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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

EXAMINING THE NEXUS BETWEEN AGRICULTURAL FINANCING REFORMS AND NIGERIA'S MACROECONOMIC PERFORMANCE: A COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS (2012-2020)

Henry Onyebuchi CHIOGOR[*]
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Olugbenga Omotayo ALABI[***]

Abstract

This study conducted a computable general equilibrium analysis (2012-2020) to investigate the relationship between Nigeria's agriculture financing reforms and the country's overall macroeconomic performance. Specifically, the study evaluated the impact of the agricultural financing reforms on household income and household welfare. The study finds that agricultural financing reforms through a decrease in interest rates on agricultural loans by 10% and 8% have positive significant impact on household welfare. While the impact of the policy options (decrease in interest rates on agricultural loans by 10% and 8%) on household income is not significant. The study therefore recommends a review in the interest rates on agricultural loans to improve household income. This recommendation is premised *on* the findings that both 10% and 8% reductions failed to improve the income levels of the households.

Keywords: Macroeconomic Performance, Agricultural Financing Reforms, A Computable General Equilibrium Analysis (CGE), Nigeria.
Jel Classification: B23, B26, E17, E4, G28

1. Introduction

Agriculture contributes immeasurably to the Nigerian economy in a variety of ways, including providing food for a growing population, supplying suitable raw materials (and labour input) to a growing industrial sector, providing a key source of employment, generating foreign exchange earnings, and establishing a market for the industrial sector's products. (Okumadewa et al., 1999

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and FAO, 2006). For a developing country with a mono-item oil economy, such as, Nigeria's, insufficient agriculture financing connotes incredible threats, one of which is fluctuating food prices which are precedents to inflation. Agriculture funding is typically dictated by the public sector, which creates institutional support for the enhanced growth of agriculture in the form of agricultural research, extension services to farmers, product marketing, input supply such as improved seeds and fertilizers and land use legislation. Furthermore, private sector participation is not limited to local or foreign direct investment, but also includes sponsorship of agricultural research and breakthroughs in universities, farmer capacity building, and, most importantly, the availability of capital to agribusinesses. International governmental and non-governmental organizations, such as the World Bank and the United Nations' Food and Agriculture Organization, among others, contribute through on-farm and off-farm support in the form of finance, input supply, and technical know-how enhancement of other support organizations, amongst other areas of support. There has been considerable debate among economists and policymakers about the shift towards a more friendly market-oriented economy (Schafer, 2018). The explanation is that the implementation of the neoclassical economic dogma, as viewed by policy makers, can push the economy on the path of sustainability, progress and growth. Prior to and after Nigeria's independence, the financial sector has undergone several transformations. Reforms play an indispensable role in the growth and development of any organization or system. As part of their monetary change program, the Nigerian government embraced alterations within the financial sector, with the intention of effecting substantial changes and securing entry into the banking sector (Omankhanlen, 2012). Nigeria's financial sector is one of the largest and most diversified in Sub-Saharan Africa and with the introduction of the structural adjustment program in the 1980's, the framework for the sector was liberalized (Afangideh, 2010). The sector has recently undergone substantial changes in terms of the policy landscape, the number of organizations, the structure of ownership, the scope and depth of markets, as well as the e-regulatory framework. According to Finance Maps of World (2012) the Central Bank of Nigeria (CBN) provided some incentives for banks to allow for the achievement of the minimum capital base in 2005. These include permitting banks to deal through foreign exchange by CBN, enabling the banks to take deposits from the public sector while the fiscal authorities were made responsible for the collection of revenue from the public sector. Furthermore, certain tax benefits in the area of stamp duty and capital allowance were given to banks; transaction costs were reduced, and an expert panel was created by the government to provide banks with technical support (Onoja et al., 2011).

Other reform processes included the merger of banking institutions and the implementation of a regulatory structure based on certain rules; the establishment of a web portal for all people to share any confidential details on banking systems with the Central Bank; the development of an electronic process for reporting bank returns; the revision and updating of the banking system. These reforms empowered banks to expand their capital base. The government setup an effective and disciplined banking system by combining numerous local banks, therefore, there was no compelling justification for the Nigerian Government to rely entirely on foreign banks. Computable General Equilibrium (CGE) models use real-world data to predict how

an economy will react to changes in policy, technology, or external factors. CGE models are appropriate whenever it is necessary to estimate the impact of changes in one part of the study, such as agricultural finance reforms and economic growth, on the rest. There has been little or no research on the impact of agricultural financing reforms in Nigeria, particularly on the use of CGE to estimate how the economy will react to policy changes or other external forces. Additionally, the analysis of literature suggests that few studies have examined the influence of policy experiments on macroeconomic variables and household welfare in terms of standard of living in Nigeria using the Hicksian Equivalent Variation as a welfare metric.

1.1. Research Questions

This study aimed to address the following research questions: (i) What is the impact of agricultural financing reforms on household income in Nigeria? and (ii) How does agricultural financing reform influence household welfare in Nigeria? By examining these questions, the study aimed to shed light on the effects of agricultural financing reforms on both income and overall well-being of households in Nigeria.

1.2. Objectives of the Study

The broad objective of this research is to examine the nexus between agricultural financing reforms and Nigeria's macroeconomic performance: a computable general equilibrium analysis (2012-2020). Specifically, the study seeks to:

i. examine the impact of agricultural financing reforms on household income in Nigeria.
ii. investigate the impact of agricultural financing reforms on household welfare in Nigeria.

1.3. Research Hypotheses

This study was guided by the following hypotheses stated in the null forms:

i. H_{01}: Agricultural financial reforms do not have significant impact on household income in Nigeria.
ii. H_{02}: Agricultural financial reforms do not have significant effect on household welfare in Nigeria.

2. Literature Review

A few studies have distinguished financing as an obstruction to the increase in agricultural yield in Nigeria. (CBN, 2004; Bernard, 2009). Similarly, the International Food Policy Research Institute (IFPRI, 2008), (Bernard, 2009), Dim and Ezenekwe (2013), and (Kamil et al., 2017) have determined that the agriculture sectors' insufficient support hinders the sectors' full potential for growth and economic development in the country. Using survey data and a probit regression

model, Dong et al. (2010) evaluated the relationship between credit constraints and rural household income in China. The study examined how credit constraints influence agricultural productivity and rural household income in China. The findings of the study indicate that under credit constraints, production inputs, along with the skills and education of farmers, cannot be completely utilized. By eliminating credit restrictions, agricultural output and rural household income can be enhanced. Increased government agricultural investment was explored by Iorember and Jelilov (2018) in Nigeria, where they looked at the influence on the well-being of both wealthy and impoverished households. A computable general equilibrium model was utilized in the study because of its applicability for managing the economy-wide and welfare consequences of specific economic policies, as well as its ease of use. The results of the simulations suggest that increasing the share of farm expenditure in household income increases the welfare of both rich and poor households. Households and the general economy benefited the most from a 25 percent boost in agricultural expenditure in Nigeria, according to the World Bank.

2.1. Concept of Economic Growth

Economic growth, according to Tadaro and Smith (2012), is a process in which the economy's productive capacity is raised over time, resulting in higher levels of national output and income. Thus, economic growth is defined as a persistent increase in a country's per capita output or income, as well as an increase in its labour force, consumption, capital, and trade volume Jhingan (2013). Economic growth, as defined above, is a long-term process characterized by an increase in real per capita income and volume of production associated with a significant increase in the economy's productive capacity, urbanization, and an equitable distribution of income and wealth among the population, all of which contribute to the reduction of poverty and unemployment.

2.2. Agriculture Finance and Economic Growth

The theories of the link between finance and economic growth may be traced back to Schumpeter's (1982) work, as well as Demirguc-Kunt et al. (2001), Shaw's (1973), and Mckinnon's (1973); King and Levine's (1993). These studies suggest that finance and economic growth have a beneficial link. Finance is a significant factor in the process of economic growth, according to Demetriades and Hussein (1996). According to Olagunju and Ajiboye (2010), the absence of a formal national credit policy and an insufficient number of credit institutions in Nigeria is a significant reason for the agricultural sector's reduction in economic contribution. Agricultural credit can be described as the mobilization of resources at all levels for the purpose of increasing agricultural production and productivity and strengthening productive capacity. Similarly, Shepherd (2002) asserts that credit affects farmers' access to all available resources. As a result, implementing suitable macroeconomic policies and facilitating institutional financing for agricultural growth has the potential to support agricultural development by increasing the sector's contribution to employment, income, and foreign exchange creation (Olomola, 2017).

2.3. Financial Sector Development and Economic Growth

Okpara (2010) examined the effect of capital market performance on economic growth in Nigeria. Using a vector autoregression model and Granger causality test, the study established a long-run relationship between real GDP, market capitalization, new issues, share value traded, and turnover ratio in the Nigerian capital market. Okpara (2010) reached the same conclusion as Popoola (2014), who asserts that the market capitalization of the Nigerian Stock Exchange has a favorable effect on economic growth in Nigeria. Nkoro and Uko (2013) examined the association between financial sector expansion and economic growth in Nigeria using annual time series data from 1980 to 2009 using an analytical approach based on co-integration and error correction. The broad money stock in relation to GDP, private sector credit in relation to GDP, market capitalization in relation to GDP, bank deposit liability in relation to GDP, and prime interest rate were used as proxies for financial sector development, whereas real GDP was used as a proxy for economic growth. Despite the fact that market capitalization and private sector lending had no effect on economic growth, the study identified a favorable association between financial sector development and economic growth. Similarly, Maduka and Onwuka (2013) evaluated the relationship between financial market structure and economic growth using Nigerian data from 1970 to 2008 and concluded that financial market structure had a negative and significant effect on economic growth. Balago (2014), on the other hand, discovered a favorable association between banking sector expansion and economic growth in Nigeria using Ordinary Least Squares Regression and Vector Error Correction Models. He discovered that the development of the financial sector (as measured by banking sector credits, total market capitalization, and foreign direct investment) accelerated economic growth. Numerous other researches, such as Dandume (2014), Adeniyi et al. (2015), Obinna (2015), and Iheanacho (2016), have re-evaluated the association.

2.4. Empirical Review

Paul and Gylych (2018) examined the influence of increased government agricultural spending on the well-being of wealthy and impoverished households in Nigeria. A computable general equilibrium model was employed due to its relevance in managing the economy-wide and welfare consequences of specific policies. The simulation results indicate that increasing agriculture expenditure as a share of total expenditure improves the welfare of both rich and poor households. The biggest gain in household and general economic welfare was shown in Simulation 1 (a 25% increase in agriculture spending share), followed by Simulation 2 (10% increase in agriculture expenditure share), and Simulation 3 (a 25% increase in agriculture expenditure share) (5 per cent increase in agriculture expenditure share). They recommended that the government significantly increase support for agriculture through increased allocation to the agricultural sector, in compliance with the Food and Agriculture Organization and the Maputo (2003) declarations on agriculture.

3. Methodology

3.1. Research Design

Creswell (2003) described research design as the plan used to generate answers to the various research problems by the researcher. Welman et al. (2005) in agreement with Creswell (2003) also defined research design as a specific plan set out by a researcher to obtain information from research participants and research tools. This study is designed to examine the macroeconomic implications of agricultural financing reforms on the household welfare and household income in Nigeria; it is descriptive in nature and will therefore employ the descriptive research design.

3.2. Study Area

The study was conducted in Nigeria. In the Gulf of Guinea in Western Africa, the country has a total land area of 923 768 km2 (356 669 sqm), ranking it as the world's 32nd largest country by land area. Located between 40 – and 140-degrees' north latitude and 20 to 150 degrees' east longitude, Nigeria is a country in West Africa.

3.3. Method of Data Collection

This study employed time series data from secondary sources such as the Central Bank of Nigeria (CBN) database and other relevant entities; including the updated Social Accounting Matrix (SAM) derived from the 2006 Input-Output Table; (ii) the Central Bank of Nigeria's (2019) sectoral output data; and (iii) the National Bureau of Statistics' (NBS) Year 2019 household income and expenditure data for Nigeria in conjunction with the World Bank Living Standard Measurement Study (LSMS). The re-aggregated SAM comprises the agricultural, manufacturing, mining and petroleum industries, electrical and telecommunications sectors, and services sectors of the Nigerian economy. These industries create a variety of commodities for home consumption or export, as well as two households (rich and poor) who make money from labor and capital employed in the manufacturing process. The wealthy are resource owners who live in transcendently urban homes, whereas the poor are working people who are classified as rural farmers and urban poor. Information from the Nigerian Living Standard Survey for 2019 was used to obtain Shares of household income and expenditure.

3.4. Method of Data Analysis

3.4.1. Specifying CGE model

Based on the work of Dervis et al. (1982) and its adaptation to Nigeria by Olofin et al. (2003) and Obi-Egbedi et al. (2012), the CGE structure was modeled to suit the objectives of this study. All Cobb Douglas and Leontief types were used, and the Constant Elasticity of Substitution (CES) functions were used. The CES is homogenous to a degree of one, suggesting that when inputs rise, output will rise as well. The study utilized a basic Cobb–Douglas production function to reflect

the value created in each area. As shown in Equation 1, each sector's output comprises value-added, which is the product of two main inputs: labor and capital.

$$XV = avLAB_i^{\propto} CAP_i^{(1-\propto)} \tag{1}$$

Where XV stands for value added, LAB for labor, CAP for capital, av for value-added shift, and a for value-added share for a certain sector. The demand for the primary input is determined by minimizing the value-added equation (Equation 1).

As a result, Equations 2 and 3 can also be used to calculate labor and capital in each sector.

$$LAB_i = \propto_i PV_t \frac{X_t}{W} \tag{2}$$

$$CAP_i = (1 - \propto_i) PV_t \frac{Xt}{PK_i} \tag{3}$$

PVt, Xi, W, PKi are the price value-added, domestic output, current wage rate in the economy, and capital price in sector I respectively.

The household income function is written as follows

$$HHY_h = \sum hfylshi(LAB_i W) + \sum hfykshiCAP_i PK_i(1 - depr_i) \tag{4}$$

where HHYh is the household income of household (h) (rich or poor), is a function of labor supplied at the ruling wage rate (W) and capital stock (K) of the households at the ruling price of capital (PK) and depreciation rate (depri), and hfylshi is the share factor income from labor received by household (i) and hfykshi is the share factor income from capital received by household (i). Households spend their money on items produced by the sectors, including rival commodities imported from other countries. Imports and domestic demand, on the other hand, are believed to be imperfect substitutes under the Armington assumption (Armington,1969). Hence, the quantity of composite commodity *(i)* consumed by household *(h)* is given by

$$HEXPQ_{(h,i)} = \frac{hexp_{shi} * HHY_h}{PQ_i} \tag{5}$$

Where $HEXPQ_{(h,i)}$ is the quantity of composite commodity *(i)* consumed by household *(h)*, $hexp_{shi}$ is the expenditure share for household (h) on goods from sector (I) PQ_i and is the price of a composite commodity sector (I) and $hexp_{shi}$ as defined earlier. Each household maximizes a Cobb–Douglas utility function subject to their income, thus the household utility function is given by

$$HHU_h = \sum hexp_{shi} logHEXPQ_{hi} \tag{6}$$

where HHU_h is household utility, $hexp_{shi}$ and are as defined. Household savings are defined as the difference between household income and expenditure, but total household savings are calculated by adding the savings of all households together.

$$SAV_h = HHY_h - \sum hexpS_i HHY_h \quad (7)$$

$$HSAV = \sum SAV_h \quad (8)$$

Where SAV_h and $HSAV$ are household savings and total households' savings respectively and the Agricultural loan disbursement function is given as:

$$AGRLOANEX_{AGR} = GSEC * \frac{GRTOT}{P_{AGR}} \quad (9)$$

Where $AGRLOANEX_{AGR}$ is Agricultural loan disbursement due to reforms, $GSEC_{AGR}$ is government sectoral consumption, $GRTOT$ is government total revenue and P_{AGR} is the price of the composite agricultural commodity (domestically produced and imported).

3.4.2. Simulation Designs

To achieve the objectives of the study, two policy scenarios were formulated and simulated in this study. These scenarios involve reducing the base-year share of agriculture loan interest rate by some magnitude, given that financial reforms in agriculture are directly related to output. The two scenarios include:

(1) 10 percent decrease in the interest rate on agriculture loan in line with the Interest draw-back policy of the CBN.

(2) 8 percent decrease in the interest rate on agriculture loan in line with single-digit interest rate policy

The evaluation of the effect of decreases in the interest rate on agriculture loans on households' welfare regarding utility gained or lost will be analyzed using the Hicksian Equivalent. Following Obi-Egbedi et al. (2012) and Abachi and Iorember (2017). The Hicksian Equivalent Variation (EV) is given as:

$$EV^h = \left[\frac{U_n^h - U_0^h}{U_0^h}\right] Y_0^h \quad (10)$$

Where,

Y_0^h =Income of household (h) before the policy change,

U_0^h =Utility of household (h) before the policy change,

U_n^h = Utility of household (h) after policy change, and

EV^h =Equivalent Variation of household (h).

A policy is said to affect households if the calculated value of the equivalent variation (Hicks in a coefficient) is greater than zero.

0 (i.e., if EV > 0). The higher the value of the equivalent variation, the more impactful the policy is to the households (Abachi and Iorember, 2017).

4. Results

4.1. Macroeconomic Impact of Increase in Agricultural Financing through 10 Percent Decrease in Interest Rate

In order to ascertain the impact of increase in agricultural financing on the macroeconomic variables of economic growth, household income and household welfare in Nigeria, scenario one (10 percent decrease in the interest rate on agriculture loan) was simulated and the results are presented in Table 1).

Table 1: Simulation One (SIM1 – 10% decrease in interest rate) Results of the Impact of Increase in Agricultural Financing on Macroeconomic variables of Household Income and Welfare in Nigeria

	Baseline Impact (N'Billion)	Simulated Impact (N'Billion)	Percentage Change (%)
Household Income	8,788.39	9,081.87	3.34
Household Welfare (EV)	-	1,300.11	-

Source: Author's computation using GAMS

Result in Table 1 shows that household income increases marginally from N8,788.39 to N9,081.87 representing 3.34% change due to increase in agricultural financing through 10% reduction in interest rate on agricultural loans. Regarding household welfare, the results revealed a Hicksian Equivalent Variation value of 1300.11 (EV = 1300.11) which shows improvement in the household welfare due to the policy change. Furthermore, for all the indicators, the results showed a positive increase suggesting that a policy of 10% reduction in interest rate on agricultural loans have significant positive impact on the macroeconomic variables.

4.2. Macroeconomic Impact of Increase in Agricultural Financing through 8 Percent Decrease in Interest Rate

In order to ascertain the impact of increase in agricultural financing on the macroeconomic variables of, household income and household welfare in Nigeria, scenario one (8 percent decrease in the interest rate on agriculture loan) was simulated and the results are presented in Table 2.

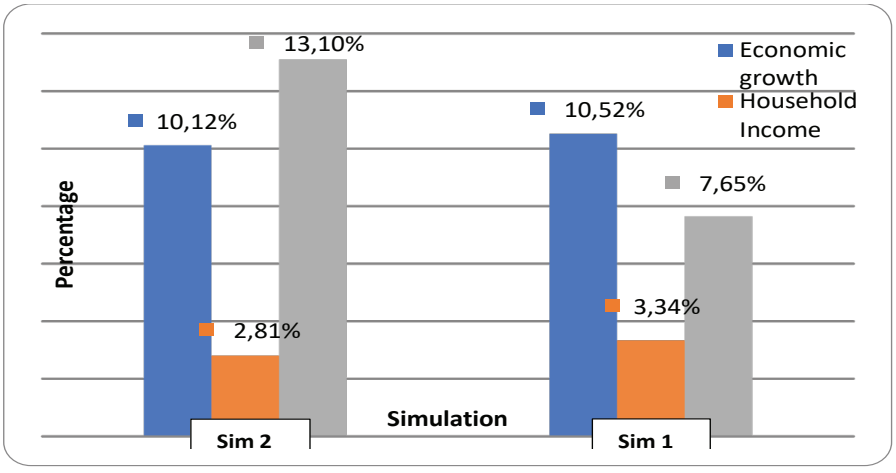
Table 2: Simulation Two (SIM2 – 8% decrease in interest rate) Results of the Impact of Increase in Agricultural Financing on Macroeconomic variables of Household Income and Welfare in Nigeria

	Baseline Impact (N'Billion)	Simulated Impact (N'Billion)	Percentage (%) Change
Household Income	8,788.39	9,035.19	2.81
Household Welfare (EV)	–	1289.13	-

Source: Author's computation using GAMS

Result in Table 2 reveal that, household income increases from N8,788.39 to N9,035.19 representing 2.81% change due to increase in agricultural financing through 8% reduction in interest rate on agricultural loans. Regarding household welfare, the results revealed a Hicksian Equivalent Variation value of 1289.13 (EV = 1289.13) which shows improvement in the household welfare as a result of the policy change. For all the indicators, the results showed a positive increase suggesting that a policy of 8% decrease in interest rate on agricultural loans have significant positive impact on the macroeconomic variables. To further buttress the findings, the results of simulation one (SIM 1) and simulation two (SIM 2) is presented on Figure 1. For SIM 1, Figure 1 shows that the impact of the policy (10% decrease in interest rate on agricultural loans) has higher impact on household income. While for SIM 2, Figure 1 indicates that the policy (8% reduction in interest rate on agricultural loan) has a lower impact on household income compared to Sim 1.

Figure 1: Percentage Change in the Macroeconomic Indicators Due to Simulation One and Simulation Two



4.3. Diagnostic and Sensitivity Checks

To determine the robustness and reliability of the simulations results, the study employed two diagnostics and sensitivity checks; to evaluate if the model has been able to replicate the

benchmark or initial equilibrium, and to verify the non-violation of the Walras law which states that the Walras variable must be approximately zero. In the first case, the results indicated that the baseline simulations replicated the benchmark equilibrium, and in the second case, the results showed that the values of the Walras variable for both the baseline simulation and the counterfactual simulations are approximately zero as required. These suggest that the model has goodness of fit and has performed well; hence, the findings of the study are robust and reliable.

4.4. Test of Hypotheses

The first hypotheses of the study were tested using 5% as the threshold, while the second hypothesis was tested using the Hicksian Equivalent Variation, this is consistent with the study of Ishola et al. (2013); Iorember and Jelilov (2018).

4.4.1. Decision Rule:

For hypotheses one, the decision rule is to reject the null hypothesis (H_0) if a policy option has greater than 5% impact on the macroeconomic economic variables. Otherwise, do not reject H_0.

For hypotheses two, the decision rule is that to reject the null hypothesis if the value of the estimated Hicksian Equivalent Variation is greater than zero, otherwise, do not reject it. The Hicksian Equivalent Variation as a measure of welfare is also used to quantify the impact of the various policy measures – a policy experiment (simulation type) that has higher value of the Hicksian Equivalent variation is considered more desirable than the one with smaller value.

All the two hypotheses were tested using the results in Tables 1 and 2.

4.4.2. Decision

Hypothesis One: Since the percentage change in household income is less than 5% due to agricultural financing reforms (simulations one and two), the study fails to reject the null hypothesis and conclude that agricultural financing reforms have no significant impact on household income in Nigeria.

Hypothesis Two: Since the value of the estimated Hicksian Equivalent Variation is greater than zero (positive) due to agricultural financing reforms (simulations one and two), the study rejects the null hypothesis and conclude that agricultural financing reforms have significant impact on household welfare in Nigeria.

5. Discussions

5.1. Discussion of Findings

The discussion of the findings of the study is in line with the objectives and hypotheses of the study. The study confirmed that agricultural financing reforms through reduction in agricultural

loans does not necessarily lead to improvement in households' income. This is because, while agricultural financing reforms through reduction in agricultural loans may lead to increase in agricultural output, it does not determine the prices of agricultural produce. In fact, prices of agricultural produce may decline when the supply is high, and this may affect household income negatively. This study is in line with the study of Ayodele (2019). The study further showed that agricultural financing reforms through reduction in agricultural loans exert positive impact on household welfare in terms of utility gained. In addition to the income effect of the policy reforms, the positive impact of the policy options on agricultural output may in turn increase household consumption, thereby improving the welfare of the households. This finding agrees with the finding of Iorember and Jelilov (2018) and Obi-Egbedi et al. (2012) who also submitted that agricultural loans have a significant impact on household welfare with respect to utility gained.

6. Conclusion

The study investigated the impact of an increase in agricultural financing on macroeconomic aggregates such as household income and household welfare in Nigeria using a computable general equilibrium model. To achieve the objectives of the study, two policy scenarios (10% and 8% reduction in interest rate on agricultural loans) were simulated and the results for both cases indicated that all the macroeconomic indicators except household income increased significantly due to the policy options. The improvement of household's welfare was however found to be highest under simulation one (10 per cent decrease in interest rate on agricultural loan) compared with simulation two (8 per cent decrease in interest rate on agricultural loan). This is expected because, the cheaper agricultural loans are, the higher the rate of investment in the agricultural sector and of course, the higher the rate of consumption which translate to welfare of the people.

7. Recommendations

Based on the findings of the study which indicate that agricultural financing reforms have a positive significant impact on macroeconomic aggregates of household income and household welfare, the study recommends the implementation of the policy scenarios that lead to this conclusion. That is, a 10 percent or 8 percent reduction in interest rate on agricultural loans in line with the interest draw-back policy of the CBN.

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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

THE UNEXPECTED SHORTFALL: AN ALTERNATIVE RISK MEASURE*

Ekrem KILIÇ**

Abstract

The international prudential regulation standard – the Basel standards – introduces a substantial change to its market risk framework. The change is part of a comprehensive revision of the standard to address the weaknesses discovered during the global financial crisis (GFC) of 2008. One of the key changes is the replacement of Value-at-Risk (VaR) with Expected Shortfall (ES) as the primary risk measure in the framework. By incorporating the tail events, ES partially answers the concerns raised about the VaR during the GFC. However, ES as well lacks a mechanism to extrapolate the historical shocks. This paper proposes an alternative measure – unexpected shortfall (US) – which aims to serve as a better safety barrier for financial institutions. Based on the evidence from 3 conventional currency pairs (EUR/USD, USD/TRY, EUR/TRY) and 1 cryptocurrency pair (BTC/USD), the new measure displayed violations in a reasonably close range of the expected values and backtest analyses suggested that the incurred excessive losses for US are less than both VaR and ES.

Keywords: Market Risk, Capital Adequacy, Value at Risk, Expected Shortfall, Basel IV, FRTB
Jel Classification: G170, G180, G280

1. Introduction

The global financial crisis (GFC) of 2008 has become one of the most significant turning points in the financial markets. The collapse of the US housing market has been followed by the bankruptcy of some major US banks such as Lehman Brothers and Bear Sterns. After such big failures in the market, the crisis has quickly spread globally. Although the first wave of the crisis has eased out by 2010, the global recession after the crisis has been prolonged for almost a decade.

Aftermath of the GFC, the failures in the financial system initiated a series of new regulations and rules. The Basel Committee on Banking Supervision (BCBS) also responded by introducing some new capital requirements as well as starting a comprehensive review of the existing ones. In 2016, after eight years from the crisis, an extensive review on minimum capital requirements for market risk – better known as the Fundamental Review of Trading Book (FRTB) – has been concluded with a

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revised framework. Among others, one of the major changes of the new framework is the replacement of the Value-at-Risk (VaR) based internal model approach with Expected Shortfall (ES).

Starting from 1990s, VaR emerged as being the standard risk measure for risk practitioners and eventually it become the main risk measure of Basel framework with 1996 amendments. Although the technique initially introduced for market risk, it has been applied to all types of risks. However, especially during the GFC, the perception of VaR has been dramatically changed and VaR started to be considered as an inadequate or even misleading measure of risk. One source criticism to VaR was about its insensitivity to tail events. VaR as a measure gives a false sense of security as if in the case of a financial shock, the loss would be as much as VaR itself. However, VaR rather represents a threshold, or a truncation point of the tail, so the loss that exceeds the VaR may be quite larger than the VaR value itself. This is more likely especially if the financial portfolio contains derivative or highly leveraged financial products. The seconds popular criticism to VaR, also known as Black Swan theory, suggested that using the historical price movements to forecast the future losses is deemed to fail in case there is an unprecedent shock occurs. In its original form as pioneered by Taleb (2009), the Black Swan theory may imply that it is simply not possible to measure such risks. However, at least it indicates that a better risk measure should not rely solely on the historical changes, in some way it should also extrapolate and potentially amplify the historical losses.

ES addresses the first criticism by simply replacing the notion of worst loss at a certain significance level, with the value of the losses which exceeds the VaR. In this way, ES is sensitive to the extreme values in the tail. However, similar to VaR, ES as well doesn't extrapolate the price movements, instead aims to represent what the historical return distribution implies as the potential loss.

This study proposes a new risk measure aims to extrapolate the risk by modelling directly the violations and their magnitude. The second section of the study explains the VaR and ES methodologies used as well as the new measure, unexpected shortfall. The third section delivers an empirical comparison of different risk measures. Finally, the last section summarises the findings of this study.

2. Methodology

VaR is a measure of the worst loss on a financial portfolio of assets due to changes in the risk factors over a given time horizon and at a confidence level. From a statistical point of view, VaR can be derived using the inverse of the cumulative distribution function (CDF) of the returns.

$$V_t^{\alpha} = -\Phi^{-1}(\alpha|\Im_t)$$

where V_t^{α} is VaR at time and at a significance level α, $\Phi^{-1}(.)$ is the inverse of the conditional cumulative distribution function of the returns, $\Im_t$ is the information set available at time *t*.

ES, on the other hand, is the expected value of the losses exceeding VaR and can be formulated as follows;

$$ES_t^{\alpha} = -\mathbb{E}(r_{t+1}|r_{t+1} < -V_t^{\alpha})$$

where ES_t^{α} is ES at time *t* and at a significance level α, $\mathbb{E}(.)$ is the expected value operator and r_{t+1} is the portfolio return at *t*+1.

2.1. Parametric Approach

The first group of VaR/ES models assumes the profit/loss distribution of the portfolio follows a parametric distribution. If we assume the portfolio/loss distribution follows a normal distribution, the estimation of VaR simply requires fitting the normal distribution to the historical data. The normal distribution is defined by mean and the standard deviation;

$$r_t \sim N(\mu_t, \sigma_t)$$

where μ_t is the mean and σ_t is the standard deviation. Therefore, to fit the normal distribution to a data set, one needs to estimate these two parameters. Referring to the market efficiency hypothesis, it is also quite common to assume $\mu = 0$; in this case, VaR calculation would only require the estimation of standard deviation.

After fitting the normal distribution, VaR can be calculated as;

$$V_t^{\alpha} = z_{\alpha} \cdot \sigma_t \cdot \mathbb{V}_t$$

where z_{α} is the threshold value for significance level α calculated using the inverse CDF of normal distribution and $\mathbb{V}_t$ is the present value of the financial assets at time .

Since standard deviation or the volatility is the key element of the parametric approach, a difference in the volatility estimation between VaR calculations imply a different parametric VaR model. This study reports the results of the parametric VaR uses moving average (MA), exponentially moving average (EWMA) and generalised autoregressive heteroscedacity (GARCH) (Bollerslev, 1986) volatility estimators.

Under the normal distribution assumption ($N(0, \sigma_t)$), similar to VaR, ES can also be calculated analytically as;

$$ES_t^{\alpha} = -\frac{\sigma_t}{1-\alpha} \cdot \phi(\Phi^{-1}(\alpha)) \cdot \mathbb{V}_t$$

where $\phi(.)$ probability density function and $\Phi^{-1}(.)$ is the inverse cumulative density function.

2.2. Simulation-based Approaches

The second class of VaR/ES calculation approaches is the simulation-based approach which relies on scenario creation and evaluation for generating the profit/loss distribution. Therefore, the general algorithm for all methods under this category shares the following common steps;

i. Generate the market scenario with the corresponding fx rates, yield curves etc.

ii. Calculate the value change of the portfolio under each scenario

iii. Calculate the desired percentile of the value changes (profit/loss) for VaR

iv. Calculate the mean of the losses exceeding VaR for ES

Then the differences between alternative simulation-based approaches arise in the way how a certain step above is implemented.

2.2.1. Historical Simulation

The main assumption of the historical simulation is that the best representation of the possible market scenarios that may occur in the next time horizon is the past movements of the risk factors.

For calculating under the historical simulation method, first, the past risk factor movements need to be calculated. Then the series of the past returns can be defined as;

$$\{x_{i,n}\} = \left\{ \ln\left(\frac{p_{i,t-n}}{p_{i,t-k-n}}\right) \right\}_{n=0}^{h-1}$$

where $\{x_{i,n}\}$ is the return series of the i-th risk factor, $p_{i,t}$ is the market value of the i-th risk factor (e.g. FX rate) at time *t*, *k* is the time horizon for the returns and *h* is the number of scenarios. Then the scenario series;

$$\{s_{i,n}\} = \{p_{i,T} e^{x_{i,n}}\}_{n=0}^{h-1}$$

where $\{s_{i,n}\}$ is the series of scenarios for the i-th risk factor projecting *k*-days ahead and $p_{i,T}$ is the most recent value of the i-th risk factor. The next step is to ccalculate implied profit loss for each scenario. Then, the profit/loss series can be defined as;

$$\{R_n\}_{n=0}^{h-1} = \{V(\boldsymbol{s}_n) - \mathbb{V}_t\}_{n=0}^{h-1}$$

where $\{R_n\}$ is the series of profit or losses projecting *k*-days ahead, $\boldsymbol{s}_n$ series of vectors contain scenario values of each risk factor, $v(.)$ valuation function and $\mathbb{V}_t$ is the current value of the portfolio.

Finally, VaR, then, is the desired percentile of the profit/loss series;

$$V_t^{\alpha} = -\mathbb{P}(\{R_n\}, \alpha)$$

where $\mathbb{P}(.)$ is the percentile function and α is the significance level. ES, under the historical simulation method, can be calculated by taking the average of the losses that exceed;

$$ES_t^{\alpha} = -\frac{\sum_{n=0}^{h} R_n I_{V_t^{\alpha}}(R_n)}{\sum_{n=0}^{h} 1_{V_t^{\alpha}}(R_n)}$$

where $I_{V_t^{\alpha}}(.)$ Is defined as follows;

$$I_{V_t^{\alpha}}(r) := \begin{cases} 1, & r \leq -V_t^{\alpha} \\ 0, & r > -V_t^{\alpha} \end{cases}$$

Although the historical simulation is a relatively straightforward way to calculate VaR, one of the main disadvantages is having few observations in the profit/loss distribution tails. For instance, if is estimated using 252 scenarios (with 1-year data) and under 99% significance level; 1% tail of the distribution will be represented by the worst 3 scenarios. Therefore, if the dataset covers a relatively low volatile period, then it will tend to underestimate the risk. Similarly, if the dataset is of a high volatility period, would overestimate the risk. In addition, the historical simulation implicitly treats all the scenarios equally likely to occur in the next time horizon; therefore, if there is a significant volatility increase in the market, the historical simulation is slow to respond.

2.2.2. Filtered Historical Simulation

Hull and White (1998) introduced a volatility adjustment scheme for the realisation of the daily changes in the risk factors. Following a similar notion, Barone-Adesi et al. (1999) developed a more general form of the same adjustment mechanism for n-day changes and called this method as Filtered Historical Simulation (FHS).

In line with the conditional heteroscedasticity models, under the FHS method, the changes in the risk factors are standardised using the volatility estimate of that day;

$$e_t = \frac{x_t}{\sigma_t}$$

where e_t is the standardised return, x_t is the change in the risk factor at time *t* and σ_t is the volatility estimate at time *t*. Then, the adjusted changes can be derived as;

$$x_t^* = \sigma_T e_t$$

where x_t^* is the volatility adjusted return derived using the return at time t and σ_T is the current estimate of volatility. Finally, the adjusted returns are translated into scenarios;

$$\{s_{i,n}\} = \{p_{i,T}e^{x^*_{i,n}}\}_{n=0}^{h-1}$$

The rest of the calculation follows the same steps as the standard historical simulation method described in the previous subsection.

2.2.3. Weighted Historical Simulation

Another method that attempts to improve the performance of the historical simulation is the weighted historical simulation (WHS) developed by Boudoukh et al. (1998). The WHS method follows the same steps for generating scenarios and deriving the profit/loss distribution as the standard historical simulation. However, in the calculation of the percentile, opposed to the regular percentile calculation where implicitly all the scenarios are treated as equally likely, WHS implements a time-dependent weighting scheme.

WHS uses a decaying weighting for the scenarios based on the date of the realised returns used in the derivation of that particular scenario. The weight of each scenario in WHS is defined as;

$$w_t = \frac{1-\lambda}{1-\lambda^T}\lambda^{T-t}; \qquad for\ t = 1 \dots T$$

where λ is the decay factor. Boudoukh et al. (1998) compare results of WHS using two values for the decay factor; 0.97 and 0.99. In this study, the results are calculated by setting the decay factor to 0.99.

2.2.4. Bootstrapped Historical Simulation

Bootstrapping is a technique in statistics for increasing the sample size by replacing the existing observations and re-sampling. The use of bootstrap techniques in VaR was relatively less popular, mainly due to the fact that re-shuffling of the observations makes better sense when VaR is calculated for a time horizon longer than 1-day. Zenti and Pallotta (2000) have implemented bootstrapping for multi-day time horizons in one of the early studies. Since the new Basel IV increases the calculation time horizon for VaR/ES to 10-days; the use of the Bootstrapped Historical Simulation (BHS) might become more popular.

Under the BHS method, the daily returns constitute the pool of samples. Then, for creating an n-day scenario, n daily returns are randomly drawn from the pool; and converted to n-day returns (in the case of logarithmic returns simply by summation).

2.2.5. Monte Carlo Simulation

The Monte Carlo simulation method for VaR/ES as well follows the same notion and incorporates stochastic processes for modelling the movement of the risk factors. Apart from the way how the scenarios are generated, the Monte Carlo simulation for VaR/ES follows the same steps as the historical simulation.

There are several different stochastic processes developed for different classes of risk factors. However, for the asset prices such as commodities, stocks and FX rates, the most commonly used model is the geometric Brownian motion (GBM) [1] which is shown in the following equation;

$$\hat{x}_{t+\delta} = \left(\mu - \frac{1}{2}\sigma^2\right)\delta + \sigma\varepsilon\sqrt{\delta}$$

where $\hat{x}_{t+\delta}$ is the simulated return from *t* to $t+\delta$, δ , is the time increment with $0 < \delta < 1$, μ is the average return of the risk factor, σ is the volatility of the risk factor, and ε is random with $\varepsilon \sim N(0,1)$.

Then a scenario price that is produced by the process can be shown as;

$$s_{t+\delta} = s_t e^{\hat{x}_{t+\delta}}$$

By repeating the same process $1/\delta$ times, the scenario process for the next day (or next time interval) can be produced. Therefore, after $1/\delta$ iterations, one scenario can be produced for VaR/ES calculation; however, by repeating the whole experiment many times, thousands of scenarios can be generated. In this study, a business day is represented by 100 iterations, therefore δ is set to 1/100.

2.3. New Measure: Unexpected Shortfall

ES delivers a better risk buffer than VaR by taking to account the possibility of extreme events in the tail of the profit loss distribution. However, ES as well limited to the observed historical data and does not extrapolate the magnitude of the potential losses. As per its definition, ES deals with the expected value of the losses exceeding VaR, therefore does not aim to project the unexpected.

The shortfall, by definition, is observed on the violation days. Therefore, the realised shortfalls can be used for modelling the distribution of the shortfall conditionally on a VaR estimate. However, considering the heteroscedasticity of VaR and ES, instead of the nominal shortfall, it would be preferable to define the shortfall as a magnitude relative to VaR. Then the shortfall magnitude can be defined as;

1 Glasserman (2004) can be seen for extensive review of stochastic processes in finance and particularly for the derivation of GBM.

$$SM_t = 1 - \frac{R_t}{V_t^{\alpha}} \qquad for\ R_t < -V_t^{\alpha}$$

By definition *SM*, will take values from zero to positive infinity. Intuitively, it is expected that *SM* follows a left-skewed size distribution. In the context of credit risk, CreditRisk+ [2] framework uses gamma distribution to model the severity multiplier of the losses (Gordy, 2002) which is conceptually very similar to *SM* . The actuarial models as well use gamma distribution for modelling the size of the losses (Kleiber & Kotz, 2003). If we assume *SM* follows a gamma distribution, then we can calculate a VaR like unexpected shortfall magnitude (USM) at a certain significance level.

$$USM_t = -\Gamma^{-1}(k, \theta, \gamma)$$

where k and θ are the shape and scale parameters of the gamma distribution and γ is the significance level of *USM*. The unexpected shortfall magnitude indicates the highest shortfall magnitude under the chosen significance level. The final step is to convert this magnitude of shortfall to the nominal loss amount, then the unexpected loss can be shown as;

$$US_t = (1 + USM_t) \cdot V_t^{\alpha}$$

The current BCBS framework requires the banks to calculate the VaR at a 1% significance level. Basel IV, on the other hand, mandates an ES calculation under 2.5% significance level. As far as US is concerned, there are 2 confidence levels involved; the first one for the underlying VaR, and the second is the significance level of the measure itself.

In this study, 2 sets of confidence levels are considered. The first set uses Basel IV's 2.5% significance level assumption for shortfall observations and combines it with 1% for US. The second set uses, 5% and 1% respectively.

3. Model Validation and Comparison

3.1. Backtesting

Since there are many methodologies to calculate VaR, validation of VaR is essential and an integral part of the capital adequacy framework. The process to measure the performance of VaR estimates and validate their statistical significance is called backtesting. The procedure involves the comparison between VaR estimate and the realised profit/loss.

Backtesting methodologies check if the violation series – derived from VaR and the realised profit/loss series – fits into the expected statistical properties of such series. A violation occurs when the realised loss is larger than VaR calculated for a certain day. Then, the violation series can be defined as;

2 CreditRisk+ is a well-known Credit VaR methodology introduced by Credit Suisse.

$$\{I_t\}_{t=0}^{H} = I_t = \begin{cases} 1, & R_t \leq -V_t^{\alpha} \\ 0, & R_t > -V_t^{\alpha} \end{cases}$$

where I_t is an indicator function, R_t is the realised return at time t, H is the number of days used in backtesting and V_t^{α} is VaR calculated for time t. Then the expected value of the I_t is equal to α, the significance level of VaR.

Kupiec (1995) introduced a statistical test focusing on the distance between the observed density of the violations and the assumed density. Christoffersen (1998) improved the idea by introducing a likelihood ratio test of conditional coverage which would be applied to the smaller samples. The likelihood ratio of both unconditional coverage (UC) and conditional coverage (CC) follows a Chi distribution asymptotically with degrees of freedom 1 and 2 respectively.

3.2. Reality Check

Basel IV mandates the use of VaR for validating ES-derived capital adequacy numbers, but the horizon of the calculation is not consistent with the backtest either. In the literature, unfortunately, this aspect seems to be neglected and no study investigated backtesting VaR or ES results with a longer horizon (i.e 10-day). Considering, that the capital requirement aims to be a buffer for the potential losses, in this study, the results are compared against both the realised return after 10-days and the maximum loss born in the same time interval.

4. Empirical Analysis

4.1. Data

Sample data consists of 3 pairs of FX rates and 1 crypto currency price from January 2014 to March 2022. The FX rates comprise 1 hard currency pair (EUR/USD) and 2 emerging market pairs (USD/TRY & EUR/TRY). On the other hand, the cryptocurrency analysed is BTC (BTC/USD). All the data is obtained from Yahoo Finance.

Table 1 shows the descriptive statistics of all 4 data sets used. The sample data represents different volatility profiles. Both the standard deviation and the range of the returns indicates that EUR/USD is less volatile while TRY rates shows higher volatility and BTC is the most volatile. This allows comparing the performance of the models under both high and low volatility. TRY pairs exhibit positive skewness and therefore more extreme values on the positive tail of the distribution.

Table 1: Descriptive Statistics of Daily Logarithmic Returns

	EUR/USD	USD/TRY	EUR/TRY	BTC/USD
Mean	-0.0089%	0.0973%	0.0871%	0.2439%
Median	-0.0088%	0.0365%	0.0386%	0.2001%
St. Dev.	0.4875%	1.2596%	1.2539%	3.8827%
Min	-2.7752%	-18.8638%	-17.8132%	-37.1695%
Max	2.8545%	22.7990%	20.9004%	25.2472%
Skewness	(0.0370)	1.7485	1.2498	(0.1357)
Excess Kurtosis	3.1957	83.2896	66.1116	7.2491
Count	2,149	2,149	2,150	2,753

The descriptive statistics of 10-daily logarithmic returns are shown in Table 2. In general, 10-daily returns exhibit the same features as the daily returns. However, the mean and the medians seem to diverge from zero for all series except EUR/USD. As it would be expected, another difference is that the standard deviations for all return series are higher.

Table 2: Descriptive Statistics of 10-Daily Logarithmic Returns

	EUR/USD	USD/TRY	EUR/TRY	BTC/USD
Mean	-0.0886%	0.9774%	0.8749%	2.5204%
Median	-0.0883%	0.5685%	0.5045%	1.4584%
St. Dev.	1.4552%	4.0406%	3.9717%	12.8479%
Min	-7.1710%	-21.9982%	-21.9372%	-45.0320%
Max	5.7399%	42.4045%	38.4444%	82.3086%
Skewness	(0.1098)	2.4040	2.0679	0.5393
Excess Kurtosis	1.4720	19.8108	16.0880	1.8901
Count	2,140	2,140	2,141	2,744

4.2. Backstest Result

The results in this section are calculated using 1512 daily VaR calculations at 99% significance level and 1-day liquidity horizon. Therefore, the expected value of the number of violations is 15.12.

Table 3 displays the likelihood ratio test results for EUR/USD. Considering a 10% significance level for the likelihood ratio test, 6 out of 11 models can pass the test for both unconditional coverage and conditional coverage tests. The historical simulation model can pass the likelihood ratio test only for conditional coverage.

Table 3: LR Tests of EUR/USD VaR 99% with 1-Day Liquidity Horizon

VaR Method	Violations	UC Test	UC Prob	CC Test	CC Prob
FHS EWMA	27	7.64	0.57%	8.66	1.31%
FHS GARCH	26	6.51	1.07%	7.45	2.41%
FHS MA	24	4.47	3.45%	5.28	7.15%
HIS	23	3.58	5.86%	4.32	11.54%
MC EWMA	21	2.06	15.12%	2.68	26.18%
MC GARCH	25	5.45	1.96%	6.32	4.24%
MC MA	21	2.06	15.12%	2.68	26.18%
PAR EWMA	19	0.93	33.49%	1.44	48.69%
PAR GARCH	22	2.77	9.59%	3.45	17.80%
PAR MA	21	2.06	15.12%	2.68	26.18%
WHS	10	1.99	15.85%	2.14	34.38%

The likelihood ratio test results for USD/TRY are shown in Table 4. Majority of the models pass the LR tests for USD/TRY. The historical simulation model passes the unconditional coverage test, but fails the conditional coverage. It is also interesting to note that FHS MA models fails due to having more violations than expected, but WHS contrarily fails as it has too few violations.

Table 4: LR Tests of USD/TRY VaR 99% with 1-Day Liquidity Horizon

VaR Method	Violations	UC Test	UC Prob	CC Test	CC Prob
FHS EWMA	19	0.93	33.49%	1.44	48.69%
FHS GARCH	17	0.23	63.38%	0.64	72.74%
FHS MA	24	4.47	3.45%	5.23	7.33%
HIS	21	2.06	15.12%	6.66	3.58%
MC EWMA	11	1.25	26.31%	1.43	48.95%
MC GARCH	19	0.93	33.49%	1.44	48.69%
MC MA	16	0.05	82.17%	0.41	81.28%
PAR EWMA	10	1.99	15.85%	2.14	34.38%
PAR GARCH	17	0.23	63.38%	0.64	72.74%
PAR MA	16	0.05	82.17%	0.41	81.28%
WHS	6	7.20	0.73%	7.26	2.65%

The results for EUR/TRY data display more violations, and therefore less models pass the unconditional coverage test. However, 9 out of 11 models pass the conditional coverage test. This is largely because the violation numbers do not diverge largely from the expected values and independence criteria is satisfied.

Table 5: LR Tests of EUR/TRY VaR 99% with 1-Day Liquidity Horizon

VaR Method	Violations	UC Test	UC Prob	CC Test	CC Prob
FHS EWMA	23	3.58	5.86%	4.32	11.54%
FHS GARCH	14	0.09	76.94%	0.37	83.26%
FHS MA	22	2.77	9.59%	3.45	17.80%
HIS	25	5.45	1.96%	17.57	0.02%
MC EWMA	9	2.93	8.71%	3.05	21.80%
MC GARCH	17	0.23	63.38%	2.02	36.42%
MC MA	21	2.06	15.12%	2.68	26.18%
PAR EWMA	9	2.93	8.71%	3.05	21.80%
PAR GARCH	17	0.23	63.38%	2.02	36.42%
PAR MA	19	0.93	33.49%	1.44	48.69%
WHS	3	14.63	0.01%	14.65	0.07%

The results for BTC/USD are displayed in Table 6. None of the VaR models can pass both of the likelihood ratio tests. Only WHS pass the conditional coverage test, however the rest of the models yielded quite large numbers of violations.

Table 6: LR Tests of BTC/USD VaR 99% with 1-Day Liquidity Horizon

VaR Method	Violations	UC Test	UC Prob	CC Test	CC Prob
FHS EWMA	33	15.97	0.01%	20.34	0.00%
FHS GARCH	25	5.45	1.96%	6.10	4.73%
FHS MA	32	14.41	0.01%	19.09	0.01%
HIS	31	12.92	0.03%	14.95	0.06%
MC EWMA	39	26.53	0.00%	26.58	0.00%
MC GARCH	45	39.00	0.00%	39.16	0.00%
MC MA	44	36.80	0.00%	38.67	0.00%
PAR EWMA	35	19.26	0.00%	19.35	0.01%
PAR GARCH	34	17.58	0.00%	17.70	0.01%
PAR MA	36	20.99	0.00%	22.22	0.00%
WHS	8	4.09	4.32%	4.18	12.34%

In the second part of this section, the likelihood ratio test results for VaR under 97.5% significance level and with a 10-day liquidity horizon are displayed. Considering there are 1512 data points, the expected value of the number of violations is 37.8 instances.

EUR/USD results exhibit dramatical differences from the 1-day VaR results calculated at 99%. Only FHS GARCH, MC EWMA and BHS models pass the unconditional coverage test and all models fail the conditional coverage test.

Table 7: LR Tests of EUR/USD VaR 97.5% with 10-Day Liquidity Horizon

VaR Method	Violations	UC Test	UC Prob	CC Test	CC Prob
FHS EWMA	50	3.67	5.53%	146.04	0.00%
FHS GARCH	40	0.13	71.96%	21.33	0.00%
FHS MA	50	3.67	5.53%	173.75	0.00%
HIS	55	7.05	0.79%	237.06	0.00%
MC EWMA	31	1.34	24.79%	67.02	0.00%
MC GARCH	27	3.51	6.10%	14.42	0.07%
MC MA	106	85.40	0.00%	317.96	0.00%
PAR EWMA	28	2.86	9.09%	66.72	0.00%
PAR GARCH	25	5.04	2.48%	17.16	0.02%
PAR MA	108	89.76	0.00%	330.62	0.00%
WHS	23	6.89	0.86%	93.61	0.00%
BHS	35	0.22	64.05%	137.91	0.00%

USD/TRY results are also parallel to EUR/USD. FHS GARCH and BHS models pass the unconditional coverage test. However, none of the models passes the conditional coverage test.

Table 8: LR Tests of USD/TRY VaR 97.5% with 10-Day Liquidity Horizon

VaR Method	Violations	UC Test	UC Prob	CC Test	CC Prob
FHS EWMA	49	3.12	7.75%	131.21	0.00%
FHS GARCH	37	0.02	89.48%	34.99	0.00%
FHS MA	49	3.12	7.75%	148.76	0.00%
HIS	56	7.85	0.51%	212.53	0.00%
MC EWMA	2	60.71	0.00%	60.71	0.00%
MC GARCH	18	13.16	0.03%	24.37	0.00%
MC MA	56	7.85	0.51%	157.13	0.00%
PAR EWMA	1	67.25	0.00%	67.25	0.00%
PAR GARCH	15	18.22	0.00%	47.28	0.00%
PAR MA	55	7.05	0.79%	150.96	0.00%
WHS	22	7.95	0.48%	77.37	0.00%
BHS	35	0.22	64.05%	148.61	0.00%

The models performed slightly better with EUR/TRY data. Half of the models pass the unconditional coverage test and produced violation numbers reasonably close to the expected value. However, again all the models failed in the conditional coverage test.

Table 9: LR Tests of EUR/TRY VaR 97.5% with 10-Day Liquidity Horizon

VaR Method	Violations	UC Test	UC Prob	CC Test	CC Prob
FHS EWMA	41	0.27	60.30%	117.36	0.00%
FHS GARCH	39	0.04	84.41%	38.57	0.00%
FHS MA	37	0.02	89.48%	111.09	0.00%
HIS	52	4.91	2.68%	206.67	0.00%
MC EWMA	1	67.25	0.00%	67.25	0.00%
MC GARCH	15	18.22	0.00%	39.07	0.00%
MC MA	47	2.13	14.40%	174.13	0.00%
PAR EWMA	1	67.25	0.00%	67.25	0.00%
PAR GARCH	14	20.17	0.00%	42.28	0.00%
PAR MA	43	0.70	40.18%	168.65	0.00%
WHS	26	4.24	3.96%	91.64	0.00%
BHS	37	0.02	89.48%	120.48	0.00%

BTC/USD data confirms the same message. This time WHS passes the unconditional coverage test, but none of the models pass the conditional coverage.

Table 10: LR Tests of BTC/USD VaR 97.5% with 10-Day Liquidity Horizon

VaR Method	Violations	UC Test	UC Prob	CC Test	CC Prob
FHS EWMA	56	7.85	0.51%	132.56	0.00%
FHS GARCH	92	57.28	0.00%	144.97	0.00%
FHS MA	62	13.36	0.03%	130.29	0.00%
HIS	69	21.31	0.00%	268.04	0.00%
MC EWMA	28	2.86	9.09%	75.39	0.00%
MC GARCH	57	8.68	0.32%	48.00	0.00%
MC MA	114	103.30	0.00%	353.58	0.00%
PAR EWMA	15	18.22	0.00%	47.28	0.00%
PAR GARCH	53	5.58	1.81%	39.28	0.00%
PAR MA	91	55.44	0.00%	293.72	0.00%
WHS	43	0.70	40.18%	95.40	0.00%
BHS	58	9.54	0.20%	187.28	0.00%

4.3. Reality Check Results

In this section, VaR and ES results are compared using the realised shortfall. The results display the accumulated difference between the risk measure and the realised loss when the loss exceeds the amount predicted by the measure. Since the required base liquidity horizon is 10 days, the losses are derived using 10-day returns.

If the bank would have used the risk measure as a direct indicator of the capital buffer without any adjustments, how much loss would have been accumulated during the analysis period (last 1250 observation).

Table 11: Cumulative Realised Shortfall with 10-Day Returns

		EUR/USD	USD/TRY	EUR/TRY	BTC/USD
FHS EWMA	VaR @99	-5.51%	-11.16%	-9.79%	-79.91%
	ES @97.5	-5.15%	-10.67%	-10.65%	-88.53%
FHS GARCH	VaR @99	-4.44%	-14.62%	-16.49%	-231.10%
	ES @97.5	-4.78%	-14.45%	-16.02%	-191.70%
FHS MA	VaR @99	-5.16%	-16.80%	-18.12%	-102.53%
	ES @97.5	-5.60%	-15.92%	-18.19%	-101.96%
HS	VaR @99	-21.82%	-92.07%	-89.47%	-245.37%
	ES @97.5	-21.14%	-90.30%	-90.87%	-245.96%
MC EWMA	VaR @99	-1.27%	0.00%	0.00%	-44.64%
	ES @97.5	-0.85%	0.00%	0.00%	-41.51%
MC GARCH	VaR @99	-3.44%	-7.89%	-8.23%	-146.93%
	ES @97.5	-3.38%	-7.16%	-7.09%	-140.71%
MC MA	VaR @99	-17.95%	-19.47%	-31.79%	-288.80%
	ES @97.5	-16.89%	-17.65%	-30.06%	-277.03%
PAR EWMA	VaR @99	-0.64%	0.00%	0.00%	-15.38%
	ES @97.5	-0.62%	0.00%	0.00%	-14.51%
PAR GARCH	VaR @99	-2.86%	-5.86%	-7.13%	-113.00%
	ES @97.5	-2.76%	-5.68%	-6.93%	-110.73%
PAR MA	VaR @99	-15.52%	-15.95%	-27.55%	-180.74%
	ES @97.5	-15.16%	-15.52%	-26.96%	-176.00%
WHS	VaR @99	0.00%	-8.03%	-8.62%	-59.85%
	ES @97.5	-2.09%	-37.54%	-26.84%	-109.23%
BHS	VaR @99	-13.95%	-38.21%	-27.69%	-211.16%
	ES @97.5	-13.75%	-37.05%	-26.07%	-212.03%
FHS EWMA	VaR @99	-5.51%	-11.16%	-9.79%	-79.91%
	ES @97.5	-5.15%	-10.67%	-10.65%	-88.53%

VaR@99, VaR at 99% significance level; ES@97.5, ES at 97.5% significance level.

Although the BCBS requires banks to calculate the risk measure for a liquidity horizon of 10-days, the 10-day returns don't reflect the worst loss during each 10-day period. Table 12 reports the cumulative shortfalls calculated using the maximum loss. The results indicate that the potential losses during the liquidity horizon could be quite larger than the simple return value.

Table 12: Cumulative Realised Shortfall with 10-Day Min-Max Returns

		EUR/USD	USD/TRY	EUR/TRY	BTC/USD
FHS EWMA	VaR @99	-8.81%	-176.46%	-243.12%	-361.21%
	ES @97.5	-8.45%	-165.55%	-240.36%	-354.50%
FHS GARCH	VaR @99	-26.05%	-89.64%	-84.16%	-511.34%
	ES @97.5	-25.98%	-73.80%	-82.29%	-406.15%
FHS MA	VaR @99	-21.93%	-313.71%	-250.28%	-1013.44%
	ES @97.5	-21.33%	-288.70%	-250.90%	-988.50%
HS	VaR @99	-19.48%	-652.86%	-584.25%	-1056.47%
	ES @97.5	-18.89%	-621.74%	-568.03%	-1071.18%
MC EWMA	VaR @99	-1.94%	-18.97%	-21.09%	-79.89%
	ES @97.5	-1.75%	-18.24%	-19.49%	-74.02%
MC GARCH	VaR @99	-16.89%	-38.93%	-38.54%	-285.09%
	ES @97.5	-16.12%	-37.76%	-37.18%	-273.47%
MC MA	VaR @99	-40.60%	-301.39%	-255.95%	-1483.90%
	ES @97.5	-37.75%	-290.08%	-249.37%	-1448.46%
PAR EWMA	VaR @99	-1.35%	-9.47%	-9.90%	-22.44%
	ES @97.5	-1.27%	-9.00%	-9.43%	-21.36%
PAR GARCH	VaR @99	-14.71%	-35.56%	-34.28%	-225.41%
	ES @97.5	-14.33%	-34.93%	-33.56%	-221.50%
PAR MA	VaR @99	-36.89%	-271.47%	-228.15%	-1148.59%
	ES @97.5	-36.12%	-267.21%	-223.80%	-1131.80%
WHS	VaR @99	-16.39%	-563.72%	-524.59%	-886.77%
	ES @97.5	-15.34%	-598.10%	-545.05%	-1013.94%
BHS	VaR @99	-15.37%	-475.13%	-383.86%	-1201.36%
	ES @97.5	-15.18%	-467.11%	-375.13%	-1160.55%
FHS EWMA	VaR @99	-8.81%	-176.46%	-243.12%	-361.21%
	ES @97.5	-8.45%	-165.55%	-240.36%	-354.50%

Note: VaR@99, VaR at 99% significance level; ES@97.5, ES at 97.5% significance level.

4.4. Unexpected Shortfall Results

In this section, the unexpected shortfall results are reported. The results consist of the outcome of 2 significance level pairs.

Table 13 shows the US results for EUR/USD. Shortfall column displays the total of the realised losses exceeding the US for the entire analysis period of 1250 days. The number of US violations, similarly, shows the number of days where the realised loss was larger than the estimated US. Since, the US results are calculated at 99% significance level, it is expected 1 loss will exceed US out of 100 VaR violations. Therefore, when the VaR exhibit less violation, the expected number of the US violations will also be smaller. The expected number of US violations for the US measure which uses 97.5% VaR estimates is 0.3125. On the other hand, the US measure which uses 95% VaR has twice as many expected US violations, 0.625. In the light of these expected values, PAR MA result seems to produce too many US violations. The other models produce less than or equal to 2 US violations.

Table 13: US Results for EUR/USD

Model	US Sig Level	Shortfall	# of US Violation
FHS EWMA	US@97.5/99	0.00%	0
	US@95/99	-0.04%	1
FHS GARCH	US@97.5/99	0.00%	0
	US@95/99	-0.21%	1
FHS MA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
HS	US@97.5/99	-0.28%	1
	US@95/99	-1.28%	2
MC EWMA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
MC GARCH	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
MC MA	US@97.5/99	-0.07%	2
	US@95/99	-0.47%	2
PAR EWMA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
PAR GARCH	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
PAR MA	US@97.5/99	-0.02%	1
	US@95/99	-0.41%	5
WHS	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
BHS	US@97.5/99	0.00%	0
	US@95/99	-0.08%	1

Note: US@97.5/99, US using VaR results at 97.5% significance level and calculated at 99% significance level; US@95/99, US using VaR results at 95% significance level and calculated at 99% significance level.

Both USD/TRY and EUR/TRY results for US produced the US violations less than or equal to 2 violations. The results also exhibit the expected feature of having less US violations for US@97.5/99 results.

Table 14: US Results for USD/TRY

Model	US Sig Level	Shortfall	# of US Violation
FHS EWMA	US@97.5/99	-0.12%	1
	US@95/99	-0.56%	2
FHS GARCH	US@97.5/99	0.00%	0
	US@95/99	-0.31%	1
FHS MA	US@97.5/99	0.00%	0
	US@95/99	-0.40%	1
HS	US@97.5/99	0.00%	0
	US@95/99	-0.99%	1
MC EWMA	US@97.5/99	0.00%	0

	US@95/99	0.00%	0
MC GARCH	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
MC MA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
PAR EWMA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
PAR GARCH	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
PAR MA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
WHS	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
BHS	US@97.5/99	0.00%	0
	US@95/99	0.00%	0

Note: US@97.5/99, US using VaR results at 97.5% significance level and calculated at 99% significance level; US@95/99, US using VaR results at 95% significance level and calculated at 99% significance level.

Table 15: US Results for EUR/TRY

Model	US Sig Level	Shortfall	# of US Violation
FHS EWMA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
FHS GARCH	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
FHS MA	US@97.5/99	0.00%	0
	US@95/99	-0.21%	2
HS	US@97.5/99	-0.01%	1
	US@95/99	-1.50%	2
MC EWMA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
MC GARCH	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
MC MA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
PAR EWMA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
PAR GARCH	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
PAR MA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
WHS	US@97.5/99	0.00%	0
	US@95/99	-1.16%	2
BHS	US@97.5/99	0.00%	0
	US@95/99	0.00%	0

Note: US@97.5/99, US using VaR results at 97.5% significance level and calculated at 99% significance level; US@95/99, US using VaR results at 95% significance level and calculated at 99% significance level.

The US measure produces promising results for BTC/USD as well. Again, all the violations are within the expected range. One major difference, however, is in the aggregate loss amount. Although, BTC/USD exhibits few US violations as the other dataset, the magnitude of the losses is much larger.

Table 16: US Results for BTC/USD

Model	US Sig Level	Shortfall	# of US Violation
FHS EWMA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
FHS GARCH	US@97.5/99	-10.51%	1
	US@95/99	-11.09%	1
FHS MA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
HS	US@97.5/99	-7.88%	1
	US@95/99	-8.84%	2
MC EWMA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
MC GARCH	US@97.5/99	-9.26%	1
	US@95/99	-12.40%	1
MC MA	US@97.5/99	-0.99%	1
	US@95/99	-3.68%	2
PAR EWMA	US@97.5/99	0.00%	0
	US@95/99	0.00%	0
PAR GARCH	US@97.5/99	-6.81%	1
	US@95/99	-10.38%	1
PAR MA	US@97.5/99	-0.35%	1
	US@95/99	-1.53%	1
WHS	US@97.5/99	-2.92%	1
	US@95/99	-3.78%	1
BHS	US@97.5/99	0.00%	0
	US@95/99	-0.69%	1

Note: US@97.5/99, US using VaR results at 97.5% significance level and calculated at 99% significance level; US@95/99, US using VaR results at 95% significance level and calculated at 99% significance level.

5. Conclusion

The Basel IV reforms replace VaR with ES as the primary risk measure for the internal model approach. In this study, a capital measure unexpected shortfall is proposed as an alternative. The replacement of VaR with the ES addresses the problems related to the fat tails. However, similar to VaR itself, ES as well forecasts the risks as much as it has been observed in the past. In addition, the capital requirement amount is expected to provide a cushion for financial institutions. Neither VaR nor ES is directly translated into a capital requirement. Because, by definition, both measures

are expected to fail a number of times that is not acceptable for a safety cushion. Therefore, BCBS uses an arbitrary mechanism to transform the VaR results into capital requirement amounts. This calculation makes use of an average of the last 60 days of VaR, stressed VaR and some multipliers. Basel IV as well defines an arbitrary process for deriving the capital requirement from the ES results.

The proposed risk measure, the unexpected shortfall, addresses both of these issues. First, it allows extrapolating the violation information gathered from the VaR and forecasts the magnitude of upcoming shortfalls. Secondly, it delivers a measure suitable for the use of capital requirements without arbitrary transformations. In this study, the results for 99% US based on 95% VaR and 99% US based on 97.5% are displayed. The expected violation for these US estimates is 0.025% and 0.05% respectively. In a real capital requirement context, more conservative significance levels might be selected to reduce the possibility of a US violation near impossible. However, for the sake of demonstrating the approach, less conservative significance levels are selected, to allow observing US violations.

The results for US are very promising. Almost all the models generated US violations in a reasonably close range of the expected values. Although the underlying VaR analysis displayed a large number of violations for a 10-day liquidity horizon, the US measure in a way fixed the inaccuracy of the model and delivered a reasonable capital cushion. Similarly, the US measure seems to work with BTC/USD data as good as the other datasets. However, the magnitude of the US violation for BTC/USD is relatively higher than the others.

The findings in this study suggest that the replacement of VaR by ES may partially address the problems faced in the GFC. However, the new capital framework doesn't bring completely a new way of measuring the risk. In fact, the findings indicate that the results produced by both measures are quite parallel in many cases. This thesis also proposes an alternative way of approaching the problem; rather than modelling only the profit loss distribution, modelling the distribution of shortfall magnitude brings a new dimension.

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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

THE IMPACT OF INFORMATION AND COMMUNICATION TECHNOLOGIES ON ECONOMIC GROWTH: THE CASE OF SELECTED EUROPEAN COUNTRIES*

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Abstract

This paper investigates the impact of information and communication technologies on economic growth in 35 selected European countries during 2001-2021. With rapid advancements in information and communication technologies, understanding its influence on economic growth becomes imperative for policymakers and researchers alike. Utilizing a comprehensive dataset, this study employs rigorous econometric techniques to analyze the relationship between information and communication technologies indicators and economic growth indicators by applying system generalized method of moments method. According to the Levin–Lin–Chu unit root test, all variables are stationary at the I (0) level except TEL which is stationary at the I (1) level. According to the results of the two-step system generalized method of moments estimator, lagged GDP, telephone lines, mobile use, and internet usage positively affected GDP, although consumer price index, trade and final consumption expenditure affected negatively. In terms of significance of the effects, the effect of lagged GDP, consumer price index, final consumption expenditure and mobile use was significant, whereas the effect of trade, telephone lines and internet usage were not significant. The Arellano-Bond test showed that there is no autocorrelation, and according to the Sargan and Hansen tests results, the instrumental variables are appropriate and consistent in the model and the model has no speciation errors. From the results it can be concluded that information and communication technologies positively affected economic growth in 35 selected European countries. These findings strongly confirm the theoretical assumption that information and communication technologies are now a critical strategic aspect in assuring economic development and high long-term growth.

Keywords: ICT, Economic Growth, Panel Data Analysis, GMM, European countries
JEL Classification: O11, O20, O33, O40

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1. Introduction

Rapid advances in information and communication technologies (ICT) have transformed economies and societies around the world. In European countries, ICT has emerged as an important driver of economic growth, innovation, and competitiveness. Increasing integration and dependence on digital technologies has reshaped industries, increased productivity, and opened new avenues for socio-economic development. As a result, understanding the relationship between ICT and economic growth in European countries has become a critical issue for policymakers, researchers, and stakeholders.

This paper aims to investigate the effect of information and communication technologies on economic growth in 35 selected European countries during 2001-2021. By analyzing this relationship, we seek to shed light on the potential benefits and implications of ICT adoption for sustained economic development within the European countries' context. Understanding how ICT influences economic growth is essential for developing successful policies and strategies that leverage digital technologies to foster prosperity, innovation, and competitiveness.

Previous studies have examined the impact of ICT on economic growth, highlighting its role as a catalyst for productivity improvements and innovation. However, the specific context of the European countries necessitates a comprehensive examination of this relationship within the region. The European countries, with its diverse economic structures, varying levels of ICT adoption, and distinct policy frameworks, presents a unique environment to explore the nuances and dynamics of the ICT-economic growth nexus.

To achieve our research objectives, we have developed a comprehensive dataset including a set of ICT and economic growth indicators for 35 European countries. Using a system GMM approach, we aim to identify empirical evidence on the relationship between ICT and economic growth. The analysis considers key ICT indicators such as fixed telephone lines, mobile subscriptions, and internet users, alongside relevant economic growth indicators, such as gross domestic product (GDP).

This study's findings are expected to add to the existing research by offering useful insights on the role of ICT in promoting economic growth in European countries. Furthermore, the empirical information gathered will educate policymakers, stakeholders, and researchers on the potential benefits, challenges, and policy implications of ICT adoption for long-term economic development. Policymakers may design focused plans and programs that utilize the transformative power of ICT to boost productivity, build innovation ecosystems, and promote inclusive growth by understanding the specific dynamics inside the European countries' context.

In the following parts, we will describe the methodology used, discuss the empirical analysis and results, interpret the findings, and finish with policy implications and future research avenues. We hope that by conducting this extensive analysis, we will contribute to a better understanding of the complicated relationship between information and communication technologies and economic growth in European countries, providing insights that can drive evidence-based decision-making in the digital era.

2. Literature Review

The relationship between ICT and economic growth has been an important research topic in the growth literature for the last 20 years. It is observed that the first studies on this subject have been conducted in developed countries since the mid-1990s, when the aforementioned technologies emerged. However, as economic activities gained a global dimension and started to find widespread use in national and international activities, the effects of ICTs, whose economic efficiency increased in developing countries, started to be investigated in developing countries since the beginning of the 2000s. The general finding of these studies, which benefited from data and panel data approaches, is that ICTs make a positive contribution to growth in developed and developing countries, although their direction and size differ according to the period of study, the econometric analysis method applied and the level of development of the countries under consideration.

Haldar et al. (2023) examined the effect of ICT on economic growth for 16 emerging economies between 2000 and 2018. According to the findings, internet-use, which is one of ICT components, increases economic growth significantly in the lower and middle-income quantiles of the emerging economies. Colecchia and Schreyer (2002) studied the effect of information and communication technology capital accumulation on economic growth in 9 OECD member countries (Australia, France, Germany, Canada, France, Italy, Japan, USA, and England) for the period 1980-2000 with the growth accounting approach. They found that the investments made in these technologies make a positive contribution to economic growth, and this contribution varies between 0.2% and 0.5% annually depending on the disparities in the economic systems of the countries studied.

By using a panel of 123 countries – 45 high-income countries, 58 middle-income countries, and 20 low-income countries from the period 2002 to 2017, Appiah-Otoo and Song (2021) investigated the possible effect of ICT on economic growth. The findings show that ICT increases economic growth in these countries. Pohjola (2002) investigated the impact of ICT investments on economic growth for 39 developed and developing countries. According to the results of the regression analysis covering the 1980-1995 period, it was concluded that when developed and developing nations were analyzed jointly, ICT investments had a considerable effect on economic growth in developed countries but not in developing countries.

Kurniawati (2022) investigated the causal association between ICT and economic growth in high – and middle-income Asian countries utilizing data from 25 Asian countries from 2000 to 2018. According to the findings, rising Internet penetration has resulted in good and significant economic development in high-income Asian countries. In addition, middle-income countries are beginning to realize the benefits of ICT Internet. The findings showed that increasing telephone line and mobile phone penetration can increase economic growth in middle-income Asian countries. In his study on the Turkish economy, Dağdelen (2002) investigated the contribution of the use and production of information and communication technologies to economic growth.

According to the EKK analysis performed using annual time series data, although it is quite weak, information and communication technologies positively affect growth in Turkiye.

In their research, Brodny and Tutak (2022) found that an increase in ICT leads economic growth to increase in EU-27 countries. From 2001 to 2012, the causal linkages between information and communication technology (ICT) infrastructure and economic growth in Asian countries were studied. It was concluded that these variables have been determined to be cointegrated with various short and long-term causal linkages between ICT infrastructure and economic growth, financial development and economic growth, and ICT infrastructure and financial development (Pradhan et al., 2015). Usman et al. (2021) analyzed the effects of ICT on economic growth by using the data from 1990 to 2018 and found that overall, ICT considerably and favorably helps to India's economic growth.

Cheng et al. (2021) investigated the relationship between ICT and economic growth using panel data from 72 countries from 2000 to 2015 and the GMM method. They discovered that in middle and low-income countries, mobile growth increases economic growth while increasing Internet or secure Internet servers does not. Daveri (2003) in his study investigating the effect of ICT expenditures on economic growth in G-7 countries between 1990 and 2000, stated that the contribution of ICT to economic growth in countries other than the USA is extremely low.

By using data from 2001 to 2017, Sinha and Sengupta (2022) found that ICT has positive and significant effects on economic growth in Asia-Pacific Developing Countries. Pazarlıoğlu and Gürler (2007) estimated the relationship between telecommunication investments and economic growth in European Union (EU) core countries, member states and candidate countries by using fixed effects panel data method. When the results of the analysis applied using the annual panel data for the period 1990-2004 are examined, it is observed that the effect of telecommunication infrastructure investments on GDP, which is used as an economic growth indicator, is positive. Accordingly, a 1% increase in investments increases the growth by 0.33% in the countries covered.

Konak (2020:238) investigated the relationship between ICT exports and economic growth for 7 selected countries. According to the results of the panel data analysis created with the annual data of the 2000-2015 period, it has been concluded that ICT exports in the mentioned countries have a positive effect on economic growth. In their research, Pradhan et al. (2021) stated that in the long term, strong economic growth contributes significantly to ICT infrastructure development in the Indian states.

Datta and Agarwal (2004) examined the long-term relationship between telecommunication infrastructure investments and economic growth for 22 OECD countries and found that there is a significant and positive relationship between telecommunication infrastructure and GDP. In their study, Ahmad and Satrovic (2023a) analyzed together effect of economic complexity and technological innovation on energy productivity and carbon productivity and investigated how monetary policy moderates this effect in Group of Seven (G7) countries in 1995-2019. The results showed that both economic complexity and technological innovation positively affected

environmental sustainability. In terms of moderating effects, expansionary monetary policy was being used to manifest the positive environmental effects of economic complexity and technological innovation.

The effect of ICT on economic growth and unemployment has been examined in terms of 23 EU countries and Turkey. Data from 1996 to 2016 were used. FGLS Panel Data Analysis method was applied. Findings revealed that ICT has positively affected economic growth in the EU and Turkey, and reduced unemployment to a minimum level between the years investigated (Alper, 2017: 45). By using panel data of 7 OECD countries, Ahmad and Satrovic (2023b) studied fiscal decentralization's role in moderating the impact of economic complexity and government intervention on environmental sustainability in the presence of GDP from 1995 to 2018. Their findings revealed that economic complexity and government intervention decrease energy efficiency and economic growth is the driving factor behind long-term environmental sustainability.

Yousefi (2011) examined the influence of ICT on economic growth in 62 high, upper-middle, low-middle, and low-income countries from 2000 to 2006. Yousefi concluded in his study utilizing panel data analysis that ICT has a vital role in the economic growth of high – and upper-middle-income nations but does not contribute to the economic growth of low – and lower-middle-income countries.

Erdil et al. (2010) evaluated the influence of ICT on growth in 131 underdeveloped countries, including Turkey. According to the results obtained from the econometric analysis using the GMM method, when considered as a production factor such as physical and human capital accumulation and when used with some control variables, these technologies positively affected on economic growth in underdeveloped and developing countries. Based on these results, the researchers drew attention to the importance of continuing the investments made in these technologies. Nejati and Shah (2023) also found that there is a positive relationship between ICT and economic growth.

The joint influences of ICT and financial development on economic growth were examined in 43 developing countries between 2000 and 2014 by using GMM method. It is concluded that ICT positively affects economic growth, but does not financial development (Das et al., 2018: 928). Ahmad and Satrovic (2023c) investigated how fiscal policy instruments are effective in moderating the effect of economic openness on environmental sustainability for G7 countries in 1990–2019 in the presence of technological innovation and they found that technological innovation positively affects environmental sustainability and fiscal policy instruments increase the demand for environmentally friendly products, resulting in a reduction in consumption-based anthropogenic emissions associated with economic openness.

Samimi and Leadary (2010), who stated that ICT affects growth positively through innovation and productivity, analyzed the influence of ICT on economic growth for the period 2001-2006 in 30 developing countries. GDP was taken as the growth indicator and the Digital Opportunity

Index (DOI) was taken as the indicator of technology, and from the analysis using the random effects panel data approach, it was determined that ICT had a statistically significant positive influence on economic growth. Accordingly, a 1% increase in the use of these technologies causes an increase of 0.000792% growth.

Artan et al. (2014) studied the impact of ICT development on economic growth for 17 transition economies with annual data for the period 1994-2011. In the study, in which 3 different models were created and static panel data analysis method was used, the results obtained from all three models showed that the use of telephone and internet positively affected economic growth. In his research. Ramzan et al. (2022) found that ICT causes economic growth to rise in Pakistan. Satrovic et al. (2023) revealed that technological innovation and economic growth decrease the harmful environmental influence of natural resources that causes environmental degradation.

In the study conducted by Kooshki and Ismail (2011), it has been estimated whether ICT effectively influences economic growth in OECD, BRICs, NICs countries from 1990 to 2008. In the analysis using GMM method, it was found that ICT had a positive effect on economic growth. Based on their findings, the researchers concluded that these technologies play an important part in the economic process, and that countries seeking to accelerate their growth should boost their investments in these technologies and at the same time support these investments with complementary investments.

Kılıç et al. (2017) researched the relationship between ICT exports and economic growth for 7 selected countries. According to the results of the panel data analysis created with the annual data of the 2000-2015 period, ICT exports in the mentioned countries positively affect economic growth.

Farhadi and Fooladi (2011) studied the relationship between economic growth and the use of ICT in 159 countries for the period 2000-2009 by applying GMM. According to results, the positive effect of the use of ICT on economic growth varies depending on the income levels of the countries and this positive effect increases as the income level rises. Based on these results, the researchers stated that the technologies have a critical role in growth and therefore, it is necessary for countries aiming at a sustainable and high rate of growth to implement policies that increase the diffusion of these technologies.

3. Material and Method

3.1. Methodology

Information and communication technologies have become essential components of modern economies, dramatically influencing numerous industries and spurring innovation. While there is broad consensus on the relevance of ICT, there is a need for a better understanding of how ICT investments and usage specifically contribute to economic growth in the European context. This paper contends that a thorough examination of the relationship between ICT and economic

growth, using advanced econometric methodologies such as the two-step system Generalized Method of Moments GMM, can yield nuanced insights that go beyond conventional wisdom.

The purpose of this research is to examine the impact of information and communication technologies on economic growth in 35 European countries. The research intends to provide a clear and intuitive knowledge of the relationship between ICT adoption and economic development by adopting a rigorous two-step system GMM technique. We use the System Generalized Method of Moments (GMM) technique, because it successfully addresses endogeneity and allows for efficient estimate in the presence of persistent variables, the System GMM technique is particularly well suited for panel data analysis. This study seeks to produce strong and reliable estimations of the association between ICT and economic growth in the selected European countries by applying the System GMM technique. The use of panel data, in conjunction with a rigorous econometric technique, allows for a thorough analysis that reflects the dynamic nature of the ICT-economic growth nexus. The methodology enables endogeneity control and provides significant insights into the impact of ICT on economic development in Europe.

This study proposes the following main hypothesis:

Hypothesis 1:

Greater adoption and effective use of ICT positively correlate with higher rates of economic growth across the selected 35 European countries.

Hypothesis 1a:

Fixed telephone lines positively affect economic growth in the chosen 35 European countries.

Hypothesis 1b:

Mobile phone usage are positively associated with economic growth in the selected 35 European countries.

Hypothesis 1c:

Increased internet usage is linked to enhanced economic growth across the 35 European countries under examination.

The study predicts that nations with more robust ICT, paired with strategic policies to exploit the potential of ICT, will see faster economic growth than those with lower ICT adoption and use.

The econometric representation of the System GMM estimator model can be expressed as follows:

$$Y_{it} = \alpha + \rho Y_{i,t-1} + \beta X_{it} + \eta_i + \varepsilon_{it}$$

where:

- Y_{it} denotes the dependent variable of interest, such as economic growth statistics, observed for country i at time t.
- α is the intercept term.
- $Y_{i,t-1}$ represents the lagged dependent variable, capturing the persistence in the relationship between ICT and economic growth.
- X_{it} refers to a vector of exogenous variables that include ICT indicators and other control variables that affect economic growth.
- β is the vector of coefficients related to exogenous variables.
- η_i denotes country-specific fixed effects, which account for time-invariant features that influence economic growth but differ between nations.
- ε_{it} represents the error term, which captures the relationship's unobserved components and random disturbances.

The System GMM estimator uses lagged levels as instruments to address endogeneity and other omitted variable biases. The model's orthogonality criteria are used to build the instrumental variables (IV). The first-difference transformation is used to reduce time-invariant country-specific effects and increase parameter estimation efficiency.

The moment conditions produced from the instrumental variables are used to calculate the System GMM estimator. The system of equations is estimated jointly while taking the relationship between the differenced variables and the lagged levels into consideration. This estimation method alleviates worries about endogeneity, accounts for unobserved heterogeneity, and provides accurate parameter values.

There are two steps to the estimating technique. The differenced equations are estimated using the GMM estimator in the first stage. This phase removes the country-specific fixed effects and decreases the possibility of endogeneity issues. In the second stage, the system GMM estimator is used, with lagged levels acting as additional instruments. This stage considers the dynamic nature of the link between ICT and economic growth.

The system GMM estimator gives consistent and efficient estimates of the model's coefficients, taking both differenced variables and delayed levels into account. It resolves endogeneity concerns and contributes to the understanding of the causal relationship between ICT and economic growth in the selected European countries.

This study intends to use the System GMM estimator to accurately estimate the parameters and obtain reliable insights into the impact of ICT on economic growth in the European context, while addressing potential endogeneity issues and controlling for unobserved heterogeneity.

In order to investigate the effect of information and communication technologies on economic growth, we use the following econometric model:

$$\ln GDP_{ti} = \beta_0 + \beta_1 \ln GDP_{ti-1} + \beta_2 \ln ICT_{ti} + \beta_s \ln Z_{ti} + y_i + \eta_i + \varepsilon_{it} \qquad (1)$$

Where $\ln GDP_{ti}$ is the logarithm of GDP per capita; β_0 is a constant term; $\beta_1 \ln GDP_{ti-1}$ is the one period lagged logarithm of GDP per capita. β_1 coefficient is anticipated to be statistically significant in order to validate the dynamic process of this model, that is, the previous GDP per capita may have an impact on current GDP. $\beta_2$displays the estimated parameter of ICT variables, with each proxy estimated in its own equation. The type of proxy employed in the ICT option causes a difference in these calculations, while all other independent variables remain constant. ICT's proxies are presented by the number of fixed telephone lines per 100 inhabitants, the number of mobile phone user per 100 inhabitants and the number of internet user per 100 inhabitants.

β_s donates the estimated parameters of each control variable Z. That is to say it can reflect the value of consumer price index (β_3), trade openness (β_4), and final consumption expenditure (β_5). For this study, five independent variables are defined, including a lag dependent variable, ICT, and three control variables for each equation that will be calculated. As a result, based on neoclassical growth theories and empirical evidence, their coefficient should be positive. And y_i represents time dummies and it is included to prevent any possible cross-individual correlation, η_i donates unobserved particular terms for each country, while ε_{it} donates the error terms that are supposed to be white noise.

The Stata 15 package program was used to estimate the model in this investigation.

3.2. Variables and Data Collection

To conduct our analysis, we have compiled a rich dataset incorporating relevant ICT and economic growth indicators for the selected European countries. The ICT indicators encompass various dimensions of digital technology adoption and infrastructure, such as fixed telephone lines, mobile subscriptions, and internet users. These indicators reflect the extent to which countries have embraced and integrated ICT into their economies.

Additionally, economic growth indicator, which is gross domestic product (GDP), has been incorporated into the dataset. This indicator captures the overall economic performance and provide insights into the relationship between ICT and key economic outcomes. In the study, apart from these variables, different variables were also used according to the chosen method. The variables that were used in the study and summary statistics of each variable are given in Table 1.

The dataset employed in this study is derived from reputable international source, as the World Bank. By utilizing established and reliable data sources, we aim to assure the correctness and consistency of the variables used in the analysis. The time period coveres specified period from

2001 to 2021, allowing for a longitudinal analysis of the relationship between ICT and economic growth. The availability of historical data enables us to capture trends and identify potential shifts in the ICT-economic growth dynamics within the selected European countries.

By utilizing this robust dataset, we aim to provide a comprehensive and rigorous analysis of the influence of ICT on economic growth in the European countries. The dataset's breadth and depth allow for a nuanced exploration of the multifaceted relationship between ICT and economic development, providing valuable insights for policymakers, researchers, and stakeholders interested in leveraging ICT for sustainable economic growth in the Europe.

Table 1: Variables

Variables	*Definition*	*Source*	*Values*	
GDP	GDP per capita	World Bank	Mean	9.90
			SD	1.04
			Min	6.22
			Max	11.80
TEL	Fixed telephone lines (per 100 inhabitants)	World Bank	Mean	3.48
			SD	0.52
			Min	1.31
			Max	4.31
MOB	Mobile phone user (per 100 inhabitants)	World Bank	Mean	4.62
			SD	0.43
			Min	1.52
			Max	5.14
INT	Internet user (per 100 inhabitants	World Bank	Mean	4.00
			SD	0.72
			Min	-1.12
			Max	4.60
CPI	Consumer price index	World Bank	Mean	4.59
			SD	0.21
			Min	3.62
			Max	5.75
TRD	Trade openness	World Bank	Mean	4.60
			SD	0.44
			Min	3.81
			Max	5.96
PCNS	Final consumption expenditure	World Bank	Mean	4.32
			SD	0.14
			Min	3.58
			Max	4.73

Our study' theoretical underpinning is based on the awareness that technical improvements, particularly in the field of ICT, have become powerful drivers of economic progress. Our selection of variables shows careful examination of factors that influence economic growth both directly and indirectly. We establish GDP as the dependent variable, indicating the ultimate measure of

economic performance. Recognizing the temporal structure of economic processes, we include lagged GDP as an endogenous variable that captures the inertia of past economic activity.

We examine the crucial function of fixed telephone lines, mobile phone usage, and internet usage as core components of ICT to develop a logical connection between variables. These explanatory factors indicate how far countries have progressed in adopting information and communication technology, which can boost efficiency, innovation, and market reach. These factors reflect the assumption that a technologically enabled society is ready for increased economic growth through rapid business interactions, information transmission, and digital commerce.

We include critical control variables with our primary variables to account for external influences on economic growth. The Consumer Price Index (CPI) captures inflationary pressures, influencing consumer purchasing power and thus economic performance. Trade and final consumption expenditure variables, respectively, provide insights into external trade dynamics and domestic consumption patterns, both of which play important roles in establishing a country's economic trajectory.

Our study tries to unravel the numerous paths by which ICT, inflation, trade, and consumption interact to form economic growth patterns in the European setting by interlinking these variables within a robust analytical framework. This theoretical foundation not only strengthens our study design, but it also contributes to the scholarly discourse on the complex dynamics that underpin the transformational potential of ICT in promoting socioeconomic advancement.

The analysis in this study focuses on 35 selected European countries, encompassing a diverse range of economies and varying levels of ICT adoption. The countries included in the dataset represent different regions within the Europe, providing a comprehensive coverage of the economic landscape across the continent. This paper aims to investigate the effect of information and communication technologies on economic growth in 35 selected European countries during 2001-2021. The dataset of the study was obtained from the World Bank and the countries involved in the study are shown in Table 2.

Table 2: Countries

Albania	France	Luxembourg	Russian Federation
Austria	Germany	Malta	Slovak Republic
Belgium	Greece	Moldova	Slovenia
Bulgaria	Hungary	Netherlands	Spain
Croatia	Ireland	North Macedonia	Switzerland
Denmark	Iceland	Norway	Sweden
Czechia	Italy	Poland	United Kingdom
Estonia	Lithuania	Portugal	Ukraine
Finland	Latvia	Romania	

4. Findings

The findings of the study, which was conducted on 35 selected European countries that we aim to analyse the effect of ICT on economic growth, were obtained by applying the stationarity test, pooled OLS, fixed and random effects estimators, and finally, two step system GMM estimators.

4.1. Stationarity Condition

Since it is a necessary condition for the series to have stationarity in panel data analysis. As it is known, when working with non-stationary data, test statistics will lose their reliability and spurious regression problems occur between variables. The LLC unit root test was used to determine stationarity of the variables. LLC unit root test results have been shown in Table 3.

Table 3: Levin, Lin, and Chu Unit Root Rest Results

Variables	In level and with intercept	One difference and with intercept	Variable	In level and with intercept	One difference and with intercept
GDP	-11.23*** (.000)	-11.39*** (.000)	TEL	7.64 (1.000)	-2.96** (.001)
CPI	-5.77*** (.000)	-6.30*** (.000)	MOB	-9.47*** (.000)	-7.73*** (.000)
TRD	-5.41*** (.000)	-11.91*** (.000)	INT	-17.87*** (.000)	-14.23*** (.000)
PCNS	-3.04** (.001)	-11.65*** (.000)			
Notes: p-value in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%					

According to the LLC unit root test, all variables are stationary at the (I_0) level except TEL. But when we check one difference for TEL, we see that TEL becomes stationary at the (I_1) level.

4.2. Pooled OLS, Fixed Effect and Random Effect Estimators

After the stationarity test, the pooled OLS, fixed, and random effects estimators were used to estimate the effect of ICT on economic growth. Pooled OLS (Pooled Ordinary Least Squares) is a regression method used in data analysis. This approach is ideal for analyzing panel data amongst different units or groupings. Panel data are data sets that have the same units observed over time. Pooled OLS uses regression analysis and takes all panel data as a single data set. In this approach, the entire data set is put to a single regression model, with no regard for distinctions across units or groups. As a result, discrepancies between units or groups are ignored, and all units are studied collectively. In panel data analysis, it is supposed that one of the ways to include the findings obtained from the changes that occur between the units or the changes that occur over time between the units in the analysis is that the existing change will cause differences in the coefficients in the regression analysis. Fixed-effect models are those that take this shift into consideration. Random effects analysis is used if the data to be analyzed are selected at random or as a sample from the entire universe, whereas fixed effects analysis is used otherwise (Baldemir and Keskiner, 2004: 48). Pooled OLS, Fixed Effect and Random Effect test results have been shown in Table 4.

Table 4: Pooled OLS, Fixed Effect and Random Effect Results

Dependent variable: GDP per capita (GDP)			
Variables	Pooled OLS	Fixed Effect	Random Effect
GDP (-1)	0,9605*** (0,000)	0,8044*** (0,025)	0,9598*** (0,004)
CPI	-0,0598* (0,028)	-0,0174 (0,030)	-0,0592 (0,036)
TRD	-0,0017 (0,006)	-0,0735* (0,035)	-0,0023 (0,005)
PCNS	-0,1372*** (0,031)	-0,4208*** (0,073)	-0,1425*** (0,025)
TEL	-0,0002 (0,004)	-0,0198 (0.010)	-4,6800 (0.006)
MOB	0,0292* (0,012)	0,0999*** (0.015)	0,0308*** (0.009)
INT	0,0056 (0,006)	0,0008 (0,007)	0,0048 (0,005)
Number of observations	700	700	700
Number of countries	35	35	35
R^2	0.9972	0.9938	0.9972

Notes: The significance level of 10%, 5%, and 1% are indicated, respectively, by *, **, and ***. The coefficient estimates are followed by the standard errors, which are given in parentheses.

According to the Pooled OLS, Fixed Effect and Random Effect estimators' results, among the variables CPI, TRD, PCNS and TEL negatively affect GDP whereas GDP (-1), MOB and INT positively affect. In terms of significancy of the effects, in Pooled OLS estimator, GDP (-1), CPI, PCNS and MOB significantly affect the dependent variable, GDP, although TRD, TEL and INT do not significantly affect. According to Fixed Effect estimator results, the effect is significant in GDP(-1), TRD, PCNS and MOB, but is not significant in CPI, TEL and INT. Lastly, Random Effect estimator results show that GDP(-1), PCNS and MOB significantly affect GDP, whereas CPI, TRD, TEL and INT do not.

4.3. GMM Estimator

To examine the effect ICT on economic growth in the 35 selected European countries, we employ the System GMM approach. The System GMM method is particularly suitable for panel data analysis, as it effectively addresses endogeneity and allows for efficient estimation in the presence of persistent variables. By employing the System GMM method, this study aims to provide robust and reliable estimates of the relationship between ICT and economic growth in the selected European countries. Two-step system GMM test results have been shown in Table 5.

Table 5: Dynamic Panel Data Estimation, Two Step System GMM Results

Dependent variable: GDP per capita (GDP)						
Variables	Coef.	Corrected Std. Err.	t	P > t	[95% Conf. Interval]	
GDP (-1)	0.9255492	0.0213465	43.36	0.000***	0.8821678	0.9689306
CPI	-0.3192687	0.1484919	-2.15	0.039*	-0.6210405	-0.017497
TRD	-0.0166675	0.0146777	-1.14	0.264	-0.046496	0.0131611
PCNS	-0.2329599	0.0575615	-4.05	0.000***	-0.3499389	-0.1159809
TEL	0.0094694	0.017558	0.54	0.593	-0.0262127	0.0451515
MOB	0.0863847	0.0306785	2.82	0.008**	0.0240385	0.148731
INT	0.0477272	0.044741	1.07	0.294	-0.0431975	0.1386518
Arellano-Bond test AR (1):	z = – 2.95 Pr > z = 0.003					

Arellano-Bond test AR (2):	z = – 2.31 Pr > z = 0.121
Sargan test:	chi2(18) = 116.47 Prob > chi2 = 0.000
Hansen test:	chi2(18) = 19.08 Prob > chi2 = 0.387
Number of observations	700
Number of countries	35

Note: Variables with "*," "**," and "***" are significant at p<1%, p<5%, and p<10% respectively. The estimation includes year dummies as well.

According to the results of the two step system GMM estimator, GDP(-1), TEL, MOB and INT positively affect economic growth whereas CPI, TRD and PCNS negatively affect. In terms of significant levels of the effects, GDP (-1), CPI, PCNS and MOB significantly affect economic growth although TRD, TEL and INT insignificantly affect. All in all, ICT positively affects GDP in 35 selected European countries. And it means, we accept H1, H1a, H1b and H1c. The positive effect of ICT on economic growth findings were also found by Das et al. (2018), Erdil et al. (2010), Farhadi and Fooladi (2011), Kooshki and Ismail (2011) and Yousefi (2011).

The Arellano-Bond test AR(1) and AR(2) results in the table show the results of the statistical tests used to evaluate the presence of serial correlation.

- Arellano-Bond test AR(1): It tests the hypothesis of the first autoregressive (AR(1)) model. The z-value is – 2.95 and the p-value is 0.003. This indicates that the hypothesis is rejected and serial correlation exists. That is, there is a correlation between the previous period values of the dependent variable.
- Arellano-Bond test AR(2): It tests the hypothesis of the second autoregressive (AR(2)) model. The z-value is – 2.31 and the p-value is 0.121. In this case, the hypothesis cannot be rejected and no conclusive evidence can be provided for the existence of serial correlation. It indicates weak or no quadratic autoregressive correlation.

Sargan test and Hansen test are statistical tests used to evaluate the suitability and validity of the panel data regression model used.

- Sargan test: This test checks that it provides accurate and consistent estimates of instrumental variables. According to the results in the table, the chi-square statistic is 116.47 and the p value is 0.000. This indicates that the Sargan test rejects the hypothesis and that the instrumental variables are appropriate and consistent in the model.
- Hansen test: This test checks whether the regression model has specification errors. According to the results in the table, the chi-square statistic is 19.08 and the p value is 0.387. This indicates that the Hansen test does not reject the hypothesis and that the model has no speciation errors.

As a result, the Arellano-Bond test showed there is evidence of first-order autocorrelation but there is no evidence of second-order autocorrelation in the first difference, while the Sargan test

showed that the instrumental variables were correct and the model was appropriate. The Hansen test, on the other hand, shows that there are no specification errors.

The analysis of our research findings sheds light on some notable patterns in the complex interaction between ICT and economic growth. Our research highlights the positive influence of ICT components, such as telephone lines, mobile phone usage, and internet usage, on economic growth in the selected 35 European countries. These findings are consistent with the growing body of literature indicating that technological developments have the ability to promote economic progress. Furthermore, our research dives deeper by uncovering the subtle mechanisms by which improved communication technologies drive innovation, foster business connections, and facilitate market reach, ultimately promoting economic growth.

When compared to previous studies, our findings fit with and enhance current data supporting the favorable relationship between ICT and economic growth. Notably, the positive influence of ICT on economic growth contrasts with the found negative effects of the consumer price index, trade, and final consumption spending on economic growth in our environment. This disparity highlights the complex interplay of factors influencing economic performance, emphasizing the necessity for a complete analysis that considers both technological and macroeconomic components. Our research goes beyond past studies by delving further into specific ICT components and their direct contributions to economic growth, increasing the granularity of our understanding.

However, it is important to recognize that differences between our findings and earlier work may be due to differences in sample selection, econometric techniques, and contextual factors. As a result, the found detrimental effects of specific macroeconomic variables necessitate additional research to understand the underlying mechanisms and relevant policy consequences.

5. Conclusion

This paper aimed to investigate the effect of information and communication technologies on economic growth in 35 selected European countries during 2001-2021. By analyzing this relationship, we seek to shed light on the potential benefits and implications of ICT adoption for sustained economic development within the European countries' context. Understanding how ICT influences economic growth is essential for formulating effective policies and strategies that leverage digital technologies to foster prosperity, innovation and competitiveness.

To conduct our analysis, we have compiled a rich dataset incorporating relevant ICT and economic growth indicators for the selected European countries. The ICT indicators encompass various dimensions of digital technology adoption and infrastructure, such as fixed telephone lines, mobile subscriptions, and internet users. Additionally, an economic growth indicator, which is gross domestic product (GDP), has been incorporated into the dataset. This indicator captures the overall economic performance and provides insights into the relationship between ICT and key economic outcomes. In the study, apart from these variables, different variables such as consumer price index, trade openness and final consumption expenditure were also used according to the chosen method.

To examine the effect ICT on economic growth in the 35 selected European countries, we employed the System Generalized Method of Moments (GMM) approach. The System GMM method is particularly suitable for panel data analysis, as it effectively addresses endogeneity and allows for efficient estimation in the presence of persistent variables.

Since it is a necessary condition for the series to have stationarity in panel data analysis. The LLC unit root test was used to determine stationarity of the variables. According to the LLC unit root test, all variables are stationary at the (I0) level except TEL. But when we checked one difference for TEL, we saw that TEL became stationary at the (I1) level.

After the stationarity test, the pooled OLS, fixed and random effects estimators were used to estimate the effect of information and communication technologies on economic growth. According to the Pooled OLS, Fixed Effect and Random Effect estimators' results, among the variables CPI, TRD, PCNS and TEL negatively affected GDP whereas GDP (-1), MOB and INT positively affected. In terms of significancy of the effects, in Pooled OLS estimator, GDP (-1), CPI, PCNS and MOB significantly affected the dependent variable, GDP, although TRD, TEL and INT were not significantly affected. According to Fixed Effect estimator results, the effect was significant in GDP(-1), TRD, PCNS and MOB, but was not significant in CPI, TEL and INT. Lastly, Random Effect estimator results showed that GDP(-1), PCNS and MOB significantly affected GDP, whereas CPI, TRD, TEL and INT did not.

According to the results of the two-step system GMM estimator, GDP (-1), TEL, MOB, and INT positively affected GDP, although CPI, TRD and PCNS negatively affected. In terms of significance of the effects, the effect of GDP (-1), CPI, PCNS and MOB was significant, whereas the effect of TRD, TEL and INT were not significant. The Arellano-Bond test showed that there is no autocorrelation, and according to the Sargan and Hansen tests results, the instrumental variables are appropriate and consistent in the model and the model has no speciation errors. From the results it can be concluded that ICT positively affected GDP in 35 selected European countries. Based on the results of the study, some suggestions can be made for European countries to increase the positive effect of ICT on economic growth:

- Given that the developed countries that produce and export ICT have a high impact on economic growth, it can be stated that the sectors producing goods and services related to these technologies should be backed up by a variety of credit and incentive applications. As a result of the policies that will be adopted in this regard, the expanding sector will be able to contribute significantly to growth by increasing production and exports.
- Infrastructure expenditures in information and communication technology should be enhanced; however, because technology alone cannot affect growth, these investments should be accompanied by complementary investments such as physical and human capital investments.

- The employment of these technologies in economic activity, particularly as a basic factor of production, should be ensured. Because these technologies allow us to produce goods and services at a cheaper cost and in less time, they contribute to economic growth by increasing productivity.
- Foreign trade policies that restrict access to sophisticated technologies should be relaxed or eliminated entirely.

Our study's consequences go beyond the academic sphere, providing tangible insights that might influence policy decisions aimed at encouraging long-term economic growth. The favorable influence of ICT components such as telephone lines, mobile phone usage, and internet usage on economic growth emphasizes technology's vital role in promoting wealth. To ensure equal distribution across areas, policymakers should prioritize programs that promote universal access to these ICT tools, including investments in infrastructure development and connectivity advancements. Furthermore, creating an atmosphere that encourages innovation and entrepreneurship in the technology industry can increase the favorable impacts of ICT on economic growth.

Our findings also emphasize the significance of tackling negative factors including the consumer price index, trade, and final consumption expenditure. Policymakers should take steps to reduce inflationary pressures by implementing sensible monetary and fiscal policies, guaranteeing price stability, and increasing consumer purchasing power. Strategic trade policies that foster diversity of exports and imports can boost economic resilience and reduce a country's vulnerability to external shocks. Furthermore, policies focused at optimizing consumption patterns and fostering responsible resource allocation might assist in redirecting expenditures toward productive investments, boosting long-term economic growth.

This study adds to the current body of knowledge by providing unique insights on the relationship between ICT and economic growth in 35 European countries. While prior studies have acknowledged the overall importance of ICT in driving economic development, our work advances the field by giving a detailed analysis that identifies processes by which ICT influences economic growth. We reveal a nuanced and contextually rich perspective on how these ICT components contribute to the socioeconomic growth of European nations by methodically studying the combined influence of mobile phone usage, fixed telephone lines, and internet usage. Furthermore, our findings shed light on the complex interplay between ICT adoption, policy frameworks, and macroeconomic indicators, providing a new understanding of the multidimensional dynamics underlying the observed positive benefits. This study not only emphasizes the importance of ICT as a driver of economic growth, but it also presents a unique perspective that adds to the scholarly conversation in this field.

While this study provides useful insights on the relationship between ICT economic growth in European countries, some limitations should be considered. For starters, our analysis is limited to a subset of European countries, which may restrict the generalizability of our findings to a broader

global setting. Future study could broaden the analysis to include a broader range of countries, considering differences in economic structures, technical readiness, and policy contexts. Furthermore, the variables used in our analysis capture multiple aspects of ICT adoption but do not go into the qualitative components of technology implementation or examine the subtle impacts on different sectors. A more detailed examination of these issues could provide a more complete picture of the methods through which ICT promotes economic growth.

Additionally, our research assumes a linear link between ICT factors and economic growth, ignoring any nonlinearities or threshold effects. Investigating such nonlinear dynamics could lead to a better understanding of the complicated interplay between technology and economic progress. Furthermore, as technical improvements and economic policies evolve over time, the observed associations may be influenced by the time period under examination. A longitudinal investigation spanning multiple time intervals could shed light on temporal fluctuations in the ICT-economic growth nexus.

Future study could use different econometric approaches or explore causal linkages using experimental or quasi-experimental designs to improve the robustness of our findings. In addition, given the multifaceted character of economic growth, future research may include additional indicators that reflect aspects such as human capital development, social well-being, and environmental sustainability.

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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

INFLATION AND MONTHLY STOCK RETURNS RELATIONSHIP IN THE AIRLINE MARKET

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Abstract

The aim of this manuscript is to make an empirical analysis on the relationship between stock return and inflation in selected airlines from different regions of the world and airline alliances on a monthly selected dataset. The main results show regional, continental, or specific – country-based activities have got more impacts on inflation-stock return relations than airline alliances in the period between March 2014 and May 2022. Especially, inflation rates have got a causal, explanative and cointegrating relation with airline stock returns in Eastern countries or Asia.

Keywords: Airlines, Inflation, Fourier Analysis, Toda-Yamamoto causality test.
Jel Codes: B26, O18, R11

1. Introduction

World conjuncture offers airline companies two ways; being a big company that should sustain and complete all the necessary aviation works on its own or being a member of a partnership. Especially, a cumbersome structure is the indispensable result of the first opportunity, the latter one is open not only to new challenges such as code-sharing activities, slot activities etc. but also to alliances in a large framework.

The challenges, which relate to airlines and alliances have been analyzed also in the literature, Ivaldi et al. (2022) evaluate airline alliances with three important concepts that are market dispersion, ticket price and costs. According to their analysis, there are lower average prices, dispersion and lower costs in the situation of alliances (e.g., Star Alliances, Oneworld and SkyTeam). Considering eco-sustainability shortly here, alliances are drivers of eco-sustainability via partnerships, networks, and market forces (Fernandez, 2022). The same results are reached by Abdi et al. (2022) especially with the variables of government, other airlines or air carriers and passengers strategically. For Calzada et al. (2022), airlines may be one cause of the expansion of flights due to their research on Russian Aeroflot. Airline alliances have got also had deep impacts on airport and airport development in terms of air traffic competition, besides, this situation

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has got financial results (Peng and Lu, 2022). According to Winzar et al. (2022), all types of costs can be eliminated by airline alliance activities that are a great part of aviation trade wars. Alliances also affect airlines in all performance criteria such as personnel costs, fuel costs, repair and maintenance costs, station and ground handling costs and the number of flights, passenger kilometres and seat kilometres (Yen and Li, 2022). Yamaguchi (2022) states that alliances can increase oligopolistic behaviours in the airline markets. Considering Button et al. (2022) arguments, it can be said that alliances will have got definitive impacts on African Airlines.

Inflation, on the other hand, is one of the major variables in the macro-economic world and is definitive and decisive in all industries and household budgets and the aviation industry and passengers across the globe. It is not possible to sustain an analysis of the deep roots of the main economic and socio-economic crises such as war and negative events unless it is not looked at macro-economic variables such as inflation, unemployment and GDP. Shortly, it can be accepted as increasing in general and total price levels of selected *meta*s, inputs of industry and inputs and necessities of households. Especially, inflation rates are one of the important veins of aviation-related economies and there should not be an important analysis without them like oil prices, workforce prices, human and intellectual capital and inside dynamics of companies such as ROI (return on investment), ROE (return on equity), ROA (return on asset) and EBITDA (earnings before interest, taxes, depreciation, and amortization) analysis and investment-related variables analysis like volatility analysis or event studies.

Considering all the explanations above, we aim in this paper that whether or not there is a relationship between stock price and inflation rates of countries. When we conduct this research, we benefited from a classification of airline companies due to airline alliances. In the production process of this research, A Fourier-type econometric cointegration method by Tsong et al. (2016) is utilized to search for a Fourier-type econometric cointegration relationship between air carriers and inflation due to alliances. In the first section of this paper, there is a short literature scanning in terms of cointegrating relationships between aviation-related financial and economic activities and other activities. We also aimed to take some important insights from the literature on the "What is the importance of cointegration in aviation business?" question and "What is the importance of stock returns and inflation rates relationship?". In the methodology and analysis section, there will be a short communication of the results of the analysis. At the end of the research, in the discussion, conclusion and suggestion section, we realized a special analysis and interpretation of the results.

2. Literature Review

Time series data can show financial and economic even social information with efficient and effective utilization. Especially, causality relationships between time series take great attention from econometric theoreticians and empiricists in economics. A Cointegration analysis, which shows the direction and power of correlative relationships between two or more time series, is a product of the efforts of

scientists from different fields. And, it should be added here that aviation science did not stay away from this development of the causal relationship. For example, Pot and Koster (2022) show a causal relationship between air accessibility and GDP in a country base benefiting from cointegration. In the cointegration analysis of Zhang et al. (2022) and Raghoo and Surroop (2020) aviation fuel is considered an important variable with its clear and frank impacts on the sustainability of world resources and fuel economics. Baker et al. (2015) investigate the relationship between regional aviation and economic growth in Australia, and according to their findings, there is a causal relationship between these two important variables. Hakim and Merkert (2016) find a causality between air transport and economic growth. Besides, in the light of their analyses, we can reach the conclusion that economic growth, which can be accepted as an indispensable variable in aviation infrastructure, is in a strict, strong and comprehensive relationship with air transportation. Tsui et al. (2021) claim that there is a causal relationship between aviation and tourism growth depending on a cointegration analysis. Hanson et al. (2022) state that state-dependent income elasticities can have some improving impacts on aviation forecasts. Inflation is an important macroeconomic variable that should have an impact on airline management. For Seçilmiş and Koç (2016) inflation rate has got a negative deep impact on the airline demands in European Sample. Jamuna (2016) states that inflation has got negative impacts on aviation fuels. There are a lot of works in the literature related to the stock return and inflation relationship, for example, Fama (1981) describes the negative relationships between stock returns and inflation rate. Balduzzi (1995) finds a negative correlation between the inflation rate and stock returns in NYSE. For Amihud (1996), the causes of the relationships between inflation rate and stock returns can be nominal contracting, tax effects, and investors' misperceptions. According to Pearce and Roley (1988), the debt structure of companies can help to investigate the relationship between the inflation rate and stock returns. Eldomiaty et al. (2020) state that there is a negative cointegrated relationship between the inflation rate and stock prices in DJIA30 and NASDAQ100 for the period of 1999-2016. Bui (2019) draws attention to Vietnam Market as a developing country, where policymakers can develop suitable policies to control and develop a stable stock market. Li et al. (2010) reach the conclusion that inflationary regimes are dangerous for stable stock markets. On the other hand, there is no work in the literature which directly measures the impacts of inflation on the stock returns in airline markets.

Based on the arguments above, we can state that cointegration analysis and the aviation sector are not far from each other. Especially, economic growth and development are the most investigated variables, and they are often subjects of different types of analyses and utilization of cointegration tests or analyses.

3. Dataset and Research Design

As Alliances are so important variables in aviation management and aviation business management, they have greatly impacted every industrial segment in especially the last 10 years.

The starting point of this research is these alliances. Especially, concentrating on the development of national airlines and air carriers, the impacts of alliances can observe easily. For example, membership of Turkish Airlines to Star Alliances, or membership of Chinese Eastern Airlines, Air China, and China Airways to the same or different alliances. On the other hand, the aviation

industry is the third largest industry in the global economy and airlines, or air carriers are the visible faces of them. Therefore, financial approaches and analyses about air carriers and alliances, and behaviours of investors towards airline stocks have great importance. It is a well-known scientific reality that because of not only their power in financial markets but also their impacts on company analysis, stock returns gain importance.

In this research, we made an analysis of stock returns and inflation and we aim to realize an analysis using 15 airline companies that are selected randomly (their names are given in the Appendix), data has a time interval between March 2014 and May 2022 monthly. The stock price data is taken from investing.com and inflation data is taken from OECD's database. The stock prices are utilized to get the stock returns. The main cause of selecting data from these intervals is extraordinary situations such as Covid-19, the political drawing of the US from the Open skies agreement and resource-based problems related to OECD and the data resource of Investing.com.

4. Methodology, Analysis and Results

On the research design side, there are two important and main analyses. We realized, firstly, ADF (Augmented Dickey-Fuller), PP (Phillips Perron), and KPSS unit root analyses for both inflation and stock returns. Secondly, we utilized Fourier Tsong et al. (2016) cointegration analysis (TLTH) and the Toda-Yamamoto causality analysis. We utilize these methodologies, because, first of all, we follow Fama (1981)'s time series analysis strategy to develop a model, secondly, we should seek causality that Toda-Yamamoto is the most suitable way with its assumptions, and then explain cointegrated relationships between time series, there are a lot of cointegration tests, but Fourier based TLTH test is so sound, strong and innovative form of this cointegration tests with all of its power of explaining also linearity of time series. We utilize and interpret them and make some discussions, conclusions, and suggestions. In the first section of our analysis, unit root analyses are realized the results of the unit root test are attached in the following table. According to the analysis results, almost all the return series have stationary in the first difference.

Table 1: Augmented Dickey-Fuller (ADF), Phillips Perron (PP) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) Test Results for Inflation and Stock Returns

Augmented Dickey-Fuller (ADF) Null hypothesis: There is a unit root in the time series (p-values ***=. 01, **=.05, *=0.1)				
	inflation[0]	**stock returns[0]**	**inflation[1]**	**stock returns[1]**
AAL	0.102	-10.475	-5.512***	-11.653***
AC	-1.025	-10.746	-9.100***	-9.589***
AFLT	-0.709	-9.467	-1.532***	-8.404***
AGNR	3.531	-12.08	-4.161***	-10.960***
AIR CHINA	-2.523	-10.377	-9.100***	-11.502***
ASIANA	0.459	-10.679	-8.860***	-11.714***
CATHAY	-2.523	-11.358	-9.100***	-8.894***
CEA	-2.523	-10.144	-9.100***	-12.979***
CHINA	-2.523	-12.056	-9.100***	-9.431***

DELTA	0.102	-10.221	-5.512***	-12.966***
ELAL	0.368	-9.227	-7.885***	-13.314***
FINNAIR	3.991	-9.366	-4.194***	-8.198***
KOREAN	0.459	-8.966	-8.870***	-9.575***
LHAG	1.768	-9.616	-10.161***	-12.069***
QAN	1.444	-10.015	-7.992***	-13.506***
THYAO	-0.021	-9.306	-2.415***	-7.9154***
Phillips Perron (PP) Null hypothesis: There is a unit root in the time series (p-values ***=. 01, **=.05, *=0.1)				
	inflation[0]	**stock returns[0]**	**inflation[1]**	**stock prices[1]**
AAL	1.007	-10.459	-5.352***	-49.027***
AC	-0.791	-10.724	-9.082***	-41.352***
AFLT	-0.876	-9.468	-1.892***	-46.113***
AGNR	2.562	-12.330	-7.894***	-53.519***
AIR CHINA	-2.743**	-10.366	-9.082***	-52.043***
ASIANA	0.706	-10.676	-8.800***	-69.614***
CATHAY	-2.743**	-11.366	-9.082***	-96.242***
CEA	-2.743**	-10.150	-9.082***	-46.458***
CHINA	-2.743**	-11.878	-9.082***	-68.778***
DELTA	1.007	-10.213	-5.352***	-28.427***
ELAL	-0.025	-9.299	-7.892***	-53.466***
FINNAIR	3.894	-9.397	-9.635***	-46.584***
KOREAN	0.707	-8.970	-8.811***	-76.525***
LHAG	2.109	-9.679	-10.180***	-22.094***
QAN	1.204	-10.030	-7.997***	-43.830***
THYAO	3.938	-9.388	-4.425***	-66.923***
Kwiatkowski–Phillips–Schmidt–Shin (KPSS) Null hypothesis: The time series is stationary (p-values ***=. 01, **=.05, *=0.1)				
	inflation[0]	**stock returns[0]**	**inflation[1]**	**stock returns[1]**
AAL	0.658**	0.102	0.423***	0.211***
AC	0.301	0.123	0.051***	0.067***
AFLT	0.472**	0.394**	0.310**	0.178***
AGNR	0.495**	0.031	0.452**	0.041***
AIR CHINA	0.107	0.077	0.051***	0.191***
ASIANA	0.313	0.175	0.409**	0.436***
CATHAY	0.107	0.055	0.051***	0.219***
CEA	0.107	0.230	0.051***	0.060***
CHINA	0.107	0.253	0.051***	0.237***
DELTA	0.658**	0.053	0.423***	0.025***
ELAL	0.501	0.345	0.454***	0.135***
FINNAIR	0.610**	0.175	0.708*	0.048***
KOREAN	0.313	0.113	0.409**	0.134***
LHAG	0.589**	0.075	0.552**	0.023***
QAN	0.429**	0.297	0.482**	0.068***
THYAO	0.753	0.308	0.427**	0.230***

The second unit root test groups are Fourier KSS and Fourier ADF Unit Root tests groups. Fourier ADF results of inflation and stock price are given in Table 2.

Table 2: Fourier ADF Unit Root Test for Inflation and Stock Returns

INFLATION (FADF-m: Test result; Fm(k)= F test results, k=lags)					
COUNTRY	**k**	**FADF-m**	**Fm(k)**	**Optimal lag**	**MinSSR**
CANADA	2	-7.060	3.748	1	15.912
RUSSIA	2	-5.414	6.094	1	93.947
GREECE	3	-4.733	4.876	1	31.073
CHINA	4	-7.077	2.628	1	22.390
INDONESIA	2	-6.021	2.078	1	12.469
USA	2	-6.209	6.137	1	11.866
ISRAEL	2	-6.966	4.226	1	9.677
FINLAND	2	-4.928	4.378	1	9.755
KOREAN	2	-6.013	2.076	1	12.466
GERMANY	2	-6.495	3.442	1	17.410
CANADA	2	-7.060	3.748	1	15.912
TURKIYE	2	-5.240	7.926	1	578.200
AIRLINES (STOCK RETURNS)					
AAL	4	-7.185	2.202	1	1.485
AC	4	-8.554	2.700	1	1.919
AFLT	2	-7.868	4.609	1	1.097
AGNR	5	-12.540	1.379	0	1.525
AIR CHINA	4	-11.033	2.804	0	1.204
ASIANA	4	-7.066	2.498	1	7.889
CATHAY	2	-11.768	1.703	0	0.675
CEA	3	-7.861	2.164	1	1.184
CHINA	1	-12.563	1.528	0	0.861
DELTA	5	-10.698	2.007	0	0.844
ELAL	2	-7.189	2.971	1	1.993
FINNAIR	5	-10.155	4.281	0	1.797
KOREAN	4	9.607	4.590	0	0.801
LHAG	5	-6.173	2.249	1	1.069
QAN	4	-7.566	2.484	1	0.971
THYAO	2	-10.769	7.104**	0	1.335

According to the results of Fourier ADF in Table 2, which is a powerful form of unit root test, due to its definitive vulnerability on important economic events with its structural sinusoidal waves like other Fourier type econometric tests, all the airline stock series have stationary in the first difference according to Beckers, Enders and Lee (2006) [1]. For it's another stronger version, the other unit root test of Fourier KSS (Christopoulos, 2010) is utilized, and the results can be given in Table 3

1 Looking at Fm(k) statistical results first, then FADF-m (Hepsağ, 2022), we can observe all of the reuslts are significant. For this reason, ADF results are suitable in Table 1 to evaluate these series.

Table 3: Fourier KSS Unit Root Tests Inflation and Stock Returns

COUNTRY(INFLATION) (FKSS: F-tnl-m= Test result; Fm(k)= F test results, k=lags)					
	k	**F-tnl-m**	**Fm(k)**	**Optimal lag**	**MinSSR**
CANADA	2	-3.721	3.748	1	15.912
RUSSIA	2	-1.490	5.575	1	94.865
GREECE	3	-2.711	4.876	1	31.073
CHINA	4	-3.919	2.628	1	22.390
INDONESIA	2	-4.318	2.078	1	12.469
USA	2	-3.922	6.137	1	11.866
ISRAEL	2	-3.414	4.226	1	9.677
FINLAND	2	-3.238	4.378	1	9.755
KOREAN	2	-4.308	2.076	1	12.466
GERMANY	2	-2.648	3.442	1	17.410
CANADA	2	-3.721	3.748	1	15.912
TURKIYE	2	-2.908	7.926	1	578.200
AIRLINES (STOCK RETURNS)					
AAL	4	-5.691	2.202	1	1.485
AC	4	-5.038	2.700	1	1.919
AFLT**	2	-4.363	4.609	1	1.097
AGNR	5	-2.231	1.379	1	1.525
AIR CHINA	4	-3.728	2.804	1	1.204
ASIANA	4	-3.646	2.498	1	7.889
CATHAY	2	-2.907	1.703	1	0.675
CEA	3	-4.386	2.164	1	1.184
CHINA	1	-4.818	1.528	1	0.861
DELTA	5	-2.775	2.007	1	0.844
ELAL	2	-2.607	2.971	1	1.993
FINNAIR	5	-1.922	4.281	1	1.797
KOREAN**	4	-4.916	4.590	1	0.801
LHAG	5	-2.806	2.249	1	1.069
QAN	4	-5.344	2.484	1	0.971
THYAO*	2	-5.784	7.104	1	1.335

According to Fourier KSS unit root tests, all the series do not have a unit root. For other stock prices, we should look at the KSS unit root test in Table 1, so the inference is the same, the series are stationary in the first difference [2].

Utilization of the Toda-Yamamoto test is the next step. It is a VAR-dependent test, and its most basic and important feature is that it can be utilized with a simple reasoning and without employing a unit root test. The results of this analysis are given in Table 4.

2 Regarding Fm(k) statistical results firstly, then FADF-m (Hepsağ, 2022), we can observe that all of the results are not statistically significant. For this reason, Fourier KSS results are suitable for these series.

Table 4: Toda-Yamamoto Causality Test for Inflation and Stock Returns

INFLATION TO STOCK PRICES	RESULTS	LAG	P value (0.05 Significance)
AAL	2.979	2	0.225
AC	1.426	1	0.232
AFLT	7.235	3	0.064*
AGNR	2.547	2	0.279
AIR CHINA	17.740	6	0.006
ASIANA	1.3119	1	0.252
CATHAY	6.876	1	0.008
CEA	1.313	1	0.251
CHINA AIRLINES	6.302	1	0.012
DELTA	9.311	8	0.316
FINNAIR	2.729	3	0.435
KOREAN	22.384	7	0.002
LHAG	3.808	3	0.282
QANTAS	2.513	1	0.1128
THYAO	15.573	4	0.003

According to analysis results, Air China, Cathay, China Airlines, Finnair, Korean Airlines and Turkish Airlines stock prices have a relationship between country inflation rates. More scientifically, the country's inflation rate has descriptive impacts on this airline's stock prices.

A strong unit cointegration test is our next step, and TSTH is utilized to get more powerful results. One of the main conditions of the TSTH test is, the data should complete all of the necessary Fourier unit root tests such as Fourier ADF and Fourier KSS. According to alliances, the results are given in Table 5.

Table 5: Tsong, Lee, Tsai and Hu (2016) Cointegration Test for Stock Returns and Inflation

ALLIANCES	AIRLINES	K	C_10_F	FM(K)	MINSSR	LOPT
ONEWORLD	AAL (USA)	1	0.054	43.525	1.466	4
STAR ALLIANCE	AC (CHINA)	2	0.105	55.676	1.787	4
SKYTEAM	AFLT (CHINA	1	0.064	52.645	0.898	4
STAR ALLIANCE	AGNR (GREECE)	2	0.071	71.828	1.367	4
STAR ALLIANCE	AIR CHINA (CHINA)	2	0.103	51.804	1.136	4
STAR ALLIANCE	ASIANA (SOUTH KOREA)	1	0.052	55.491	7.788	4

ONEWORLD	CATHAY (CANADA)	2	0.153	63.941	0.628	4
SKYTEAM	CEA (CHINA)	3	0.191	51.117	1.131	4
SKYTEAM	CHINA AIRLINES (CHINA)	2	0.218	65.655	0.766	4
SKYTEAM	DELTA (USA)	2	0.099	46.395	0.827	4
INDEPENDENT	ELAL (ISRAEL)	1	NA	35.360	1.704	4
ONEWORLD	FINNAIR (FINLAND)	1	0.042	37.735	1.746	4
SKYTEAM	KOREAN (SOUTH KOREA)	2	0.081	36.748	0.801	4
STAR ALLIANCE	LHAG (GERMANY)	2	0.344	46.504	0.987	4
ONEWORLD	QAN (AUSTRALIA)	3	0.197	45.223	0.896	4
STAR ALLIANCE	THYAO (TURKEY)	2	0.081	45.738	1.154	4

According to TSTH Cointegration test results, Lufthansa (Germany), Qantas (Canada), China Airlines (Taiwan), China Eastern Airlines (China), Cathay Pacific (China), and Air China (China) stock returns are in a cointegrating relationship with the Inflation rate of related countries in parentheses. For Israeli ELAL, there is no meaningful relationship between these two variables according to C_i0_f test statistics, and Fm(k) F-statistic results in Table 5.

5. Discussion, Suggestion and Conclusion

According to the research results, it is not possible to explain the cointegration and causality relationship with airline alliances. Nevertheless, the research gives some important insights from the airline companies' world. Especially, the inflation rate can be accepted as an indicator of the economic power of states in airline-related – financial markets. The most specific and clear feature of this research, besides being the first research to analyze the direct stock return and inflation cointegration and causality with a powerful form. During financial crises and normal times, governing inflation with strong and consistent policies is an indicator of a strong state like aviation policies of states that show the national independence of the state according to the Paris Agreement of 1919 and the Chicago Convention of 1944. Especially, the relationship between inflation and stock returns for eastern (China) airline companies, these findings can shed more light on the next research and market players. Besides, underlining here that the first foreign trade partner of Germany is China, according to important economical magazines such as Economist, Deutsche Welle etc., the situation of Lufthansa is not so strange. The question of "Can policymakers reshape their inflation politics according to the interests of the airline financial market?" may be asserted here further research.

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Appendix: Airline Codes

Airline Code	**Airline Name**
AAL	American Airlines
AC	Air China
AFLT	Aeroflot
AGNR	Aegean Airlines
AIR CHINA	Airchina
ASIANA	Asiana Airlines
CATHAY	Cathay Pacific
CEA	China Eastern Airlines
CHINA	China Airways
DELTA	Delta Airlines
ELAL	Elal Airlines
FINNAIR	Finland Airlines
KOREAN	Korean Airlines
LHAG	Lufhansa Airlines
QAN	Quantas Airways
THYAO	Turkish Airlines

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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

OPTIMAL SIZE OF TURKIYE'S GROWING CITY: TEKİRDAĞ

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Abstract

Migration from rural areas to cities is increasing day by day as cities offer more opportunities in terms of education, employment and health. According to 2022 TURKSTAT data, around 68% of the population in Turkiye resides in cities. Total urban population worldwide is expected to reach 4.9 billion by 2030 and 68% of the world population to live in cities by 2050 (PRB, 2007 & UN, 2017). Hence, it is predicted that uncontrolled population growth, especially in cities, will render resources insufficient and necessitates optimal city size measurements for sustainable development. In this study, the optimal city size is examined for Tekirdağ, as one of the cities in Turkiye that is exposed to irregular migration inflows and having the highest population growth rate in the recent years. This study applies the happiness degree model to estimate the optimal city size for Tekirdağ utilizing several resource indicators for the years 2018 and 2021. It is argued that the resources of the city will be depleted and therefore the happiness level of the residents will decline should this trend continues. According to 2022 statistics, it is concluded that the city is observed to be overpopulated for Tekirdağ, which has a population of over one million.

Keywords: Optimum Population, Happiness Degree Model, Tekirdağ
Jel Codes: C10, J10, R10

1. Introduction

The optimal size of a city is the marginal size when there are inefficiencies in city governance or when a city loses its appeal to citizens (Choi, 2017). Urban populations are increasing day by day as individuals living in rural areas are moving to cities for reasons such as higher job opportunities and better living conditions. According to UnHabitat World Cities Report (2022), while the urban share of the population has doubled from 25% in 1950 to about 50% in 2020, it is projected to increase to 58% over the next 50 years. However, due to the ever-increasing urban population, resources of the cities are depleted and hence are expected to become inadequate for the residents. Many cities continue to experience population growth that far outstrips the ability and resources of local authorities to expand infrastructure coverage and provide adequate health services. Increased traffic, rising energy costs, high levels of waste and pollution, and rising carbon emissions threaten the sustainability of cities in the new century.

The size of a city is essential not only to represent the scale of the urban system, but also to support prosperity, order and rapid development (Feng et al., 2021). To remain sustainable, cities

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need to improve their infrastructure, take measures to minimize the environmental impact of dense populations, create new employment opportunities and develop projects that focus on growth and development. This is why the concept of a 'technologically connected city', or the Internet of Things (IoT) using big data, is being promoted to achieve efficiency and intelligence in the management of urban resources.

There are several empirical papers in which the optimal city size is calculated using different indicator in economic, social and environmental terms. Li et al. (2018) estimate the impact of changes in city population and industrial structure on CO2 emissions. The study analyzes 50 cities with different population sizes according to various indicators between 2005 and 2014. Kong (2022) addresses the impact of prefecture level city financial development on urbanization and conducts an empirical study using the correlation between financial development level and city size. Castells-Quintana et al. (2020) examines the relationship between city size and income inequality for 153 functional urban areas in OECD countries. Frick and Rodriguez-Pose (2018) analyze whether there are certain city sizes that increase growth for 113 countries between 1980 and 2010 and how additional factors highlighted in the literature affect the relationship between city size and growth with an econometric model. Jie and Yang (2017) conduct an empirical analysis on the relationship between city size and city energy consumption efficiency based on the energy consumption data of 286 cities. Lianos and Pseiridis (2016) focus on the question of what the maximum population of 50 countries should be based on ecological footprint and biocapacity data to estimate a sustainable level of prosperity.

In this study, optimal city size is examined for Tekirdağ, one of the cities in Turkiye with the fastest population growth in recent years that provides living space 1.14 million people in 2022 (TURKSTAT, Provincial Indicators, 2022). It has the status of a metropolis receiving migration due to its proximity to another metropolis with developed business, infrastructure, energy, water and environmental facilities, Istanbul, located in the eastern border. Therefore, it is of great importance that the population size of Tekirdağ, which is a center of attraction mainly due to its location and being a developing city, increases in a conditional on ensuring the optimal use of resources and not depleting them. Following the methodology of Shi et al. (2010), this paper aims to estimate the optimal population for Tekirdağ using the happiness level of the residents that is dependent on the consumption of the resources. Several indicators reflecting economic, infrastructural, social and environmental dimensions are utilized for the recent and available years, 2018 and 2021, for a more robust analysis over the years.

The paper is organized as follows. Section 2 introduces the theoretical model. Section 3 presents the findings for the case study. Section 4 concludes the paper.

2. Theoretical Model

Urban optimum population is determined by the resources and services provided by infrastructure, economy, society, resources, environment and household subsystems (Shi et al., 2010). With the

idea that individuals who make good use of these subsystems offered by cities achieve a high level of happiness. The theoretical model uses a basic utility function (U) of a representative agent defined as the happiness degree (h) which is determined by the level of consumption (c).

$$h = U(c) \tag{1}$$

The optimal city size is based on maximizing the product of individual happiness $U(c)$ and population N, and the degree of urban happiness of households is denoted by H.

$$H = N\ x\ U(c) \tag{2}$$

When the equation is rewritten by expressing the consumption level of a person (c) as the ratio of the total amount of resources (T) to the population (N), the following expression is obtained.

$$H = N\ x\ U\left(\frac{T}{N}\right) \tag{3}$$

To maximize the utility, i.e., the total degree of happiness, the first derivation of the above function should be taken and set equal to zero. Then, by replacing $\frac{T}{N_s}$ by c_s, the problem of finding the optimum population is reduced to finding the per capita consumption. In this case, the following equation is obtained.

$$\frac{T}{N_s} = \frac{U'\left(\frac{T}{N_s}\right)}{U\left(\frac{T}{N_s}\right)} = c_s = \frac{U'(c_s)}{U(c_s)} \tag{4}$$

According to the rule of diminishing marginal utility, U will increase with the population when the population is low, while it will increase at a decreasing rate when the population is high. Given that a and β be positive parameters, where β is the least upper boundary of U and $(1+a)$ is the elasticity of marginal happiness, the following equation is proposed:

$$U(c) = \beta - \frac{1}{c^{\alpha}} \tag{5}$$

After proving that the first derivative of $U(c)$ is greater than zero and the second derivative is less than zero, in other words, that the degree of happiness function is consistent with the rule of diminishing marginal utility, the optimal consumption level per person c_s can be induced as follows:

$$c_s = \frac{\left(\beta - \frac{1}{c_s{}^{\alpha}}\right)'}{\left(\beta - \frac{1}{c_s{}^{\alpha}}\right)} \Longrightarrow \sqrt[\alpha]{\frac{\alpha+1}{\beta}} \tag{6}$$

A standard of living where the level of happiness is zero is defined as $U(c_0) = 0$, where (c_0) is defined as the population that the amount of resources the city can support. The coordinate for $(c_0,0)$ is easily determined on the function. *U(c)* Defining a second point for (c_t) as $(c_t 90\% \beta)$ brings the target consumption level at the optimal level of utility, the equation is set up as follows:

$$U(c_0) = \beta - \frac{1}{c_0^{\alpha}} = 0$$
$$U(c_t) = \beta - \frac{1}{c_t^{\alpha}} = 90\%\beta \tag{7}$$

The parameters a and β are obtained as follows:

$$\alpha = log_{\frac{c_t}{c_0}} 10$$
$$\beta = \frac{1}{c_0^{\alpha}} \tag{8}$$

Following these calculations, the happiness degree function can be obtained and the optimal consumption level can be calculated. Given the level of resources, the optimal population can be calculated using the below calculation.

$$N_s = \frac{T}{c_s} \tag{9}$$

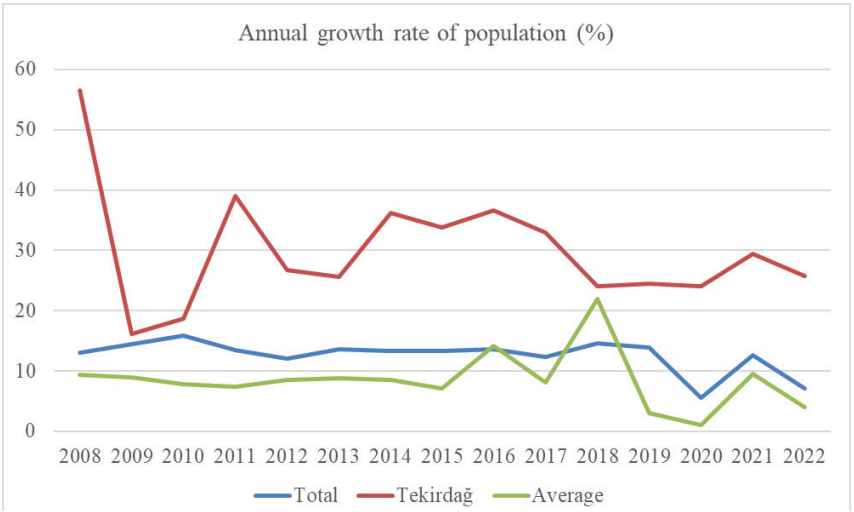
Lastly, Shi et al. (2010) states that the optimal population out of the optimal populations based on different resources will be determined by selecting the minimum one. This procedure is also followed in the empirical part of this analysis.

3. Case Study

The theoretical model estimates the optimal city size for Tekirdağ, which is the 20th largest city in Turkiye according to the population size constituting around 1.34% of the overall population of 85,279,553 (TURKSTAT, 2022). However, Tekirdağ ranks first in terms of the population growth out of the cities with population size larger than 1 million[1]. Figure 1 depicts the annual population growth rates of Tekirdağ, Turkiye and the average of all 81 cities of Turkiye. The graph reflects that Tekirdağ's population growth rate is clearly above overall and average over the time horizon of 2008-2022 with an average of 30%.

1 Population grew by 1.98% from 2000 to 2022 and by 1.08% from 2018 to 2021. The latter time period is chosen regarding the data availability of the indicators used as resources in the model. Out of the whole 81 countries, Tekirdağ ranks second following Yalova with a population of 296,333 by 2022.

Figure 1: Comparison of Annual Population Growth Rates



Considering the utility function explained in the theoretical framework, this study estimates the optimal population for Tekirdağ using several dimensions. For 2018, the economic dimension is defined by the gross national product per capita (dollar) indicator, represented as ***GDP***; the social dimension is represented as ***TNT*** in terms of the number of primary-secondary teachers per student and ***TE*** in terms of the number of enterprises per capita; the utilities dimension is represented as ***EW*** in terms of the total electricity consumption per capita (kWh) and ***AW*** in terms of the amount of drinking water per capita distributed by municipalities through drinking and potable water networks (m^3); the infrastructure dimension is represented as ***AB*** in terms of the building permit area per capita (m^2); and artificial green land per capita represent the environment dimension as ***AGA***. Data were obtained from TSI Official Statistics, Ministry of Agriculture and Forestry Corine report and General Directorate of Highways Official statistics.

For the parameter values of c_0 and c_t, the data of the cities with minimum and maximum values for each indicator among all cities of Turkey are used. The parameter values to be calculated for each indicator using the equations in the model are presented in Table 1.

Table 1: Parameter Values for Resource Indicators in 2018

Dimensions	Indicator	c_0	c_t	T (Unit: Million)	N_s (Unit: Million)
Economic	GDP	2,999	16,627	13,778.36	2.44
Utilities	EW	786	8,325	7,977.81	5.05
	AW	17.85	73.37	46.08	1.43
Social	TNT	0.05	0.10	0.06	0.77
	TE	0.02	0.07	0.05	1.60
Infrastructure	AB	0.57	4.25	3.20	2.86
Environment	AGA	16.88	709.42	308.50	8.38

In the theoretical model, it is stated that the minimum population value out of the whole optimal populations based on several is selected as "optimal out of optimals". Accordingly, the optimal population of Tekirdağ city is calculated as 770,000, indicated by the TNT indicator. Analysis based on the indicators reflect that the optimal population should be 2.44 million according to the economic dimension; 1.43 million according to the utilities dimension; 770,000 according to the social dimension; and 2.86 million according to the infrastructure dimension. Last but not least, it is found that the green areas are sufficiently available given around 8.38 million population that maximizes the happiness of the residents based on the environment dimension.

For 2021, the economic dimension defined with the gross national product per capita (dollar) indicator, represented as ***GDP***; the social dimension is represented as ***TNT*** in terms of the number of primary-secondary teachers per student and ***TE*** in terms of the number of enterprises per capita; the utilities dimension is represented as ***EW*** in terms of the total electricity consumption per capita (kWh); the infrastructure dimension is represented as ***AB*** in terms of the building permit area per capita (m^2) and ***TAR*** in terms of the total asphalt road length per ten thousand inhabitants. The parameter values to be calculated for each indicator using the equations in the model are presented in Table 2.

Table 2: Parameter Values for Resource Indicators in 2021

Dimensions	Indicator	c_0	c_t	T *(Unit:Million)*	N_s *(Unit:Million)*
Economic	GDP	2,988	17,089	16,463.85	2.91
Utilities	EW	944	11,004	8,503.04	4.45
Social	TNT	0.05	0.09	0.06	0.82
	TE	0.02	0.08	0.06	1.63
Infrastructure	AB	0.69	5.32	2.61	1.93
	TAR	0.21	28.76	3.67	7.64

In 2021, the optimal population value given the resources explaining all dimensions for Tekirdağ is 820,000 which is specified by the TNT indicator of the social dimension. Analysis based on the indicators reflect that the optimal population should be 2.91 million according to the economic dimension, 4.45 million according to the utilities dimension and 1.93 million according to the infrastructure dimension.

For each indicator, N_{si} values were calculated by changing the population value between 10,000 and 7,000,000 and index values were standardized between 0 and 100. *SH* is the standardized value of H, H_{max} and H_{min} represent the maximum and minimum value of H varying with population; H_p is the happiness degree when population is p. Figure 2 and 3 depict the utility function (happiness degree) for Tekirdağ with the standardized values of the degree of happiness for each index where the standard value of happiness degree is given on the y-axis and the varying population values on the x-axis.

$$SH = 100\ x\ \frac{H_p - H_{min}}{H_{max} - H_{min}}$$

Figure 2: Standard Value of Happiness Degree Varies with Urban Population in Tekirdağ for 2018

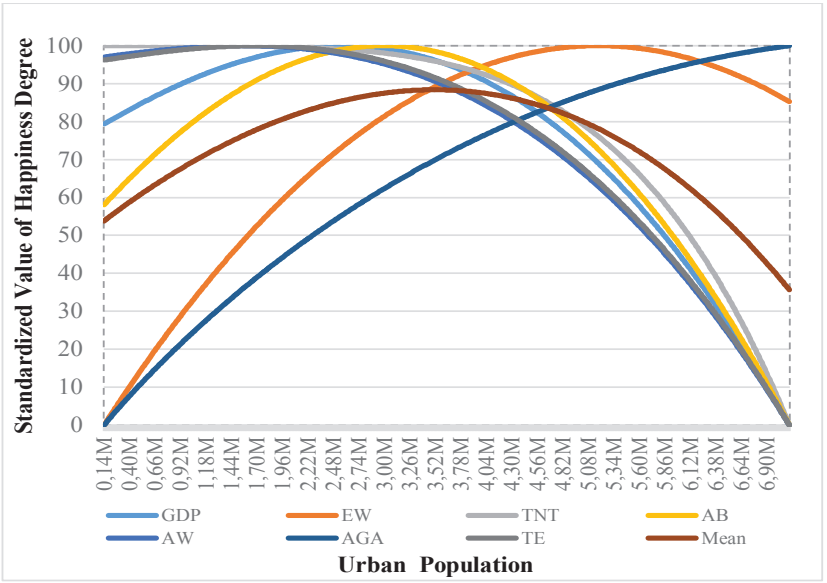
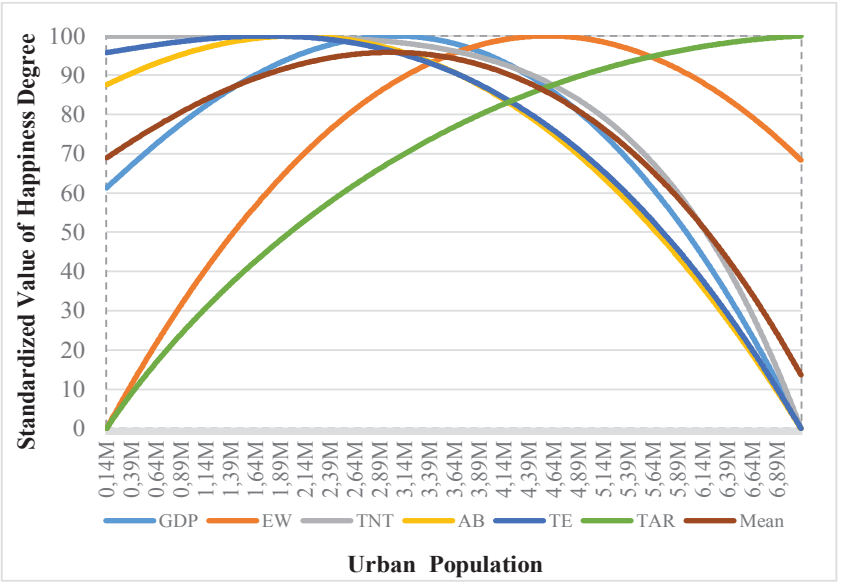


Figure 3: Standard Value of Happiness Degree Varies with Urban Population in Tekirdağ for 2021



4. Discussion and Conclusion

Although large cities offer more job opportunities, infrastructure and superstructure services, and technological competence compared to the small cities, the population balance must be well maintained in order to ensure a sustainable development. Population should not be determined solely on the basis of area size. On the basis of different criteria, the optimal population that the city's resources can support should be taken into consideration since a society with high population density that cannot provide access to resources at an adequate level and fairly distributed will lose its happiness degree, which is a classical theoretical way to describe social welfare.

The aim of this study is to investigate the optimal population for Tekirdağ, as a case study for Turkiye. Happiness degree model is applied for two different years, 2018 and 2021, using various indicators. The findings reflect that the optimal population of Tekirdağ should be between 770,000 and 820,000, successively. The result suggests that the city, which currently has a population of over one million, is overpopulated. Accordingly, it can be argued that the sustainability of the will be disrupted if the trend of growth rate persists. Especially, the index regarding the number of teachers per student (gives the minimum optimal population), which represents the social aspect of the resource indicators, may turn out to be a social issue in the upcoming years considering the increase in the young population of the city. Concludingly, bringing general/local governments and the relevant ministries (especially Ministry of Environment, Urbanization and Climate Change) together to call for an urgent country-wide urbanization policy should be the priority to ensure the long-term social welfare.

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