis should be expanded to explore emerging research topics and evolving conceptual frameworks. Advanced text-mining techniques, such as machine learning and natural language processing, could be used to analyse large datasets and detect latent patterns in the literature. Identifying new research directions through systematic literature reviews would contribute to the development of novel theoretical perspectives and interdisciplinary connections.

Future studies should focus on policy-oriented and applied research to assess the impact of social entrepreneurship on economic and social development. Comparative analyses across different regions revealed variations in policy frameworks, institutional support, and financing mechanisms for social enterprises. Investigating the role of government interventions and regulatory policies would provide insights into the factors that enhance or hinder the growth of social entrepreneurship.

There is a need to analyse the financial sustainability of social enterprises and the mechanisms through which they secure funding. The increasing prominence of crowdfunding and impact investing suggests that alternative financing models deserve greater attention in academic research. Examining sector-specific applications of social entrepreneurship could also provide valuable insights into industry-based variations in business models and strategic approaches.

This study has provided a bibliometric overview of social entrepreneurship research, but further analyses are required to refine and expand the understanding of the field. The application of additional bibliometric techniques, methodological classifications, and policy-driven research would contribute to a more comprehensive examination of the social entrepreneurship literature. The integration of quantitative bibliometric analysis with qualitative systematic reviews would further strengthen the field by identifying theoretical gaps and practical implications for researchers, policymakers, and practitioners.

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Volatility Dynamics of the Inflation Expectation

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Abstract This study investigates how the Central Bank of the Republic of Turkey fulfilled its responsibility of ensuring price stability by focusing on inflation and inflation expectations volatility between August 2001 and November 2023. The study utilised ARCH models, preferred in financial series, to demonstrate time-varying volatility and volatility clustering to examine the alterations in the volatility of inflation and inflation expectations. Achieving price stability, these are considered as indicators. The threshold model analysed inflation behaviour around a specific threshold by presidential terms and presented different coefficients and standard errors. Raising concerns about recent policy changes weakening the institutional and operational independence of the CBRT, the analysis is structured around the CBRT governors' tenures. The findings show Serdengeçti's tenure as the most successful, with inflation in single digits. Yılmaz and Başçı also maintained stability despite the crises. During the Çetinkaya term, the independence of the CBRT was questioned, inflation rates climbed, and tensions with policymakers increased. Uysal pursued a low-interest rate policy and kept inflation high but stable. Ağbal raised interest rates but was dismissed early. Kavcıoğlu's tenure saw record inflation and volatility. In June 2023, Erkan's appointment promised a return to orthodox policies, but their effectiveness in controlling inflation and managing expectations remains uncertain.

Keywords Inflation · expectation · ARCH · Threshold

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Volatility Dynamics of the Inflation Expectation

The primary functions of central banks are to ensure price stability, and the monetary policies implemented in accordance with these functions are reflected in the economy through various channels in the transmission mechanism. Among these, the expectations channel allows central banks to direct the economy not only through policy implementations but also through their discourse and statements. In particular, the prominence of the relationship between expectations and inflation in the 1970s has made expectations management more important in the fulfilment of the basic duties of central banks. The ability to manage expectations is closely related to the reliability of the central bank (Mishkin, 2007). The design of monetary policies and the targets and commitments embedded within these policies serve as pivotal factors in shaping inflation expectations. The trust of economic actors in the policies, targets and commitments of the monetary authority facilitates the management of expectations, but it also causes inflation expectations and, consequently, price and wage increases to be more moderate. Conversely, the practices of central banks and their deviation from their targets and commitments can engender a loss of confidence, thereby complicating the management of expectations. Such a scenario can precipitate higher wage and price increases, which in turn makes it difficult to control inflation and reduce it to reasonable levels (Bernanke, 2005).

Many studies in the literature underscore the significance of inflation expectations in ensuring price stability. However, they also emphasise that issues such as the identification of the economic actors that create and direct expectations and the process by which expectations are formed in the pricing process will invariably be among the academic debates (Mankiw, Reis, & Wolfers, 2003).

This study aims to examine the success of the Central Bank of the Republic of Turkey (CBRT) in ensuring price stability, its fundamental responsibility. This examination is conducted through an analysis of inflation and the volatility of inflation expectations. Considering the recent changes in policy that have led to the strengthening of views that suggest a weakening of the institutional and operational independence of the CBRT, the present study aims to conduct a volatility analysis by considering the terms of office of the CBRT governors. The study will determine the effects of the interventions in question that changed the attitude of the CBRT in environments of instability. In this study, the CBRT's policies to combat inflation in the 2000s are first addressed, as well as the attitudes and realisations during the terms of office of the CBRT governors. Finally, the analysis of volatility in inflation and inflation expectations is given. The analysis then proceeded to determine how inflation behaves around certain levels or threshold values according to the CBRT governors' tenures, and how it presents different coefficients and standard errors depending on these thresholds, using the threshold model.

Expectations Theoretical Framework

The notion of expectation, when contemplated from an economic vantage point, pertains to the predictions of economic decision-making entities concerning economic variables such as income, price, sales, and taxes. the expectations of two significant actors in the economy, namely individuals and firms, have a considerable impact on the present period's decisions. In this context, the formation process and analysis of expectations continue to be among the current topics of theoretical and empirical studies. Different theoretical approaches have been developed to explain the formation processes of expectations, which play a decisive role in economic decision-making processes, and to analyse their economic results. The first systematic analyses of expectations in economic terms emerged with the studies of H. Thornton in 1802 and

E. Cheysson in 1887. Then, it was addressed in different ways with the economic movements that started with the Classical theory. The role of expectations in economic decision-making, as discussed by classical economists, was not considered a significant phenomenon due to the assumption that the economy was constantly in a stationary state (Evans & Honkapohja, 2001). The Keynesian school of economics, which emerged in the aftermath of the Great Depression, emphasised the significance of expectations in the context of long-term investments. However, the absence of a scientific theory can be attributed to the prevailing notion that expectations were considered uncontrollable in an uncertain environment. The seminal work of P. D. Cagan (1956), M. Friedman (1957) and M. Nerlove (1958) marked the inception of the adaptive expectations theory, which posited that future expectations regarding economic variables were determined according to the averages or weighted averages of the relevant variables in the past period. Subsequently, the rational expectations theory was advanced based on the study entitled "Rational Expectations and Price Movements Theory", which was published by J. Muth in 1961. This theory posited that decision-making units considered all information regarding the past and current periods. This theory became a subject that many economists, especially R. Lucas, T. Sargent and N. Wallace, worked on in the late 1970s (Aktan, 2010). The rational expectations theory (Muth, 1961), predicated on the assumption that economic agents who formulate predictions regarding economic variables possess complete information regarding all the factors that affect the value of the relevant variable and that they utilise this information in the most effective manner, has also formed the basis of the policy inefficiency approach in the New Classical school.

While the theories of adaptive and rational expectations treat the expectations of economic actors as homogeneous, the post-Keynesian school has highlighted the heterogeneity of expectations. It has been contended that economic decision-making units cannot possess uniform knowledge or past experiences and that this will result in divergent approaches to analogous economic developments. The limited rationality caused by uncertainty, limited knowledge, and limited abilities will have a detrimental effect on optimisation behaviours (Davidson, 1991; Drakopoulos, 1999). The Bayesian learning model, Mankiw and Reis' (2001) sticky information model, Carrol's (2003) epidemiological expectations model and Sims' (2003) rational inattention model, which can be considered within the heterogeneous expectations approach, have presented different approaches to expectation formation.

Empirical studies in the literature indicate that models advocating heterogeneous expectations produce more successful results than traditional rational expectations models in explaining and predicting pricing dynamics, exchange rate changes and other economic variables (Ellen, & Verschoor, 2018).

The CBRT's Post-2001 Policy Framework

In the Turkish economy, since the 1990s, stability programmes aimed at controlling inflation have been implemented, but the targeted results of these programmes could not be achieved. The economic crisis encountered in the early 2000s resulted in the implementation of a new program including important structural reforms within the framework of the agreement made with the IMF.

The stability program signed with the IMF in December 2000, following the crisis in November 2000, led to the strengthening of the independence of the CBRT's monetary policy and the transition from an exchange rate-focused approach to inflation targeting (Bakır, 2007). This process, with its emphasis on price stability, entailed the transition from a fixed exchange rate to a floating exchange rate, with the objective of achieving a gradual reduction in inflation. Implicit inflation targeting was first implemented within the framework of inflation targeting, and this practice continued from 2002 to 2006. During this period, inflation, which had been a major concern, witnessed a significant decline, reaching single digits by 2004. However, since 2006,

when open inflation targeting was introduced, inflation has generally been above targeted due to global developments and rose to double digits in 2008. However, the subsequent emergence of the global financial crisis led to a decline in inflation to the single digits in 2009.

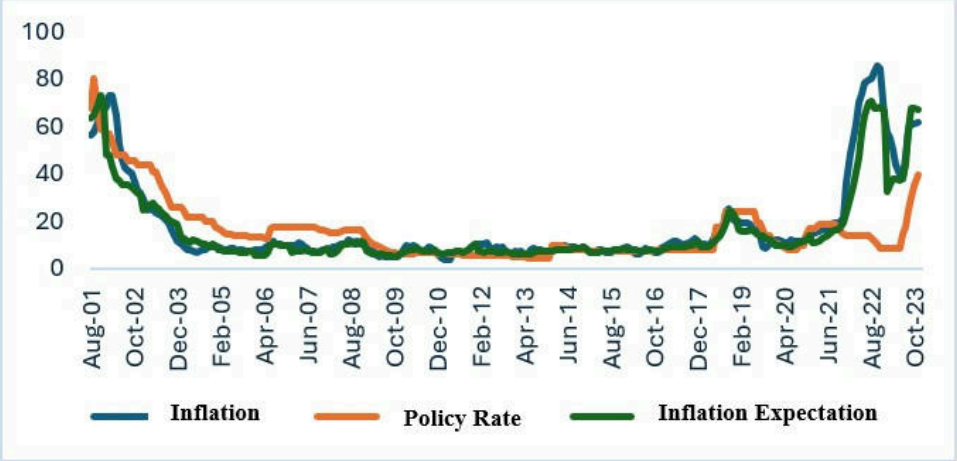
The implicit inflation period was characterised by the CBRT's utilisation of short-term interest rates as the primary policy instrument within a floating exchange rate regime, complemented by an emphasis on monetary performance criteria in alignment with the programme implemented in collaboration with the IMF. In this context, the monetary base was designated as the target variable and employed as the nominal anchor. Given the potential impact of macroeconomic variables on future inflation, short-term interest rates were identified as the most effective instrument. Among the targets established for the central bank balance sheet, the monetary base, net domestic assets and net international reserves were used as indicators and performance criteria (CBRT, 2005). The failure to attain inflation targets during the 2006-2008 period led to the weakening of the target's function as an anchor for expectations. In anticipation of the escalating costs associated with the ongoing battle against inflation, if this situation was to become permanent, the CBRT issued an open letter to the government in June 2008, proposing the establishment of novel medium-term targets. After this recommendation, the revised targets were delineated for the years 2009, 2010, and 2011. This policy was maintained in conjunction with a tight monetary policy to manage inflation expectations and mitigate the adverse effects of changing targets (CBRT, 2008). Moreover, starting from 2008, inflation estimates were diversified according to energy and food prices due to the uncertainty surrounding commodity prices. To limit the impact on long-term expectations, the estimates were extended to three years, and accountability was ensured through open letters (Kara & Orak, 2008). The global financial crisis led to a contraction in demand, thereby curbing inflation. However, it also demonstrated the importance of financial stability, as evidenced by the increase in asset prices and debt ratios before the crisis. This ultimately deteriorated financial stability, which subsequently turned into a global crisis. Consequently, financial stability was incorporated into the remit of the central banks. In the post-crisis period, short-term interest rates remained the primary instrument of inflation targeting, complemented by additional mechanisms such as the option mechanism and required reserve ratios (CBRT, 2008). After 2011, regulatory measures were implemented to enhance the efficacy of the required reserves (Eroğlu, Söylemez, & Alıç, 2016). Despite the presence of low interest rates, inflation remained in the single digits until 2017, a period that also saw the impact of global economic conditions. However, in 2017, inflation rose to double digits once again, reaching 20.3% in 2018 due to exchange rate fluctuations and global economic uncertainties. Despite a decline in 2019, the global inflation problem was brought to the agenda in 2021 due to the disruptions caused by the pandemic to supply chains. During this period, the CBRT pursued a policy of interest rate cuts with the aim of reducing the current account deficit through the implementation of competitive exchange rates. However, the subsequent dismissal of CBRT officials served to erode perceptions of independence, and a precipitous rise in inflation ensued as a consequence of exchange rate volatility and mounting inflation expectations (Kara & Sarıkaya, 2024).The persistent inflation rate, which exceeded the target, in conjunction with the unrelenting commitment to a low interest rate policy, precipitated an inflationary environment reminiscent of that witnessed in the 1990s. The repeated dismissals of central bank governors and MPC members have eroded the sense of autonomy, while interventions in the foreign exchange market have contributed to a decline in foreign exchange reserves. The preponderance of swap agreements in the reserve composition has rendered the CBRT susceptible to external pressures. Consequently, the rise in inflation, attributable to the accommodating monetary policy, has precipitated an escalation in inflation expectations and a deterioration in the pricing of credit and securities in financial markets (Gürkaynak et al., 2023). The

failure to control inflation, the widening of the current account deficit, and the negative CBRT net reserves all indicated the unsustainability of the low-interest rate policy, which led to a policy change in 2023. This change included the replacement of the CBRT governor and the initiation of interest rate hikes. However, concerns regarding independence and the perception of political boundaries created uncertainties about the effectiveness of the policy. While inflation exhibited a downward trend in the first half of 2023, when the low-interest rate policy was implemented, it showed an increase in the second half, despite the interest rate hikes.

Gürkaynak et al. (2015) proposed a division of the developments in monetary policy following the economic crisis experienced by Turkey in the early 2000s into two periods. During the initial period (2002-2008), the implementation of inflation targeting proved effective. However, despite the expansionary monetary policy applications initiated in 2009 to mitigate the impact of the crisis, inflation persisted in its decline, reaching 6.4% in 2010. This decline was attributed to the global economic downturn, which led to a contraction in demand. The subsequent period, from 2010 onwards, signified a shift in the Central Bank's monetary policy focus towards promoting growth in an economy that was undergoing accelerated development. This transition resulted in a deviation from the previous strategy of inflation targeting, leading to a less pronounced response to inflation compared to the earlier periods (Gürkaynak et al., 2015). Notwithstanding the low interest rates and high liquidity that persisted until 2017, the inflation rate remained in the single digits. However, the central bank's emphasis on price stability declined during this period. As demonstrated in Figure 1, which presents the trajectory of actual inflation, expected inflation and policy interest rates in Turkey since the early 2000s, the strategy aimed at curbing inflation, which was devised as a consequence of the stabilisation program implemented following the economic crisis, inflation targeting and reforms based on the autonomy of the central bank, was executed with a concentration on elevated real interest rates. Concurrently, the policy interest rate underwent a rapid decline, while real interest rates remained positive until 2009, a period marked by the severe repercussions of the global financial crisis. The global financial crisis led to an abundance of liquidity, which in turn resulted in low interest rates and high liquidity. However, these conditions did not trigger inflationary pressures due to the stagnant global demand. Consequently, this scenario resulted in the real interest rates in Turkey declining to remarkably low levels, and at times, even entering negative territory.

Figure 1

Actual Inflation, Expected Inflation, and Policy Rate in Türkiye



When looking at the changes in policy rates, it is possible to mention four periods in the 2010s when the CBRT intervened by increasing interest rates. Three of these interventions were aimed at the increases in exchange rates and the inflationary pressures arising from exchange rates. The first was to reduce negative real interest rates to positive, albeit low, to stop the increase in exchange rates during the presidency of Erdem Başçı in 2014, while the second was to intervene in exchange rate shocks and inflationary pressures caused by global trade wars and tensions between Turkey and the US during the presidency of Murat Çetinkaya in 2018, and the third was to prevent exchange rate increases and avoid the effects of global inflation that began to be felt during the presidency of Naci Ağbal, who was appointed after Murat Uysal, who implemented a low interest rate policy, was dismissed. The final interest rate wave, which commenced in June 2023 during the presidency of Hafize Gaye Erkan, signifies a reversion to conventional policies in an environment where inflation and inflation expectations have escalated to remarkably elevated levels, real interest rates have assumed exceedingly negative values due to the low interest rate policy, and exchange rates have been constrained by the CBRT reserves and the Exchange-rate Protected Deposits (EPD) application. The CBRT's loss of confidence in this process may significantly impede its ability to manage expectations and effectively curb inflation.

Table 1

Inflation and Policy Rates During the Tenure of the CBRT Governors

CBRT Governors	Inflation Rate at the Beginning of Tenure (%)	Inflation Rate at the Ending of Tenure (%)	Policy Rate at the Beginning of Tenure (%)	Policy Rate at the Ending of Tenure (%)
N. Süreyya Serdengeçti	56,3	8,2	68	13,5
Durmuş Yılmaz	8,2	4	13,5	6,25
Erdem Başçı	4	7,5	6,25	7,5
Murat Çetinkaya	7,5	15,7	7,5	24
Murat Uysal	15,7	11,9	24	10,25
Naci Ağbal	11,9	16,2	10,25	19
Şahap Kavcıoğlu	16,2	39,6	19	8,5
Hafize Gaye Erkan	39,6	61,98	8,5	40

Note: *Starting dates for Süreya Serdengeçti are taken as August 2001.

**Since Hafize Gaye Erkan continues as the chairman, the last date is November 2023.

As demonstrated in Table 1, which illustrates the inflation and policy interest rates of the CBRT governors during their respective tenures, it is evident that the period under Süreyya Serdengeçti witnessed the most pronounced decline in both inflation and policy interest rates. Furthermore, significant decreases were attained during the Durmuş Yılmaz period, with a consistent positive real interest approach being adopted. Conversely, the period under Erdem Başçı witnessed protracted negative real interest rates, which were addressed through interest rate increases in the latter stages. During Murat Çetinkaya period, substantial inflation and interest rate increases, due to the repercussions of both global and domestic political factors. The process that started with the dismissal of Murat Çetinkaya was a period in which significant ruptures were experienced in the CBRT's policy approaches, and the independence of the central bank was weakened. The CBRT, which adopted a low-interest rate policy with the appointment of Murat Uysal, started to increase interest rates again with the dismissal of Murat Uysal and the appointment of Naci Ağbal. The dismissal of Naci Ağbal and the appointment of Şahap Kavcıoğlu led to the beginning of a period in which the

CBRT ignored price stability and acted in the opposite direction to all central banks in the world with high negative real interest rates. During this period, the relationship between policy rates and market interest rates was broken, pricing mechanisms were disrupted and further increases in inflation were attempted to be prevented by suppressing exchange rates. The dismissal of Şahap Kavcıoğlu and the appointment of Hafize Gaye Erkan marked the beginning of a return to orthodox policies. During this period, when policy rates were gradually increased, inflation rates continued to rise due to the damage to the environment of trust, the fact that real interest rates were still at negative levels and the suppressed exchange rates were released. Notably, prior to the tenure of Governor Çetinkaya, previous central bank governors had completed their full five-year terms.

In addition to the data from the periods when the CBRT governors started and vacated their positions, the average and median data during their respective tenures are also pivotal in delineating the characteristics of these periods. As illustrated in Figures 2 and 3, the periods of Erdem Başçı (8.1), Durmuş Yılmaz (8.6), Murat Uysal (11.9) and Murat Çetinkaya (15.1) witnessed the lowest average inflation rates. In addition, the lowest median inflation rates were observed during the periods of Erdem Başçı (8.1%), Durmuş Yılmaz (8.6%), Murat Uysal (11.9%), Murat Çetinkaya (13.1%), Naci Ağbal (15.1%), Süreyya Serdengeçti (25%), Şahap Kavcıoğlu (49.9%) and Hafize Gaye Erkan (55%), respectively. The median values in the inflation rate were 8% in the Erdem Başçı period, 9% in the Durmuş Yılmaz period, 11% in the Murat Çetinkaya period, 12% in the Murat Uysal period. The figures then increased to 13% in the Süreyya Serdengeçti period, 15% in the Naci Ağbal period, 52% in the Şahap Kavcıoğlu period and 60% in the Hafize Gaye Erkan period.

Figure 2

Average Inflation and Policy Rates During the Tenure of the CBRT Governors

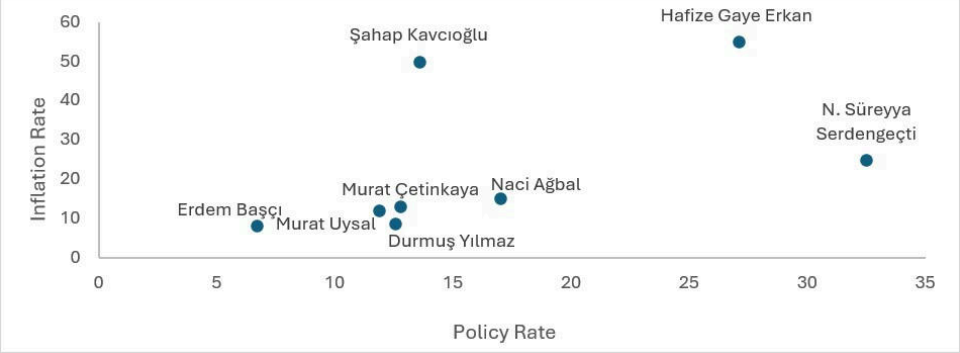
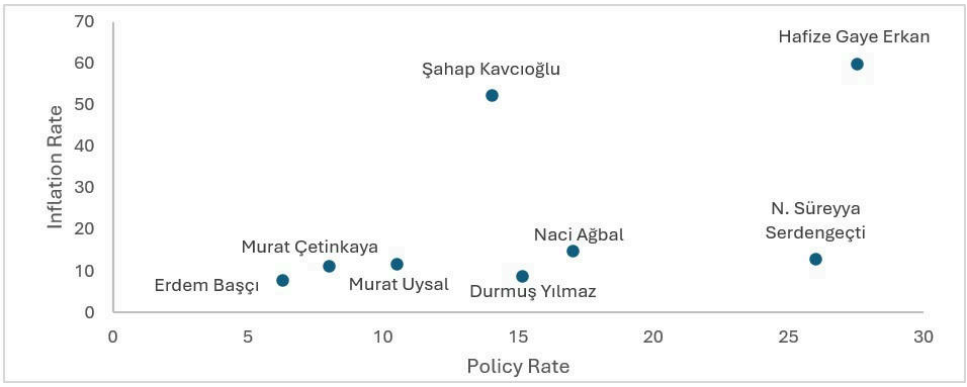


Figure 3

Median Inflation and Policy Rates During the Tenure of the CBRT Governors



Conversely, the lowest average policy interest rates were observed during the periods of Erdem Başçı (6.7), Murat Uysal (11.9), Durmuş Yılmaz (12.5), Murat Çetinkaya (1 2.8), Şahap Kavcıoğlu (13.6), Naci Ağbal (17), Hafize Gaye Erkan (27.1), and Süreyya Serdengeçti (32.5), respectively. The median values in the aforementioned periods were 6% in the Erdem Başçı period, 8% in the Murat Çetinkaya period, 11% in the Murat Uysal period, 14% in the Şahap Kavcıoğlu period, 15% in the Durmuş Yılmaz period, 17% in the Naci Ağbal period, 26% in the Süreyya Serdengeçti period and 28% in the Hafize Gaye Erkan period. It can be understood that in periods when the average and median values of both the policy interest rate and inflation rates are close to each other, relative stability is achieved, and in periods when they diverge, upward or downward trends occur. In this context, it is observed that the difference increased during the Süreyya Serdengeçti period, when the inflation rate decreased rapidly, and in the Şahap Kavcıoğlu and Hafize Gaye Erkan periods, when inflation tended to increase. Conversely, the difference decreased during the periods when inflation and interest rates stabilised, such as in the Erdem Başçı and Durmuş Yılmaz periods.

Data and Methodology

Data

In the study, the volatility behaviours in inflation and inflation expectations are addressed by considering the terms of office of the CBRT governors. By determining the behavioural changes in the volatility in question, it is aimed to determine in which governor's term the Central Bank managed the process better, whose main purpose is to ensure price stability. In this context, the Current Month Monthly CPI (Enf_t), Current Year End Annual CPI ($Enfy_t$), Current Month Monthly CPI Expectation ($Enfbc_t$), 1 Month Ahead Monthly CPI Expectation ($Enfb1c_t$), 2 Month Ahead Monthly CPI Expectation ($Enfb2_t$), Current Year End Annual CPI Expectation ($Enfby_t$), Istanbul Monthly Living Index (1985) ($Geca_t$) and Monthly ITO Wage Earners Living Index ($ITO95_t$) data obtained from the EVDS database of TSI, ICC and CBRT were used. The data of the variables covering the period August 2001-November 2023 were examined with the ARCH family methods.

Methodology

The present study utilised ARCH (Autoregressive Conditional Heteroscedasticity) models, which are generally preferred in financial series that demonstrate time-varying volatility and volatility clustering, to examine the alterations in the volatility of inflation and inflation expectations. These are considered as indicators of the CBRT's success in achieving price stability. Subsequently, the threshold model was utilised to analyse the behaviour of inflation around specific threshold values according to presidential terms and to present different coefficients and standard errors depending on these thresholds.

ARCH Models

The ARCH model developed by Engle (1982) examined the inflation series belonging to the United Kingdom and revealed that the assumption of constant variance of the error term in time series modelling may not be valid. The basic idea of the ARCH model is that the variance of the error term u in period t depends on the square of the error term in period t-1. The fundamental premise of the ARCH model is that the variance of the error term u in period t is contingent on the square of the error term in period t-1. Subsequent GARCH models developed by Bollerslev (1986) addressed the heteroscedasticity issue encountered in financial time series, thereby facilitating the analysis of variances of shock variables by employing the moving average of the squares of the values of lagged error terms as a foundation. The conditional variance is incorporated into the average equation as an explanatory variable. However, the presence of hypothetical constraints within

the ARCH and GARCH models causes modelling challenges. Consequently, EGARCH (Exponential GARCH) models were proposed by Nelson (1991) and TGARCH (Threshold GARCH) models were proposed by Glosten, Jagannathan and Runkle (1993) to eliminate these hypothetical constraints and to calculate asymmetric effects.

The linear ARCH(q) model, first proposed by Engle (1982), assumes that the conditional variance is a linear function of past q-squared innovations, namely:

$$\sigma_t^2 = \omega + \sum_{i=1,q} \alpha_i \varepsilon_{t-i}^2, q \equiv \omega + \alpha(L)\varepsilon_{t-1}^2 \tag{1}$$

The GARCH model, as implemented by Bollerslev (1986), allows the conditional variance to depend on its own lags (Brooks, 2008). The GARCH (p,q) model is defined as follows::

$$\sigma_t^2 = \omega + \sum_{i=1,q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1,p} \beta_j \sigma_{t-j}^2 \equiv \omega + \alpha(L)\varepsilon_{t-1}^2 + \beta(L)\sigma_{t-1}^2 \tag{2}$$

It is defined as. For the conditional variance in the GARCH (p, q) model to be well defined, all coefficients in the relevant infinite linear ARCH model must be positive. In other words, it is assumed that $\alpha_i \geq 0$ and $0 \leq \beta_i$.

After the symmetric ARCH family models, the TGARCH and EGARCH models that include asymmetric effects were investigated.

The GJR-GARCH or TGARCH model proposed by Glosten, Jagannathan and Runkle (1993) allows the conditional variance to respond differently to negative and positive innovations in the past.

$$\sigma_t^y = \omega + \sum_{i=1,q} \alpha_i^+ I\left(\varepsilon_{t-i}^2 > 0\right)\left|\varepsilon_{t-i}^2\right|^y + \alpha_i^- I\left(\varepsilon_{t-i}^2 \leq 0\right)\left|\varepsilon_{t-i}^2\right|^y + \sum_{j=1,p} \beta_j \sigma_{t-j}^y \tag{3}$$

Thus

$\{I_{t-1} = 1 \;\; u_{t-1} < 0$

$\quad 0 \qquad others$

Zakoian (1990) estimated the threshold ARCH (TARCH) model with γ = 1 and Glosten, Jagannathan, and Runkle (1993) with γ = 2. This model allows for a quadratic response of volatility to news with different coefficients for good and bad news. However, it maintains the claim that minimum volatility occurs when there is no news. The leverage effect is seen when $\gamma > 0$ and statistically significant. This means that negative news has a stronger effect on the variance than positive news (Geyer, 2013). GARCH successfully captures heavy-tailed returns and volatility clustering. However, it is not suitable for detecting the leverage effect. In the exponential GARCH (EGARCH) model of Nelson (1991), σ_t^2 depends on both the size and sign of the lagged residuals

$$ln(\sigma_t^2) = \omega + \left(1 + \sum_{i=1,q} \alpha_i L^i\right)\left(\sum_{j=1,p} \beta_j L^j\right)^{-1} \{\theta z_{t-1} + \gamma[|z_{t-1}| - E|z_{t-1}|]\} \tag{4}$$

Therefore, { $ln(\sigma_t^2)$ } follows an ARMA (p, q) process with the usual ARMA stationarity conditions.

The modelling of $ln(\sigma_t^2)$, will ensure that σ_t^2 is positive even if the parameters are negative. Therefore, the non-negative restriction on the model parameters is removed. On the other hand, under the EGARCH formulation, if the relationship between volatility and returns is negative by allowing for an asymmetric structure, γ is adjusted to be negative (Brooks, 2008). If bad news has a stronger effect on volatility, the expected signs are $\gamma < 0 \; and \; \gamma + \alpha > 0$ (Geyer, 2013).

Threshold Model

The fundamental premise of threshold regression lies in the recognition that economic relationships may not be adequately captured by a single, linear model. Instead, the true nature of the relationship may involve multiple regimes, each governed by a unique set of parameters. The identification of distinct regimes and their corresponding thresholds provides researchers with critical insights into the nonlinear dynamics that underpin economic phenomena. These include the effects of policy interventions, fluctuations in asset prices, and the behaviour of macroeconomic variables under varying economic conditions (Coulombe, 2020; Ballarin, 2023).

The methodological foundation of the threshold regression involves estimating a piecewise linear model, where the transition between regimes is determined by the value of a threshold variable in relation to an estimated threshold parameter. This approach enables the detection of structural breaks or regime shifts, offering a more detailed understanding of the underlying economic processes. Such insights are essential for informing policy decisions that are context-sensitive and tailored to specific economic environments.

The threshold regression framework is based on the premise that the relationship between the dependent and independent variables cannot always be adequately captured by a single linear model. Instead, the true relationship may involve multiple regimes, each governed by a unique set of parameters. The threshold regression model can be expressed as follows:

$Y = \beta_1'X + \varepsilon$, if $c \leq \gamma$

$Y = \beta_2'X + \varepsilon$, if $c > \gamma$

In the threshold regression model, Y represents the dependent variable, X is the vector of the independent variables, β_1 and β_2 are the corresponding parameter vectors, ε is the error term, c denotes the threshold variable, and γ is the estimated threshold parameter.

A defining feature of the threshold regression model is the presence of the threshold parameter γ, which determines the transition point between the two distinct regimes. The estimation of γ is typically performed using a grid search or an optimisation algorithm. The optimal threshold value is identified as the one that minimises the residual sum of squares (RSS) or maximises the likelihood function.

Once the threshold parameter has been estimated, the model can be fitted separately for each regime. This allows for the identification of distinct patterns in the relationship between the dependent and the independent variables, reflecting the underlying structural shifts.

Threshold regression has been widely applied across various economic fields. Its applications include the analysis of economic growth, the study of financial market dynamics, the examination of labour market phenomena and the investigation of nonlinear relationships among macroeconomic variables. By accounting for regime-specific behaviours, threshold regression offers a nuanced approach to understanding complex economic phenomena and contributes to both theoretical advancements and evidence-based policymaking (Lee & Lemieux, 2010; Hamilton, 2016; Jacob et al., 2012; Marinescu, Triantafillou, & Kording, 2022).

Findings

ARCH Models Findings

In the study, volatility related to inflation and inflation expectations was examined using the ARCH family models with monthly data for the period from August 2001-November 2023. To conduct an analysis using

the ARCH family models, the first step is to determine the appropriate ARMA (p, q) models for the theoretical framework under investigation. Then, the volatility of the dependent variable to be analysed should be examined by a graphical method, and the presence of an ARCH effect in the ARMA (p, q) models should be confirmed with the ARCH-LM test.

To identify the appropriate ARMA (p, q) model for the inflation series, the most appropriate ARMA(p, q) model among the different models created was determined by taking into account the Akaike, Schwarz and Hannan-Quinn information criteria. The variance effect was tested for the models with the ARCH LM Test. The findings show the existence of a heteroscedasticity effect in the error terms of the models. In other words, the test results confirmed the existence of the ARCH effect in ARMA(p,q) models (See: Appendix Table 1)

Given the identified ARCH effect in the ARMA(p,q) models, it was determined that the study should proceed with conditional variance models. When selecting the most appropriate model among the ARCH family models, the statistical significance of the variables and the values of the information criteria were considered.

In the EGARCH models, which were determined as the most suitable model for realised inflation series, it was determined that all variables in the mean-variance equation were statistically significant. The ARCH-LM test results in the EGARCH models show that the conditional variance problem in the ARMA(p,q) model is not present in this model.

The parameter γ_j, which represents the leverage effect in the model, is statistically significant but has a negative value. In the EGARCH models, the γ parameter measures the asymmetry, i.e., the leverage effect, and when $\gamma<0$, it is evaluated that positive shocks produce less volatility than negative shocks. In the models included in the study, the fact that this variable, which shows the leverage effect, is statistically significant and negative indicates the existence of the leverage effect in the inflation series. The α parameter in the EGARCH models signifies the impact of past period shocks on the current period conditional variance, while the β parameter, which demonstrates volatility resistance, indicates the permanence of past period shocks on the current period conditional variance. The determination of the $\alpha+\beta$ value for the models to be greater than 1 signifies the continuity of the shocks in the conditional variance. The observation of a negative leverage effect in the model of realised inflation demonstrates the efficacy of positive external shocks. As demonstrated in Figure 1, the effects under consideration are higher in the ITO95 monthly wage index, yet they are similar in the Geca subsistence index and inflation index. Furthermore, it has been determined that the current period conditional past period shocks have a higher effect on realised inflation, while it has been determined that they have a relatively lower effect in the ITO95 and Geca indexes.

The TGARCH model, the most suitable model for the inflation expectation series, revealed that all variables in the mean-variance equation were statistically significant. The conditional variance problem in the ARMA(p,q) models in the TGARCH models was eliminated according to the ARCH-LM test results. γ_j, representing the leverage effect in the model, was found to be statistically significant and had a positive value. The positive value of this quantity in the TGARCH models indicates the leverage effect. The positive identification of the leverage effect in models pertaining to inflation expectations signifies that negative occurrences exert a more pronounced influence on expectations, particularly two months hence, and to a comparatively lesser extent one month hence. A parallel phenomenon is observed in the impact of past period shocks on the current period. The permanence of past period shocks conditional on the current period increases in the same direction as the expectation periods.

Table 2

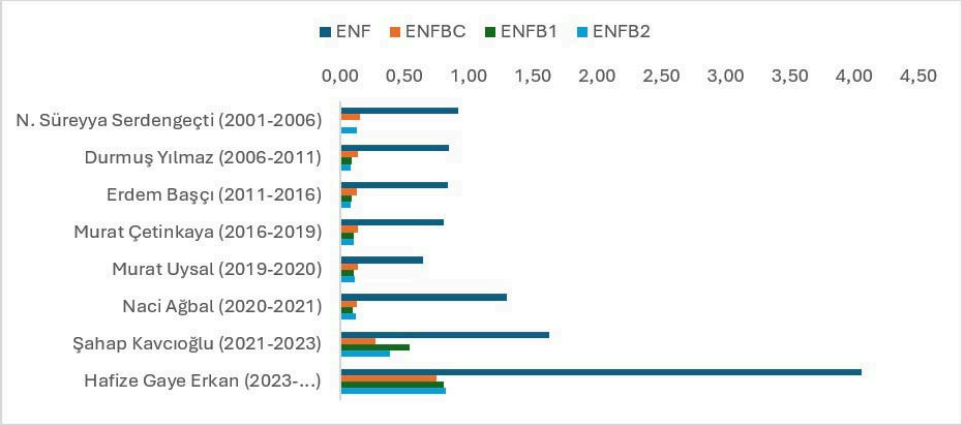
EGARCH vs. TGARCH

	EGARCH Model Realise						TGARCH Model Expectation					
	ENF		Ito95		Geca		ENFBC		ENFB1		ENFB2	
Variable	**Coef.**	**Std. Error**	**Coef.**	**Std. Error**	**Coef.**	**Std. Error**	**Coef.**	**Std. Error**	**Coef.**	**Std. Error**	**Coef.**	**Std. Error**
						Mean Equation						
β_0	1.066	0.266	0.977	0.07	0.94	0.089	1.036	0.103	0.738	0.063	0.777	0.082
β_1	0.97	0.016	−0.21	0.111	−0.246	0.094	0.71	0.042			0.616	0.066
β_2			0.258	0.087	0.141	0.078						
β_3			−0.507	0.068	−0.598	0.06						
θ_1	−0.345	0.048	0.744	0.132	0.679	0.119	0.296	0.061	0.828	0.082	0.377	0.059
θ_2	−0.466	0.04	−0.197	0.13	−0.256	0.12			0.38	0.074		
θ_3									0.259	0.0004		
						Variance Equation						
	−1.5	0.199	−0.193	0.095	−0.022	0.1	0.087	0.016	0.051	0.02	0.046	0.011
	0.744	0.142	0.264	0.111	0.239	0.12	0.423	0.118	0.285	0.119	0.509	0.007
	1.253	0.09										
	0.172	0.065	0.286	0.067	0.356	0.081						
	−0.28	0.085	−0.896	0.036	−0.265	0.14	0.613	0.117	0.49	0.142	0.764	0.052
	0.561	0.079			0.565	0.152	0.38	0.109	0.459	0.2	0.468	0.072
Akaike information criteria	2.911		3.261		4.064		1.142		0.788		0.699	
Schwarz criteria	3.045		3.396		4.212		1.236		0.915		0.793	
Hannan-Quinn criteria	2.965		3.315		4.124		1.18		0.84		0.736	
ARCH-LM Test	F statistic	$N*R^2$	F statistic	$N*R^2$	F statistic	$N*R^2$	F statistic	$N*R^2$	F statistic	$N*R^2$	F statistic	$N*R^2$
5	0.84	4.229	1.535	7.626	0.627	3.168	1.073	5.38	0.392	1.999	0.84	4.229
10	0.643	6.544	1.119	11.179	0.809	8.187	1.045	10.476	0.22	2.297	0.643	6.544

Note: * All variables used in the study were determined to be stationary using ADF and PP unit root tests.

The mean values of the GARCH series, obtained from the EGARCH and TGARCH models, were examined, and the change in the mean volatility of the series according to the periods of the centre heads was analysed. While the volatility of the monthly inflation series realised in the relevant periods was observed to be higher than expected, it was noted that the lowest volatility was observed in the periods of Murat Uysal, Erdem Başçı and Durmuş Yılmaz, respectively.

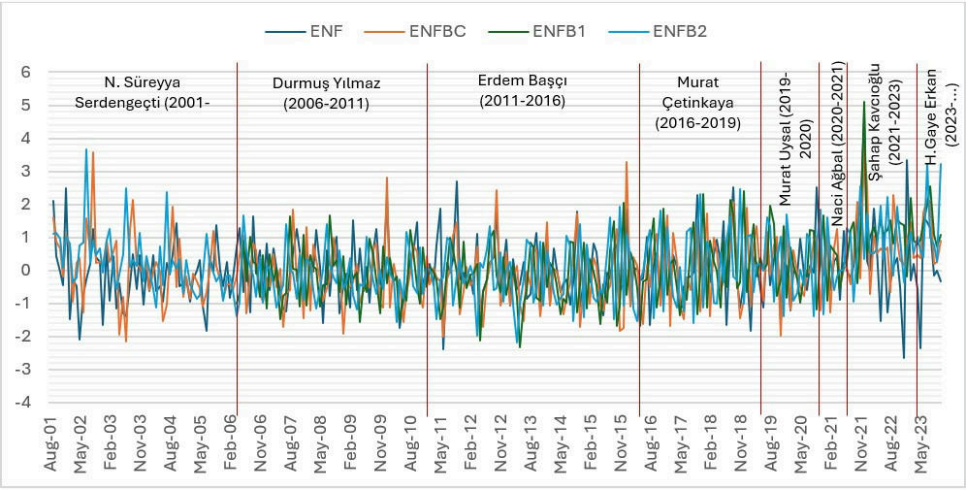
Figure 4
Median GARCH Series



Following the economic crisis of 2001, a series of policies were implemented with the aim of reducing inflation and inflation expectations. These policies were gradually successful in achieving this, with a stabilisation of inflation and inflation expectations occurring in the mid-2010s. This was despite the expansionary policies implemented during this period and the steadily increasing exchange rates. In this context, the period of Süreyya Serdengeçti, who was the governor of the CBRT during the 2001 economic crisis and the period following it, can be stated as the periods when the volatility in inflation and inflation expectations decreased the most, and the periods of Durmuş Yılmaz and Erdem Başçı, who were the governors of the CBRT between 2006 and 2016, can be stated as the periods when the volatility in single-digit inflation rates was the lowest and most stable.

The period experienced in 2015 and afterwards was the period when the increase in the exchange rate accelerated and the increase in inflation and inflation expectations began to become evident. The military coup attempts, and various political problems experienced during this period were effective in these developments. Due to the trade war that started between the US and China and the political tensions between Turkey and the US, 2018 was the year when exchange rate shocks were experienced and inflation exceeded 20%.

Figure 5
Model Residuals by Tenure of the CBRT Governor



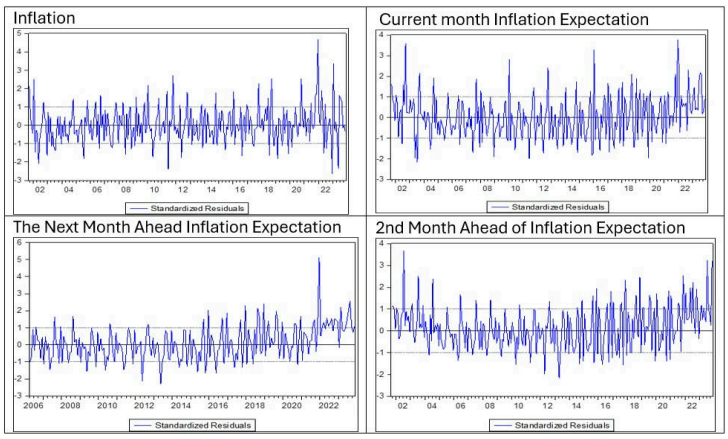
Throughout this period, when the policy rate was gradually increased from 8% to 24%, the increase in inflation was limited by the interventions of the CBRT and inflation expectations were tried to be kept under control. Therefore, the term of Murat Çetinkaya, who served as the CBRT Governor between 2016 and 2019, was a period when volatility in inflation and inflation expectations increased and central bank interventions were experienced in a tightening direction. In place of the CBRT Governor Murat Çetinkaya appointed Murat Uysal in July 2019. After his appointment as the CBRT Governor, the policy rate began to be lowered. During this period, low interest rates were implemented, and inflation decreased due to the decrease in political risks and tensions. However, the upward trend in the exchange rate continued and new peaks were reached. This situation created effects that disrupted economic stability, especially inflationary pressures. The dismissal of Murat Uysal in November 2020 and the appointment of Naci Ağbal in his place, while damaging the independence of the central bank, increased expectations that orthodox policies would be implemented in the new period.

During Naci Ağbal's tenure as governor, the policy rate underwent a gradual increase in accordance with market expectations, while exchange rates, inflation, and volatility in inflation expectations experienced notable declines. However, the increases in the policy rate did not yield the expected results and Naci Ağbal was dismissed in March 2021 and Şahap Kavcıoğlu was appointed in his place. The appointment of Kavcıoğlu was met with expectations of a shift away from Orthodox policies. Following the maintenance of the policy rate until August 2021, interest rate reductions were initiated in September 2021. This led to a rapid increase in exchange rates and heightened inflationary pressures. In October 2022, the policy rate was reduced to 11%, coinciding with a surge in inflation to 85.5%, which subsequently entered a downward trajectory due to the base effect.

During this period, while nearly all central banks increased their policy rates in response to global inflationary pressures, the CBRT adopted an opposing course, deviating from Orthodox policies. This shift led to substantial volatility in inflation and inflation expectations. The Currency Protected Deposit (CCD) application was introduced to prevent increases in the exchange rate that trigger inflation, and interventions using CBRT reserves were initiated. In an environment where the policy rate fell to 8.5%, but the link between policy rates and market rates was largely broken, the inflation rate fell to 39.6% as of May 2023. However, this was accompanied by a decline in CBRT net reserves, leading to speculation that the exchange rate was being suppressed.

Figure 6

Standardise Residuals of the Inflation Expectation



After the general elections in Turkey in May 2023, a policy shift occurred, resulting in the dismissal of CBRT Governor Şahap Kavcıoğlu and his replacement by Hafize Gaye Erkan in June 2023. The return to orthodox policies gave rise to expectations of a decrease in inflation; however, inflation began to trend upward again as a result of lower-than-expected increases in policy rates and the gradual removal of pressure on exchange rates. Although the policy rate was gradually increased to 40% in November 2023, the effect of the tightening policy on market rates was more limited since the link between the policy rate and market rates had already been broken. Consequently, real interest rates persisted at negative levels, and the volatility of inflation and inflation expectations remained substantial.

Threshold Model Findings

In the 2001M10-2006M03 period, it was observed that the constant term and Enf coefficients differed depending on whether the threshold value was below or above 1.5. While the values were lower in the periods below the threshold, they were observed to increase in the periods above the threshold. In the subsequent 2006M04-2011M03 period, the Enf effect was pronounced in the periods below the threshold, while its effect diminished in the periods above the threshold. In the final 2011M04-2016M03 period, it was ascertained that the Enf effect was high in the periods below the threshold, while its effect decreased in the periods above the threshold. In the subsequent 2016M05-2019M06 period, the Enf coefficient exhibited a decline in the periods below the threshold, while these values increased in the periods above the threshold. The final period (2019M07-2023M05) witnessed a significant shift in the Enf coefficient in accordance with the threshold value. A comparison of the relevant periods with those previously observed reveals three distinct thresholds. When the threshold value is below 1.16, the Enf coefficient is low; when the threshold value is between 1.16 and 2.56, the Enf coefficient increases; and when the threshold value is above 2.56, the Enf coefficient remains low. In the context of inflation volatility, it is observed that the threshold value does not exert any influence on volatility in the models up to the 6th month of 2019. Inflation exerts its own effect on current period expectations. While volatility generally indicates a positive effect on expectations, it was determined that this effect was negative in the 2011M04-2016M03 period. After the 7th month of 2019, it was determined that the effect of volatility differs according to the threshold value, with the volatility coefficient being positive and significant for the threshold value of 1.16. Between the threshold value of 1.16-2.56, this coefficient is even higher, indicating that the increase in previous period volatility has a strong positive effect on current period expectations.

Conversely, when the threshold exceeds 2.56, the volatility coefficient approaches zero, indicating its ineffectiveness. This observation underscores the potential for divergent economic dynamics within the system, depending on the specific conditions present. The fact that the system reacts differently according to the past values of ENFBC reveals that the system may have different economic dynamics under certain conditions and therefore may require different policies or strategies.

Table 3

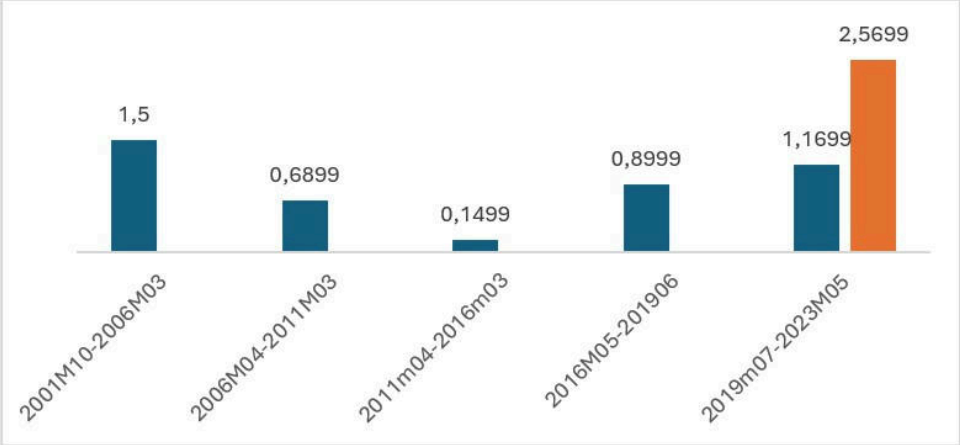
Threshold models

	ENFBC	COEF	STD		THRES		N	R2	ADJ R2	F	P
2001M10-2006M03	C	0.412	0.123		ENFBC (-2)	<1.5	30.000	0.875	0.865	85.846	0.000
	ENF	0.446	0.129								
	C	0.968	0.166	1.5<=	ENFBC (-2)		24.000				
	ENF	0.667	0.060								
	ENFVOL (-1)	0.010	0.048		NON						
2006M04-2011M03	C	0.036	0.059		ENFBC (-1)	<0.6899	31.000	0.575	0.544	18.598	0.000
	ENF	0.335	0.063								
	C	0.619	0.066	0.6899<=	ENFBC (-1)		29.000				
	ENF	0.231	0.049								
	ENFVOL (-1)	0.012	0.025		NON						
2011M04-2016M03	C	0.619	0.156		ENFBC (-3)	<0.1499	9.000	0.689	0.666	30.408	0.000
	ENF	0.374	0.087								
	C	0.357	0.050	0.1499<=	ENFBC (-3)		51.000				
	ENF	0.287	0.045								
	ENFVOL (-1)	−0.005	0.027		NON						
2016M05-201906	C	0.383	0.077		ENFBC (-9)	<0.8999	25.000	0.727	0.694	21.958	0.000
	ENF	0.259	0.039								
	C	0.543	0.129	0.8999<=	ENFBC (-9)		13.000				
	ENF	0.412	0.088								
	ENFVOL (-1)	0.069	0.021		NON						
2019M07-2023M05	C	0.751	0.084		ENFBC (-6)	<1.16999	25.000	0.955	0.945	99.695	0.000
	ENF	0.193	0.026								
	ENFVOL (-1)	0.031	0.003								
	C	0.465	0.122	1.16999<=	ENFBC (-6)	<2.56999	13.000				
	ENF	0.472	0.030								
	ENFVOL (-1)	0.147	0.024								
	C	2.397	0.189	2.56999<=	ENFBC (-6)		12.000				
	ENF	0.099	0.055								
	ENFVOL (-1)	−0.001	0.001								

Figure 7 shows how the threshold values of the inflation expectation (ENFBC) change over time. In the 2001M10-2006M03 period, the threshold value was determined as 1.5, and it is observed that inflation expectations exhibit different behaviours above and below this value. In the 2006M04-2011M03 period, the threshold value decreased to 0.6899, indicating a significant change in the inflation dynamics. In the 2011M04-2016M03 period, the threshold value decreased further to 0.1499. In the 2016M05-2019M06 period, the threshold value increased again and was determined as 0.8999, indicating a change in the inflation dynamics compared to the previous period. Two different threshold values (1.16999 and 2.56999) were determined in the 2019M07-2023M05 period, which means that inflation is affected by different coefficients between and above these two values.

Figure 7

Inflation expectation of threshold to terms



Conclusion

The CBRT, whose institutional and operational independence was increased in the early 2000s, focused on price stability, allowing inflation to be rapidly brought under control and inflation expectations to be managed with the credibility gained. Considering that expectations are affected by realised inflation and inflation is affected by expectations, the ability of the central bank to manage these expectations in line with its targets played a critical role in achieving a stable process. This situation demonstrates that a credible and independent central bank, firmly committed to price stability, can significantly enhance macroeconomic stability by shaping expectations and anchoring inflation at sustainable levels.

In this study, the volatility changes in inflation and inflation expectations were analysed, and the CBRT's success in combating inflation and managing expectations was examined. The most successful CBRT governor in combating inflation was N. Süreyya Serdengeçti, and despite various crises and shocks during the Durmuş Yılmaz and Erdem Başçı terms, inflation was consistently maintained at single-digit levels. During the periods, the CBRT successfully managed inflation and inflation expectations in line with its mandate to maintain price stability. The fact that the average and median values were quite close to each other during the periods of stability also indicated low volatility. During the Murat Çetinkaya period, although the CBRT intervened in accordance with orthodox policies to curb exchange rate shocks and inflation despite global and national developments, significant increases in inflation were experienced. At this point, with the appointment of Murat Uysal as the governor of the Central Bank, policy rates began to be gradually reduced, and a negative real interest rate policy was adopted. Although inflation decreased due to the interventions

made and political stability, it remained sticky at double-digit levels. Inflation and inflation expectations volatility decreased during this period as well.

Although inflation and inflation expectation volatility decreased during the Murat Uysal period, increases in the exchange rate could not be prevented. In this context, the Central Bank governor was dismissed once again and Naci Ağbal was appointed in his place. During Naci Ağbal's term, the Central Bank increased the policy rate in line with expectations and aimed to prevent increases in the exchange rate and its reflections on inflation. However, the increases in the policy rate did not yield the expected results and Naci Ağbal was dismissed shortly thereafter.

The appointment of Şahap Kavcıoğlu as the governor of the Central Bank of the Republic of Turkey (CBRT) has signalled the commencement of a new era, characterised by the implementation of a low-interest rate policy. The decrease in policy interest rates and the impact of the pandemic on the global economy, excessive increases in inflation have resulted in negative real interest rates reaching elevated levels, prompting a comprehensive shift in consumer, savings and investment behaviours. Consequently, a significant degree of volatility regarding inflation, along with inflation expectations, has been evident during this period. Despite the emphasis placed on the reversion to Orthodox policies and the prioritisation of price stability following the dismissal of Şahap Kavcıoğlu and the appointment of Hafize Gaye Erkan in June 2023, the efficacy of the implemented policies in managing inflation expectations and curbing inflation. Consequently, the high inflation experienced in the early 2000s was mitigated by the CBRT's emphasis on price stability and its increasing institutional and operational autonomy. This approach ensured the management of inflation and inflation expectations for a considerable period, building credibility throughout this process. After the Global Financial Crisis, the low-interest rate policy implemented on a global scale was adopted in Turkey as in the advanced and emerging economies adopted exceptionally low-interest rate policies to stimulate economic growth, support financial markets, and restore confidence. This period was marked by cheap credit and efforts to support households and businesses through easier financial conditions. However, the economic landscape changed dramatically after the COVID-19 pandemic. Disruptions in supply chains, surging prices for goods and energy, and large government spending programs caused inflation to rise sharply across many countries. In response, central banks reversed course, raising interest rates to try to rein in inflation and steady people's expectations about the future. The periods when the Central Bank changed its interest rate policies to adapt to global and national conditions have provided the institution with significant experience in dealing with emerging vulnerabilities. The changes in monetary policy in Turkey over time in the 21st century show that the price stability target and the institutional autonomy of the Central Bank play a critical role in ensuring economic stability and confidence. Despite recent efforts to return to orthodox policies, it is of great importance to further strengthen elements such as consistency, institutional independence, and expectation management in the implementation of monetary and fiscal policies to permanently reduce inflation. Furthermore, it should not be overlooked that effective coordination among all economic actors, through a holistic approach to policy, can significantly enhance the efficacy of measures taken in times of heightened vulnerability.

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