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Journal of Yaşar University dergisinin 2026 yılı Nisan ayına ait Cilt 21, Sayı 82 sayısını sizlerle buluşturmaktan büyük memnuniyet duymaktayız. Bu sayımızda yer alan beşi İngilizce, ikisi Türkçe olmak üzere yedi özgün araştırma makalesi; turizm, tedarik zinciri yönetimi, sürdürülebilirlik, enerji ekonomisi, maliye politikası ve kalkınma ekonomisi gibi farklı disiplinlerde güncel araştırma konularını ele almaktadır. Çalışmalar, hem kuramsal hem de ampirik yaklaşımlarıyla literatüre katkı sunarken uygulamaya yönelik önemli çıkarımlar da ortaya koymaktadır.

Sayının açılış makalesinde Serhan Oral ve çalışma arkadaşları, turistlerin seyahat davranışlarında akış deneyimini Amerikan Müşteri Memnuniyeti Endeksi (ACSI) modeli çerçevesinde incelemektedir. Bulgular, algılanan kalitenin akış deneyimini, akış deneyiminin ise müşteri memnuniyetini anlamlı biçimde etkilediğini ortaya koyarak turizm pazarlaması literatürüne katkı sağlamaktadır.

Burçin Özdamar, Aysu Göçer ve Ceren Altuntaş Vural, hanehalkı atıklarını tedarik zinciri sistemleri içerisinde süreç temelli bir bakış açısıyla ele almaktadır. Çalışma, döngüsel ekonomi ilkeleriyle bütünleşik kavramsal bir çerçeve sunarak atıkların stratejik bir kaynak olarak değerlendirilmesi gerektiğini vurgulamaktadır.

Hüseyin Şentürk, Brent petrol fiyatları ile döviz kuru oynaklığının üretici fiyatları ve sanayi üretimi üzerindeki etkilerini BEKK-GARCH modeliyle analiz etmektedir. Bulgular, enerji ve döviz piyasalarındaki oynaklığın üretim üzerinde belirleyici olduğunu gösterirken yenilenebilir enerjiye geçişin önemine dikkat çekmektedir.

Augustine Castro Singine ve Hilmi Yüksel, Tedarik Zinciri 4.0'ın benimsenmesini etkileyen örgütsel faktörleri ve bunun görünürlük ile verimlilik üzerindeki etkilerini incelemektedir. Çalışma, dijital dönüşümde strateji, entegrasyon ve otomasyonun kritik rolünü ortaya koymaktadır.

Şeyma Elmastaş ve Murat Aydın, yenilenebilir enerji yatırımları ile sürdürülebilir kalkınma hedefleri arasındaki ilişkiyi maliye politikası perspektifinden değerlendirmektedir. Bulgular, yenilenebilir enerji yatırımlarının etkisinin tamamlayıcı politikalarla desteklenmesi gerektiğini göstermektedir.

Cenk Murat Koçoğlu ve İsa Uğur, Bodrum'u ziyaret eden yerli turistlerin motivasyonları, deneyimleri ve satın alma sonrası davranışsal niyetleri arasındaki ilişkileri incelemektedir. Araştırma, özellikle sosyal motivasyon ve estetik deneyimin destinasyona yönelik olumlu davranışsal niyetleri güçlendirdiğini ortaya koymaktadır.

Son olarak Özge Arpacıoğlu Özdemir, Türkiye'de insani gelişme ile seçilmiş makroekonomik değişkenler arasındaki ilişkiyi zaman serisi analizleriyle değerlendirmektedir. Bulgular, uzun dönemde kişi başına düşen gelirin İnsani Gelişme Endeksi üzerinde anlamlı ve pozitif etkiye sahip olduğunu göstermektedir.

Bu sayıda yer alan çalışmalar birlikte değerlendirildiğinde, dijital dönüşümden sürdürülebilir kalkınmaya, enerji ekonomisinden turizm ve tedarik zinciri yönetimine uzanan geniş bir yelpazede disiplinlerarası ve uygulamaya dönük önemli katkılar sunduğu görülmektedir. Sayımızın gelecekteki araştırmalara değerli bir referans oluşturacağına inanıyoruz.

Bu sayının hazırlanmasında emeği geçen tüm yazarlarımıza, değerli hakemlerimize ve editöryal sürece katkı sağlayan tüm paydaşlarımıza teşekkür eder; çalışmaların akademik literatüre ve uygulamaya önemli katkılar sunmasını temenni ederiz.

Prof. Dr. Yiğit Kazançoğlu
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Alignment of Flow Experience in Tourists' Travel Behavior with the American Customer Satisfaction Index (ACSI) Model

Turistlerin Seyahat Davranışlarında Akış Deneyiminin Amerikan Müşteri Memnuniyeti Endeksi (ACSI) Modeli ile Uyumlaştırılması

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Abstract: This study aims to examine the integration of flow experience within the ACSI model. The study was conducted with tourists traveling on Turkish Airlines. Data were collected from 368 voluntary participants using a survey form. Hypotheses were tested with PLS-SEM. Customer expectation and perceived value did not significantly affect the flow experience. Perceived quality significantly affected the flow experience. Additionally, the flow experience significantly affected customer satisfaction. The results contribute to a deeper understanding of flow experience within the ACSI framework and provide theoretical and practical implications.

Keywords: American Customer Satisfaction Index, ACSI, Flow Experience, Travel, PLS-SEM.

JEL Classification: L93, M31, C38, L83, D12

Öz: Bu araştırma, akış deneyimini ACSI modeli ile ilişkilendirmek amacıyla yapılmıştır. Çalışma, Türk Hava Yolları ile seyahat eden turistler üzerinde gerçekleştirilmiştir. Veriler, 368 gönüllü katılımcıdan anket formu kullanılarak toplanmıştır. Hipotezler PLS-SEM yöntemiyle test edilmiştir. Müşteri beklentisi ve algılanan değer, akış deneyimini anlamlı şekilde etkilememiştir. Algılanan kalite, akış deneyimini anlamlı şekilde etkilemiştir. Ayrıca, akış deneyimi müşteri memnuniyetini anlamlı şekilde etkilemiştir. Bulgular, ACSI modeli kapsamında akış deneyiminin anlaşılmasına katkı sağlamakta ve kritik çıkarımlar sunmaktadır.

Anahtar Kelimeler: Amerikan Müşteri Memnuniyeti İndeksi, ACSI, Akış Deneyimi, Seyahat, PLS-SEM.

JEL Sınıflandırması: L93, M31, C38, L83, D12

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1. Introduction

The flow experience can be described as a deep and immersive feeling of satisfaction. Experiencing the flow state during a tourist activity can enhance satisfaction (deMatos, Duarte, and de Sa 2023; Zhang et al. 2019). This relationship is explained within the context of flow theory. Flow theory describes consumers' states of deep engagement in an activity. The flow experience can be viewed as consumers achieving desired satisfaction. This demonstrates the connection between the flow experience and consumer satisfaction variables. Consumer satisfaction with an event can be examined through various theoretical approaches. ACSI, which is considered in many sectors and defined as a performance measure, is one of these approaches (Fornell et al. 1996). ACSI examines factors linked to customer satisfaction. It can measure customer satisfaction related to a specific sectoral activity.

Previous studies consistently indicate a relationship between flow experience and customer satisfaction. The presence of strong evidence in the literature for this relationship is the primary rationale for this research. This rationale necessitates an integrated examination of flow experience within the ACSI model. There are many studies highlighting this relationship. However, unlike the existing literature, considering flow experience and the ACSI model together provides a more comprehensive perspective. Moreover, the findings resulting from this positioning can contribute new insights to the literature. Therefore, considering the rationale of our research, our theoretical and practical conclusions are original.

2. Theoretical Background

2.1. American Customer Satisfaction Index (ACSI)

Customer satisfaction indexes are measurement models that assess the degree of satisfaction customers experience from the services they consume (Fornell 1992). ACSI, which is frequently used to assess customer satisfaction (Liu and Zhang 2021; Hult et al. 2019; Zhou et al. 2023; Yilmaz, Ari, and Oguz 2021), is a performance benchmark for business (Fornell et al. 1996; Angelova and Zekiri 2011). ACSI creates information about the quality of products or services (Fornell et al. 1996; Anderson and Fornell 2000). Its purpose is to measure overall customer satisfaction (Kim et al. 2013). It also focuses on the behaviors that will occur in consumers after satisfaction (Hult et al. 2019). ACSI consists of six structural variables. According to ACSI, perceived quality, perceived value and expectations affect satisfaction.

Additionally, satisfaction affects commitment and complaint (Zhan, Luo, and Luo 2020; Dani 2013; Kim et al. 2013; Hsu 2008; Deng, Yeh, and Sung 2013; Zhang et al. 2016).

Consumers make performance predictions about a product before making a purchasing decision. This situation is expressed as customer expectation (Park et al. 2018). Knowing what customers expect and need from a service during the product or service experience is considered important to make high customer satisfaction more effective. Meeting customers' expectations is crucial for ensuring customers have a satisfying experience (Pitt and Jeantrout 1994; Coye 2004). Thus, it is observed that expectation affects satisfaction (Moslehpour et al. 2018).

Perceived quality emerges as a result of consumers' evaluations of the product (Hallak, Assaker, and El-Haddad 2018). The consumer's evaluations about the unique and superior features of a product constitute perceived quality (Muskat et al. 2019). Perceived quality is the primary determinant of a customer's evaluation of the last consumption experience in the serviced market. In the light of this information, it can be thought that perceived quality will affect satisfaction (Angelova and Zekiri 2011).

Perceived value can be evaluated from many different perspectives. The ACSI model considers perceived value from a price perspective. In the ACSI model, perceived value evaluates the price customers pay for the product in the context of quality satisfaction (Angelova and Zekiri 2011; Hult et al. 2017). Perceived value is evaluating the benefits and perceived costs of the product to be consumed (Choi et al. 2004). The resulting increase in perceived quality increases perceived value. This provides customer satisfaction (Hapsari, Clemes, and Dean 2015).

Satisfaction encompasses feelings such as pleasure, relaxation, and indecision (Xue and Yang 2008). Satisfaction is the evaluation based on whether customers meet their needs and expectations. Ensuring customer satisfaction that results from experiencing the service is a key issue because customer satisfaction positively impacts a business's reputation (Gronholdt, Martensen, and Kristensen 2000). As customer satisfaction increases, loyalty increases (Suhartanto et al. 2020).

Customer loyalty is considered as customers' intention to repurchase the product or service (Xue and Yang 2008). In other words, it is the probability that the customer will refer to the same seller when intending to purchase a product or service (Hult et al. 2017). Acquiring loyal customers is a significant goal of a business strategy. Customer loyalty is a phenomenon that must be taken into account in order for a business to maintain its presence in

the market (Anton, Camarero, and Laguna-Garcia 2017). Bezerra and Gomes (2020) have pointed out that dissatisfaction can reduce customer loyalty and lead to complaints.

2.2. Flow Theory

Flow is a concept that describes the process where individuals filter out negative emotional experiences and engage in an activity continuously without interruption (Nakamura and Csikszentmihalyi 2009; Tse, Nakamura, and Csikszentmihalyi 2022; Hyun, Thavisay, and Lee 2022). Flow theory explores individuals' decisions to devote themselves to challenging and demanding activities, to enjoy them, and to engage in them repeatedly. This theory particularly centers around the concept of autotelic activities, suggesting that individuals choose specific activities due to their intrinsic rewards. Autotelic activities are those in which individuals engage for their own sake, finding enjoyment and intrinsic motivation (DeMatos, de Sa, and Duarte 2021). Flow theory proposes that an individual's engagement in an activity can transform it into an experiential service (Ayazlar and Yuksel 2018).

The flow experience is the most desired experience for consumers (Xu et al. 2021). The flow experience is identified by a customer's concentration on an activity, a lack of concern for anything outside the task at hand, the experience of pleasure and creativity through the action performed, and a sense of being entirely immersed in the moment (Csikszentmihalyi 1990; Csikszentmihalyi and Csikszentmihalyi 1992). The flow experience is applied in many industries as an enhanced form of experience that plays a significant role in consumer experience (Chu and Wen 2021). It is derived from perceptions focused on happiness and satisfaction that consumers gain from any activity they engage in (Wu and Liang 2011). Thus, flow experience is considered an important theory to study tourists' experiences and satisfaction (Kim and Thapa 2018). Measuring flow experience can be an important method to examine experience quality (Adam 2015). Given its significance as a key determinant for tourist satisfaction and loyalty, it can endure for a long time and is memorable (Chen et al. 2017). Therefore, offering a flow experience for services in destinations is an important step for success (Zhang et al. 2019). Tourists' satisfaction with the services they purchase is directly proportional to their flow experience. For this reason, destination managers should focus their strategies in this direction (Karasakal and Albayrak 2022).

3. Hypothesis Development

3.1. Customer Expectation - Flow Experience

Customers aim to derive maximum benefit from the services/products they will purchase or the businesses they will shop from. Dong, Wang, and Qin (2023) have mentioned that the formation of the flow experience is accompanied by high excitement and satisfaction, similar to customer expectations. Hsu, Chang, and Chen (2012) found a significant relationship between flow experience and customer characteristics in the online shopping experience. Additionally, Lin and Lekhawipat (2014) determined a relationship between customer expectations and the intention to repurchase. Kazancoglu and Demir (2021) suggested in their study during the Covid-19 period that flow experience affects repurchase intention. The study revealed a connection between these two variables. In light of this information, Hypothesis H1 is formulated.

H₁: Customer expectation has a positive effect on flow experience.

3.2. Perceived Quality - Flow Experience

The concept of perceived quality among consumers is generally accepted as the price-performance ratio. Obada (2014) states that perceived quality affects the flow experience on online websites. Aboelmaged (2018) found that perceived quality explained the streaming experience in Twitter's success in healthcare. Kim and Thapa (2018) express that perceived quality influences tourists' flow experiences and increases their loyalty to the destinations they visit. Cuevas, Lyu, and Lim (2021) found that when the perceived quality of textual information is high, the flow experience in the social search process will also be high. Based on the findings of these studies, Hypothesis H2 is formulated.

H₂: Perceived quality has a positive effect on flow experience.

3.3. Perceived Value - Flow Experience

Perceived value explains how a product's cost and benefits are compared with competing products (Ofori et al. 2022). Perceived value is the key to attracting users to experience products/services (Yapp and Yeap 2023). Similarly, the flow experience is an important variable for product/service producers to retain customers and build long-term competitiveness (Bilgihan et al. 2014). Researchers have been examining these two variables in different concepts and areas. A new multi-mediator-regulatory model has been developed to explore how uniqueness, perceived value, and engagement can enhance the flow experience

(Zhang et al. 2019; Zielke 2014). Accordingly, it has been suggested that uniqueness in destinations can increase the flow experience. Additionally, perceived value has been identified as a critical mediator in this relationship. Park, Ko, and Do (2023) state that perceived value affects the flow experience on metaverse platforms. Proving the relationship between perceived value and flow experience in competitive games, Chu and Wen (2021) emphasized that the gaming industry should not overlook this relationship. Goker (2022) found that the perceived value of equipment in ski areas positively affects the flow experience. Kim and Thapa (2018) found a positive relationship between these two variables in tourism activities in natural areas. All of this information has supported the formulation of Hypothesis 3.

H₃: Perceived value has a positive effect on flow experience.

3.4. Flow Experience - Customer Satisfaction

Experiencing flow can positively impact customer satisfaction and allow customers to enjoy their experience more. In other words, flow experience is a decisive variable in predicting customer satisfaction (Bilgihan et al. 2014; Wu and Liang 2011). A study by Chang and Zhu (2012) found that the flow experience in social networking services positively affects customer satisfaction. It can be stated that tourist satisfaction is significantly increased not only by service quality but also by flow experience (Mannell and Isoahola 1987). Kuo et al. (2016) say that the satisfaction of tourists traveling to Kimnien war zones in Tavyan increases as a result of the flow they experience in the destination. A study conducted by Ayazlar and Yuksel (2018) aimed to investigate the factors affecting tourists' life satisfaction in paragliding activities and also reflects the role of flow experience in adventure activities. Flow experience not only directly influences tourists' life satisfaction but also indirectly affects it through experience satisfaction. Flow experience increases tourists' level of recall of the experience. This situation is closely related to satisfaction (deMatos, Duarte, and de Sa 2023). In this regard, Hypothesis H4 has been developed.

H₄: Flow experience has a positive effect on customer satisfaction.

4. Materials and Methods

4.1. Research Model and Hypotheses

The variable of flow experience has been positioned within the ACSI model in line with the research objective. Accordingly, the research model is shown in Figure 1.

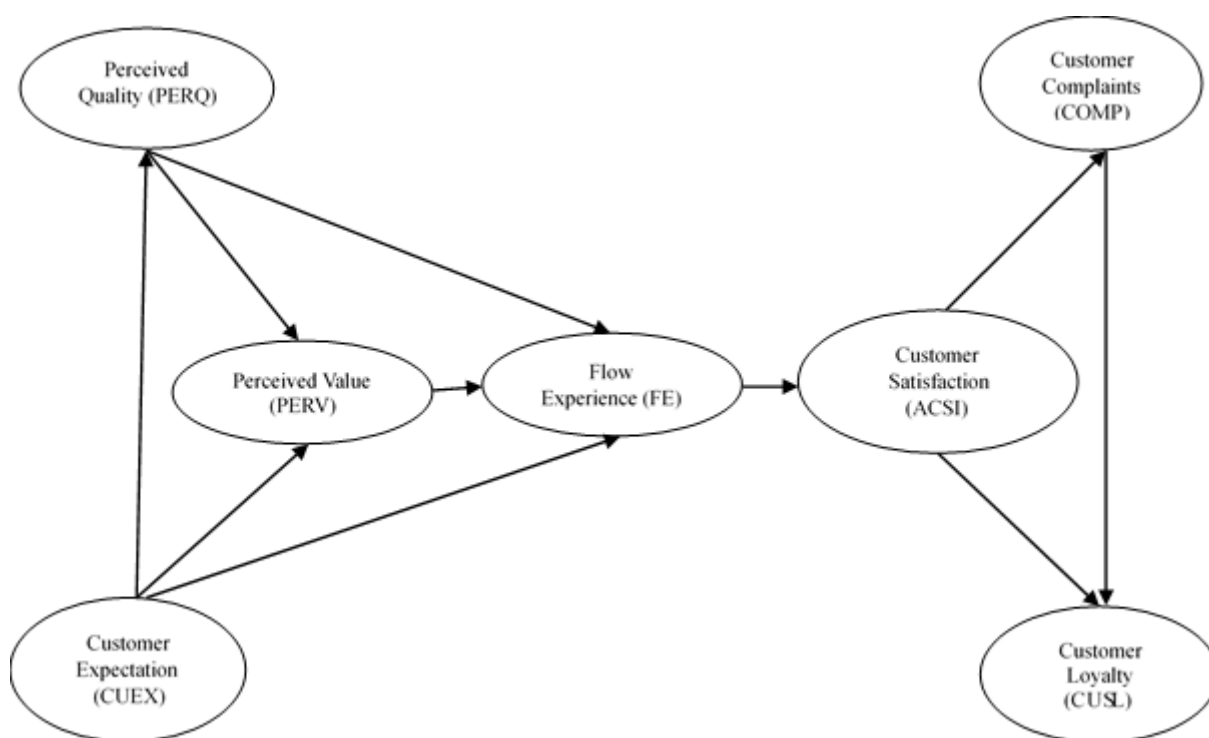


Figure 1. Research Model

H₁: Customer expectation has a positive effect on flow experience.

H₂: Perceived quality has a positive effect on flow experience.

H₃: Perceived value has a positive effect on flow experience.

H₄: Flow experience has a positive effect on customer satisfaction.

4.2. Sample and Data Collection

Research data were collected through a survey form. A language expert was consulted to examine the language appropriateness of the scales. The survey form was delivered to participants digitally. The survey form was designed in two parts. The first section contains the personal information area consisting of 4 items. The second part includes 18 items measuring 6 ACSI variables and the flow experience variable. Research data were collected from tourists traveling with Turkish Airlines between 12 August and 15 October 2025. The survey was administered online, and participants were reached on a voluntary basis after completing their travel experience.

According to Hair et al. (2009), having at least 10 participants for each parameter in the scale is an important criterion for structural equation modeling. In our study, there are 18 parameters in all the scales used. In this context, research data was obtained from 368

volunteer participants. This number indicates that sufficient sample size was reached. All participants were included in the study on a voluntary basis.

4.3. Measures

The flow experience scale and the scales included in the ACSI model are established scales in the literature with proven validity and reliability. The flow experience scale has 3 items and a single dimension. The scale taken from Kim and Thapa (2018)'s study measures flow experience in the context of travel behavior. The ACSI model includes customer expectations, perceived quality, perceived value, customer satisfaction, customer loyalty, and customer complaints scales taken from the study conducted by Morgeson et al. (2023). Morgeson et al. (2023) thoroughly examined the ACSI model and evaluated how the model works in different sectors. Thus, they provided important insights into how the variables of the model should be measured. Accordingly, the customer expectations variable is measured with 3 items and a frequency scale ranging from 1 to 10 points. The perceived quality scale consists of 3 items, the perceived value scale includes 2 items, customer satisfaction scale comprises 3 items, the customer loyalty scale has 1 item, and the customer complaints scale has 1 item. These scales are measured on a 1-10 point scale.

5. Results

5.1. Descriptive Statistics

368 volunteer tourists participated in the research. Personal information of the participants is presented in Table 1.

Table 1. Descriptive Statistics

<i>Trait</i>	<i>Variable</i>	<i>n</i>	<i>%</i>
Gender	Woman	192	52,2
	Man	176	47,8
Age	18-26	112	30,4
	27- 36	116	31,5
	37 - 46	88	23,9
	47 and over	52	14,1
Education Status	Primary School	5	1,4
	Secondary School	27	7,3
	Associate Degree	62	16,8
	Bachelor's Degree	151	41,0
	Graduate Degree	123	33,4
Monthly income	Less than minimum wage	59	16,0
	Minimum wage-20.000 ₺	117	31,8
	20.001 ₺ – 30.000 ₺	87	23,6
	30.001 ₺ and over	105	28,5

Of the participants, 52.2% were female, and 47.8% were male. The highest participation was in the age groups of 18-26 (30.4%) and 27-36 (31.5%), while the lowest participation was in the 47 years and older age group (14.1%). When examining the participants' educational backgrounds, the highest education level was a bachelor's degree at 41.0%, while the lowest education level was primary school education at 1.4%. Additionally, 31.8% of the participants had income between the minimum wage and 20,000 TL, and 16.0% had income below the minimum wage.

5.2. Outer Model

Research hypotheses were analyzed using the PLS-SEM method and the SmartPLS4 program. The research model was evaluated reflectively, as recommended in the literature. The validity and reliability analysis results are presented in Table 2.

Table 2. Results Summary for the Outer Model

<i>Items</i>	<i>Outer Loadings</i>	<i>VIF</i>
<i>CUEX</i>		
CE1	0.883	1.916
CE2	0.783	1.916
CE3	0.292	1.052
<i>PERQ</i>		
PQ1	0.870	2.662
PQ2	0.891	2.651
PQ3	0.324	1.088
<i>PERV</i>		
PV1	0.744	2.319
PV2	1.014	2.319
<i>ACSI</i>		
ACSI1	0.914	2.523
ACSI2	0.736	2.014
ACSI3	0.838	2.475
<i>COMP</i>		
CC	1.000	1.000
<i>CUSL</i>		
CL	1.000	1.000
<i>FE</i>		
FE1	0.985	1.895
FE2	0.747	3.871
FE3	0.794	3.730

The abbreviations and factor loadings of scale items used for the research model are presented in Table 2. Accordingly, the variable "customer expectation" is abbreviated as "CUEX," "perceived quality" as "PERQ," "perceived value" as "PERV," "customer satisfaction" as "ACSI," "customer complaints" as "COMP," "customer loyalty" as "CUSL,"

and "flow experience" as "FE." When examining the factor loadings of the items, it was observed that the factor loading for item CE3 related to the "customer expectation" variable was below 0.30 and was, therefore, removed from the scale (Hair et al. 2019). Upon reviewing the factor loadings of the other items in the scales, it was found that item PQ3 for the "perceived quality" variable had a factor loading of 0.324, which was deemed acceptable. When examining the other items, it was determined that all factor loadings were above 0.70. In the PLS-SEM analysis, the high correlation between indicators leads to multicollinearity issues. Therefore, VIF values were discussed. VIF values should be below 5.0. When the entire model was examined, it was seen that the VIF coefficients were below 5.0, indicating that there were no multicollinearity problems. Additional evidence regarding reliability and validity is presented in Table 3.

Table 3. Reliability and Validity

<i>Measurements</i>	<i>Items</i>	<i>Cronbach Alpha</i>	<i>CR (rho_a)</i>	<i>CR (rho_c)</i>	<i>AVE</i>
Customer Expectation	2	0.818	0.826	0.821	0.697
Perceived Quality	3	0.703	0.861	0.764	0.552
Perceived Value	2	0.860	0.920	0.881	0.791
Customer Satisfaction	3	0.868	0.879	0.871	0.693
Flow Experience	3	0.887	0.901	0.883	0.719

As shown in Table 3, it was determined that the AVE values of all variables were above 0.50 and met the necessary criteria. Composite reliability (CR/rho_a- rho_c) values for all variables are above 0.70, indicating positive construct reliability (Hair et al. 2019). Cronbach Alpha values are above 0.70, demonstrating sufficient reliability. The discriminant validity of the structure was tested based on the HTMT analysis. Details are in Table 4.

Table 4. Discriminant Validity- HTMT

	<i>COMP</i>	<i>CUEX</i>	<i>CUSL</i>	<i>ACSI</i>	<i>FE</i>	<i>PERQ</i>	<i>PERV</i>
<i>COMP</i>	1						
<i>CUEX</i>	0.364	1					
<i>CUSL</i>	0.597	0.433	1				
<i>ACSI</i>	0.624	0.548	0.756	1			
<i>FE</i>	0.447	0.363	0.410	0.604	1		
<i>PERQ</i>	0.603	0.738	0.787	0.949	0.584	1	
<i>PERV</i>	0.583	0.374	0.645	0.848	0.489	0.749	1

Discriminant validity was examined using HTMT, the most comprehensive and less restrictive analysis recommended for least squares structural equation modeling (Qin and Chen 2022). The HTMT value between variables must be below 0.90 (Hair et al. 2019). According to Table 4, discriminant validity is established among all variables. However, the

HTMT value between PERQ and ACSI is above 0.90. Researchers have examined this situation and found that the items related to PERQ and ACSI variables in the American Customer Satisfaction Index model are similar to each other. Therefore, it is believed that participants responded similarly to the items related to these two variables. The high HTMT value between PERQ and ACSI variables is thought to be due to this similarity. It is clear that this difference is small and all other HTMT values are acceptable. In this case, it can be said that the research model provides discriminant validity. All these results confirm that the model is valid and reliable.

5.3. Inner Model

Hypotheses were analyzed using the bootstrap technique. Accordingly, model fit indices were examined. Details of the fit indices are in Table 5.

Table 5. Model Fit Indices

	<i>SRMR</i>	<i>d_ ULS</i>	<i>d_ G</i>	<i>Chi-Square</i>	<i>NFI</i>
<i>Saturated Model</i>	0.037	0.161	0.225	429.238	0.889
<i>Estimated Model</i>	0.053	0.331	0.281	518.530	0.866

When examining the model fit values, SRMR value, which should be below 0.80 according to fit criteria, has been calculated as 0.037. According to the fit criteria, the *d_ ULS* and *d_ G* values should be greater than 0.05, and our model meets these criteria. The NFI value is expected to be between 0 and 1. As the NFI value approaches 1, the fit increases. In this context, the NFI value of our model is at a good level (Hair et al. 2019). The explanatory power, effect size and predictive fitness value of the structural model were examined. Accordingly, R2, f2 and Q2 values are in Table 6.

Table 6. Explanatory Power of the Structural Model

<i>Exogenous -> Endogenous</i>	<i>f²</i>	<i>Endogenous variables</i>	<i>R²</i>	<i>Q²</i>
<i>COMP -> CUSL</i>	0.065	<i>COMP</i>	0.385	0.102
<i>CUEX -> ACSI</i>	0.102	<i>CUSL</i>	0.599	0.148
<i>CUEX -> FE</i>	0.001	<i>ACSI</i>	0.835	0.213
<i>CUEX -> PERQ</i>	1.069	<i>FE</i>	0.340	0.095
<i>CUEX -> PERV</i>	0.089	<i>PERQ</i>	0.517	0.363
<i>ACSI -> COMP</i>	0.627	<i>PERV</i>	0.545	0.098
<i>ACSI -> CUSL</i>	0.607			
<i>FE -> ACSI</i>	0.071			
<i>PERQ -> ACSI</i>	2.069			
<i>PERQ -> FE</i>	0.095			
<i>PERQ -> PERV</i>	0.897			
<i>PERV -> FE</i>	0.016			

When looking at the explanatory power of the variables in the model, it can be observed that R^2 values are above 0.10 (Hair et al. 2019). In all 6 endogenous variables within the model, Q^2 predictive values are positive, and the mean of the PLS-SEM prediction error is zero for all variables (mean of PLS-SEM prediction error = ± 0.000). Positive predictive values and small prediction error values for all endogenous variables and indicators indicate that the final model has sufficient predictive power (Chua 2022).

Effect sizes for the model were calculated according to f^2 values. According to the results, the paths $PERQ \rightarrow PERV$ ($f^2=0.897$), $PERQ \rightarrow ACSI$ ($f^2=2.069$), $ACSI \rightarrow CUSL$ ($f^2=0.607$), $ACSI \rightarrow COMP$ ($f^2=0.627$), and $CUEX \rightarrow PERQ$ ($f^2=1.069$) have a high degree of effect size. The paths $PERQ \rightarrow FE$ ($f^2=0.291$), $COMP \rightarrow CUSL$ ($f^2=0.065$), $CUEX \rightarrow ACSI$ ($f^2=0.102$), $CUEX \rightarrow PERV$ ($f^2=0.089$), and $FE \rightarrow ACSI$ ($f^2=0.071$) have a weak degree of effect size. The paths $PERV \rightarrow FE$ ($f^2=0.016$) and $CUEX \rightarrow FE$ ($f^2=0.001$) do not have an f^2 effect size (Cohen 1992).

5.4. Path Analysis

This study tests the fit of the flow experience with the ACSI model variable. Accordingly, the ACSI model was tested on the sample of tourists who use Turkish Airlines. Following this test, the flow experience variable was positioned in the model. Path results for the ACSI model are shown in Figure 2. The path analysis results for the research model created by adding the flow experience variable are shown in Figure 3.

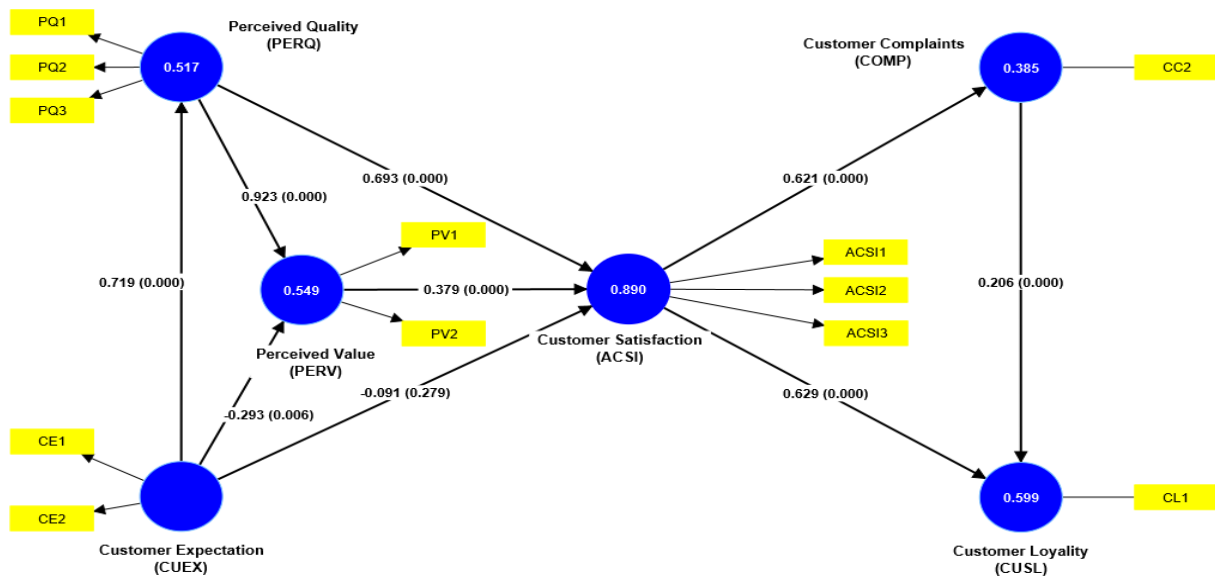


Figure 2. ACSI Path Analysis

There are many studies using the ACSI model in various studies with different samples. These studies have been conducted in various sectors, including airlines, processed foods, internet service providers, banks (Morgeson et al. 2023), tourism (Sun and Kim 2013; Deng, Yeh, and Sung 2013), e-commerce (Hsu 2008), healthcare (Nazi 2010) among others. The results of the ACSI model in the Turkish Airlines sample can be seen in Figure 2. Accordingly, significant relationships were found between all variables. However, an insignificant relationship emerged between CUEX and the ACSI variable. When examining other studies, insignificant or low-level significant results between CUEX and ACSI can also be found. The relationship between CUEX and PERV is significant and negative in our study. According to the ACSI model described by Fornell et al. (1996), CUEX affects PERV. Our study yielded different results. However, in the literature, studies conducted in different sectors have identified this relationship as negative. To test the research hypotheses, the FE variable was positioned within the ACSI model. Path analysis results are presented in Figure 3.

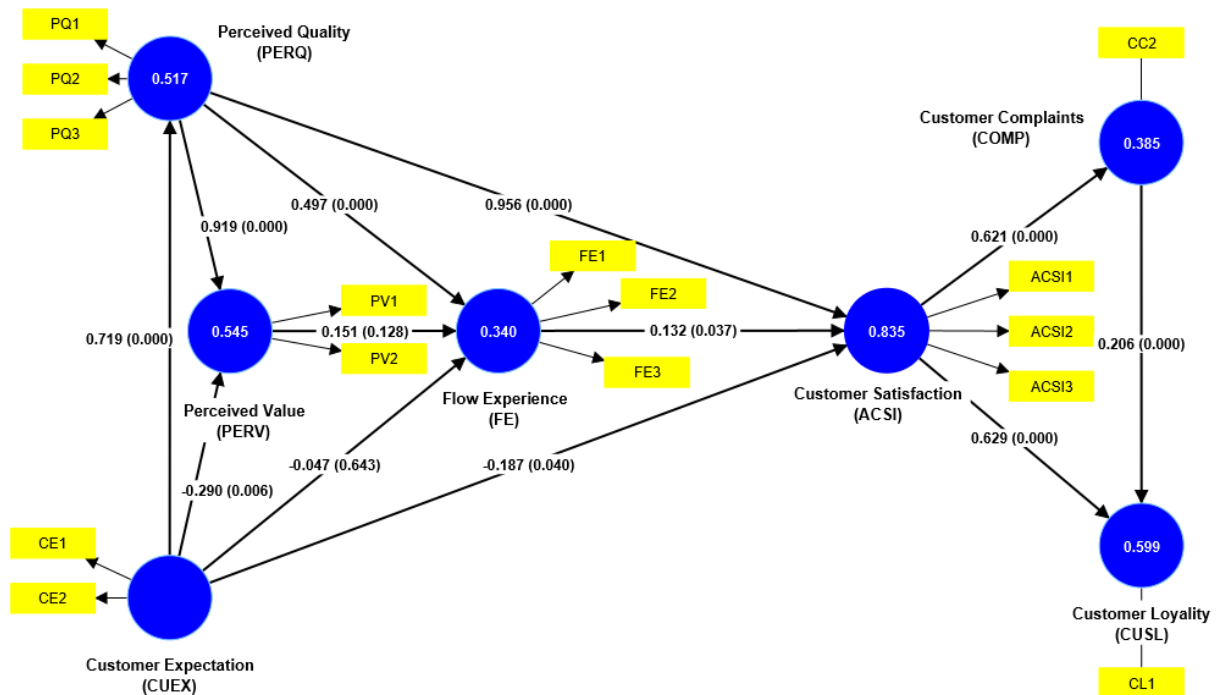


Figure 3. PLS-SEM Path Model Results

The structural model results, in which the flow experience variable is included in the ACSI model, are in Figure 3. When the literature is examined, there is strong evidence that flow experience affects satisfaction (Bilgihan et al. 2014; Chang and Zhu 2012; Kuo et al. 2016; Wu and Liang 2011). According to the path analysis results, the relationship between

CUEX and FE (H1) is statistically insignificant ($\beta=-0.047$; $p>0.05$). The relationship between PERQ and FE (H2) is significant and positive ($\beta=0.49$; $p<0.001$). The relationship between PERV and FE (H3) was found to be insignificant ($\beta=0.15$; $p>0.05$). When examining the relationship between FE and the ACSI variable (H4), it is seen to be significant and positive ($\beta=0.13$; $p<0.05$). According to these results, it can be stated that the FE variable fits the ACSI model. Additionally, when the ACSI model was tested on its own, the relationship between CUEX and the ACSI variable was found to be insignificant ($\beta=-0.091$; $p>0.05$). However, with the addition of the FE variable to the model, this relationship has become significant (CUEX→ACSI; $\beta=-0.18$; $p<0.05$). After positioning the FE variable into the ACSI model, no change was observed in the relationship levels of other variables.

6. Discussion and Conclusion

This research, which aims to determine the compatibility of the flow experience variable with the ACSI model, was conducted in the context of tourists using Turkish Airlines. The path results of the ACSI model examined with the PLS-SEM technique in the sample of Turkish Airlines are in line with the literature (Morgeson et al. 2023; Romero-Subia et al. 2023; Cheng et al. 2022; Xie, Xie, and Guo 2022; Zhou et al. 2023; Yilmaz, Ari, and Oguz 2021). The ACSI model, tested in many fields in the literature, has yielded appropriate results in the sample of this research. Therefore, the basic logic of the study is to determine the compatibility of flow experience with the ACSI model. In accordance with the literature, the FE variable was positioned in the model as an exogenous variable for the ACSI variable. According to the path results, the FE variable significantly influences the PERQ variable and predicts the ACSI variable. Based on these results, our study has theoretical and practical implications.

6.1. Theoretical Implications

The first step in the study was to test whether the ACSI model yielded appropriate results in the Turkish Airlines sample. According to the results, there was no significant relationship between the CUEX and ACSI variables, while significant relationships were found among all other variables. The relationship between CUEX and PERV was negative, while the relationships between other variables were positive. The only relationship that was found to be insignificant was between the CUEX and ACSI variables. Accordingly, previous studies using the ACSI model were investigated. In some studies, no significant relationship was found between CUEX and ACSI, similar to our results. Moreover, in most previous studies, a

weak or non-significant relationship between CUEX and ACSI was established (Cheng et al. 2022; Xie, Xie, and Guo 2022; Zhou et al. 2023; Ding et al. 2021; Liu and Zhang 2021). Therefore, the research results are compatible with the existing literature. There have been previous studies that also identified an insignificant relationship between CUEX and PERV (Romero-Subia et al. 2023; Xie, Xie, and Guo 2022). Therefore, this insignificant relationship can be explained. As a result of the analysis, a positive relationship emerged between the ACSI variable and the COMP variable. While some studies in the literature show results similar to this (Yilmaz, Ari, and Oguz 2021), some studies indicate a negative relationship (Liu and Zhang 2021). This situation demonstrates that our result is acceptable in the literature.

The focus of the study is to determine the fit of the flow experience variable in the ACSI model. Therefore, as the second step of the research, the FE variable has been added to the model. In the literature, there is strong evidence that the flow experience affects satisfaction (Kang, Lee, and Namkung 2018; Ding et al. 2010; Kim and Ko 2019; deMatos, Duarte, and de Sa 2023). In line with this, the flow experience variable has been positioned as exogenous to customer satisfaction variable in the ACSI model. The results show that perceived quality affects the flow experience. Kiili et al. (2014) express the flow experience as a variable that can be used to measure the quality. Therefore, the information that perceived quality affects the flow experience is consistent with the literature. According to the research results, perceived value and customer expectation do not affect the flow experience. In the study by Kim and Thapa (2018), the perceived value variable is considered in terms of the dimensions of "quality, emotional, price, and social." In the ACSI model, the perceived value variable is related to consumers' perceptions of price (Fornell et al. 1996). Kim and Thapa (2018) revealed that the quality, emotional and social dimensions of perceived value affect the flow experience, but stated that the price dimension does not affect the flow experience. Additionally, Zhang et al. (2019) suggest that perceived value affects the flow experience, but this effect is weak ($\beta = 0.054$). This information is consistent with the results of our study. When the analysis results are examined, it is understood that customer expectations do not affect the flow experience. Since there was no other study revealing the relationship between customer expectation and flow experience, this hypothesis emerged through indirect variables. Jeong, Parks, and Hyun (2019) and Li-Hua (2012) found that the relationship between customer expectation and quality is insignificant. Yu et al. (2005) suggests that customer expectation does not affect customers' overall satisfaction. The absence of direct

evidence for a relationship between customer expectation and the flow experience supports our result. According to our research, there is a significant and positive relationship between the flow experience and customer satisfaction. In the literature, there are strong pieces of evidence indicating that the flow experience affects the customer satisfaction variable (Ayazlar and Yuksel 2018; Bilgihan et al. 2014; Chang and Zhu 2012; deMatos, Duarte, and de Sa 2023; Kuo et al. 2016; Wu and Liang 2011). This indicates that our research result is consistent with the existing literature.

6.2. Practical Implications

This research highlights the importance of the flow experience in customer satisfaction model. The results indicate that the flow experience significantly influences customer satisfaction, along with quality. Therefore, tourism businesses should primarily focus on the concept of quality to ensure customer satisfaction (Canalejo and del Río 2018). According to the research results, tourists' flow experiences during their travels are significantly influenced by quality. Kiili et al. (2014) emphasizes the importance of the flow experience variable in measuring service quality. Therefore, it would be beneficial for tourism businesses to consider improvements in service quality within the framework of the flow experience. The results show that the flow experience significantly affects customer satisfaction. This indicates that the key variable for increasing tourists' satisfaction levels is the flow experience (deMatos, Duarte, and de Sa 2023; Kim and Ko 2019). Based on these findings, tourism businesses should prioritize and develop strategies for customer satisfaction around the concepts of perceived quality and the flow experience.

6.3. Limitation and Future Research

The research results are evaluated within the framework of some limitations. The first limitation is that the research was designed as a cross-sectional study. The research findings have been interpreted in this context. Future research should adopt longitudinal approaches to generalize the findings. The second limitation is that the sample of the research consists of tourists using Turkish Airlines. The research findings have been interpreted within this framework. Future research can test tourist behaviors in other sectors and compare them with the findings of this research. The third limitation is the insignificant relationship between the PERV variable and the FE. This may be due to the fact that the PERV variable is considered in the "price" dimension of the ACSI model, as seen in the literature. In future research, evaluating the PERV variable within the framework of the ACSI model's "quality, emotional,

and social" dimensions can provide a different perspective on the model. The fourth limitation is the explanatory power of customer satisfaction. Future studies may enhance the explanatory power of the model by incorporating additional variables.

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Reframing Household Waste within Supply Chain Systems: A Systematic Review and Conceptual Framework

Tedarik Zinciri Sistemleri İçinde Hanehalkı Atıklarının Yeniden Çerçevenmesi: Sistematik Bir Derleme ve Kavramsal Çerçeve

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Abstract: According to the United Nations Environment Programme, global municipal solid waste generation reached approximately 2.3 billion tons in 2023, a significant share of which originates from households. In parallel, the growing emphasis on circular economy (CE) practices has highlighted household waste as a critical resource within supply chain systems. This paper consolidates the state of the art research on household waste supply chain management. The purpose of this study is to systematically synthesize this literature by adopting a process-based supply chain management (SCM) perspective. Using a content-analysis based systematic literature review approach, 493 peer-reviewed journal articles retrieved from the Web of Science database published between 2015 and 2025 were analyzed. The findings identify the dominant research streams associated with major SCM processes, from which a household waste supply chain framework integrating CE principles with established SCM processes is proposed. This study provides insights that are particularly relevant for countries facing increasing household waste generation and offers a structured foundation for future research and policy development.

Keywords: Household Waste Supply Chain Management, Circular Economy, Waste Logistics, Returns Management, Systematic Literature Review

JEL Classification: M11, Q53, Q56

Öz: Birleşmiş Milletler Çevre Programı verilerine göre, dünya genelinde katı atık üretimi 2023 yılı itibarıyla yaklaşık 2,3 milyar tona ulaşmış olup, bu atıkların önemli bir bölümü hanehalkı kaynaklıdır. Döngüsel ekonomi uygulamalarının giderek artan önemi ise hanehalkı atıklarını tedarik zinciri sistemleri içerisinde kritik bir kaynak olarak öne çıkarmıştır. Bu çalışma, hanehalkı atık tedarik zinciri yönetimi alanındaki literatürü bütüncül bir biçimde ele almaktadır. Çalışma, süreç temelli bir tedarik zinciri yönetimi bakış açısı benimseyerek bu literatürü sistematik olarak sentezlemeyi amaçlamaktadır. Bu doğrultuda içerik analizi temelli sistematik literatür incelemesi yaklaşımı kullanılarak Web of Science veri tabanından elde edilen 2015–2025 yılları arasında yayımlanmış 493 hakemli dergi makalesi analiz edilmiştir. Bulgular, temel tedarik zinciri yönetimi süreçleriyle ilişkili baskın araştırma akımlarının belirlenmesine katkı sağlamış olup ilgili süreçlerle döngüsel ekonomi ilkelerini bütünleştiren bir hanehalkı atık tedarik zinciri çerçevesi önerilmiştir. Çalışma, hanehalkı atık oluşumunun giderek arttığı ülkeler açısından özellikle önem taşıyan çıkarımlar sunmakta ve gelecekteki araştırmalar ile politika geliştirme süreçleri için yapılandırılmış bir temel oluşturmaktadır.

Anahtar kelimeler: Hanehalkı Atık Tedarik Zinciri Yönetimi, Döngüsel Ekonomi, Atık Lojistiği, İade Yönetimi, Sistematik Literatür İncelemesi

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1. Introduction

Recent global disruptions such as COVID-19 pandemic along with shocks to energy and resource supplies have reshaped household consumption patterns and waste generation pushing household waste flows to the center of sustainability debates (UNEP 2024). These changes have intensified the pressure on existing waste management systems and highlighted the strategic role of household waste within broader supply chain structures. Recent studies emphasize the increasing importance of household-generated food, plastic, and medical waste, alongside growing behavioral and institutional challenges in managing these flows (Ananda et al. 2024; Hu et al. 2024; Madden and Florin 2024; Mavlutova et al. 2023). In this context, waste management has emerged as a critical component of the reverse logistics and has been widely studied both in developing and developed countries (Batista et al. 2018; González-Sánchez et al. 2020). Growing scholarly interest in reverse logistics with a focus on waste supply chain activities has resulted in a broader examination of waste management practices. However, the rapid shifts triggered by recent global developments have also revealed the need for further investigation of innovative waste management practices (Popa et al. 2024; Rogowska et al. 2024).

Circular economy (CE) thinking has emerged as a dominant paradigm in addressing these challenges by fundamentally reconfiguring how physical resources are perceived, created, managed, and configured in current economic systems (Geissdoerfer et al. 2017). To enhance circularity, resource loops must be narrowed, slowed, or closed (Bocken et al. 2016), a transformation that is often operationalized through so-called “R” frameworks such as reduce, reuse, recycle, and recover (Kirchherr et al. 2017). Recent household-focused studies increasingly tend to frame food waste, packaging waste, textile waste, and e-waste as critical leverage points for advancing CE objectives at the urban and municipal level (Yu et al. 2022; Koshta et al. 2024; Tam and Anh 2024). Within this perspective, household waste is no longer viewed only as an end-of-life output but rather as a valuable resource stream contributing to circular supply chains (CSCs) (Jain et al. 2018). Emerging digital and organizational solutions, including blockchain-based incentive systems and smart collection infrastructures, further support this transition (Saeedi 2024).

In this context, the concept of CSCs provides a useful analytical lens by emphasizing the preservation of value through reverse flows, extended actor networks, and collaborative relationships. CSCs typically involve a larger number of stakeholders and more complex interaction patterns compared to linear supply chains, thereby creating new coordination and governance challenges (Bressanelli et al. 2019). Performance objectives in CSCs increasingly depend on effective integration across value chain actors, highlighting the importance of

collaboration, information sharing, and inter-organizational alignment (Jain et al. 2018; Farooque et al. 2019; Lahane et al. 2020; Saeedi 2024).

Supply chain management (SCM) literature offers well-established frameworks for understanding supply chain dynamics and interdependencies. Early contributions by Cooper et al. (1997) conceptualized SCM through the interaction of business processes, supply chain structure, and management components. Building on this foundation, Lambert and Cooper (2000) identified key business processes in SCM, which were later revised to reflect developments in research and practice (Lambert and Enz 2017). Despite their analytical strength, these frameworks are primarily rooted in linear supply chain logic. Recent household waste studies increasingly call for integrating waste collection, sorting, recycling, and redistribution processes into broader SCM frameworks to better reflect CSC realities (Farooque et al. 2019; Nguyen et al. 2024). Consequently, an important research gap remains regarding how these SCM process frameworks can be adapted and extended to capture the dynamics of circular and household waste-oriented supply chains. Motivated by these gaps, the purpose of this study is to develop a comprehensive framework for household waste supply chains (HWSCs) from a CE perspective. By systematically reviewing the existing literature, the study aims to identify dominant research domains, map household waste-related processes onto established SCM frameworks, and highlight understudied areas for future research. To operationalize this purpose, the study addresses the following research questions:

- 1) What are the main domains of research in HWSCs with respect to established SCM process frameworks?
- 2) Which future research topics need to be addressed to enhance circularity through HWSCs?

The remainder of the paper is structured as follows. The next section outlines the research methodology and systematic literature review (SLR) process, followed by descriptive and thematic analyses, the development of a HWSC framework, and a discussion of key findings and future research directions.

2. Systematic Literature Review

Considering the discovery-oriented nature of research questions, and the aim to combine two different research streams, SLR was selected as the method to synthesize and structure the existing body of knowledge on HWSCs. SLR is a widely used method in SCM research (Seuring and Muller 2008) because it allows existing patterns and topics in a certain field to be summarized, and also is suitable for the application of thematic analysis with respect to emergent or pre-defined categories. Following established guidelines for conducting rigorous

SLRs in SCM research, this study is designed to ensure transparency, replicability, and analytical rigor throughout the review process.

2.1. Research Design

The methodological approach of this study is grounded in the SLR procedures proposed by Seuring and Müller (2008) and further refined by Seuring and Gold (2012) and reported in a PRISMA-informed manner (Page et al. 2021) to ensure transparency and replicability of the literature identification and screening stages. These approaches emphasize a structured and rule-based review process supported by qualitative content analysis. Accordingly, the review process consists of four main stages: (i) literature identification, (ii) inclusion and exclusion screening, (iii) coding and categorization, and (iv) synthesis and framework development.

2.2. Data Collection

The SLR is conducted based on the following steps: (i) selection of the database, (ii) identification of the keywords, (iii) selection of the related articles and defining exclusion criteria, (iv) data evaluation (Khan et al. 2003). This study further applies the content analytic approach described by Seuring and Gold (2012).

i) Selection of the database

Web of Science database was limited to the period between January 2015 and January 2025, covering the years in which scholarly interest in household waste, CE, and SCM this time frame allows capturing both the early conceptualization of household waste within CE discussions and the more recent process-oriented and supply chain-focused studies.

ii) Identification of the keywords

The keywords were searched in two steps; (a) waste AND circular AND household (b) waste AND “supply chain” AND household (c) waste AND logistics AND household.

These keyword combinations were selected to ensure a comprehensive coverage of studies addressing household waste from CE, SCM, and logistics perspectives, while avoiding an overly broad inclusion of studies unrelated to household-generated waste.

iii) Selection of the related articles and defining exclusion criteria

The database is limited to articles in English. Search criteria were compared with “or” command to remove duplications, and the search returned 901 articles. The distribution of the articles per year involved in the study is represented in Figure 1.



Figure 1. Distribution of the articles per year

Source: Created by the authors

At the very beginning of the study, the criteria included articles, book chapters and abstract-only access papers. The search included only articles published in English, and non-English publications were excluded during early screening stage. The search terms included the keyword “waste”; however, some results referred to unrelated uses of the term, such as “child waste,” or to studies focusing on general health conditions not linked to household consumption. Accordingly, these articles were excluded from the final dataset. Another key inclusion criterion was that the source of waste originated from households. Accordingly, articles addressing waste sources other than household consumption such as industrial or exclusively commercial waste streams were excluded from the final evaluation. After all inclusion and exclusion criteria were applied, the final sample comprised of 493 household waste-related articles included in the overall analysis (Figure 2).

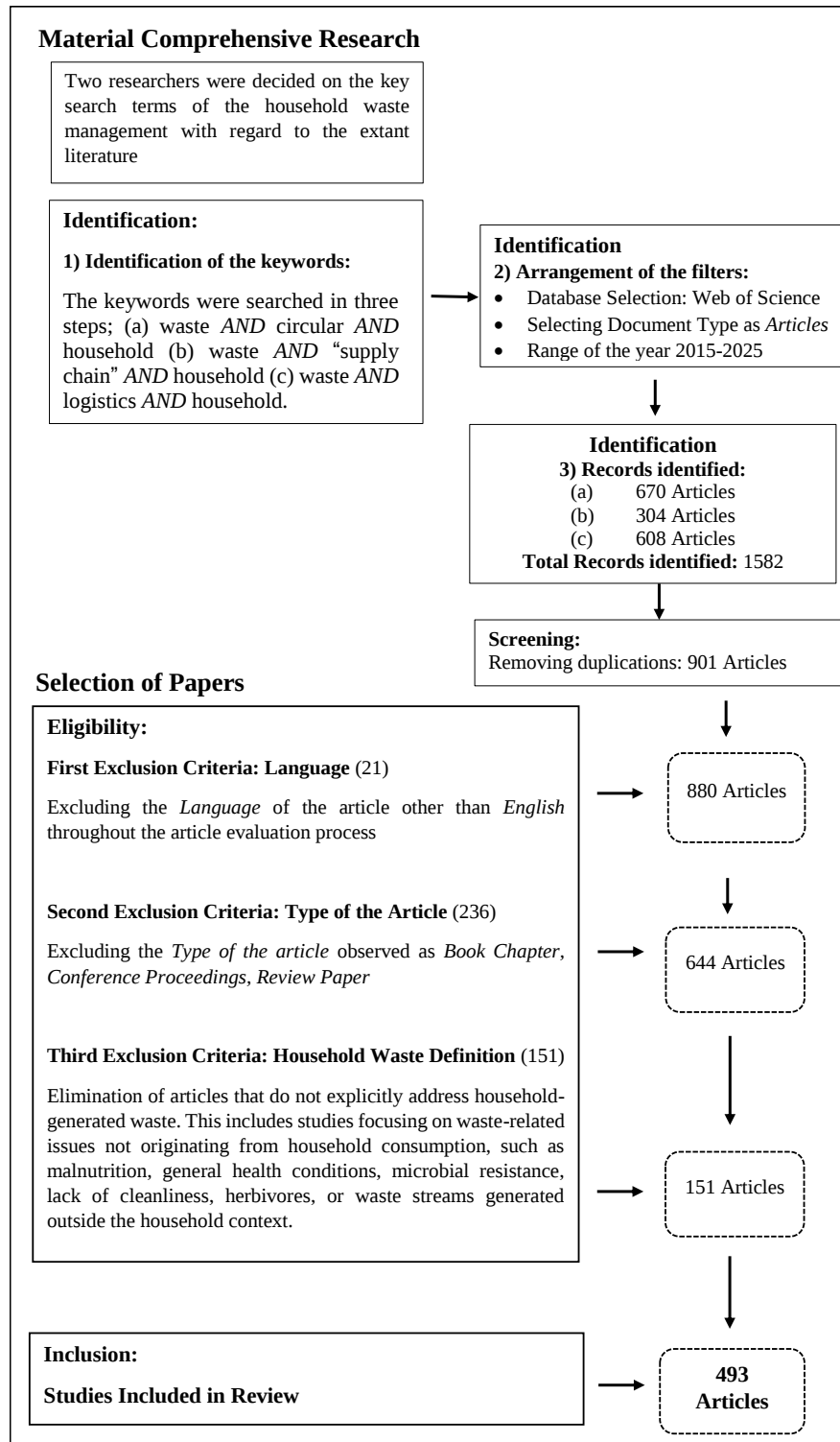


Figure 2. PRISMA-informed flow diagram

Source: Created by the authors

iv) Data Evaluation

Data was extracted by categorizing different research focuses and grouped according to predefined and emergent analytical categories. Following the content analysis principles

suggested by Seuring and Gold (2012), a structured coding scheme was developed to systematically analyze the reviewed articles.

To provide a more transparent and rigorous account of the analytical procedure, the coding process followed a qualitative content analysis approach consisting of two main coding phases, open coding and focused coding (Berelson 1952; Charmaz 2006), followed by a final integrative stage. In the open coding phase, each article in the final dataset was systematically examined and coded on a line-by-line basis using a structured coding scheme. This scheme captured multiple dimensions of the reviewed studies, including bibliographic information, research scope, waste type, geographical context, methodological characteristics, theoretical foundations, and supply chain-related aspects. At this stage, key concepts, research focuses, and process-related elements were identified inductively, allowing recurring themes and patterns across HWSC studies to emerge.

In the focused coding phase, the initial codes were compared, refined, and grouped into higher-order categories following a hybrid analytical logic that combined inductive category development with deductive alignment to established supply chain process frameworks. This process involved aligning emergent themes with predefined supply chain process dimensions (e.g. manufacturing flow management, supplier relationship management, returns management, product development and commercialization, demand management, order fulfillment), as well as consolidating topic-subtopic structures and actor-based categorizations. Inconsistencies across codes were iteratively reviewed and resolved to ensure internal coherence and consistency within the coding structure. In the final stage, the refined categories were integrated into a coherent analytical structure, enabling the synthesis of findings across the reviewed literature. The proposed HWSC framework was derived through the systematic integration of inductively developed categories with established supply chain process structures. Specifically, the emergent themes and categories identified during the coding process were mapped onto core supply chain business processes, enabling the conceptualization of household waste activities within a process-oriented supply chain perspective. Overall, the analytical process can be characterized as abductive, involving an iterative back-and-forth interplay between data-driven insights and theory-informed structuring, whereby emerging interpretations were continuously revisited and refined throughout the analysis (Langley 1999).

To enhance the validity and reliability of the coding process, multiple researchers were involved in the analysis. A subset of the articles was independently coded by two researchers, and the results were compared to ensure consistency. Discrepancies were discussed and resolved through consensus, leading to further refinement of the coding scheme. This iterative

procedure strengthened inter-coder reliability and ensured the robustness and reproducibility of the analysis. The analysis helped to understand the overall framework of the household waste system and enabled the synthesis of diverse research streams into an integrated HWSC perspective.

3. Findings

3.1. Descriptive Results

To gain a deeper understanding of the field, the papers were first evaluated descriptively. To ensure an up-to-date understanding a specific time interval was selected at the beginning of the study. Furthermore, the extant literature focuses on several categories of household waste. Trends in the last five years (2015 to 2025) show that municipal solid waste was the most common type of waste, followed by food waste, waste from electric and electronical equipment (WEEE), and plastic/packaging, medical, hazardous and textile waste (Baybars et al. 2024; Güzel and Kavalcı 2024; Popa et al. 2024).

In terms of research focus, 79% of the papers (390) were empirical. This type of papers helps researchers to identify the current conditions from various point of views. Regarding methodology preferences, 73% (361) quantitative methodology, 15% (72), mixed methods and followed 12% (60), qualitative methodology. In addition, 16% were policy papers (80), allowing countries to exchange views and determine the best practices in the ongoing waste process. 5% of the papers (23) were of the life cycle assessment (LCA) type, allowing the researchers to follow the life-cycle stages of a particular product or service.

The level of coverage varied among the reviewed papers. Approximately equal shares of studies assessed waste management principles at the city (42%) and national (41%) levels, whereas district- and international-level investigations were relatively limited.

Among the 493 studies reviewed, the large majority did not employ a theoretical framework ($n = 447$), while only 46 studies were theory-informed. Within this group, behavioral theories (primarily the Theory of Planned Behavior and its extensions) were the most frequently applied ($n = 20$). CE-based frameworks constituted the second largest group ($n = 9$), followed by utility/choice-based theories ($n = 4$) and systems-based theories ($n = 4$). Practice-based approaches ($n=2$), economic and institutional theories ($n=3$), and stakeholder/governance theories ($n = 2$) were used only to a limited extend.

With respect to waste categories, research on relationship structures among SCM actors predominantly focuses on single actors, particularly households, consumers, prosumers, and patients. These studies mainly examine end-user behavioral and characteristic factors related to waste generation, recycling, and environmental satisfaction across food, solid, and medical

waste streams. Dyadic relationships are addressed at the household–stakeholder and household–local authority levels, where household behavior is shaped by regulatory interventions and waste collection policies. At the stakeholder level, pricing strategies are frequently analyzed using game-theoretic approaches. Triadic relationship studies are comparatively rare and primarily explore interactions among producers, retailers, and consumers, focusing on key competencies and collaboration strategies. Studies adopting a network-based perspective remain limited, especially those examining interactions among distributors, resellers, consumers, and public authorities, often within alternative reverse logistics models.

In addition to the descriptive characteristics of the reviewed studies, the analysis also identified the most prominent journals publishing research on household waste and CSCs. The reviewed articles are concentrated in a limited number of journals with a strong focus on sustainability, waste management, and supply chain research. Leading outlets include journals such as *Journal of Cleaner Production*, *Waste Management*, *Sustainability*, *Science of the Total Environment and Resources*, *Conservation & Recycling*. These journals serve as primary publication platforms for interdisciplinary research at the intersection of CE and SCM.

3.2. Thematic Analysis

The thematic analysis assesses the reviewed articles based on their scope within HWSCs. Household waste management has received growing attention across environmental studies, public policy and operations related disciplines (Farooque et al. 2019; McLean and Roggema 2019). The reviewed literature reflects a strong empirical orientation, with a predominant focus on household behavior, policy instruments and waste separation practices. However, engagement with established frameworks remains unclear. When the theory is employed, behavioral models (mainly Theory of Planned Behavior) are most frequently adopted while CE perspectives appear as a secondary research stream. Systems-based, governance-oriented, and supply chain–focused theoretical lenses remain comparatively limited.

SCM literature offers a well-established theoretical foundation for addressing such coordination challenges. Early contributions by Cooper et al. (1997) conceptualized SCM as the integration of business process, supply chain structure and management components. Building on this foundation, Lambert and Cooper (2000) and Lambert and Enz (2017) defined a set of core supply chain business processes including manufacturing flow management (MFM), supplier relationship management (SRM), returns management (RM), product development and commercialization (PDC), demand management (DM), order fulfillment

(OF) and customer relationship management (CRM). This SLR study describes a review of 493 papers, which enabled the researchers to identify the interactions among the actors of HWSC regarding household waste management practices within the framework of Lambert and Enz (2017)'s supply chain model processes. While these SCM frameworks were originally developed for linear, forward-oriented SCs, the reviewed HWSC literature increasingly points to the need for their adaptation to circular and reverse flow contexts. Herein, household waste systems differ fundamentally from traditional supply chains in at least three aspects; i) households act simultaneously as consumers and suppliers of the materials (Du Rietz 2023; Ozdamar and Göçer 2025), ii) waste flows are characterized by high uncertainty in quality and quantity (Nourbakhshsamani et al. 2021), iii) coordination relies heavily on behavioral aspects, institutional incentives and public governance mechanisms (Yu et al. 2022; Saeedi 2024). Operationalizing the adapted SC process perspective in the context of household waste management requires the brief identification of the actors involved and the clarification of their roles within the HWSCs.

HWSC actors include, households, local authorities, service providers, waste collecting companies, waste processing companies and producers. Among the most critical actors in HWSC, households, whom are accepted as end-users in HWSC, are conceptualized in this framework as active suppliers of waste materials, as they determine both the quantity and quality of waste generated through consumption, separation and disposal practices. Respective amount of waste is produced by households. This partner's interaction within HWSCs mostly shapes the general framework.

Local authorities including governmental and non-governmental organizations, semi-governmental institutions which have a power on mostly legislative issues and ability to take initiatives and policy development processes. Rather than directly managing material flows, local authorities shape the institutional environment within which other actors operate. In HWSC framework, service providers have multidimensional meanings according to the relationships between the actors. For example, service providers as wholesalers, retailers, shopping places, catering services or school canteens mostly in contact with the households during various operations. Service providers should therefore be understood as a role-based category rather than a single homogenous actor type. On the other hand, in downstream interactions, waste collecting companies (waste collectors), accepted as a service provider where the triadic operations observed within households, local authority and service providers. Even they are connected numerous actors, they also have connections between commercial and industrial sectors. In addition, waste processing companies represent focal company in HWSC. This actor gathers the waste from households or related partners (e.g.

service providers) in HWSC, including the various processes and afterwards reselling the materials. In this sense, waste processing companies function as transformation and valorization hubs. Another actor, producers, as consumers who demand/use/recycle the waste materials as a raw material in HWSC. Last but not least, incineration facilities in HWSC identifies the process where recycling and reuse options of operations take place. The hierarchy of main themes and sub-themes identified through the coding process is summarized in Table 1.

Table 1. Hierarchical Structure of Main Themes and Sub-Themes in HWSC Studies

<i>Supply Chain Management Process</i>	<i>Main Theme</i>	<i>Sub-Themes</i>
<i>Manufacturing Flow Management (MFM)</i>	Waste Generation	Consumption patterns, product design, behavioral interventions (nudging, COVID-19 effects)
	Waste Separation	Source separation practices, quality control of waste streams; household preferences
	Waste Collection Operations	Collection system design, operational efficiency, stakeholder coordination; household participation and willingness to pay
<i>Supplier Relationship Management (SRM)</i>	Waste Collection Methods & System Design	Service design, system optimization, barriers in collection systems
	Household Motivation	Behavioral factors, incentives, nudging strategies, social norms; digital engagement tools
	Organization of Waste Handling	Coordination mechanisms, multi-actor platforms
	Waste Separation Practices by Partners	Partner-level sorting practices, operational alignment

<i>Returns Management (RM)</i>	Waste Classification	Sorting accuracy, composition identification
	Re-evaluation of Waste as a Source	Acceptance/rejection decisions, quality thresholds
<i>Product Development and Commercialization (PDC)</i>	Waste-based Product Development	Bio-based products, recycled materials
	Commercialization of waste—based products	Market acceptance, labeling, consumer awareness
<i>Demand Management (DM)</i>	Waste Requirement Estimation	Forecasting, planning, uncertainty
	System Performance & Satisfaction	Service quality, infrastructure effectiveness
	Demand for Waste-Derived Outputs	Recycled products, energy demand
	Demand Uncertainty and Forecasting Challenges	Impact of participation variability; Post-COVID volatility
<i>Order Fulfillment (OF)</i>	Ordering of Secondary Materials	Compost, secondary aggregates
	Ordering Strategies	Flexibility, adaptive strategies, uncertainty management

Table 1 provides a structured overview of how the reviewed studies are organized across supply chain process categories and their corresponding research domains, serving as a bridge between the thematic analysis and the detailed process-based discussion. The interactions among the actors described above are explained in the following part of the study.

3.3. Reconceptualizing Supply Chain Business Processes in HWSCs

3.3.1. Manufacturing Flow Management

Lambert and Enz (2017) define MFM as the coordination of material flows from suppliers to end users in line with observed demand. In HWSCs, this process is reinterpreted through waste-oriented flows, where raw material sourcing is replaced by household waste generation, production and quality control by waste separation and classification, and inventory and

distribution by waste collection and aggregation. The dominant research stream within MFM focuses on household waste generation, examining consumption patterns, product design, and consumer attitudes as key drivers of waste behavior, while also assessing waste management systems, waste reduction opportunities, and material recovery potential for future forecasting purposes (Bocken et al. 2016; Ananda et al. 2024; Baybars et al. 2024; Madden and Florin 2024; Nguyen et al. 2024). Recent studies emphasize the growing influence of behavioral interventions, contextual conditions, and external disruptions, including nudging approaches, societal crises, and COVID-19 related changes in consumption, on household waste generation patterns, adding further volatility to MFM processes (Ananda et al. 2024; Baybars et al. 2024; Popa et al. 2024; Rogowska et al. 2024; UNEP 2024). Herein, waste separation functionally replaces quality control by determining the purity and usability of waste streams, with separation behavior shaped by household preferences and source separation practices (Yu et al. 2022; Popa et al. 2024; Rogowska et al. 2024; Tam and Anh 2024). As waste collection constitutes the final stage of MFM, focusing on collection system design, operational efficiency, and stakeholder coordination, while household participation and willingness to pay reflect the role of policy and governance structures, particularly under health-related and COVID-19 disruptions (Nguyen et al. 2024; Madden and Florin 2024; Rogowska et al. 2024; Popa et al. 2024).

3.3.2. Supplier Relationship Management

SRM in Lambert and Enz's (2017) framework refers to managing interactions and coordination mechanisms among supply chain actors. In HWSCs, SRM differs from contract-based supplier management and is primarily shaped by behavioral compliance, institutional incentives, and public governance mechanisms. Households are conceptualized as suppliers, and SRM processes involve managing relationships among households, service providers, and producers.

The literature identifies several SRM-related categories, including waste collection methods, household motivation for recycling participation, organization of waste handling processes, waste management policy decisions, coordination for waste reduction, and waste separation practices. Studies on waste collection methods focus on service providers' operational perspectives and system design (Farooque et al. 2019; Halldórsson et al. 2019; Madden and Florin 2024; Nguyen et al. 2024), as well as barriers and optimization opportunities within collection systems (Corsini et al. 2017; Bressanelli et al. 2019; Madden and Florin 2024; Nguyen et al. 2024). Trust, service quality, and institutional credibility

significantly influence household–collector relationships and related compliance behaviors (Rogowska et al. 2024; Popa et al. 2024; Tam and Anh 2024).

In addition to waste collection methods, existing research also focuses on household motivation to transfer waste into recycling systems. This household motivation is shaped by environmental transportation practices, behavioral factors, and strategic waste management decisions (Yu et al. 2022; Baybars et al. 2024; Popa et al. 2024). Recent studies emphasize the role of nudging strategies, social norms, and digital engagement tools in enhancing participation and strengthening household–system relationships (Du Rietz 2023; Rogowska et al. 2024; Saeedi 2024).

Beyond household motivation, the literature also emphasizes the organization of waste handling processes across HWSCs. Effective organization of waste handling processes requires coordination among HWSC partners and appropriate treatment methods for different waste types (Bressanelli et al. 2019; Madden and Florin 2024). This coordination increasingly relies on multi-actor platforms and technology-enabled engagement mechanisms (Nguyen et al. 2024; Saeedi 2024). Waste management policy decisions further shape SRM by facilitating the identification of barriers and system inefficiencies when households are recognized as suppliers (Popa et al. 2024; Rogowska et al. 2024). Regulatory clarity, enforcement credibility, and transparency directly affect household compliance and inter-actor trust, while multi-stakeholder involvement supports more effective policy design (Yu et al. 2022; UNEP 2024).

3.3.3. Returns Management

RM in traditional supply chains focuses on reverse logistics and product returns (Lambert and Enz 2017). In HWSCs, however, RM plays a limited and conditional role, as households do not return products within contractual exchange relationships. Consequently, most reverse material flows are addressed within MFM and SRM processes. RM in HWSCs becomes relevant primarily under CE conditions, where secondary materials derived from household waste are evaluated, accepted, or rejected by downstream actors. RM-related activities include waste classification for acceptance decisions, re-evaluation of waste-derived materials as raw inputs, and transformation of rejected materials into usable secondary resources.

Within these processes, waste classification plays a central role in identifying waste composition and determining appropriate downstream processing options (Madden and Florin 2024; Nguyen et al. 2024). This becomes especially important when waste streams are heterogeneous, as classification errors can lead to rejection or re-routing (Yu et al. 2022; Madden and Florin 2024). Re-evaluation of waste as a raw material supports sustainable

consumer behavior and reuse strategies (Geissdoerfer et al. 2017; Tong et al. 2018; Kasulaitis et al. 2019). Recent studies emphasize that these processes are influenced by household participation levels, source separation accuracy, and quality thresholds imposed by downstream users (Nourbakhshsamani et al. 2022; Popa et al. 2024; Rogowska et al. 2024).

From an operational perspective, the transformation of waste into secondary raw materials is shaped by broader institutional and market conditions. Transforming waste into secondary raw materials requires compliance with regulatory frameworks and responsiveness to market demand. Post-COVID operational conditions further constrain RM processes, reinforcing their conditional role within HWSCs (Mavlutova et al. 2023; Ozdamar and Göçer 2025)

3.3.4. Product Development and Commercialization

PDC represents the innovation dimension of SCM (Lambert and Enz 2017). In HWSCs, PDC focuses on converting processed waste into new products and value propositions, primarily led by waste processing companies. The literature addresses policy frameworks that support product development from waste, emphasizing the role of waste treatment policies in guiding processing decisions (Bocken et al. 2016; Geissdoerfer et al. 2017; Kirchherr et al. 2017). Recent studies highlight a growing focus on bio-based products, recycled construction materials, secondary plastics, and compost-derived outputs aligned with CE objectives (Tong et al. 2018; Kasulaitis et al. 2019; Mavlutova et al. 2023).

Building on these developments, research also highlights the commercialization challenges associated with waste-derived products. Developing new products from waste enables economic value creation and supports the evolution of recycling practices (Tong et al. 2018; McLean and Roggema 2019). Effective commercialization depends not only on technical recovery processes but also on environmental performance assessments and long-term recovery system design (Batista et al. 2018; Bressanelli et al. 2019). Demand-side engagement mechanisms, such as labeling strategies and consumer awareness initiatives, play an increasingly important role in overcoming resistance to recycled products (Du Rietz 2023; Madden and Florin 2024; Saeedi 2024).

3.3.5. Demand Management

DM traditionally balances supply and demand within a supply chain (Lambert and Enz 2017). In HWSCs, demand is driven not by primary consumption needs but by the utilization potential of waste-derived materials, products, and energy. DM processes involve households, local authorities, waste collectors, processors, and producers.

Within this context, the literature identifies several key research areas related to DM in HWSCs. Key research areas include waste requirement estimation, satisfaction with waste supply services, effectiveness of waste infrastructure, demand for waste-derived products, and forecasting demand for waste-based energy. Waste requirement estimation supports strategic planning by forecasting material availability and storage needs (Madden and Florin 2024; Nguyen et al. 2024; Kostha et al. 2024). However, uncertainty in household participation and source separation accuracy significantly affects forecasting accuracy, particularly under post-COVID conditions (Nourbakhshsamani et al. 2022; Yu et al. 2022).

Beyond forecasting considerations, demand-related outcomes are also shaped by service quality and system performance. Satisfaction with waste supply services influences overall system performance, as inconsistent waste quality reduces downstream demand for secondary materials (Corsini et al. 2017; Popa et al. 2024; Rogowska et al. 2024). Assessing infrastructure effectiveness and coordination among actors further supports strategic decision-making (Bressanelli et al. 2019; Farooque et al. 2019; Nguyen et al. 2024). Demand for recycled products and waste-derived energy is shaped by consumer acceptance, policy incentives, energy prices, and regulatory targets (Du Rietz 2023; Mavlutova et al. 2023; Madden and Florin 2024).

3.3.6. Order Fulfilment

OF refers to network design and order execution processes in SCM (Lambert and Enz 2017). In HWSCs, OF focuses on producers' orders for decomposed and processed waste materials. These processes are primarily conducted by waste processing companies and producers.

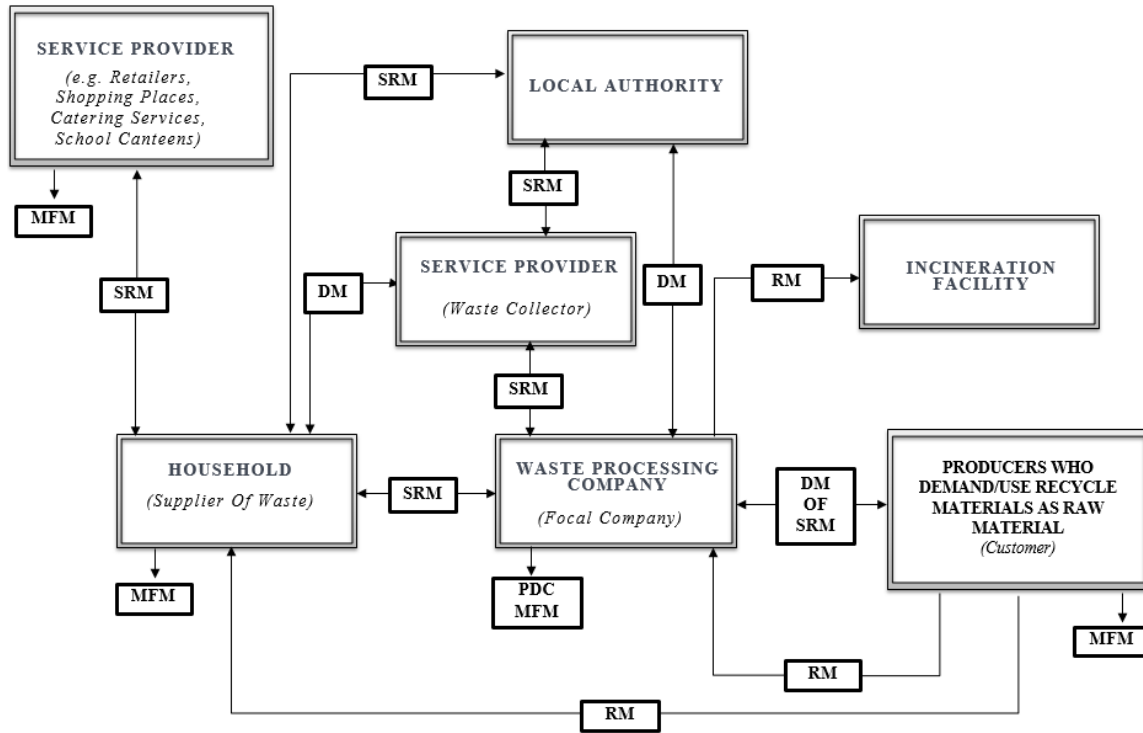
Within this framework, the literature emphasizes the role of ordering waste-derived materials in supporting sustainable consumption and circular CE objectives (Kasulaitis et al. 2019). Empirical studies document orders for compost, recycled polymers, and secondary aggregates derived from household waste streams (Nourbakhshsamani et al. 2022; Mavlutova et al. 2023; Madden and Florin 2024). However, such orders are contingent on material quality, regulatory compliance, and supply reliability.

Given these conditions, research suggests that effective ordering strategies in HWSCs require adaptive and flexible approaches rather than fixed replenishment rules. This need arises from uncertainty in waste availability and fluctuating demand for secondary materials (Koshta et al. 2024; Madden and Florin 2024; Ozdamar and Göçer 2025).

3.3.7. Conceptual Model

The conceptual HWSC model illustrates the interactions and interdependencies among the main actors. The model encompasses households as waste generators, waste collectors and service providers responsible for collection and logistics, waste processing companies engaged in treatment and recovery processes, incineration facilities involved in final disposal and energy recovery, and local authorities managing the regulation and coordination of the system (see Figure 3). The model highlights how traditional forward-oriented supply chain processes are redistributed across actors under circular and reverse-flow conditions, with households positioned as upstream suppliers of waste, waste processing companies acting as focal coordinators, incineration facilities serving as terminal nodes for non-recyclable fractions and energy recovery, and local authorities shaping governance and relational dynamics.

Figure 3 synthesizes the findings of the SLR by visually integrating the adapted SC business processes and actor roles discussed in the study. Rather than introducing new mechanisms, the figure operationalizes the conceptual distinctions established across MFM, SRM, RM, PDC, DM, and OF by mapping them onto the HWSC structure, including downstream treatment and final disposal routes associated with incineration facilities.



MFM: Manufacturing Flow Management; RM: Returns Management; SRM: Supplier Relationship Management;

OF: Order Fulfilment; PDC: Product Development and Commercialization; DM: Demand Management

Figure 3. Process-Oriented HWSC Management Framework

Source: Created by the authors

By explicitly linking actors to specific process domains, the figure clarifies where each supply chain process is activated, interrelates with others, or remains conditional, particularly in the case of RM, which connects material recovery activities with both recycling-oriented processes and incineration-based disposal options. Overall, the conceptual model serves as an integrative representation of the HWSC, enabling a coherent interpretation of process interactions and actor interdependencies.

4. Conclusion and Discussion

The findings of this study provide a structured, process-oriented perspective on HWSCs as a critical enabler of the CE. From a CE perspective, the analyzed studies address key circularity mechanisms, including waste prevention, source separation, material recovery, reuse, recycling, and the reintegration of secondary materials into production systems, which extend material lifecycles and reduce reliance on virgin resources (Madden and Florin 2024; Nourbakhshsamani et al. 2022).

Moreover, the analysis shows that household waste circularity does not emerge from isolated actors, but from coordinated business processes involving households, service providers, waste collectors, waste processing companies, producers, and local authorities. While much of the literature focuses on single actors or limited relational settings, increasing attention is paid to behavioral coordination, information flows, and governance mechanisms (Farooque et al. 2019; Ozdamar and Göçer 2025; Popa et al. 2024; Rogowska et al. 2024; Yu et al. 2022). This underlines that circularity in household waste systems is fundamentally a supply chain coordination challenge rather than a technological one.

By mapping household waste activities to adapted supply chain business processes (MFM, SRM, RM, PDC, DM and OF), this study illustrates how traditional linear supply chain logics are transformed under CE conditions. MFM is reinterpreted through waste generation, separation, and collection processes that are strongly influenced by household behavior, policy instruments, and contextual disruptions such as COVID-19 conditions (Ananda et al. 2024; Rogowska et al. 2024; Tam and Anh 2024). Similarly, SRM shifts from contract-based arrangements toward behavioral compliance, social norms, and incentive-based coordination mechanisms (Popa et al. 2024; Rogowska et al. 2024; Saeedi 2024; Tam and Anh 2024).

RM emerges as a conditional and selective process in circular HWSCs, activated primarily when secondary materials are evaluated for acceptance or rejection by downstream users. Recent studies highlight that quality thresholds, regulatory compliance, and market demand determine whether waste-derived materials can re-enter production systems as usable inputs (Tong et al. 2018; Kasulaitis et al. 2019; Mavlutova et al. 2023). This finding reinforces that not all reverse flows in household waste systems constitute returns management, but only those linked to circular reintegration decisions.

PDC processes demonstrate how circular value is captured from household waste through the production of compost, recycled polymers, secondary construction materials, and textile-derived products (Nourbakhshsamani et al. 2022; Mavlutova et al. 2023; Madden and Florin 2024). The reviewed studies further indicate that successful commercialization increasingly depends on policy support, consumer acceptance, and incentive-based engagement mechanisms such as deposit–refund schemes and loyalty programs (Du Rietz 2023; Saeedi 2024).

DM and OF reflect the market-facing dimension of CSCs, where demand for waste-derived products and energy is shaped by supply reliability, waste quality, and institutional conditions. Recent findings show that uncertainty in household participation, post-pandemic disruptions, and governance capacity significantly affect demand forecasting and ordering strategies for secondary materials (Yu et al. 2022; Ozdamar and Göçer 2025).

Overall, the findings demonstrate that HWSCs play a foundational role in enabling CSCs by operationalizing CE principles through coordinated supply chain processes. By adopting a supply chain process perspective, this study contributes to CE research by clarifying how circularity can be systematically embedded within household waste management systems rather than treated as an isolated sustainability objective.

4.1. Implications

Despite the expanding literature on CE, the integration of circularity into SCM remains limited in the context of household waste. Existing studies on household waste largely emphasize behavioral or policy dimensions, while the SC processes through which circularity is enabled, coordinated, or disrupted are rarely examined using SCM theory. As a result, circularity is often treated as an assumed outcome of recycling activities rather than as a SC performance issue.

Household waste constitutes a critical upstream node in CSCs, where materials either remain within local recovery loops or enter national and international secondary material markets. However, the circulation of household waste across supply chains does not necessarily ensure circular outcomes, raising important questions about where, how, and for whom circular value is created. This study contributes to the literature by bridging SCM and CE through a process-based HWSC framework. By adapting the Lambert and Enz (2017) supply chain business processes to the household waste context, the study enables a structured examination of circularity across supply chain processes rather than isolated waste activities. In doing so, it provides a theoretical foundation for critically assessing CSCs, particularly with respect to actor coordination, material flows, and the distinction between local circularity and global redistribution of waste.

4.2. Avenues for Further Research

Building on the findings of this SLR and the adapted supply chain process framework, future research should conceptualize HWSCs as integral components of CSCs rather than as isolated waste management systems. Although recent studies increasingly examine household behavior, waste separation, and recycling intentions, households are still predominantly treated as passive waste generators. Future research should reposition households as strategic upstream actors whose decisions directly influence material quality, supply reliability, and downstream recovery performance, particularly across heterogeneous socioeconomic, post-conflict, and post-pandemic contexts (Yu et al. 2022; Popa et al. 2024; Rogowska et al. 2024).

Beyond the role of households, the findings further highlight the importance of actor-role differentiation and inter-actor coordination in enabling circularity within HWSCs. While existing studies often focus on individual actors, limited attention has been paid to how responsibilities, decision rights, and information flows are coordinated among households, service providers, collectors, processors, producers, and public authorities. Adopting a CSC perspective would allow future research to systematically map these interactions and assess how governance structures, trust, and institutional credibility shape coordination outcomes, particularly in developing and transition economies (Farooque et al. 2019; Popa et al. 2024; Rogowska et al. 2024).

Closely linked to coordination challenges is the role of household consumption habits in shaping circular outcomes within HWSCs. Although increasing attention has been paid to consumer intentions, awareness, and attitudes toward sorting and recycling, there remains a clear need for interdisciplinary research that links household consumption choices with upstream waste generation and downstream circular value creation. Integrating behavioral science, operations management, and CE perspectives would enable a more comprehensive understanding of how consumption patterns, product choices, and usage behaviors influence waste quantities, material quality, and overall HWSC performance (Tam and Anh 2024). Closely related to this stream is the role of product characteristics within household waste flows. Existing research on packaging, textiles, e-waste, and construction-related household waste suggests that material properties, product design, and life-cycle characteristics strongly shape recovery, reuse, and recycling potential. Future studies could therefore link product design and material selection decisions with downstream CSC performance and recovery efficiency (Güzel and Kavalcı 2024; Mavlutova et al. 2024).

In conclusion, urban and city-level planning further represents a critical interface between infrastructure design, technological development, and CSC performance. Empirical studies highlight the importance of spatial planning, collection system design, and infrastructure adequacy in enabling circular material flows within HWSCs. Future research could apply logistics and process-oriented models to evaluate trade-offs among transport distances, vehicle configurations, cost efficiency, and environmental impacts in circular household waste systems (Madden and Florin 2024; Nguyen et al. 2024). At the same time, alternative supply chain designs for household waste systems merit closer examination. Different HWSC configurations may vary substantially in their ability to support circularity, resilience, and adaptability under uncertainty and disruption, including post-COVID-19 conditions (Tran et al. 2019; Ananda et al. 2024). In this context, technological developments offer additional opportunities to enhance transparency and coordination across CSCs. Digital engagement

tools, social media analytics, blockchain-based incentive mechanisms, and data-driven monitoring systems can support information sharing, performance tracking, and adaptive coordination among CSC actors, thereby strengthening the integration of HWSCs into broader CE systems (Nourbakhshsamani et al. 2022; Saeedi 2024).

4.3. Limitations

Despite its contributions, this study is subject to several limitations that should be acknowledged. First, the literature search was limited to the Web of Science database. Although this ensures the inclusion of high-quality peer-reviewed publications, it may have led to the exclusion of relevant studies indexed in other databases such as Scopus or Google Scholar. In a similar point of view, the review only included articles published in English, which may introduce language bias and limit the representation of region-specific studies published in other languages.

Furthermore, the analysis was restricted to the period between 2015 and 2025. While this timeframe captures the most recent developments in CE and household waste research, earlier foundational contributions may not be fully reflected. In addition, the study relies on a qualitative content analysis approach. Although coding reliability was strengthened through the involvement of multiple researchers and iterative validation procedures, the interpretation and categorization of the studies may still involve a degree of subjectivity. Future research could address these limitations by expanding database coverage, incorporating multilingual sources and complementing qualitative approaches with bibliometric or other quantitative methods to enhance robustness and generalizability.

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Asymmetric Volatility Spillovers in the Turkish Economy: A BEKK-GARCH Analysis of Energy and Exchange Rate Shocks

Türkiye Ekonomisinde Enerji ve Döviz Kuru Şoklarının Asimetrik Oynaklık Yayılımları: BEKK-GARCH Analizi

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Abstract: This study examines the volatility spillover mechanisms of Brent oil price and USD/TRY currency rate volatility on the Producer Price Index and monthly Industrial Production Index in the Turkish economy, which is dependent on energy imports and affected by financial dollarization. Using monthly data from 2002:1 to 2025:10, the dynamic relationships among variables were analyzed in the first stage using a Vector Autoregressive Model, and the conditional variance-covariance dynamics were analyzed in the second stage using a multivariate BEKK-GARCH(1,1) model. The variance decomposition suggests that approximately 55% of the Producer Price Index variance can be explained by USD/TRY shocks, while 21% of the Industrial Production Index variance is associated with Brent oil shocks. The BEKK-GARCH analysis reveals while cross-market spillovers were prominent in the earlier period, volatility persistence became more dominant following the structural break in 2018:10. Furthermore, the findings suggest that uncertainty in oil prices may pose risks for industrial production and that there are mutual shock and volatility interactions between markets. To mitigate these vulnerabilities, policymakers must put a priority on limiting the real sector's dependence on intermediate goods imports and promoting a transition to renewable energy sources to protect it from global energy price fluctuations and currency risk.

Keywords: Oil Price, Exchange Rate, Volatility Spillover, BEKK-GARCH

JEL Classification Codes: E44, C58, C22

Öz: Bu çalışma, enerji ithalatına bağımlı ve finansal dolarizasyonun etkisinde olan Türkiye ekonomisinde Brent petrol fiyatı ve USD/TRY döviz kuru oynaklığının Üretici Fiyat Endeksi ve aylık Sanayi Üretim Endeksi üzerindeki oynaklık yayılma mekanizmalarını incelemektedir. 2002:1'den 2025:10'a kadar aylık veriler kullanılarak, ilk aşamada vektör otoregresif model kullanılarak değişkenler arasındaki dinamik ilişkiler analiz edilmiş, ikinci aşamada ise çok değişkenli BEKK-GARCH(1,1) modeli kullanılarak koşullu varyans-kovaryans dinamikleri analiz edilmiştir. Varyans ayrıştırması, Üretici Fiyat Endeksi varyansının yaklaşık %55'inin USD/TRY şokları tarafından açıklandığını, Sanayi Üretim Endeksi varyansının ise %21'inin Brent petrol şokları ile ilişkili olduğunu göstermektedir. BEKK-GARCH analizi, özellikle 2018:10 yapısal kırılma dönemi öncesinde şokların piyasalar arasında geçişken olduğunu, sonrasında ise oynaklık kalıcılığının ön plana çıktığını göstermektedir. Ayrıca, petrol fiyatlarındaki belirsizliğin sanayi üretimi için risk oluşturabileceği ve piyasalar arasında karşılıklı şok ve oynaklık yayılma etkileşimleri olduğu bulunmuştur. Sonuç olarak, bu kırılganlıkları hafifletmek adına politika yapıcıların, reel sektörü küresel enerji fiyatı dalgalanmalarından ve kur riskinden korumak için ara malı ithalat bağımlılığını azaltmaya ve yenilenebilir enerji kaynaklarına geçişi hızlandırmaya öncelik vermesi gerekmektedir.

Anahtar Kelimeler: Petrol Fiyatı, Döviz Kuru, Volatilite Yayılma Etkisi, BEKK-GARCH

JEL Sınıflandırması: E44, C58, C22

1. Introduction

As globalization accelerates, economies are becoming increasingly vulnerable to external shocks. In such circumstances, maintaining economic stability becomes more challenging for developing economies like Türkiye, where energy imports play a significant role. In

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particular, sudden hikes in oil price and/or sharp fluctuations in currency rates can disrupt this stability.

Since energy is one of the key inputs for almost all fundamental sectors in Türkiye, volatility in this area is critically important. For example, shock increases in energy prices tend to exert upward pressure on costs, while intensifying the impact of potential fluctuations in foreign trade, the vast majority of which is conducted in US dollars.

There are two indicators that can measure the impact of short-term fluctuations in energy and foreign exchange markets on prices and production, namely the Producer Price Index (PPI) along with the monthly Industrial Production Index (IPI). The PPI, which reflects movements in production costs, generally serves as an early indicator of consumer price inflation, making it an important reference point for central banks when determining monetary policy. IPI measures industrial production and provides a snapshot of the economic growth momentum at a given period. Therefore, it is crucial to examine how Brent prices and currency movements interact with both indices.

The Consumer Price Index (CPI) is widely regarded as the key economic indicator, but focusing on the PPI is vital for a better understanding of supply-side drivers and the real economy. Price shifts in production ultimately translate into consumer prices, leading to a theoretical link between producer and consumer prices.

The effects of currency rates and petroleum prices on macroeconomic indicators have been a subject of discussion in the literature for years. Most research has focused on the influence of changes in prices, that is, returns, on both inflation and economic growth (Hamilton, 1983; Berument et al., 2010). Since the early 1980s, one of the main focal points has been the spread of risk and, consequently, volatility across markets. The autoregressive conditional heteroskedasticity (ARCH) models developed by Engle (1982) and their generalized form, the generalized ARCH (GARCH) models proposed by Bollerslev (1986), are widely used to examine risk and clustering in financial series. Multivariate models developed on this basis are also frequently used models in the risk transmission referred to in the literature as “volatility spillover.”

Many studies conducted on Turkish markets have focused on the interactions between financial markets. For example, the strong short-term effects of exchange rates on the country's fragility are among the topics studied by researchers (Leigh and Rossi, 2002; Çakır and Kaya, 2023). Another example is the study by Dedeoğlu and Kaya (2014), which examines the impact of oil price movements on producer prices and highlights the importance

of energy costs. Other analyses reveal that oil shocks have asymmetric effects on industrial production and point to the importance of real sector dynamics (Çatık and Önder, 2013).

Studies on the relationship between exchange rates and oil prices and financial markets are limited in the literature. In particular, there are few studies that directly examine the effects of volatility in oil and exchange rates on key indicators such as the PPI and IPI.

The extent to which the uncertainties created by movements in exchange rates and oil prices affect cost structures and production plans on the producer side can be considered a gap in this field. Therefore, this study aims to fill this gap by focusing on empirically evaluating the impact of Brent oil prices (BRENT) and USD/TRY exchange rate (USD) volatility on Türkiye's PPI and IPI. The analysis is based on monthly percentage change data from 2002:1 to 2025:10. First, a Vector Autoregressive (VAR) model will be applied to capture the return and shock dynamics between the variables; second, a multivariate BEKK-GARCH model will be used to examine the conditional variance-covariance dynamics.

In the rest of the study, the second section will cover the literature review, while the third section will theoretically describe the data set and the methods to be used in the analysis. The fourth section will present the applications and findings, and the final section will state the main conclusion of the study.

2. Literature Review

Theoretical discussion on the connections amongst energy prices, exchange rates, and macroeconomic measures indicates that oil prices initially affect production costs through the cost channel, increase uncertainty by creating uncertainty in costs via the use of oil in transportation, and lead companies to update prices to reduce this risk (Jo, 2014). Bernanke (1983) and Dixit and Pindyck (1994) argue that increased price uncertainty not only forces firms to change their prices but also makes it much harder for them to make investment decisions, often postponing them.

Arslan et al. (2022) is one of the studies that uses VAR models to study the dynamic linkages between variables and the effects at the level. It shows that movements in oil prices affect inflation and growth statistics, and Aykırı (2020), which conducted cointegration and Granger causality analyses, shows that there is a long-term linkage between oil price behavior and key macroeconomic statistics in Türkiye.

As well as variations in oil prices being related to macroeconomic indicators, exchange rate volatility also comes to the fore as another factor affecting macroeconomic indicators due to the exchange rate pass-through mechanism. Domaç and Yücel (2005) argue that in import-

dependent structures such as Türkiye, exchange rate fluctuations translate directly into PPI volatility through higher and unstable costs, Kara and Ögünç (2008) demonstrate that exchange rate shocks have a strong transmission effect on price indices and emphasize that it is not only the level but also the volatility that shapes price dynamics. Dumrul and Gokalp (2022) highlight that exchange rate instability disrupts the future projections of companies in Türkiye and negatively affects their investment decisions. This fragility is often exacerbated by foreign currency-denominated debt; Aghion et al. (2009) noted that exchange rate shocks disrupt company balance sheets and lead to a decline in production volume.

Based on these theoretical foundations, empirical studies in the literature can generally be divided into two groups:

- studies analyzing dynamic relationships and level effects using VAR models in emerging markets and
- studies focusing on risk transmission and volatility spillover mechanisms in oil-importing economies.

In addition to analyzing dynamic relationships and level effects, studies focusing on risk transmission mechanisms began with research by Engle and Ng (1993), which used VARMA-GARCH and BEKK-GARCH models to show that the effect of oil price volatility on economic growth largely depends on the type of volatility shock. Elder and Serletis (2010) further expanded on this topic, revealing that oil price uncertainty significantly reduced GDP growth and investment spending and made production processes more irregular.

Specifically in the context of volatility spillovers for oil-importing economies, Demirgil et al. (2015) examined the link between oil price movements and macroeconomic outcomes in Türkiye using VARMA-GARCH and BEKK-GARCH models, revealing asymmetric effects that indicate oil price volatility is a Granger cause of production growth. Alao et al. (2023), in their study examining G7 countries, noted that asymmetric GARCH models capture the nonlinear effect of oil price uncertainty on industrial production. Among more recent studies, Salem et al. (2024) used the DCC-GARCH framework for major oil-exporting and oil-importing countries and found that oil prices acted as a net transmitter of shocks to the system, particularly during the COVID-19 pandemic and the Russia-Ukraine war. Hamida and Nasr (2024) analyzed the reflection of oil price volatility on exchange rates using the BEKK-GARCH model, concluding that oil price fluctuations cause significant volatility spillovers in real exchange rates for both oil-exporting and oil-importing economies.

While the existing literature comprehensively addresses the level effects of shocks through VAR models and the overall volatility transmission through GARCH models, studies

directly examining the simultaneous volatility spillovers of Brent oil and USD/TRY exchange rates on Türkiye's producer-side indicators remain limited. This study aims to fill this gap by empirically assessing the sources of uncertainty on production costs and industrial production using a multivariate BEKK-GARCH approach.

3. Data and Methodology

3.1 Data

To examine the volatility spillover of oil and USD/TRY exchange rates on Türkiye's producer price index and monthly industrial production index, the monthly percentage changes of these series were first obtained for the period January 2002-October 2025. The data were obtained from the Central Bank of the Republic of Türkiye website.

Table 1. Descriptive Statistics

	<i>BRENT</i>	<i>USD</i>	<i>PPI</i>	<i>IPI</i>
<i>Mean</i>	1.16	1.27	1.52	0.52
<i>Standard Error</i>	0.69	0.25	0.14	0.20
<i>Median</i>	1.32	0.80	1.00	0.52
<i>Standard</i>	11.73	4.26	2.31	3.42
<i>Kurtosis</i>	14.98	8.68	13.89	24.61
<i>Skewness</i>	0.64	2.00	2.73	-1.19
<i>Minimum</i>	-71.06	-8.41	-3.54	-29.32
<i>Maximum</i>	88.57	28.56	19.08	18.66

According to the descriptive statistics given in Table 1, while the average returns for BRENT, USD, and PPI are around 1.2%, this value remains around 0.5% for IPI. For the kurtosis values, it can be said that the IPI variable in particular exhibits a leptokurtic structure with a value of 24.61. Looking at the skewness coefficients, positive skewness is observed for BRENT, USD, and PPI, while negative skewness is observed for IPI. The observed ranges vary between approximately -71% and 89% for BRENT, while similarly wide ranges are observed for the other variables, indicating significant volatility and the presence of extreme values.

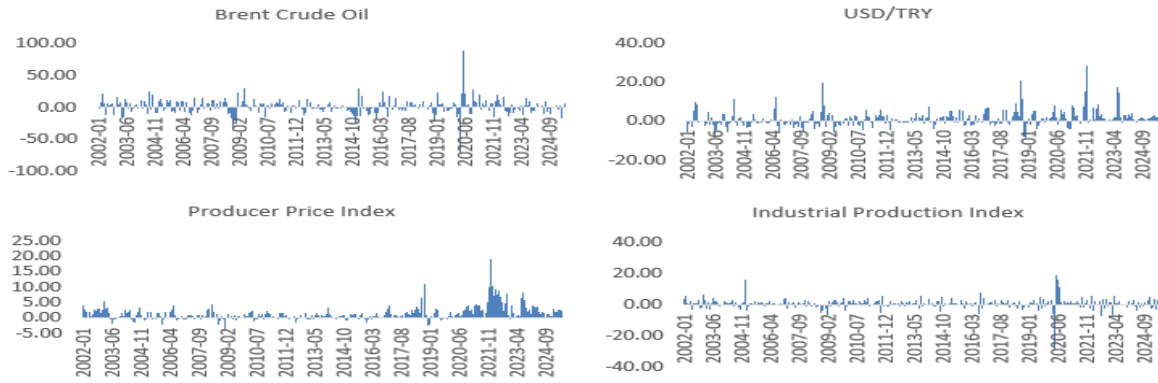


Figure 1. Time series graphs

The monthly percentage change series for BRENT, USD, PPI, and IPI presented in Figure 1 reflect the effects of crises that occurred between 2002 and 2025. Brent crude oil shows the effects of the 2008 financial crisis and the pandemic that began in 2020, while the USD/TRY exchange rate has generally shown an upward trend and exhibited increased volatility in 2008, 2018, and 2021-2023. The PPI series showed a significant increase following the currency shock in 2018, then reached new peaks linked to policies during the pandemic period. In contrast, the Industrial Production Index showed a rapid recovery after the 2008 crisis but experienced a significant contraction in 2020 due to the pandemic.

3.2 Methodology

In this step, a VAR model was initially employed to examine the interrelationships among the variables and to capture potential volatility spillovers across them. Subsequently, the conditional variance-covariance structures of the residual terms obtained from the VAR model were examined. The conditional variance-covariance structures of the residual terms were analyzed using the BEKK-GARCH model, which is among the multivariate GARCH models. This model was used to explore the volatility dynamics between variables. Below, the VAR model will be briefly explained first, followed by the BEKK-GARCH model.

3.2.1 Vector Autoregressive Model

The VAR models presented in Sims (1980) are one of the models used in econometric analysis to examine the dynamic relationships between time series. As with other structural models, VAR models do not distinguish between endogenous and exogenous variables; all variables are considered endogenous. Therefore, theoretical constraints are avoided in revealing the dynamic structure of the data.

Within a standard VAR framework, each variable is expressed as a function of its historical values as well as the lagged values of other variables in the model. For example, a VAR(p) model with k variables and lag length p can be specified as follows:

$$Y_t = c + A_1 Y_{t-1} + A_2 Y_{t-2} + \dots + A_p Y_{t-p} + \varepsilon_t \quad (1)$$

One of the prerequisites for a VAR model is that the variables included in the model are stationary.

Variables must be stationary in order to obtain reliable and meaningful results from the model. The Augmented Dickey-Fuller (ADF) test is one of the most commonly used tests for detecting stationarity in variables (Dickey and Fuller, 1979). As a result of this test, the necessary differences are taken from non-stationary variables and these series are made stationary.

Another important point in creating a VAR model is the lag lengths of the variables. Here, relatively short lag lengths can cause autocorrelation problems, while long lag lengths can cause the number of estimated variables and, consequently, the degrees of freedom to decrease. Therefore, it is important to determine the most appropriate number of lags. Information criteria such as the Akaike Information Criterion (AIC), Schwarz (Bayesian) Information Criterion (SIC), and Hannan-Quinn (HQ) Information Criterion can be used to determine the most appropriate number of lags. The lag number that minimizes the values of these criteria can be considered the most appropriate lag number.

Since it is difficult to interpret the coefficients directly in a VAR model, various analysis methods are used to understand the dynamics of the model. An impulse-response function illustrates how a one-standard deviation shock in a variable's error term affects that variable and the others in the model as time progresses. This analysis reveals the transmission mechanism of shocks and how long their effects last. Variance decomposition explains, in percentage terms, how much of each variable's estimated error variance stems from its own shocks and how much stems from other variables in the model.

3.2.2 Multivariate GARCH Models and the BEKK-GARCH Approach

Financial series usually show a feature called “volatility clustering.” Accordingly, higher volatility periods are followed by higher volatility cycles, while lower volatility periods are followed by lower volatility cycles. This indicates that the variance of the error terms is not constant, i.e., heteroscedasticity exists.

Traditional VAR analysis works under the assumption that conditional variance remains constant when examining the relationships between the conditional means of variables. While

this approach is useful for mean dynamics, it falls short when the goal is to understand risk or the transmission of shocks between financial markets. For that, it becomes necessary to capture how variance—and the covariances between variables—evolve over time.

To address this gap, Bollerslev's (1986) GARCH model has become a standard tool, as it explicitly accounts for time-varying conditional variance. Researchers developed multivariate GARCH models to analyze the volatility dynamics of multiple time series simultaneously, while also accounting for the interdependence of their variances.

In the analysis of the spillover effect, the BEKK-GARCH model developed by Engle and Kroner (1995) is adopted, as it provides a positive-definite conditional covariance matrix. It is preferred primarily because it can decompose the direct shock and volatility spillover effects between parameters and reveals the direction and magnitude of shocks through cross terms in the variance and covariance terms. The advantage of this model supports the main purpose of the study:

- analyzing the direct effects of the uncertainty of energy prices and exchange rates on production costs and industrial production,
- exploring the spillover mechanism working through the cost channel.

A general BEKK-GARCH(1,1) model for a system with k variables can be expressed as follows in Equation (2):

$$Y_t = c + \sum_{i=1}^p A_i Y_{t-i} + \varepsilon_t \quad (2)$$

In this framework, the error term, conditional on the information set Ω_{t-1} , follows $\varepsilon_t | \Omega_{t-1} \sim N(0, H_t)$, where H_t represents the conditional variance–covariance matrix. Within the BEKK-GARCH(1,1) specification, this matrix is modeled as:

$$H_t = C' C + A' \varepsilon_{t-1} \varepsilon_{t-1}' A + B' H_{t-1} B \quad (3)$$

Here, H_t captures the conditional variance–covariance structure of the system. The diagonal entries correspond to the conditional variances of each series, while the off-diagonal terms capture their conditional covariances.

The C matrix, introduced in Equation (3), represents a constant term in lower triangular form. The A matrix shown in Equation (3) represents ARCH effects. In other words, it indicates the effect of past shocks on current conditional variances. Here, each element in the A matrix shows the effect of the shock in variable j on the volatility in variable i , for example. In contrast, the B matrix represents GARCH effects and shows how past conditional variances are reflected in current volatility. These coefficients effectively measure the continuity of volatility from one period to another.

The diagonal elements of A and B (α_{ii}, b_{ii}) show how each variable responds to its own past shocks and volatility, while the non diagonal terms (α_{ij}, b_{ij}) are key to identifying volatility spillovers across markets. For example, a statistically significant α_{ij} implies that a shock in market j at time t-1 increases volatility in market i at time t. Similarly, a significant b_{ij} indicates that persistent volatility in market j transmits to market i.

4. Results

This study explores how movements in Brent oil prices and the USD/TRY currency rate influence Türkiye's Producer Price Index and Industrial Production Index. In this context, the dependencies and lagged effects between the variables were first analyzed using the VAR model, and then the BEKK-GARCH(1,1) model was applied by testing whether the residual terms of the VAR model had an ARCH effect. An ADF test was previously applied to assess whether the series exhibited stationarity. The ADF test was applied under three different models (without intercept-trend, with intercept and with intercept-trend). The results obtained are tabulated in Table 2.

Table 2. Unit Root Test

	<i>Without Intercept-Trend</i>		<i>With Intercept</i>		<i>With Intercept-Trend</i>	
<i>BRENT</i>	-14.18	0.00	-12.71	0.00	-12.72	0.00
<i>USD</i>	-7.59	0.00	-11.67	0.00	-12.42	0.00
<i>PPI</i>	-4.22	0.00	-5.38	0.00	-7.67	0.00
<i>IPI</i>	-18.28	0.00	-18.69	0.00	-18.69	0.00

According to the results obtained, the ADF statistics of all variables are well below the critical values. Furthermore, all p-values are statistically significant at the 1% significance level. These findings indicate that the variables are stable at the level. In other words, there is no unit root problem in the BRENT, USD, PPI and IPI series.

Bai and Perron (2003) test was employed to verify the presence or lack of structural breaks during the period under discussion following the investigation of stationarity conditions in the series. Given the limited available data, only one structural break was tested, and the tests showed that a structural break occurred in 2018:10. Therefore, the data for this date and later assumed a value of 1 for the dummy variable representing structural changes.

After confirming that the series were stationary at their levels and the structural break time had been verified, lag length tests were carried out up to 8 lags to determine the optimal structure for the VAR model. The AIC, SIC, and HQ criteria were then calculated to guide the

selection. Based on these criteria values, as shown in the Table 3 the optimal lag number for the VAR model to be established was chosen as 1.

Table 3. VAR Model Lag Length Criteria

<i>Lag</i>	<i>AIC</i>	<i>SIC</i>	<i>HQ</i>
0	22.61	22.71	22.65
1	21.47	21.78*	21.60*
2	21.46*	21.98	21.67
3	21.49	22.22	21.78
4	21.55	22.49	21.93
5	21.62	22.77	22.09
6	21.69	23.05	22.24
7	21.74	23.30	22.37
8	21.80	23.57	22.51

In this study, a VAR model was estimated to examine the dynamic relationships between the BRENT, USD, PPI, and IPI variables. Table 4 shows the coefficients and significance levels in the model.

Table 4. VAR Model

	<i>Constant</i>	<i>BRENT_{t-1}</i>	<i>USD_{t-1}</i>	<i>PPI_{t-1}</i>	<i>IPI_{t-1}</i>	<i>Dummy</i>
<i>BRENT_t</i>	1.09	0.20***	0.04	0.24	-0.63***	-0.79
<i>USD_t</i>	0.66**	-0.04**	0.42***	-0.15	0.09	1.14**
<i>PPI_t</i>	0.34***	0.01	0.09***	0.55***	0.05*	0.65***
<i>IPI_t</i>	0.71***	0.14***	-0.07	-0.17	-0.23***	0.35
*** indicates significance at 99% confidence level, ** at 95% confidence level and * at 90% confidence level.						

The VAR model results reveal the dynamic relationships between the BRENT, USD, PPI, and IPI variables. The USD value from the earlier period has a positive and significant effect on PPI, while IPI has a negative and strong effect on BRENT. USD is affected by its own lagged values and partly by BRENT, while PPI receives a limited response from both USD and IPI. IPI, on the other hand, receives a negative effect from its own lagged value despite the positive effect of BRENT.

Since the roots lie within the unit circle in the VAR model estimation, this confirms that the system is stationary and that any shocks will gradually diminish over time. As shown in Figure 2, the results of the root analysis reveal that all roots are within the unit circle. This confirms that the model is suitable for forecasting and causality analysis.

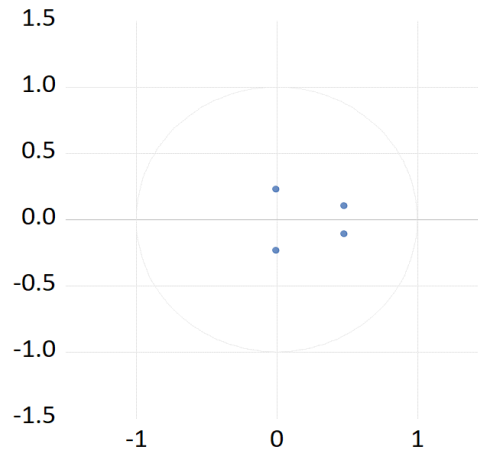


Figure 2. Companion Matrix's Eigenvalues

The graphs below display the impulse response functions derived from the VAR model, illustrating how shocks to one variable dynamically influence the others through time. Here, the dashed red lines indicate confidence intervals.

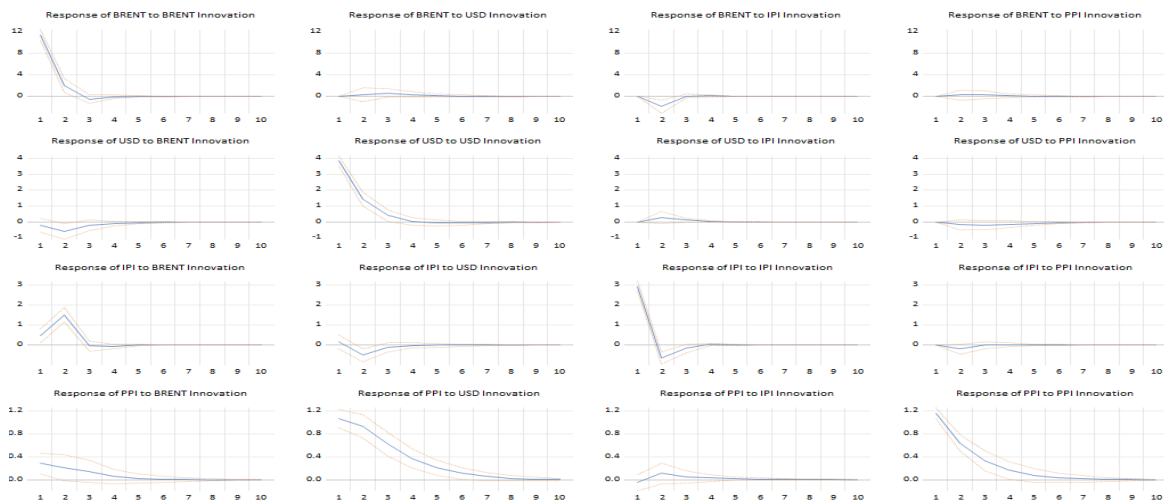


Figure 3. Impulse Response Functions

According to the impulse-response analysis shown in Figure 3, short-term reciprocal responses are observed between the USD and BRENT; a positive shock in the USD initially creates a positive effect on BRENT, while a shock in BRENT negatively affects the USD. BRENT's effect on PPI is positive but short-lived and limited; its effect on IPI is initially positive and diminishes over time. The reactions between the PPI and IPI variables are generally weak and short-lived, being more significantly affected by their own lagged values. Overall, the graphs show that interactions between variables are strong in the short run but fade in the medium term, and that the system is moving towards equilibrium.

Variance decomposition is an important tool that quantitatively reveals the contribution of interactions and shocks between economic variables to future volatility. The variance decomposition results for the variables used in the study are presented in Table 5, where the first column shows the variable for which variance decomposition was performed.

Table 5. Variance Decomposition

	<i>Period</i>	<i>BRENT</i>	<i>USD</i>	<i>PPI</i>	<i>IPI</i>
<i>BRENT</i>	5	96.89	0.50	0.15	2.47
	10	96.88	0.50	0.15	2.47
<i>USD</i>	5	2.46	96.42	0.59	0.54
	10	2.46	96.39	0.62	0.54
<i>PPI</i>	5	3.23	55.27	41.10	0.39
	10	3.22	55.41	40.97	0.40
<i>IPI</i>	5	21.26	2.44	0.34	75.96
	10	21.26	2.44	0.34	75.96

The variance decomposition results show the extent to which the variance of the four variables examined in the study is explained by other variables. Looking at the BRENT variable, it can be seen that a very large portion of its variance in the 5th and 10th periods stems from its own internal shocks. The effect of the other three variables on variance remained around 3% in total. A very similar situation applies to the USD variable. Approximately 96% of this variable's variance is also explained by itself. The situation is slightly different for the PPI and IPI variables. Approximately 55% of the variance of the PPI variable is explained by the USD variable, while only 40% is explained by itself. For the IPI variable, the variance explained by the variable itself is 76% of the total variance, followed by 21% explained by the BRENT variable. Accordingly, it can be said that, in general, internal dynamics are dominant in the BRENT and USD variables, while the USD variable is effective in the PPI variable and the BRENT variable is effective in the IPI variable.

To examine the volatility spillover of BRENT and USD on PPI and IPI, a VAR model was estimated in the first stage. To examine volatility dynamics using the model's residuals, ARCH tests will first be conducted for the periods before and after the structural break date to verify the presence of conditional heteroscedasticity.

As seen in Table 6, which uses 2018:10 as the structural break date, the results of the sample divided into two parts show that the ARCH effect is present in the error terms of most variables in both subdivided periods. Since the error terms do not have constant variance, the BEKK-GARCH model, which examines volatility interactions, can be used.

Table 6. ARCH Test p-Values

<i>Lag</i>	<i>First period</i>				<i>Second period</i>			
	<i>BRENT</i>	<i>USD</i>	<i>PPI</i>	<i>IPI</i>	<i>BRENT</i>	<i>USD</i>	<i>PPI</i>	<i>IPI</i>
1	0.00	0.62	0.00	0.56	0.10	0.00	0.10	0.01
2	0.00	0.01	0.00	0.66	0.00	0.00	0.22	0.04
3	0.00	0.02	0.00	0.35	0.00	0.01	0.18	0.06
4	0.00	0.03	0.00	0.51	0.00	0.01	0.25	0.08
5	0.00	0.05	0.00	0.62	0.00	0.03	0.36	0.09
6	0.00	0.07	0.00	0.68	0.00	0.06	0.46	0.11
7	0.00	0.09	0.00	0.77	0.00	0.08	0.58	0.12
8	0.00	0.10	0.00	0.82	0.00	0.08	0.70	0.13
9	0.00	0.12	0.00	0.89	0.00	0.09	0.78	0.16
10	0.00	0.19	0.00	0.93	0.00	0.10	0.85	0.20

The outputs for the BEKK-GARCH (1,1) models for two sub-periods are shown in Table 7.

Table 7. BEKK-GARCH(1,1) Result

<i>Coefficient</i>	<i>Explanation</i>	<i>Period 1</i>	<i>Period 2</i>
C11	Constant term in variance equation for BRENT	42.83***	43.32***
C21	Lower triangular element for USD	0.00	0.00
C31	Lower triangular element for PPI	0.00	0.00
C41	Lower triangular element for IPI	0.00	0.00
C22	Constant term in variance equation for USD	2.94***	-1.60***
C32	Lower triangular element for PPI	0.00	0.00
C42	Lower triangular element for IPI	0.00	0.00
C33	Constant term for variance of PPI	0.28*	1.84*
C43	Lower triangular element for IPI	0.00	0.00
C44	Constant term for variance of IPI	0.39**	-0.02
A11	ARCH effect of BRENT on its own volatility	0.08	-0.05
A12	Shock from USD on volatility of BRENT	0.09	-0.02
A13	Shock from PPI on volatility of BRENT	-0.08***	0.11
A14	Shock from IPI on volatility of BRENT	0.03**	-0.02
A21	Shock from BRENT on volatility of USD	-1.68	-1.33
A22	ARCH effect of USD on its own volatility	0.01	0.53**
A23	Shock from PPI on volatility of USD	-0.21***	0.28
A24	Shock from IPI on volatility of USD	-0.10***	-0.10
A31	Shock from BRENT on volatility of PPI	-1.75***	1.00
A32	Shock from USD on volatility of PPI	-0.09	0.02
A33	ARCH effect of PPI on its own volatility	0.39***	0.57
A34	Shock from IPI on volatility of PPI	-0.05	0.00
A41	Shock from BRENT on volatility of IPI	2.83	0.26
A42	Shock from USD on volatility of IPI	0.10**	0.40
A43	Shock from PPI on volatility of IPI	0.37	-0.15
A44	ARCH effect of IPI on its own volatility	0.78***	0.89***
B11	GARCH effect of BRENT on its own past volatility	-0.01	0.18***
B12	Persistence of USD on volatility of BRENT	0.07***	0.06**

B13	Persistence of PPI on volatility of BRENT	-0.04***	-0.05
B14	Persistence of IPI on volatility of BRENT	0.01	0.03**
B21	Persistence of BRENT on volatility of USD	-1.54	-3.79
B22	GARCH effect of USD on its own volatility persistence	0.46***	0.08
B23	Persistence of PPI on volatility of USD	-0.40***	0.34
B24	Persistence of IPI on volatility of USD	-0.06	-0.30**
B31	Persistence of BRENT on volatility of PPI	-3.78***	1.05
B32	Persistence of USD on volatility of PPI	0.21	0.06
B33	GARCH effect of PPI on its own volatility persistence	0.28***	-0.53
B34	Persistence of IPI on volatility of PPI	-0.35***	0.09
B41	Persistence of BRENT on volatility of IPI	-0.74	-0.08
B42	Persistence of USD on volatility of IPI	0.25	-0.34
B43	Persistence of PPI on volatility of IPI	0.22	0.29
B44	GARCH effect of IPI on its own volatility persistence	-0.03	0.42**
AIC	Akaike Information Criteria	1883.51	852.90
Q ₆	Ljung-Box test at the 6 th lag	114.50	81.50
Q ₁₂	Ljung-Box test at the 12 th lag	217.50	191.00
Q ₆ ²	Autocorrelation test of squared residuals at the 6 th lag	95.80	102.40
Q ₁₂ ²	Autocorrelation test of squared residuals at the 12 th lag	203.90	194.80
*** indicates significance at 99% confidence level, ** at 95% confidence level and * at 90% confidence level.			

In this study, the BEKK-GARCH(1,1) model was used to examine the volatility spillovers between Brent oil prices, the USD/TRY exchange rate, the Producer Price Index, and the Industrial Production Index for two periods. The conditional variance-covariance matrix calculated for the model used can be expressed with three components. These components can be denoted as the C, A, and B matrices.

The C matrix, which is the first component of the conditional variance-covariance matrix, is specified in lower triangular form. This matrix represents the constant term. An important point here is that the diagonal elements of the C matrix correspond to the constant conditional variance components of the variables. Therefore, the elements C11, C22, C33, and C44 represent the constant conditional variance components of BRENT, USD, PPI, and IPI, respectively. On the other hand, the off-diagonal elements of the C matrix indicate the fixed covariance contributions between variables. These coefficients are generally close to zero or negligible. In other words, they have a limited structure for indicating fixed covariance volatility dynamics.

The A matrix measures the impact of historical shocks on present conditional volatility by representing ARCH effects. Diagonal elements (A11, A22, A33, A44) show how their own variables are affected by previous shocks. For example, the A11 coefficient reveals the degree to which Brent crude oil is affected by its own shocks. Off-diagonal elements (A12, A14, A21, A32, etc.) represent the propagation of shocks across markets. Looking at the matrix A, it can be seen that the pre- and post-2018:10 dynamics differ. In the initial period, the effect of the Brent oil shocks on the PPI and the USD/TRY shock on the IPI were significant and demonstrated spillover effects. In the latter period, these effects weakened, the market's spillover effects diminished, but the variables remained sensitive to their own shocks. Overall, this could be interpreted as the market becoming more internally focused in the later period.

The B matrix shows the GARCH effects, i.e., the contribution of past conditional variance to current period volatility. The diagonal elements (B11, B22, B33, B44) represent the persistence of the variables' own past volatility. For example, B44 shows that the cumulative effect of IPI's past volatility continues in the current period. The off-diagonal elements (B12, B13, B32, B34, etc.) reflect volatility spillovers. Similar to the A matrix, structural changes are visible between periods. Brent crude oil did not display the GARCH effect in the first period, but it did in the second. While volatility in BRENT was stable in the first period, this did not continue in the second. USD/TRY, however, did not exhibit significant volatility persistence in either period for PPI or IPI.

According to the statistically insignificant Ljung–Box test results for two periods, it can be stated that the residuals and their squares do not exhibit autocorrelation, and therefore the model is statistically valid and reliable.

In summary, the model findings show that with the structural break in 2018:10, shocks between markets became less transmitted, giving way to persistent volatility, particularly in energy and industrial production, which was influenced by historical trends.

The transmission channels of shocks and volatility spillovers, as determined by variance decomposition and BEKK-GARCH analyses, are represented in Figure . Brent oil and USD/TRY exchange rate shocks are shown to be transmitted to production indicators through cost, uncertainty and balance sheet channels, emphasizing the important role of exchange rate propagation and persistence of volatility in the real sector.

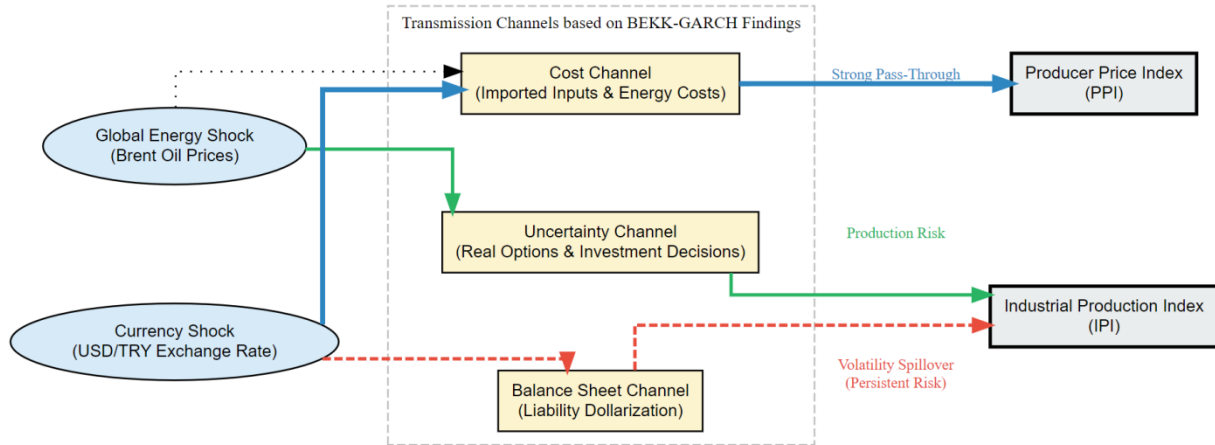


Figure 4. Transmission Channels and Volatility Spillovers in the Turkish Economy

5. Conclusion

This study examines the spillover effects of volatility in Brent oil prices and the USD/TRY exchange rate on the Producer Price Index and the Industrial Production Index. Türkiye is structurally a country that obtains raw materials and intermediate goods through imports, has experienced high inflation in the past, and generally has a high level of dollarization. In this context, it is important for Türkiye to determine whether global oil shocks and currency shocks will have an impact on both production and prices, and to what extent this impact will be. For this purpose, the BEKK-GARCH model was created using monthly data from the period 2002:1-2025:10. Considering the length of the period under analysis, one date that could be a structural change in the corresponding period was investigated, and the date 2018:10 was determined as the structural break date. Variance modeling was performed separately for the periods before and after this date. Prior to the BEKK-GARCH model, interactions between variables were analyzed using the VAR model with structural break.

While observing the dynamic relationships between variables using the VAR model, the variance interactions of the variables were subsequently observed using variance decomposition. Accordingly, while the BRENT and USD variables are influenced by their own internal dynamics, approximately 55% of the variance of the PPI variable is explained by the USD variable, and approximately 21% of the variance of the IPI variable is associated with the BRENT variable. In particular, the USD effect on the PPI variable is consistent with the exchange rate transmission mechanism for the Turkish economy. Import dependency, dollarization, and past high inflation conditions suggest that exchange rate shocks are directly reflected in prices. This result is fully consistent with previous findings in the literature, including those reported by Kara and Ögünç (2008) and Domaç and Yücel (2005).

On the other hand, it has been observed that approximately 21% of the variance in the Industrial Production Index stems from shocks in Brent oil prices. This result, which shows that uncertainty in oil prices may influence production and investment decisions, is parallel to the approaches put forward by Bernanke (1983) and Dixit and Pindyck (1994).

The outputs of the BEKK-GARCH model created after the VAR model demonstrate how risks spread across markets. BEKK-GARCH outcomes show a major change in risk transmission mechanisms in line with the structural break date, with strong volatility spillovers from Brent crude oil to the PPI and from USD/TRY to the IPI in the first period, and a significant softening of these cross-market shock transmissions in the latter period. In the second period, markets began to show an internalization behaviour, and the level of current volatility became more sensitive to its own past volatility rather than to external shocks.

The analysis of volatility persistence suggests that whereas Brent oil volatility was stable in the initial period, it exhibited significant persistence in the later period, indicating that when volatility is induced in energy markets, it becomes more persistent and creates permanent uncertainty for the industrial sector.

In general, the results indicate oil shocks have a significant effect on the industrial production index, suggesting a turn in energy policy. Increasing the transition to renewable energy sources could be seen as a mechanism to protect the industrial sector from oil price volatility, in addition to its environmental aspects. During the second period, the increase in volatility persistence pointed to the need for real sector companies to revise their risk management and suggested the important role of firms in the industry sector in effectively using finance derivatives and hedging instruments to manage cost pressures.

A comprehensive policy approach is required to mitigate the vulnerabilities observed in this study. Priority should be given to structural reforms aimed at reducing dependence on intermediate goods imports in order to protect domestic production costs from exchange rate shock, and a mechanism should be set up to increase the transition to renewable energy sources, not only for environmental goals but also to protect the industrial sector from global oil price volatility. Given the strong spillover effect of the exchange rate on producer prices, the Central Bank of the Republic of Türkiye should prioritize stabilizing exchange rate volatility, which appears fundamentally linked to pricing behavior, rather than focusing only on the exchange rate level.

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Critical Enablers for Successful Supply Chain 4.0 Adoption: Enhancing Supply Chain Visibility and Efficiency¹

Başarılı Tedarik Zinciri 4.0 Uyumu için Kritik Kolaylaştırıcılar: Tedarik Zinciri Görünürlüğünü ve Etkinliğini Artırma

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Abstract: This study investigates the influence of the critical organisational factors on Supply Chain 4.0 (SC4.0) adoption and how SC4.0 impacts supply chain visibility and efficiency. Although Industry 4.0 has gained increasing interest, there is little empirical research on SC4.0 and its impacts on operational performance, particularly in emerging economies. Drawing on the Resource-based view (RBV) and Dynamic capability theory (DCT), we assessed the influence of Industry 4.0 strategy, supply chain integration (SCI), production system automation (PSA), and lean practices (LP) on SC4.0 adoption and ultimately the impact of SC4.0 on performance. PLS-SEM was used to analyse data from Turkish manufacturing firms. This was also supported by bibliometric analysis. The findings reveal that the I4.0 strategy, SCI, and PSA significantly influence SC4.0 adoption, while LP does not. SC4.0 improves visibility, which leads to improvements in efficiency. This makes visibility an important mediating capability in digital supply chains. This study is one of the first to directly position SC visibility as a critical dynamic capability within SC4.0. The findings also challenge traditional assumptions about LP, which shows that there is a need to build digital lean strategies. Our study contributes to supply chain theory by emphasising the important role of dynamic capabilities in digital transformation. It also offers managerial guidance on how they can use I4.0 strategies, integration and automation to support SC4.0 and ultimately enhance visibility. Managers should also explore new enablers to advance SC4.0 adoption.

Keywords: Supply Chain 4.0, Digital Transformation, Enablers, Visibility, Efficiency

JEL Classification: M11, L23, O33, O14, L25

Öz: Bu çalışma, kritik organizasyonel faktörlerin Tedarik Zinciri 4.0 (SC4.0) benimsenmesi üzerindeki etkisini ve SC4.0'ın tedarik zinciri görünürlüğü ve verimliliğini nasıl etkilediğini incelemektedir. Endüstri 4.0 giderek artan bir ilgi kazansa da, SC4.0 ve özellikle gelişmekte olan ekonomilerde operasyonel performans üzerindeki etkileri hakkında çok az ampirik araştırma bulunmaktadır. Kaynak tabanlı görüş (RBV) ve Dinamik yetenek teorisinden (DCT) yararlanarak, Endüstri 4.0 stratejisinin, tedarik zinciri entegrasyonunun (SCI), üretim sistemi otomasyonunun (PSA) ve yalın uygulamaların (LP) SC4.0 benimsenmesi üzerindeki etkisini ve nihayetinde SC4.0'ın performans üzerindeki etkisini değerlendirdik. Türk üretim firmalarından gelen verileri analiz etmek için PLS-SEM kullanıldı. Bu, bibliyometrik analizle de desteklendi. Bulgular, I4.0 stratejisinin, SCI'nın ve PSA'nın SC4.0 benimsenmesini önemli ölçüde etkilediğini, LP'nin ise etkilemediğini ortaya koymaktadır. SC4.0, görünürlüğü artırarak verimlilikte iyileşmelere yol açar. Bu da görünürlüğü dijital tedarik zincirlerinde önemli bir aracı yetenek haline getirir. Bu çalışma, SC görünürlüğünü SC4.0 kapsamında kritik bir dinamik yetenek olarak doğrudan konumlandıran ilk çalışmalardan biridir. Bulgular ayrıca, LP hakkındaki geleneksel varsayımlara da meydan okuyarak, dijital yalın stratejiler oluşturulması gerektiğini göstermektedir. Çalışmamız, dijital dönüşümde dinamik

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yeteneklerin önemli rolünü vurgulayarak tedarik zinciri teorisine katkıda bulunmaktadır. Ayrıca, yönetimlere SC4.0'ı desteklemek ve nihayetinde görünürlüğü artırmak için I4.0 stratejilerini, entegrasyonu ve otomasyonu nasıl kullanabilecekleri konusunda rehberlik sunmaktadır. Yöneticiler ayrıca SC4.0 benimsenmesini ilerletmek için yeni kolaylaştırıcıları da araştırmalıdır.

Anahtar Kelime: Tedarik Zinciri 4.0, Dijital Dönüşüm, Kolaylaştırıcılar, Görünürlük, Etkinlik

JEL Sınıflandırması: M11, L23, O33, O14, L25

1. Introduction

The Covid-19 crisis exposed the limitations of traditional manufacturing and supply chain (SC) operations, which have become more apparent in this digital age. Consequently, Supply Chain 4.0 (SC4.0) attempts to develop sustainable manufacturing and logistics solutions through Industry 4.0 (I4.0). Scopus data on SC4.0 as of January 2025 demonstrates that over 6000 I4.0 related materials were published, suggesting a growing interest in this area. Overall, these publications relate to I4.0 implementations in manufacturing and SCs as an attempt to enhance sustainable performance. While I4.0 denotes a new era of industrial transformation that is involves the integration of digital technologies into operations systems and manufacturing, SC4.0 involves applying I4.0 to SC operations. SC4.0 represents the digital transformation of SC processes and manufacturing operations through the adoption of I4.0. Rossini et al. (2019) noted that decentralisation and digitisation of production processes support interconnected and autonomous production systems within the SC.

Since the emergence of I4.0, critical I4.0 technologies (I4T), such as simulation, big data (BDA), cloud computing, 3D printing, the internet of things, and AI, have been argued to transform traditional SCs. Choi et al. (2022), argued that I4.0 creates opportunities for improving visibility, efficiency, and agility all of which are very important for building more resilient and sustainable SCs. Notwithstanding theoretical discussions on the influence of I4.0 on various aspects of SCM (Ivanov et al., 2019), there still remains a need to establish and empirically investigate critical enablers that drive successful SC4.0 implementation. This is because most literature on SC4.0 and performance mainly focused on the theoretical and conceptual influence of SC4.0 in developed economies. Thus, leaving the question of whether SC4.0 can be successfully adopted to enhance the performance of firms in emerging economies unanswered. Also, what critical factors and capabilities are necessary for SC4.0 adoption in firms? According to Frederico et al. (2020), SC4.0 refers to how I4.0 concepts and technologies are integrated and implemented within the SC. By integrating enablers such as supply chain integration (SCI), production system automation (PSA), lean techniques (LP) and I4.0 strategy firms can leverage the potential of SC4.0 and improve SC visibility and operational efficiency. If firms can successfully adopt SC4.0, it can become a fundamental to sustainable supply chain (SSC) performance.

Despite several review studies discussing the potential of SC4.0 (Ghadge et al., 2020; Cugno et al., 2021; Khin and Hung, 2022), there is little empirical research addressing how the successful adoption of SC4.0 can improve visibility and efficiency in SC. Particularly, the benefits and impact of SC4.0 on SSC performance in developing economies requires investigation. We believe that understanding these relationships is critical especially for firms seeking to leverage I4T for operational and SSC performance.

Notwithstanding the growing attention given to digital SCs, SC4.0 and its impact are less studied in existing literature. Research is lacking in this area, especially in determining critical factors for successful SC4.0 and how to implement it to optimise SC performance. Although literature makes clear the relevance of I4.0 in SCM (Srivastava et al., 2022; Lin et al., 2023), we believe there is a need to assess the impact of SC4.0 as how it is influenced by organisational enablers. Our study seeks to assess the influence of critical enablers such as I4.0 strategies, supply SCI, PSA, and LP on SC4.0 adoption, as well as the impact of SC4.0 on SC visibility and efficiency. Therefore, the paper is concerned with addressing the following questions that focuses on these issues.

RQ1. How do organisational enablers influence the adoption of SC4.0?

RQ2. What impact does SC4.0 adoption have on SC visibility and efficiency?

RQ3. What is role of SC visibility in the relationship between SC4.0 and efficiency?

2. Literature Review

We combined traditional literature review (LR) with bibliometric analysis (BA) in order to provide richer and relevant LR. BA was conducted using Scopus and VOSviewer to identify important themes and concepts around SC4.0 and I4.0. LR provides insights into key technologies and applications.

2.1. Bibliometric Review

A systematic literature search was conducted to support both the bibliometric analysis and the traditional literature review. The search was carried out using the Scopus database, a widely recognised source of peer-reviewed academic literature in supply chain and operations management. Our bibliometric analysis involved studies from 2019 to 2024 to capture key themes, and significant contributions to SC4.0 research. The keywords search included “Supply Chain 4.0,” “Industry 4.0,” “digital supply chain”, and “Supply Chain”. We obtained initial 2995 publications using Boolean AND/OR notations on Scopus. The results reveal a growing interest in digital supply chains and transformation, with 175 publications directly mentioning supply chain 4.0 and 2995 focusing on I4.0 and SC. Duplicate records were first removed before title and abstract screening was conducted. This allowed us to exclude studies that were not directly

related to Supply Chain 4.0. We further excluded Conference papers, book chapters, non-English publications, and all studies that were not focused on supply chain. After this process and a thorough screening of the articles, 175 peer-reviewed articles were retained for bibliometric analysis.

2.1.1. Key Contributions to SC4.0 Research

While the works by Kagermann et al. (2013) and Ivanov et al. (2019) are popular among the early citations on SC4.0, some more recent articles (Tjahjono et al., 2017; Ivanov et al., 2019; Frederico et al. 2020; Liu et al. 2021; Queiroz et al., 2022; Mubarik et al., 2021; Chauhan et al., 2021; Marinagi et al., 2023; Surucu-Balci et al., 2024) have gained prominence. This reflects the growing importance of SC4.0 as a crucial area of study that can leverage digital transformation and I4.0-related technologies for optimised SC operations.

2.1.2 Contributing Regions

Bibliometric findings identify a growing global significance of SC4.0 research with an increasing trend toward emerging economies. Among other emerging countries like, China, Italy, Brazil, and Turkey, India has the highest number of publications. The diverse regional contribution to the topic indicates that SC4.0 is an important field that needs further empirical evaluation. Therefore, our study seeks to contribute to the growing relevance of SC4.0 in modern SCM.

2.1.3. Network Analysis of Supply Chain 4.0 and Related Research

Figure 1 below is VOSviewer generated network map (NM) which provides five main clusters that are foundational to the conceptual understanding of SC4.0. The red cluster represents digital transformation (DT) and I4.0 as core SC4.0 concepts, which include decision-making, AI, big data, sustainable development, and supply chain. It illustrates how the concept of I4.0 and DT influences SC decision-making and sustainability goals. The successful implementation of SC4.0 can contribute to the sustainable development goals SDG 9 and SDG 12, whose aims are industry innovation, responsible consumption and production. The green cluster, represents SCM and logistics as an important aspect of SC4.0. It links keywords like SC resilience, SC integration, risk assessment, SC efficiency, visibility, competitiveness, and agility. This cluster not only highlights the linkage between SC4.0 and performance improvements, but it also associates some critical capabilities and enablers with SC4.0. The blue cluster, represents the smartness and automation aspect of SC4.0 which links cyber-physical systems (CPS), production systems, smart manufacturing, automation, industrial IoT and interoperability. Not only does this highlight the potential for improving the smartness of SCs through SC4.0 adoption, but it also links PSA to SC4.0 adoption. While the purple cluster represents data analytics and AI as

essential for real-time decision making and SC efficiency, the yellow cluster represents emerging technologies in SC. Blockchain, 3D printing, and cybersecurity are some of the keywords associated with security and SC visibility among emerging technologies. Overall, the NM reveals that SC4.0 is a holistic construct which involves strategic, technological, operational, and sustainability that can be leveraged to develop responsive, resilient, data driven and sustainable SCs.

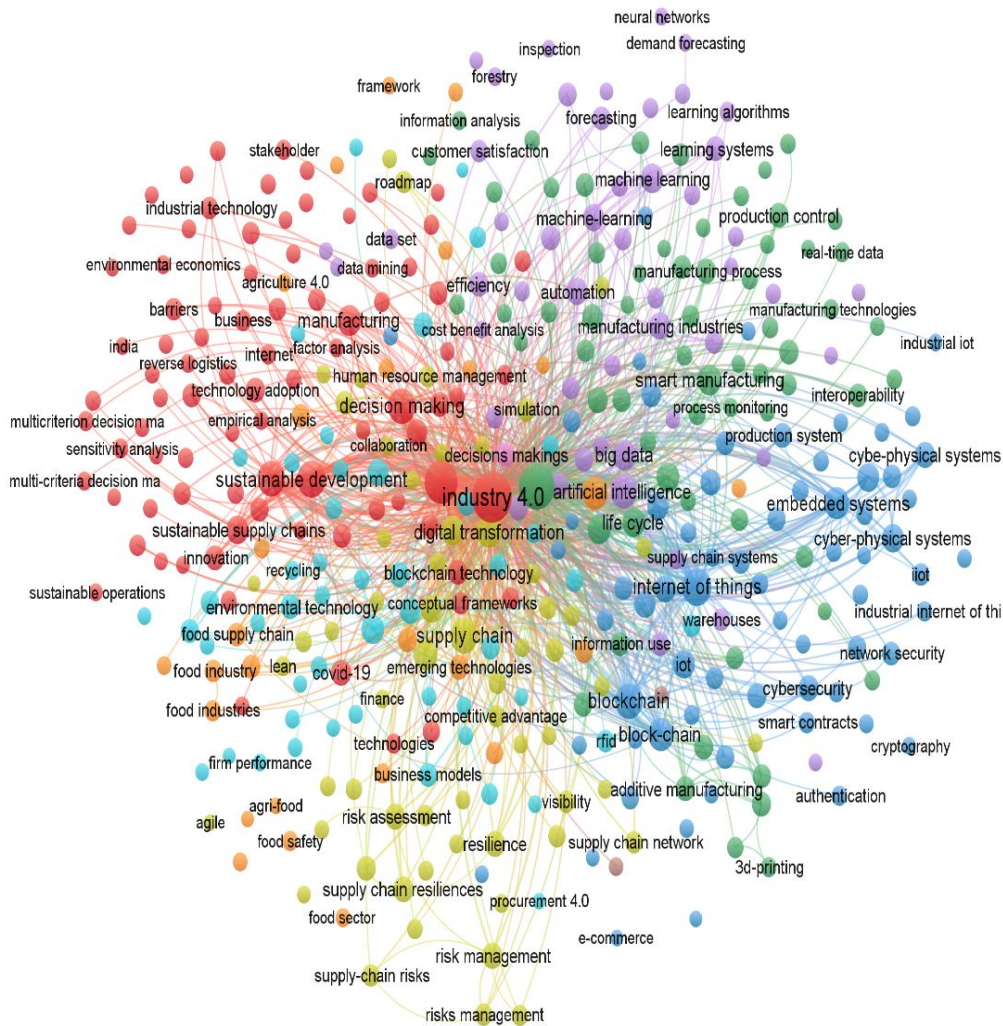


Figure 1. Network map (NM) of SC4.0

Despite an increasing focus on sustainability and industry 4.0 technology I4T, the network analysis indicates limited attention on critical enablers of SC4.0 and as well as the influence of

SC4.0 on performance. Although studies on SC4.0 have moved past the integration of I4T with SCs to focus on SC sustainability and issues to do with security, there is little research on SC4.0 enablers such as I4.0 strategies, lean technologies, SC integration, and automation.

2.2. Industry 4.0

Industry 4.0 entails the fourth industrial stage in manufacturing and operations systems that integrates digital technologies into the entire SC to add value and enhance SC sustainability. I4.0 seeks to enhance operations of SC via improved visibility, which is enabled through the intelligent integration of SC processes, technology, and people (García-Reyes et al., 2022). Technologies like IoT, AI, blockchain, CPS, and BDA enable the development of smart, sustainable, and self-optimising SCs. The transition increases SC decentralisation and digitalisation environment, which makes the production and SC operations elements more autonomous (Dalenogare et al., 2018; Tortorella et al., 2019). It also enhances interconnectivity and interactions among systems, people, and machines, which enables interconnectedness, flexibility, transparent and autonomous manufacturing systems.

Foundational to I4.0 are advanced digital technologies as indicated by the NM. CPS is the amalgamation of physical manufacturing processes with digital systems technologies to enable smart manufacturing (Ryalat et al., 2023). Xu et al. (2018) noted that IoT improves visibility and production efficiency, while BDA optimises production planning and logistics (Witkowski, 2017). AI enables advanced analytics and automation, leading to enhanced agility and risk assessment.

Digital transformation (DT), is central to I4.0 as indicated in the NM. DT involves automation and the integration of advanced technologies across the value chain. DT, through improved decision making, process automation and customer satisfaction leads to better quality, efficiency and productivity (Tao et al., 2018). It also promotes integration, real-time tracking and SC visibility.

Kazançoğlu et al. (2023), noted that the principles of I4.0 do not only enhance monitoring, visibility, and efficiency in supply chain processes, but they also help in enabling circular economy models. This leads to greater SC responsiveness and resilience. I4T like IoT, digital twins and AI-driven systems help in anticipating risks and minimising SC disruptions.

2.3. Supply Chain 4.0

SC4.0 represents the integration of digital technologies to strengthen the connectivity, improve the agility and efficiency of SCs. It seeks to support sustainability and resilience goals by optimising SC operations and performance. According to Derakhti et al. (2023), I4T enables interconnected SCs with the capability to adapt to change as the NM suggests. Overall, I4Ts

provide SCs with integration, real-time data, analytics and robust forecasting capabilities that they need.

SC4.0 promotes connectivity, interoperability, integration and collaboration within SCs (Zekhnini et al., 2021). While connectivity links production and SC functions for better visualisation (Frazzon et al. 2019 Chauhan), digitalisation facilitates decentralised and autonomous systems (Tortorella et al. 2019). SC4.0 provides firms with necessary capabilities needed to deal with SC disruptions. It also has the ability to allow for efficient use of resources, and promote SSC goals. Thus, SC4.0 can be regarded as modern SC integration that brings SC partners together and facilitates cooperation across the value chain.

SC4.0 has the potential to improve SC visibility. Tjahjono et al. (2017) indicated that SC4.0 can increase transparency across the SC. Attaran (2020), further noted that SC4.0 enables SC cooperation which shortens response times. SC4.0 through I4Ts streamlines and integrates downstream and upstream SC operations and processes, which are crucial for enhancing SC efficiency and performance. Ageron et al. (2020) argue that I4.0 enhances information sharing and cooperation among SC participants, which is essential for better SC visibility. It is crucial for achieving operational goals. According to Sobbb et al. (2020) SC4.0 will bring about improvements in many areas of the SC. Some of the improvements SC4.0 is expected to bring, include improved interoperability, collaboration, transparency, integration, flexibility, responsiveness, efficiency, and leaner operations. All of these improvements are very important for smart manufacturing and circular economy principles, which are key to SSC.

2.4. Enablers of Supply Chain 4.0

Literature review and bibliometric analysis above suggest that successful adoption of SC4.0 depends on a number of key enablers. Since SC4.0 builds on the principles of I4.0, we believe both SC4.0 and I4.0 share common enabling factors. These enablers can be categorised into organisational, technological, and environmental factors (Sony and Naik 2020). The network map (NM) identified some technological enablers of SC4.0 which include digital twins, BDA, IoT, AI, machine learning, blockchain, and cybersecurity. However, we do not focus on technological enablers because they are well established in I4.0 literature (Liu et al., 2021; Govindan et al., 2022; Marinagi et al., 2023). On the contrary, our interest is on organisational enablers which include integration, automation, lean practices, digital transformation, and strategic alignment (Mubarik et al., 2021; Surucu Balci et al., 2024). Though not the focus of this study some important environment enablers which include market dynamism, customer expectations, sustainability, and regulatory pressures were identified. However, our study is interested in determining how organisational enablers as strategic resources and critical capabilities affect the adoption of SC4.0.

2.4.1 Supply Chain Integration

SCI is crucial for effective coordination, information sharing and decision making within SC because it helps in building trust and collaboration (Flynn et al., 2010; Jajja et al., 2018; Surucu-Balci et al., 2024). Agility and SC performance can be improved when strong collaboration and relationships exist among SC partners. SCI can also help in synchronising SC processes and operations, which is an important SC4.0 capability.

H1. Supply chain integration positively influences Supply Chain 4.0 adoption.

2.4.2 Industry 4.0 Strategies

A clear DT strategy is needed to successfully implement SC4.0 in firms. This is supported by Ivanov and Dolgui (2021) who noted that an I4.0 strategy can lead to DT and improvements in SC operations. Therefore, strategic alignment (SA) in SC4.0 can help organisations to have managerial skills, technology, and direction or goals needed to adopt SC4.0. Sony and Naik (2020) also argued that SA, especially one which includes strategic planning, leadership support, and training, can overcome most barriers associated with I4.0 implementation. Equally, Queiroz et al. (2022) pointed out the need for clear SC objectives that align with I4.0. Therefore, we argue that successful SC4.0 adoption requires DT strategies that incorporate clear I4.0 and SC objectives. Without a clear strategy all efforts to implement I4.0 may prove futile. A good I4.0 strategy can provide firms with the ability to sense and seize opportunities presented by digital technologies. I4.0 can allow firms to leverage digital technologies to enhance SC operations (Richnak & Fidlerova, 2022).

H2. Industry 4.0 strategy significantly influences the adoption of Supply chain 4.0.

2.4.3 Lean Techniques

Integrating lean techniques with Industry 4.0 enables automation and digitalisation (Kolberg 2015). Lean techniques (LP) through I4T can enable real-time visibility and synchronisation of SC operations. Sony and Naik (2020) argued that digital lean practices can facilitate smart manufacturing through cyber-physical production systems (CPPS). McDermott et al. (2024) highlight the complementary effect between lean and I4.0, arguing that lean is a prerequisite to digitalisation in SCs. Integrating AI and related digital technologies into lean practices, can help in providing better resource utilisation and flexibility. Ali and Aboelmaged (2022) also argued that LP can promote the implementation of I4.0. Not only does integrating of lean with I4.0 not have the potential to improve efficiency, but it can also increase the adaptability and resilience of SCs.

H3. LP has a significant impact on the adoption of SC4.0.

2.4.4 Production System Automation

The NM links automation related I4Ts such as cyber-physical systems and autonomous warehouses to SC4.0, which suggests that PSA is essential for successful SC4.0 adoption. This argument is well supported by Yuan and Xue (2023), who noted that automation technologies and systems such as robotics, CPS, and autonomous warehouses are crucial for optimising operational costs and production processes. Similarly, Baryannis et al. (2019) noted that modern automation systems, such as digital twins, AI, and advanced robotics, enable tracking, which is crucial for reducing SC errors and optimising resources as well as improving responsiveness. Automation systems such as CPPS and robotics enhance flexibility, production efficiency and the resilience of SCs.

H4. PSA has a significant influence on the adoption of SC4.0.

2.5. Impact of Supply Chain 4.0 on Firms

Different studies have argued that the adoption of SC4.0 can bring about significant improvements to firms. For instance, Yüksel (2022) argues that I4T have the potential to significantly improve production processes, manufacturing systems, as well as SCs. Chauhan et al. (2021) also argued that I4.0 can help in building SC competency and operational performance. All this suggests that firms that adopt S4.0 would likely improve their SCs and performance. Choi et al. (2022) argued that I4T can significantly enhance visibility, and efficiency within SCs. Liu et al. (2021) also associated the integration of I4.0 with enhanced visibility. Better SC visibility can lead to improved coordination, shorter lead times, and increased agility with the SC. Kazançoğlu et al. (2022), also noted that I4.0 can provide the visibility that is required to close loops in SCs and improve resilience of SCs. Similarly, Frederico et al. (2023) demonstrated that I4.0 increases transparency which in turn improves the inventory management and SC resilience with more accurate demand forecast.

SC efficiency implies providing what is needed to the right location at the right time with the minimum cost. The NM also linked AI, big data, and automation with visibility and efficiency. SC4.0 can also streamline logistics operations and improve the performance of SC networks (Singh et al., 2023). Govindan et al. (2022) suggests that organisations that implement digitalised SC models experience improvements in productivity, cost, and customer responsiveness. Similarly, Yuan and Xue (2023) noted how automation and digital integration optimise SC operations, minimise costs and enhance customer service levels.

H5. SC4.0 adoption has a positive significant influence on SC efficiency.

H6. SC4.0 adoption has a positive impact on SC visibility.

H7. SC visibility has a positive influence on SC efficiency.

2.6. Theoretical Foundation

Adoption of SC4.0 is a strategic transformation to SC operations that requires a strong theoretical background. This paper incorporates the resource based view (RBV) and dynamic capabilities theory (DCT) to demonstrate how firms use strategic resources and dynamic capabilities to enhance visibility and efficiency. RBV posits that organisations attain a competitive advantage by acquiring and implementing resources or strategies that are valuable, rare, inimitable, and non-substitutable. In the context of SC4.0 adoption, organisational enablers such as I4.0 strategy, SCI, PSA, and LP represent critical resources that can enhance SC visibility and efficiency. However, given the dynamic and evolving nature of digital technologies as well as the SC environment as a whole, Firms must develop dynamic capabilities to reconfigure and adapt to change. Thus, this study argues that firms must possess both strategic resources and dynamic capabilities to leverage the benefits of SC4.0. By combining RBV and DCT, the study forms a stronger basis for the proposed hypotheses in figure 2.

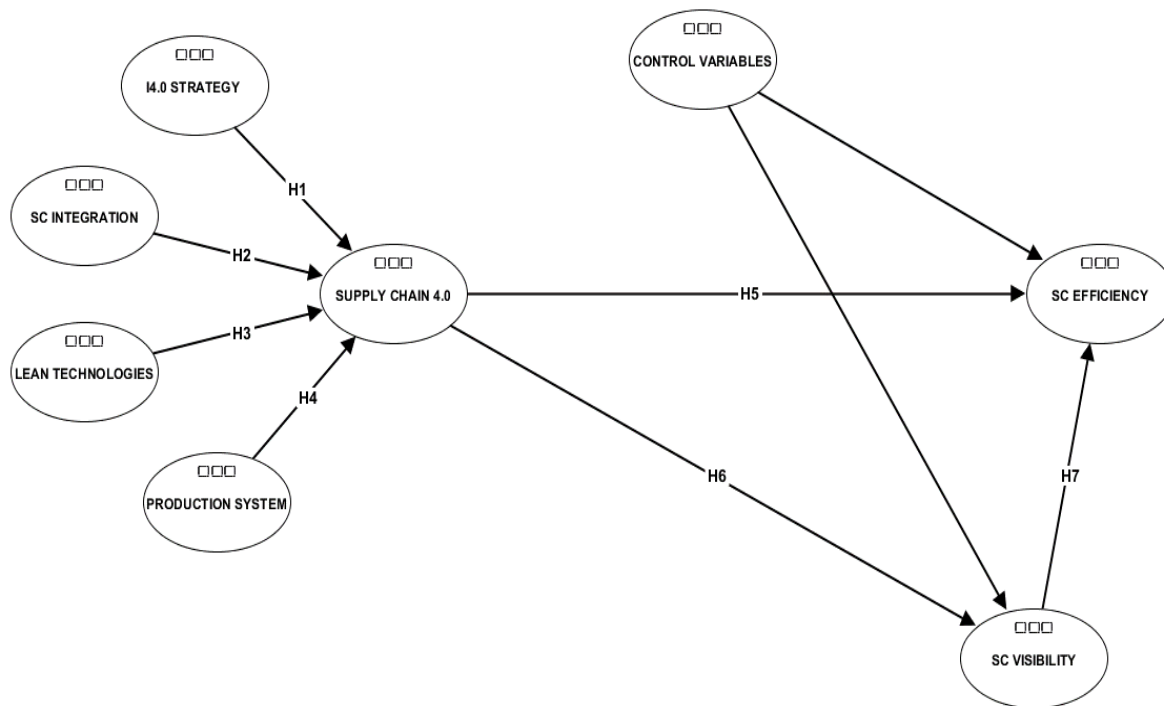


Figure 2. Conceptual relationships and hypotheses

3. Methodology

3.1. Measurement Items and Questionnaire Design

The article adopted constructs and measurement items based on their validity from previous relevant studies to ensure consistency and objectivity. For instance, the SC4.0 measurement items were based on (Liu et al., 2021; Choi et al., 2022; Roldán et al., 2023). The rest of the

constructs and their relevant sources are provided in Table 1. Figure 2 above is a representation of the conceptual framework of the study and the relationships between its constructs and their variables. All measurement items are based on a five-point Likert scale. Respondents who are acquainted with SC and I4.0 advances from Turkish Manufacturing were asked to participate in a questionnaire-based survey. They were requested to indicate their level of disagreement or agreement with several statements on these constructs. Table 1 gives a summary of the scales used to measure these items. Several control variables, such as firm size, organisational flexibility, and ERP level, were also included in the questionnaire to test whether certain variables may influence our performance outcomes.

Table 1. Summary of constructs and measurement items

Construct/ Indicator	Code	Mean	STD	FL	α	ρ	AVE
1. Supply Chain Integration					0.767	0.769	0.532
Communication among members of the supply chain	SCI1	3.243	1.287	0.572			
Integration among SC partners, operations and warehouses	SCI2	2.806	1.442	0.750			
Level of integration between units or departments	SCI3	3.408	1.240	0.840			
2. Production System Automation					1.000	1.000	
Level of production system automation	PSA	3.068	1.301	1.000			
3. Lean techniques					1.000	1.000	
Applications and level of LP	LP	2.932	1.223	1.000			
4. I4.0 Strategy					1.000	1.000	
Availability and implementation of industry 4.0 strategies	ISL	2.204	1.562	1.000			
5. Supply Chain 4.0					0.843	0.882	0.516
Incorporation of internet of things into SCs	SCA1	2.544	1.679	0.692			
Application of big data in logistic or SCs	SCA2	1.505	1.137	0.676			
The use of cloud technology in SCs	SCA3	2.796	1.574	0.746			
The use of augmented reality related systems	SCA4	1.670	1.224	0.657			
Implementation of cyber security systems in SCs	SCA5	1.631	1.245	0.700			
Additive manufacturing (3DP) or rapid prototyping	SCA6	2.097	1.411	0.785			
Adoption of artificial intelligence in SC operations	SCA7	1.680	1.300	0.762			
6. Supply Chain Visibility					0.871	0.921	0.796
Traceability of the production process	SCV1	3.806	1.276	0.932			
Real time tracking of data and decision making	SCV2	3.350	1.412	0.878			
Traceability of supply chain	SCV3	3.505	1.267	0.865			
7. Supply Chain Efficiency					0.656	0.814	0.587
Flexibility of supply chains	SCF1	3.223	1.244	0.831			
Improved stock levels	SCF2	2.971	1.339	0.577			
Level of Production efficiency	SCF3	3.437	1.160	0.864			

Note: FL = factor loading; SD = standard deviation; AVE = average variance extracted; α = Cronbach's Alpha; ρ = composite reliability.

3.2. Sampling and Data Collection

Pretesting of the questionnaire was conducted with experts and academicians for clarity and content validity. Feedback was obtained from five companies to validate the instrument. The final questionnaire was distributed to 500 Turkish manufacturing firms. The survey generated 108 responses, 103 were retained for final analysis after screening. We used simple random sampling to ensure equal representativeness of the sample. Our final sample consists of 54.6% large companies, 32% medium firms, and 13.6% small firms. 82.5% of the respondents had adopted SC4.0, while 17.5% were in the adoption stage. Our final sample represents a response rate of 20.6%, which exceeds the required minimum of 92 cases to run the analysis. The required minimum was determined through the G*Power calculator (effect size = 0.15, significance = 0.05, power = 0.80). Not only does our sample exceed the minimum required response, it is also sufficient to perform PLS-SEM in both WarpPLS 7.0 and ADANCO 2.4.

3.3. Data Analysis

Our study is exploratory and involves several latent constructs. This compelled us to employ partial least squares structural equation modelling (PLS-SEM) as the most appropriate method for analysis. PLS-SEM was chosen after considering several important issues. For instance, (Mehmetoglu & Venturini, 2021; Henseler, 2021) argue that PLS-SEM is very useful when estimating complex models or when the focus is on prediction rather than testing theory. It is also useful when the field of study is still in its early or exploratory stage. PLS-SEM neither requires strict normality conditions, nor does it discriminate against small samples like the one in our study. Furthermore, PLS-SEM gives room for models with various research objectives to be assessed simultaneously. All of these attributes rendered PLS-SEM the most appropriate method for analysing data in this research.

The simultaneous use of WarpPLS 7.0 and ADANCO 2.4 software is complementary. For instance, ADANCO 2.4 provides a better evaluation of construct reliability and validity. It provides both HTMT and HTMT2 discriminant validity results. Additionally, it generates bootstrap results which provide more robust and accurate mediation and path analysis. WarpPLS can identify and model nonlinear relationships. It provides more robust predictive power and nonlinear model fit metrics. WarpPLS also provides both the Average Block VIF (AVIF) and Average Full Collinearity VIF (AFVIF) metrics, which are very useful in assessing multicollinearity across the entire model. The advantages of both software are inexhaustible.

4. Results and Analysis

4.1. Common Method Variance Assessment

Common method variance assessment was conducted. CMV is a type of measurement error that can occur when the data for different variables in a study is obtained using the same method or from the same source. The consequence of CMV is usually inflated relationships that may appear to be related when they are not. Harman's single-factor test was performed as a preliminary CMV assessment test. Results reveal that the first factor only accounts for 39.03% of the total variance (see Appendix 1), indicating that CMV is not a major concern in our data. We also confirmed this with a full collinearity test. According to Kock (2017), average full collinearity VIF (AFVIF) is one of the suitable ways to assess CMV and collinearity in PLS-SEM. The AFVIF value of 2.130 in Table 3 is less than the threshold of 3.3. Thus, showing that CMV does not affect the results of the study.

Lastly, a comparison of the means and standard deviations allowed us to also examine whether there is extreme variability among variables that may affect our results. Table 1 shows that on a 5-point Likert scale, there is no indicator with a standard deviation value greater than 2. Equally, no indicator has a mean value that was more than twice the value of the standard deviation. Thus, showing that there is no extreme variability and the relationships among variables are asymmetric. Thus, implying that the distribution of responses is reasonable.

4.2. Measurement Model Evaluation

PLS-SEM analysis involves two main stages: measurement and structural model assessment. Thus, our model assessment begins with measurement model evaluation, performed to determine the reliability and validity of constructs. The criteria for assessing construct reliability, convergent validity and discriminant validity are derived from recommendations by many authors (Henseler, 2021; Hair & Alamer, 2022). For convergent validity to be established, the average variance extracted (AVE) should be greater than 0.5, and the factor loading for each indicator must be greater than 0.6. Our results in table 1 above shows that all AVE values are greater than 0.5, and their corresponding factors are equally greater than 0.6. This shows that convergent validity is established in our study constructs. In other words, the variables measure what they are supposed to measure.

Construct reliability, which confirms whether indicators consistently represent the constructs, was determined using Cronbach's Alpha (α) and composite reliability (ρ_c). Table 1 shows that all values except SC efficiency ($\alpha = 0.656$) meet the criteria for construct reliability ($\alpha > 0.7$; $\rho_c > 0.7$). Notwithstanding, Hair *et al.* (2010) suggested that 0.6 could be used as a threshold for α , especially when dealing with exploratory studies and complex models with small samples.

Although SC efficiency's α is lower than 0.7, it is higher than 0.6 and has pc, which is greater than 0.7. Thus, we conclude that construct reliability exists among our study variables.

Discriminant validity, which measures the extent to which a construct in a model differs from other constructs, was assessed using Heterotrait-Monotrait ratios (HTMT) and HTMT2. The results in Table 2 were obtained using ADANCO 2.4. Henseler (2021), argues that these modern approaches provide far better discriminant results than the Fornell-Larcker criterion and cross-loading approaches. HTMT values below the 0.85 threshold are indicative of conceptually distinct constructs. Both HTMT and HTMT2 are below the threshold of 0.85, which is indicative that the constructs in the model are conceptually distinct. Since two tests are similar, we conclude that discriminant validity is established in our study.

Table 2. Discriminant validity results

Construct	1	2	3	4	5	6	7
1. Supply Chain 4.0							
2. SC Visibility	0.475						
3. I4.0 Strategy	0.614	0.386					
4. Production System	0.538	0.416	0.408				
5. Lean Technology	0.378	0.338	0.228	0.428			
6. SC Efficiency	0.339	0.587	0.163	0.263	0.210		
7. SC Integration	0.472	0.725	0.194	0.339	0.267	0.830	
1							
2	0.468						
3	0.597	0.371					
4	0.531	0.416	0.408				
5	0.367	0.337	0.228	0.428			
6	0.329	0.586	0.163	0.263	0.210		
7	0.449	0.708	0.156	0.338	0.220	0.828	

Note: All ratios of correlations are below 0.850

4.3. Structural Model Evaluation

Table 3 presents statistical measures for overall model quality, validity and reliability assessment. The significant average path coefficient ($APC = 0.285$, $p = 0.010$), average R^2 ($ARS = 0.474$, $p < 0.001$), and adjusted R^2 ($AARS = 0.451$, $p < 0.001$) represent relatively strong explanatory power, where approximately 47.4% of the variations in the dependent variables are explained by the independent variables in our model. Similarly, the R^2 Contribution Ratio ($RSCR = 0.970 > 0.7$) shows that the independent variables in the model contribute significantly to explaining the variance in the dependent variables. The predictive relevance (Q^2) ranges from moderate to strong (i.e. 0.311 to 0.596), indicating significant predictive relevance. Hair et al. (2017), $Q^2 > 0$ indicate significant predictive relevance.

The average block variance inflation factor (AVIF = 1.511) and average full collinearity (AFVIF = 2.130) are below the threshold of 3.3. This implies that multicollinearity is not a major concern in the model. Sympson's paradox ratio (SPR = 0.846 > 0.7) implies that the observed relationships are consistent. Statistical suppression ratio (SSR = 1.000 > 0.7) means that there is no suppression in the model and that our model is stable. Nonlinear bivariate causality direction ratio (NLBCDR = 1.000 > 0.7) implies that all relationships in our model follow a consistent causal direction without ambiguity. Finally, the Tenenhaus Goodness-of-Fit (GoF = 0.617) reflects a large model fit (Wetzels et al., 2009). This confirms that our model is valid with substantial explanatory and predictive power.

Table 3. Model fit and quality indices

Statistical Measure	Statistic	P	Threshold
APC	0.285	0.010	
ARS	0.474	<0.001	
AARS	0.451	<0.001	
RSCR	0.970		acceptable if ≥ 0.7
AVIF	1.511		acceptable if ≤ 3.3
AFVIF	2.130		acceptable if ≤ 3.3
SPR	0.846		acceptable if ≥ 0.7
SSR	1.000		acceptable if ≥ 0.7
NLBCDR	1.000		acceptable if ≥ 0.7
Tenenhaus Goodness of Fit (GoF)	0.617		large if ≥ 0.36
Predictive relevance (Q^2)			
Supply chain 4.0	0.510		acceptable if ≥ 0
SC visibility	0.311		acceptable if ≥ 0
SC efficiency	0.596		acceptable if ≥ 0

Note: Q^2 around: 0.02= small, 0.15 = moderate, 0.35 = large

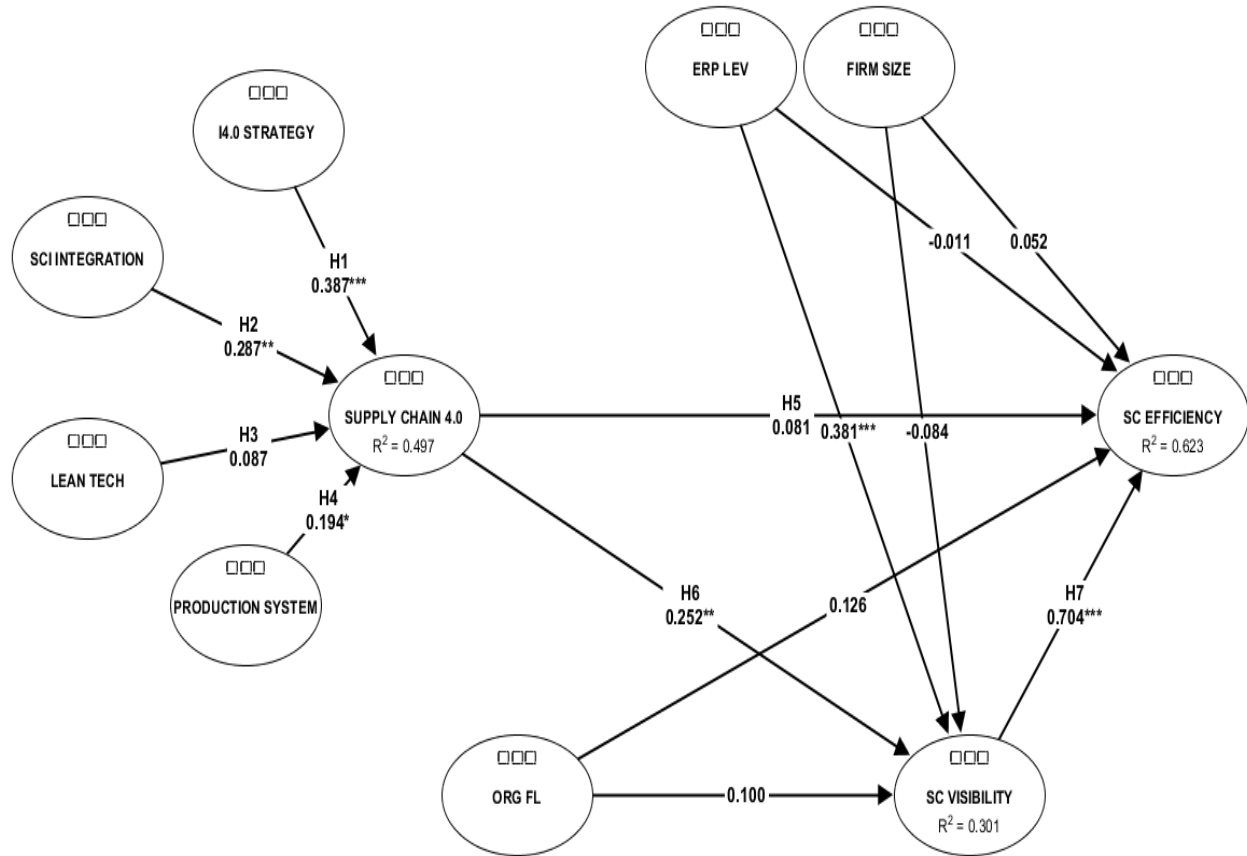


Figure 3. Structural model

Figure 3 is the output of the PLS-SEM model, which indicates construct relationships, coefficient of determination (R^2), path coefficients and their significance. While the asterisks (*) and (**) denote significance at 5% and 1%, (***) represents a very high level of statistical significance at 0.1% with p -value < 0.001. Path coefficients without asterisks indicate statistically insignificant effect. For PLS-SEM, R^2 values around 0.25, 0.50, and 0.75 can be interpreted as weak, moderate, and large explanatory power, respectively. In this study, the R^2 values range from 0.301 to 0.623, suggesting moderate to large explanatory power. In particular, supply chain visibility and supply chain efficiency exhibit relatively strong explained variance, indicating that the selected organisational enablers and SC4.0 adoption effectively account for variations in these performance outcomes. In particular, the R^2 values for supply chain visibility and supply chain efficiency are relatively high, indicating that a substantial proportion of variance in these two outcomes is explained by SC4.0 adoption and the associated organisational enablers included in the model.

The results on effect size in table 4 provide further insights into the importance of these path relationships in the structural model. The effect size (f^2) values of approximately 0.02, 0.15, and

0.35 indicate small, medium, and large effects, respectively. The relationship between SC visibility and SC efficiency exhibits a very large effect ($f^2 = 0.918$), establishing visibility as the dominant capability that enhances efficiency. I4.0 strategy ($f^2 = 0.240$) and SC integration ($f^2 = 0.129$) have medium effects on SC4.0 adoption. This shows that these organisational enablers play important but complementary roles in facilitating digital supply chain transformation. ERP also reveals a medium effect on SC visibility, which shows the importance of integrated information system for achieving visibility. On the contrary, SC4.0 shows a negligible effect on efficiency ($f^2 = 0.013$), which shows that unless mediated SC4.0 does not contribute significantly to SC efficiency. While the effects of production system automation ($f^2 = 0.051$) and SC4.0 adoption on supply chain visibility ($f^2 = 0.072$) are small, the direct effect sizes of SC4.0 on efficiency ($f^2 = 0.013$) and lean practices on SC4.0 adoption ($f^2 = 0.012$) are negligible. Overall, these effect sizes show that SC4.0 is strengthened through certain organisational enablers which in turn indirectly contributes to efficiency.

4.4. Findings and Hypothesis Testing

A bootstrapping approach using ADANCO 2.4 with a sample of 5000 was employed to test the proposed hypotheses and mediation effects. All the estimated path coefficients are evaluated at a 5% level of significance using 95% confidence intervals. Table 4 provides key results, while Table 5 provides a summary of mediation results.

4.4.1. Direct Effects

The hypotheses are tested based on their β -coefficients, t -values, p -values and confidence intervals. H1 in Table 4 confirms that I4.0 strategy significantly influences the adoption of SC4.0 ($\beta = 0.387$, $t = 4.738$, $p = 0.000$). This supports the claims that a good I4.0 strategy positively influences digital supply chains. H2 shows that SCI has a significant positive effect on SC4.0 ($\beta = 0.287$, $t = 3.278$, $p = 0.001$), thereby confirming that integration plays a significant role in supporting digital SC. Interestingly, we found that LP does not have a significant influence on SC4.0 ($\beta = 0.087$, $t = 1.349$, $p = 0.177$, CI [-0.049, 0.209]). On the other hand, H4 was supported ($\beta = 0.194$, $t = 2.358$, $p = 0.018$), which indicates that production system automation (PSA) significantly influences SC4.0 adoption. This confirms that automation is an important factor that supports the implementation of I4.0 in firms.

H5 was not supported by our results ($\beta=0.081$, $t = 1.349$, $p = 0.177$, CI [-0.029, 0.208]), thereby implying that SC4.0 does not have a direct impact on SC efficiency. However, H6 which shows the relationship between SC4.0 and SC visibility is significant ($\beta = 0.252$, $t = 2.834$, $p = 0.005$). This is evidence that SC4.0 positively influences SC visibility. H7 which represents that the relationship between SC visibility and efficiency was confirmed ($\beta = 0.704$, $t = 12.011$, $p = 0.000$). We also found that SC visibility leads to improvement in SC efficiency. This implies that

improved SC visibility plays a key role in driving efficiency. It is the path through which SC4.0 enhances SC efficiency.

While examining the control variables, we found that only ERP systems showed a significant association with visibility. firm size (FS) and organisational flexibility (ORGF) did not reveal any association. For example, the paths from FS to SC visibility ($\beta = -0.084$, $p = 0.385$) and SC efficiency ($\beta = 0.052$, $p = 0.533$) were statistically insignificant, suggesting that larger firms do not necessarily outperform smaller firms simply because they are large. Similarly, the insignificant paths from ORGF to visibility ($\beta = 0.100$, $p = 0.328$) and efficiency ($\beta = 0.126$, $p = 0.108$), shows that organisational flexibility alone does not lead to improvements in performance. On the contrary, ERP systems had a significant positive impact on SC visibility ($\beta = 0.381$, $p = 0.000$), thereby implying that ERP capabilities improve transparency across the SC.

Table 4. Hypothesis testing

Structural Path	β	SE	t	P	95% CI		f^2	Decision
H1: I4.0 Strategy $\rightarrow$ SC4.0	0.387	0.082	4.738	0.000	0.223	0.541	0.240	Accept
H2: SCI $\rightarrow$ SC4.0	0.287	0.087	3.278	0.001	0.119	0.459	0.129	Accept
H3: LP $\rightarrow$ SC4.0	0.087	0.064	1.349	0.177	-0.049	0.209	0.012	Reject
H4: Production System $\rightarrow$ SC4.0	0.194	0.082	2.358	0.018	0.034	0.354	0.051	Accept
H5: SC4.0 $\rightarrow$ efficiency	0.081	0.060	1.349	0.177	-0.029	0.208	0.013	Reject
H6: SC4.0 $\rightarrow$ visibility	0.252	0.089	2.834	0.005	0.066	0.418	0.072	Accept
H7: SC visibility $\rightarrow$ SC efficiency	0.704	0.059	12.011	0.000	0.579	0.810	0.918	Accept

Note: β = beta coefficient; SE = standard error; t = t-value; P = p -value & CI = Confidence intervals; f^2 = effect size.

4.4.2. Mediation Analysis

Mediation analysis reveals that the influence of SC4.0, I4.0 strategies, and ERP systems on SC efficiency is largely mediated by improvements in visibility. Table 5 illustrates that the total effects for both SC4.0 ($\beta = 0.258$, $p = 0.001$) and ERP systems ($\beta = 0.257$, $p = 0.018$) on efficiency are statistically significant. However, when considering their direct effects in isolation, neither SC4.0 ($\beta = 0.081$, $p = 0.177$, CI [-0.029, 0.208]) nor ERP systems ($\beta = -0.011$, $p = 0.888$, CI [-0.163, 0.148]) have a direct influence on SC efficiency. This suggests that their impact is indirect. The indirect effects reveal that SC4.0 ($\beta = 0.177$, $t = 2.764$, $p = 0.006$) and I4.0 strategy ($\beta = 0.100$, $p = 0.008$) significantly influence SC efficiency through SC visibility. Similarly, ERP systems indicate a significant indirect effect ($\beta = 0.100$, $t = 2.665$, $p = 0.008$). This shows that the contribution of SC4.0 to efficiency is primarily through improvements in SC visibility.

Table 5. Summary of Bootstrapped indirect, direct and total effect inference results

Path	β		SE	t	P	95% CI	
Total Effect							
SC4.0 → SC efficiency	0.258	0	0.08	3.228	1	0.00	0.098 0.41
ERP → SC efficiency	0.257	8	0.10	2.372	8	0.01	0.038 0.46
Indirect Effect							
SC4.0 → SC efficiency	0.177	4	0.06	2.764	6	0.00	0.045 0.30
ERP → SC efficiency	0.268	5	0.07	3.577	0	0.00	0.116 0.41
Direct Effect							
SC4.0 → SC efficiency	0.081	0	0.06	1.349	7	0.17	- 0.20
ERP → SC efficiency	-	0	0.07	-	8	0.88	- 0.14
ERP→ SC visibility	0.011	0	0.10	0.141	8	0.163	0.163 0.56
	0.381	0		3.812	0	0.00	0.171 0.56

5. Discussion and Contributions

5.1. Discussion

This study sought to establish organisational enablers of supply chain 4.0 adoption (SC4.0) and the impact of this adoption on supply chain visibility and efficiency. Our hypotheses H1 to H4 are tied to RQ1, while H5 and H6 are associated with RQ2. Ultimately, H7 is associated with RQ3.

Except for lean practices (LP), all the hypothesised enablers were supported. The confirmation of H1 implies that the I4.0 strategy directly influences SC4.0. This aligns with Sony and Naik (2020), who noted that a robust I4.0 strategy facilitates the effective implementation of I4.0 technology (I4T) in SC. Similarly, Kagermann et al. (2015) argued that there must be strategic alignment between I4.0 and transformation efforts for successful I4.0 implementation in SC operations. H2 confirms that supply chain integration (SCI) advances SC4.0. Thus agreeing with the claims of Ivanov et al. (2019) that the integration of data, systems, and processes enables digital SCs. Unsupported H3 suggests that LPs do not significantly impact SC4.0. This result, although not consistent with expectations, still agrees with Kolberg and Zühlke (2015), who noted that in digitised SCs LP may lose their relevance. This outcome reveals that there is a need for firms to modify to new paradigms such as Lean 4.0, which complement SC4.0.

The findings for H4 indicate that automation (PSA) is crucial to implementing SC4.0. This result is similar to the one by Wichmann et al. (2019), who provided evidence that systems like

smart manufacturing, robotics and CPPSs play an important role in modern SCs by increasing efficiency, precision and flexibility.

Surprisingly, hypothesis H5 showed that SC4.0 does not have a direct impact on efficiency, which aligns with the findings of Wang et al. (2024). Nonetheless, results show that SC4.0 improves visibility (H6), which then enhances efficiency (H7). In this sense visibility acts as a critical organisational capability through which firms realise operational gains in SCs. Similar conclusions were made by Culot et al. (2020) who emphasised that while I4T may not immediately bring about cost reductions or increased speed, they can enhance transparency and traceability, which ultimately leads to performance improvements. Therefore, coupled with our findings we confirm that visibility is indeed an important capability that firms must possess to translate digital transformation efforts into performance improvements.

Additionally, the significant effect of ERP systems on visibility further supports the crucial role of information transparency and sharing in SC. Firms with good ERP capabilities are better equipped to synchronise data across their SCs. Our evidence also suggests the true value of ERP in digital SC lies in its ability to provide accurate and real time visibility.

In summary, the findings emphasise the significance of organisational enablers in facilitating SC4.0 adoption. But, contrary to expectations, LP did not significantly contribute to SC4.0 adoption. This may imply that in highly automated and data-driven supply chain environments, traditional lean practices lose their relevance unless they evolve toward Lean 4.0. Our study affirms that visibility is indeed a critical capability that mediates the association between SC4.0 and efficiency in SC operations.

5.2 Theoretical Implications

Our study makes important contributions to the development of digital SC theory. It empirically demonstrates that SC visibility is a key dynamic capability of SC4.0 that enhances SC efficiency. Our study also offers empirical support for RBV and DCT theory by establishing capabilities and strategic resources required to successfully adopt SC4.0 in firms.

The study simultaneously establishes visibility as the dynamic capability that promotes SC efficiency and SCI, I4.0 strategy and PSA as strategic organisational resources for successful SC4.0. These enablers provide firms with the necessary sensing, monitoring, and coordination capabilities needed to unlock the full potential of digital SCs. Models on SC digitalisation should incorporate I4.0 strategy, SCI and automation as critical enablers alongside visibility as a central capability. However, LP results challenge existing theory; LP does not automatically translate to an enabler for leveraging SC4.0. Thus, LP must evolve to remain valuable in the digital SC. Scholars must explore this potential gap and establish how lean can be integrated into digital SC

frameworks. Both scholars and managers need to recognise that organisational resources must be enhanced to retain their strategic value in a dynamic and digital SC environment.

This study goes further than most to provide empirical evidence that positions visibility as a digital SC capability for better performance. Real-time SC visibility enables firms to leverage I4.0 for better SC performance. The expected benefits of digital SCs are primarily through better visibility capabilities, as confirmed by its mediating role. Thus, digital SC and strategies do not automatically result in operational efficiencies; rather, they result as a consequence of enhanced visibility. In other words, SC4.0 and its enablers are beneficial to performance improvements to the extent that firms can build visibility capabilities that sense, monitor, and coordinate I4.0 technologies and SC operations. Not only does this advance SC theory and emphasise dynamic capabilities, but it also implies that models on digital SCs should include visibility as a central capability for sustainable performance.

5.3 Practical Implications

There are several practical implications that can be derived from this study. Most of these implications have to do with how firms can optimise performance through digital SCs. Firstly, managers must recognise that simply adopting SC4.0 does not guarantee improved SC performance. However, gains in efficiency or SC performance come as a result of enhanced SC visibility through real-time tracking, strategic alignment, integration and automated systems. Therefore, investments in digital SC should prioritise solutions that improve visibility and transparency across the SC. For instance, technologies that promote data synchronisation, tracking, and real time decision making are critical for identifying bottlenecks, mitigating disruptions and coordinating processes. This ultimately leads to improvements in SC performance. Secondly, managers should invest in automation systems that support both operational efficiency and real-time visibility. PSA is another critical enabler that supports the implementation of SC4.0 in manufacturing firms. Through automated systems firms can improve visibility in order fulfilment processes, warehouse operations as well as quality control processes. However, system automation is more valuable when aligned to support operational efficiency.

Equally, we established that SCI is a critical factor for successful adoption of SC4.0 in firms. Consequently, we recommend that managers should focus on systems that strengthen integration like ERP to promote smooth communication and data exchange across SCs which is crucial for SC4.0. Managers should also seek advanced ERP for stronger SCI and improved SC visibility. This is because SCs with stronger SCI can strengthen collaboration and support real-time decision making, which is crucial for optimising SC performance through digital SCs. SCI can further promote interoperability within SCs. Managers should also make sure that there is clear

strategic alignment between SC4.0 implementation and their visibility goals for better performance. This implies that they should set clear DT goals that are supported by their resources and they should be actively involved in implementing these goals to accomplish overall SC4.0 objectives.

6. Conclusion

Not only does our study empirically contribute to digital SC research, but it also positions visibility as an essential dynamic capability that supports operational performance in the context of SC4.0. Thus, it extends the DCT perspective by showing that improvements in efficiency not only depend on technology adoption, but also on the capability to achieve SC visibility. Visibility acts as a core capability through which digital SC translates into SC performance gains. Our study also advances the RBV by establishing which strategic resources support the successful adoption of SC4.0 in firms. It provides valuable insight and clear guidance to practitioners on how to leverage strategic alignment, automation, supply chain integration, ERP, SC4.0, and visibility for better SC operations and performance. Leveraging these resources and capabilities would not only enhance SC performance but also help build more resilient SCs. There is also the need for both practitioners and scholars to adapt LP to support digital SC. In their current state LPs may lose their relevance in this digital age. Therefore, future studies should explore hybrid concepts such as Lean 4.0 to determine how LP can be modified to support real time visibility and efficiency.

6.1. Limitations and Future Studies

Notwithstanding the important insights provided by this study, several limitations should be acknowledged. First, the empirical data were collected from Turkish manufacturing firms operating across multiple sectors. While this allows the study to obtain insights from different manufacturing sectors, sectoral heterogeneity may influence how organisational enablers such as supply chain integration, lean practices, and automation contribute to SC4.0 adoption and performance outcomes. Therefore, we suggest that future studies should be conducted to determine whether different sectors and regions would give a different outcome. Second, our study employed a cross-sectional research design, which may limit the ability to observe dynamic changes in SC4.0 adoption, visibility, and efficiency over time. We recommend that longitudinal studies should be conducted to determine how visibility and lean would affect digital SC as digital transformation increases in firms over time. Regardless of these limitations, firms in emerging economies can still take advantage of these critical enablers and SC 4.0 to leverage digital transformation for better operational and sustainable performance. However, the findings also show that the benefits of SC4.0 are primarily realised through enhanced SC visibility, thereby establishing visibility as a critical dynamic capability in digital supply chains.

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APPENDICES

Table 1A. Harman's Single-Factor Test results

Component	Initial Eigenvalues	% of Variance	Cumulative %
1	8.195	39.03%	39.03%
2	3.034	14.45%	53.48%
3	1.280	6.10%	59.57%
4	1.067	5.08%	64.65%
5	0.944	4.49%	69.15%
6	0.894	4.26%	73.40%
7	0.794	3.78%	77.19%
8	0.728	3.47%	80.65%
9	0.700	3.33%	83.98%
10	0.564	2.69%	86.67%

Extraction Method: Principal Component Analysis (PCA)

Sürdürülebilir Kalkınmanın Sağlanmasında Yenilenebilir Enerji ve Maliye Politikası İlişkisi Üzerine Nicel Bir Araştırma

A Quantitative Study on the Relationship Between Renewable Energy and Fiscal Policy in Achieving Sustainable Development

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Öz: Maliye politikasının amaçlarından birisi sürdürülebilir kalkınmayı sağlamaktır. Sürdürülebilir kalkınmanın gerçekleştirilmesinde ise yenilenebilir enerji önemli bir rol oynamaktadır. Bu öneminden dolayı da çeşitli ülkeler tarafından yenilenebilir enerji teknolojileri çeşitli sübvansiyonlar, vergi teşvikleri ve yeşil finansman mekanizmaları kullanılarak desteklenmektedir. Bu desteklere rağmen yenilenebilir enerjinin sürdürülebilir kalkınmaya ne ölçüde katkıda bulunduğu noktasında belirsizlikler vardır. Bu çalışmada amaç, hem literatür hem de ekonometrik analizi yoluyla, yenilenebilir enerji kapasitesi ile Birleşmiş Milletler'in Sürdürülebilir Kalkınma Hedefleri arasındaki ilişkiyi maliye politikası bağlamında ortaya koymak olmuştur. Bunun için ise seçilmiş bazı Avrupa Birliği ülkeleri ile Türkiye ele alınarak incelenmiştir. Çalışmada ülkelerin yenilenebilir enerji ile üretilen elektrik kapasitesi ve Sürdürülebilir Kalkınma Hedefleri indeksindeki puanlar kullanılmıştır. Ülkelerin sürdürülebilir kalkınma hedefleri puanları Sürdürülebilir Kalkınma Çözümleri Ağı ve Bertelsmann Stiftung tarafından oluşturulan endeksten alınmıştır. Yenilenebilir enerji ile üretilen elektrik kapasitesi verileri EUROSTAT veri tabanından alınmıştır. 2000-2021 periyodundaki 22 adet yıllık verilerle 28 ülke değerlendirmeye alınmıştır. Veriler Microsoft Excel programına aktarılmış ve Eviews, STATA ve Gauss programları için uygun hale getirilmiştir. Çalışma kapsamında yapılan ekonometrik analiz sonrasında ulaşılan bulgulara göre; yenilenebilir enerji yatırımları ile belirli sürdürülebilir kalkınma hedefleri; 8, 10, 15 ve 17 arasında eşbütünleşme eksikliği olduğu görülmüştür. Bunun anlamı yenilenebilir enerji genişlemesinin tek başına otomatik olarak ekonomik büyümeye, sosyal eşitliğe veya kurumsal iş birliğine yol açmadığı yönündedir. Sürdürülebilir kalkınma hedeflerinden 5, 6, 11 ve 12 arasında ise istatistiksel olarak anlamlı olmasa da potansiyel ilişkiler tespit edilmiştir. Bu ilişki ise yenilenebilir enerji yatırımlarının sosyo-ekonomik faydalarını tam olarak gerçekleştirmek için tamamlayıcı politikaların gerekli olduğunu göstermektedir.

Anahtar Sözcükler: Sürdürülebilir Kalkınma, Yenilenebilir Enerji, Maliye Politikası, Nicel Araştırma Yöntemi

JEL Sınıflandırması: C33, H23, O44, Q42, Q56

Abstract: One of the objectives of fiscal policy is to ensure sustainable development. Renewable energy plays a crucial role in achieving sustainable development. Due to this importance, renewable energy technologies are supported by many countries through various subsidies, tax incentives, and green finance mechanisms. Despite these supports, there are still uncertainties regarding the extent to which renewable energy contributes to sustainable development. The aim of this study is to reveal the relationship between renewable energy capacity and the United Nations Sustainable Development Goals within the framework of fiscal policy, through both a literature review and econometric analysis. For this purpose, selected European Union countries and Türkiye are examined. The study uses data on electricity generation capacity from renewable energy sources and scores from the Sustainable Development Goals Index. The Sustainable Development Goals scores of the countries are obtained from the index developed by the Sustainable Development Solutions Network and Bertelsmann Stiftung, while data on electricity generation capacity from renewable energy sources are taken from the EUROSTAT database. A total of 28 countries are analyzed using 22 annual observations covering the period 2000–2021. The data are transferred to Microsoft Excel and formatted for use in EViews, STATA, and GAUSS software. According to the findings obtained from the econometric analysis conducted within the scope of the study, a lack of cointegration is observed between renewable energy investments and certain Sustainable Development Goals,

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namely Goals 8, 10, 15, and 17. This implies that the expansion of renewable energy alone does not automatically lead to economic growth, social equality, or institutional cooperation. For Sustainable Development Goals 5, 6, 11, and 12, although the relationships are not statistically significant, potential linkages are identified. These findings indicate that complementary policies are necessary in order to fully realize the socio-economic benefits of renewable energy investments.

Keywords: Sustainable Development, Renewable Energy, Fiscal Policy, Quantitative Research Method

JEL Classification: C33, H23, O44, Q42, Q56

1. Giriş

Uluslararası toplumun karşı karşıya olduğu zorluklardan birisi sürdürülebilir kalkınmanın sağlanmasıdır. Sürdürülebilir kalkınma; ekonomik kalkınma, sosyal kalkınma ve çevrenin korunması olmak üzere üçayağa sahiptir. Bu üç ayak, birbiriyle bağlantılı ve sürdürülebilirlik için alakalı olarak kabul edilmektedir (Gupta vd. 2002: 1; Sathaye vd., 2011: 713). Bu nedenle sadece ekonomik alanda düzenlemelerin yapılması tek başına sürdürülebilir kalkınma için yeterli olmayıp aynı zamanda sosyal ve çevresel alanında da düzenlemelerin de yapılması gerekmektedir. Birleşmiş Milletler Genel Kurulunda da zaten sürdürülebilir kalkınmanın sağlanabilmesi için bu üç bileşenin birbirine bağımlı ve birbirini güçlendiren ayaklar olduğu, entegrasyonunu teşvik etmek için ise eylemde bulunulmasının gerekliliği belirtmiştir. Bu görüş, belirli bir eylem kümesinin (örneğin, fosil yakıtların yenilenebilir enerji kaynaklarıyla değiştirilmesi) üç kalkınma hedefini aynı anda yerine getirebileceği anlayışına da dayanmaktadır (Sathaye vd., 2011: 713; Yıldırım ve Nuri, 2018: 134). Çünkü yenilenebilir enerji, Birleşmiş Milletler'in, Sürdürülebilir Kalkınma Hedefleri (SKH)'ne ulaşmaya yönelik küresel çabaların kritik bir kolaylaştırıcısı olarak da görülmektedir (Agbakwuru vd., 2024: 13).

Yenilenebilir enerji, çevresel sürdürülebilirlik için fosil yakıtlardan uzaklaşma anlamında da gelmektedir. Fosil yakıtlara göre temiz, bol ve uygun maliyetli bir alternatif olup ekonomik kalkınma ve çevresel sürdürülebilirliğin merkezinde yer almaktadır. Rüzgâr, güneş ve hidroelektrik gibi doğal kaynaklardan yararlanarak sera gazı emisyonlarını azaltıp, küresel ısınmayı düşürebilmektedir. Yenilenebilir enerjinin konuşlandırılması, iş yaratarak ve endüstriyel büyümeye izin vererek çevresel bozulmayı azaltabilecek, sürdürülebilir büyümeyi de teşvik edebilecektir. Ek olarak, yenilenebilir enerji, ekonomik esneklik oluşturmak için enerji fiyatlarını stabilize ederek, ithalat bağımlılığını azaltabilecek niteliktedir. Ayrıca, yüksek gelirli ekonomilerde gelir artışı ile yenilenebilir enerji tüketimi arasında pozitif bir nedensel ilişki söz konusu olup bu bir bölgede sürdürülebilir kalkınmayı gösteren ikili bir ekonomik büyüme aracı ve daha yeşil bir çevre potansiyelini tanımlamaktadır. Yenilenebilir enerji teknolojilerinin benimsenmesi, SKH 7 (Uygun Fiyatlı ve Temiz Enerji) 'ye ve SKH 13

(İklim Eylemi)'e bağlı kaldığı için küresel olarak sürdürülebilir kalkınma için çok kritik bir öneme sahiptir (Binsaeed vd., 2025).

SKH'lere ulaşmanın temel yönlerinden biri, sürdürülebilir kalkınmayı yönlendirmede enerjinin, özellikle yenilenebilir enerjinin rolüdür. SKH'ler arasında 7, özellikle herkes için uygun fiyatlı, güvenilir, sürdürülebilir ve modern enerjiye erişimi sağlamaya odaklanmaktadır. Güneş, rüzgâr, hidroelektrik gibi kaynakları içeren yenilenebilir enerji, jeotermal ve biyokütle, uzun süredir ekonomik büyümeyi yönlendiren ancak aynı zamanda çevresel bozulmaya ve iklim değişikliğine önemli ölçüde katkıda bulunan geleneksel fosil yakıtlara temiz ve sürdürülebilir bir alternatif sunmaktadır. Dünya fosil yakıtlardan uzaklaşırken, yenilenebilir enerji yalnızca iklim değişikliğini hafifletmek için bir araç (SKH 13: İklim Eylemi) olarak değil, aynı zamanda yoksulluğun azaltılması (SKH 1), sağlık ve refahın iyileştirilmesi (SKH 3), sürdürülebilir ekonomik büyümenin teşvik edilmesi (SKH 8) ve sürdürülebilir şehirler ve toplulukların teşvik edilmesi (SKH 11) gibi diğer hedeflere ulaşmanın bir yolu olarak da görülmektedir (Agbakwuru vd., 2024: 13-14). Yenilenebilir enerjinin hızla yaygınlaştırılması; ekonomik kalkınmayı ilerletme, enerji güvenliğini iyileştirme, gelecek nesiller için kaynakları koruma, enerji erişimini geliştirme ve iklim değişikliğini hafifletme gibi çok çeşitli hedefleri söz konusudur (Sawin vd., 2016: 5).

Birleşmiş Milletler Kalkınma Programına göre de enerji, geçim kaynakları, suya erişim, tarımsal üretkenlik, sağlık, nüfus seviyeleri, eğitim ve cinsiyetle ilgili konular dâhil olmak üzere sosyal, ekonomik ve çevresel kalkınma alanlarının tamamını etkilediği için sürdürülebilir kalkınma ve yoksulluk azaltımının temel anahtarı olarak görülmektedir. Bu yüzden yenilenebilir enerjiye geçiş hem kalkınmanın hem de çevresel sürdürülebilirliğin temel bir bileşeni olarak kabul edilmektedir (Ramos Pires Manso ve Behmiri, 2013: 8).

SKH'lere ulaşmadaki bu destekler ise literatürde tartışma konusudur (Binsaeed vd., 2025; Sawin vd., 2016: 5). Çünkü yenilenebilir enerji yatırımlarının karbon emisyonlarını azaltma ve iklim değişikliğini hafifletmedeki rolleri yaygın olarak tanınmasına rağmen, ekonomik ve sosyal sürdürülebilirlik üzerindeki etkileri daha karmaşık ve çok yönlü olarak görülmektedir (Doğan, Şeker, 2016; Li vd., 2023).

Literatürde, yenilenebilir enerji kaynaklarının ekonomik büyümeyi desteklediği, çevresel sürdürülebilirliği artırdığı ve fosil yakıt tüketimine bağımlılığı azalttığı sıkça dile getirilmektedir. Doğan ve Şeker (2016), yenilenebilir enerjinin gelişmekte olan ülkeler için ekonomik kalkınma açısından kritik bir rol oynadığını ifade etmektedir. Yenilenebilir enerjinin yalnızca çevresel faydalar sağlamakla kalmayıp, aynı zamanda ekonomik büyüme ve enerji güvenliği üzerinde de olumlu etkileri olduğu belirtilmektedir. Bunun yanı sıra Le vd. (2016), yenilenebilir enerjinin ekonomik sistemler üzerindeki maliyet etkinliğini ve enerji arz

güvenliğini güçlendirdiğini vurgulamaktadır. Araştırmada yenilenebilir enerji kullanımının, enerji çeşitlendirmesini teşvik ederek sera gazı emisyonlarını azaltmada önemli bir rol oynadığı ifade edilmektedir. Yaptıkları çalışmanın bulguları, yenilenebilir enerji kaynaklarının toplumun ekonomik yapısını iyileştirici etkisine dikkat çekmektedir. Diğer bir önemli çalışma olan Wuebben vd. (2020), hükümetlerin enerji politikalarında sıkı çevresel düzenlemeler ve ekolojik kısıtlamaların önemini vurgulamaktadır. Araştırmada, eko-verimli teknolojilerin teşvik edilmesi yoluyla sanayi çevre standartlarının artırılabilceği ve yeşil ekonomik büyümenin desteklenebileceği belirtilmiştir. Bu çalışma, yenilikçi enerji politikalarının hem çevresel hem de ekonomik sürdürülebilirlik hedeflerini eş zamanlı olarak destekleyebileceğini göstermektedir. Dold (2017: 2) ise yenilebilir enerjinin SKH'lerden ikisi ile doğrudan, yoksullukla mücadele başta olmak üzere diğer hedeflerinin hayata geçirilmesinde ise anahtar rol oynadığını vurgulamaktadır.

Zhu vd. (2024) tarafından yapılan çalışmada yenilebilir enerji yatırımlarının sürdürülebilir kalkınmanın sağlanmasında aracılık rolüne dikkat çekilmiştir. 1994-2019 yılları arası Ekonomik İşbirliği ve Kalkınma Örgütü (OECD) ülkelerinde yenilenebilir enerji tüketimi ile CO2 emisyonları arasındaki ilişkiyi incelemişlerdir. Çalışmada, kapsamlı bir ampirik analiz geliştirmek için gelişmiş ekonometrik metodolojiler kullanılmıştır. Çalışma bulguları özellikle üretim aşamalarında yenilenebilir enerji kullanımı çevreyi olumlu yönde etkilediğini göstermektedir. Onlara göre SKH'ler içinde önemli bir yere sahip olan hava kirliliğini azaltmanın önemli yollarından birisi fosil yakıta olan bağımlılığın azaltılarak enerji tedarikinin çeşitlendirilmesinin sağlanmasıdır. Xue vd. (2022) tarafından yapılan çalışmada ise yenilenebilir enerjinin kullanımının emisyon üretmeyen veya nadiren üreten karbonhidrat dışı enerji kaynaklarını içerdiğinden hem sürdürülebilir kalkınmayı hem de çevresel sürdürülebilirliği sağlamaya yardımcı olabileceği ifade edilmiştir. Bu arka plana karşı, ekonomik belirsizliğin olumsuz sonuçlar ortaya koyacağına da ayrıca vurgu yapılmaktadır.

Sawin vd. (2016: 5-6), yenilenebilir enerjinin varsayılan bu faydalarının, siyasi ve enerji tartışmalarında yaygın olarak temel hedefler olarak gösterilse de, bu tür faydaların belirli, belgelenmiş kanıtlar ile yeterli kavramsal çerçevelerin eksikliği, metodolojik zorluklar ve ilgili verilere sınırlı erişim gibi nedenlerle oldukça sınırlı olduğunu belirtmişlerdir. Yenilenebilir enerji faydalarının incelenmesi, gözlemlenen faydaların farklı kategorileri arasında ortak bir ölçü bulma sorunuyla karşı karşıya olduğunu ifade etmişlerdir. Ayrıca tüm faydalarının kolayca paraya çevrilemez nitelikte olduğunu, çevrilmelerinin de gerekmediğini ileri sürmüşlerdir. Çalışmalarında, kategoriler arasındaki etkilerin yenilenebilir enerji geçişinden elde edilen net faydanın tek bir ölçüde toplanmasının önemli bir zorluk teşkil ettiğini de öne sürmüşlerdir. Yıldırım ve Nuri (2018: 135) ise çalışmalarında yenilenebilir

enerji kaynaklarının sadece Güney Afrika, Brezilya, Hindistan, Çin (BASIC) değilde aynı zamanda tüm ülkelerde yerine getirmesi gerekli bir sorumluluk olduğunu, bu gelişimin tüm ülkelerde ve her alanda desteklenmediği sürece yetersiz kalacağını ifade etmişlerdir. Worldwatch Institute (2008: 4-5, 33) ise şirketlerin kaliteye değil fiyata göre rekabet ettiğini, sosyal ve çevresel maliyetleri dışsallaştırdığı ve en ucuz malzeme ve işgücü girdileri aradığını vurgulayarak, yenilenebilir enerji gelişiminin önündeki engelleri aşmak için, elektrik şebekesine garantili fiyatlarla erişimi güvence altına alan, alım garantisi yasaları da dâhil olmak üzere yenilikçi politikalar benimsenmesini gerektiğini belirtmişlerdir. Ağır çevresel maliyetlerin sürekli “dışsallaştırılmasına” izin veren ve bu nedenle sürdürülemez uygulamaların sürdürülebilir ve kârlı görünmesine neden olan sübvansiyonlar, vergi yapıları ve muhasebe yöntemleri, daha hızlı değişimin önündeki temel engeller olmaya da devam ettiği vurgusu yapılmıştır.

Genel olarak, literatürde yenilenebilir enerji politikalarının ekonomik kalkınmayı ve çevresel sürdürülebilirliği desteklemede temel bir araç olduğu kabul edilmektedir. Bununla birlikte, bu politikaların uygulama düzeyinde karşılaştığı zorluklar ve ülkeler arasındaki farklılıklar dikkat çekici bir araştırma alanı oluşturmaktadır. Yenilenebilir enerjinin bu anahtar rolü diğer ekonomi politikası araçları yanında maliye politikası araçlarıyla da özellikle desteklenmesi gerektirmektedir. Maliye politikası, sürdürülebilir kalkınmanın yörüngesini şekillendirmede kritik bir rol oynamaktadır. Çünkü hükümetlerin alacakları kararlarla, harcamaları ve vergileri yönlendirerek (Shankar, 2024: 1; Bozkurt vd., 2010: 28-29); büyüme, çevre ve insan kaynakları gelişimini başta olmak üzere sürdürülebilir kalkınmayı yönlendirebilmektedir. Maliye politikası bu yüzden sürdürülebilir kalkınmanın bileşenleri üzerinde önemli bir etkisi olduğu ifade edilmektedir (Gupta vd. 2002: 1). Nourenn vd. (2022), genişletici maliye politikalarının, artan kamu harcamaları yoluyla ekonomik büyümeyi desteklerken fosil yakıt tüketimini artırabileceği, bunun ise çevre üzerinde olumsuz etkiler yaratabileceğini ifade etmişlerdir. Turan vd. (2023) ise daraltıcı maliye politikalarının da çevresel etkileri olduğu belirtilmiştir. Örneğin, sanayicilerin daraltıcı politikalara tepki olarak yeşil teknolojiler yerine daha az çevre dostu geleneksel teknolojilere yönelmesi, çevre kirliliğini artırabilecektir. Bu durum, daraltıcı politikaların yeşil yatırımların önünde bir engel oluşturabileceği ifade edilmiştir (Razmi vd., 2022). Binsaeed vd. (2025) tarafından yapılan çalışmada 1995-2020 yılları arasında 18 OECD ülkesinin mali ademi merkeziyetçiliğin (gelirler, harcamalar ve kombinasyonlar), enerji verimliliği, yeşil inovasyon, yenilenebilir elektrik üretimi ve katma değerli üretimin sürdürülebilir kalkınma endeksini nasıl etkilediğini ölçmeyi amaçlamıştır. Çalışmada panel tanı (eğim heterojenliği ve kesitsel bağımlılık) testleri kullanılmaktadır. Ampirik analiz için çalışmada, normallik ve endojenlik sorunlarını ele

almak için moment kuantil regresyonunu kullanılmıştır. Araştırma bulgularına göre gelir, harcama ve mali açıdan ademi merkeziyetçi uygulamaların sürdürülebilir kalkınma açısından önemli itici güçleri olduğu tespit edilmiştir. Ayrıca enerji verimliliği ve katma değerli üretim, bölgede sürdürülebilirliği önemli ölçüde artırmaktadır.

Sürdürülebilir kalkınmanın sağlanmasında yenilenebilir enerji ve maliye politikası ilişkisi üzerine bu çalışmada yenilenebilir enerji yatırımlarının SKH'lerle, özellikle ekonomik büyüme (SKH 8), sosyal eşitlik (SKH 10) ve çevre koruma (SKH 13 ve 15) ile ilgili olanlarla ne ölçüde uyumlu olup olmadığı ele alınmıştır. Çalışma kapsamında seçilmiş bazı Avrupa Birliği (AB) ülkeleri ile Türkiye'ye ait veriler kullanılarak ekonometrik analizler yapılmıştır. Bu analizi yönlendiren temel araştırma sorusu: "Maliye politikası araçları yenilenebilir enerji yatırımlarını nasıl etkiler ve bu yatırımlar doğrudan SKH'ye katkıda bulunur mu?" olmuştur. Bu araştırma sorusu, yenilenebilir enerjiye geçiş, ekonomik büyüme ve sosyal politikaları dengelemeyi amaçlayan politika yapıcılar için çok önemli olup, önceki çalışmalar yenilenebilir enerjinin çevresel faydalarını ortaya koyarken (Wuebben vd.2020; Gupta vd. 2002), bu araştırma tartışmayı maliye politikası kapsamında ekonomik ve sosyal etkileri üzerinde konuyu ele almıştır. Ancak burada unutulmaması gereken sürdürülebilir kalkınmanın sağlanabilmesi için ekonomik, sosyal ve çevresel hedefleri dengeleyici politikalar uygulamak, mümkün olan her yerde bunları karşılıklı destekleyici politika ve uygulamalarla bütünleştirmek, mümkün olmadığı yerlerde de ödünleşim yapmak, kararların alınmasında esnasında ise gelecek nesillerin seçenekleri üzerindeki etkisi de hesaba katmak başarılı olmak için gerekli olduğudur.

2. Metodoloji

Bu çalışmada, seçilmiş bazı Avrupa Birliği (AB) ülkeleri ile Türkiye; sürdürülebilir kalkınma hedefleri (SKH), yenilenebilir enerji kapasitesi ve maliye politikası bağlamında bir panel veri ekonometrik modeli aracılığıyla analiz edilmiştir. Çalışmanın temel amacı, maliye politikası uygulamalarının doğrudan etkilerini ölçmekten ziyade, bu politikaların yenilenebilir enerji yatırımları ve sürdürülebilir kalkınma performansına yansıyan sonuçlarını değerlendirmektir. Bu çerçevede Sürdürülebilir Kalkınma Hedefleri (SDG) Endeksi, maliye politikalarının bütüncül çıktısını temsil eden bağımlı değişken olarak kullanılmıştır. SDG endeksi; kamu harcamaları, çevresel vergiler, eğitim ve sağlık yatırımları gibi maliye politikası araçlarının uzun vadeli etkilerini yansıtan ekonomik, sosyal ve çevresel göstergeleri kapsar. Dolayısıyla maliye politikasının "neden" değil, "sonuç" yönünü ölçmek için uygun bir bileşik göstergedir. EUROSTAT veri kaynakları ve uluslararası endekslerden derlenen veriler, AB ve Türkiye'nin yenilenebilir enerji kapasiteleri ile sürdürülebilir kalkınma performansları arasındaki

etkileşimi değerlendirmek amacıyla analiz edilmiştir. Analizde panel veri yöntemlerinin tercih edilmesi, hem ülkeler arası farklılıkların hem de zaman içerisindeki eğilimlerin birlikte incelenmesini mümkün kılmıştır.

2.1. Veri Seçimi ve Kaynaklar

Araştırmada, tutarlılık ve karşılaştırılabilirliği sağlamak için birden fazla yüksek kaliteli veri kaynağından yararlanılmıştır:

- EUROSTAT veritabanı: Yenilenebilir enerji üretim kapasitesi (hidro, rüzgâr, güneş, biyokütle vb.) ve toplam enerji göstergeleri için temel kaynaktır.
- Sürdürülebilir Kalkınma Çözümleri Ağı (SDSN) ve Bertelsmann Stiftung: Ülkelerin SKH kapsamında kaydettiği ilerlemeleri yıllık bazda ölçen SDG Endeksi verileri kullanılmıştır.

SDG Endeksi, ülkelerin sürdürülebilir kalkınma hedeflerine yönelik ekonomik, sosyal ve çevresel performansını bileşik bir puan olarak sunar. Bu puan, kamu maliyesi politikalarının uzun vadeli etkilerini bütüncül biçimde yansıttığı için, maliye politikası etkinliğinin dolaylı bir göstergesi olarak değerlendirilmiştir. Bu yönüyle endeks, literatürde (OECD, 2022; SDSN, 2023; Şentürk Ulucak, 2024) maliye politikası performansını ölçmede giderek daha yaygın biçimde kullanılan bir göstergedir. Bununla birlikte, endeksin bazı sınırlılıkları vardır:

- Ülkeler arası veri çeşitliliği ve göstergelerin ağırlıklandırma farklılıkları, karşılaştırılabilirliği sınırlayabilir.
- Bazı göstergeler doğrudan maliye politikası uygulamalarından ziyade sonuç göstergeleri (örneğin sağlık, eğitim, eşitsizlik) olabilir.

Bu nedenle sonuçlar, bu sınırlılıklar göz önüne alınarak temkinli biçimde yorumlanmıştır.

Veri seti 2000–2021 dönemini kapsamaktadır. Seçilen ülkeler: Almanya, Avusturya, Belçika, Bulgaristan, Çekya, Danimarka, Estonya, Finlandiya, Fransa, Hırvatistan, Hollanda, İrlanda, İspanya, İsveç, İtalya, Kıbrıs, Letonya, Litvanya, Lüksemburg, Macaristan, Malta, Polonya, Portekiz, Romanya, Slovakya, Slovenya, Türkiye ve Yunanistan'dır. Toplam 28 ülke ve 22 yıllık veri ile 616 gözlem içeren dengeli bir panel veri seti oluşturulmuştur.

2.2. Ülke Seçim Kriterleri

Ülkelerin belirlenmesinde üç temel ölçüt dikkate alınmıştır:

- Coğrafi ve ekonomik bütünleşme: Türkiye ve AB ülkeleri arasında enerji, ticaret ve maliye politikası bağlarının güçlü olması,
- Politika benzerliği: Yenilenebilir enerji geçişleri ve sürdürülebilir kalkınma hedeflerinde benzer stratejiler izlenmesi,

- Veri mevcudiyeti: EUROSTAT ve SDG veri tabanlarında düzenli zaman serisi verisinin bulunması.

Seçilen ülkelerin tamamı AB üyesi olup, Türkiye enerji geçişi ve sürdürülebilir kalkınma politikalarında bu ülkelerle benzer dönüşüm süreçlerinden geçtiği için karşılaştırmalı analiz açısından uygun bir örnektir.

2.3. Ekonometrik Model ve Analitik Yaklaşım

Maliye politikası uygulamalarının, yenilenebilir enerji kapasitesi ve SKH'ler üzerindeki etkisini araştırmak için çalışma, hem zaman serisi hem de kesitsel boyutlarda politika etkilerine ilişkin daha kapsamlı bir anlayış sunan panel veri ekonometrik tekniklerini kullanmaktadır (Breusch-Pagan, 1980: 242). Metodoloji, sağlamlığı sağlamak için yapılandırılmış bir ekonometrik test dizisini takip etmektedir (Pesaran, Ullah ve Yamagata 2008: 108). İlk olarak, değişkenlerin durağanlığını incelemek için Pesaran CADF Panel Birim Kök Testi kullanılarak panel birim kök testleri yürütülmüştür. Bu durum verilerin sahte ilişkiler göstermediğinden emin olmak, ekonometrik tahminlerin geçerliliğini korumak için kritik öneme sahiptir (Pesaran, 2007).

Çalışmada kullanılan model, yenilenebilir enerji kapasitesi ile sürdürülebilir kalkınma performansı arasındaki uzun dönemli ilişkiyi ölçmeye yöneliktir. Maliye politikası uygulamaları modele doğrudan değişken olarak dahil edilmemiş ancak Sürdürülebilir Kalkınma Hedefleri (SDG) Endeksi kamu maliyesi politikalarının uzun dönemli sonuçlarını yansıtan bileşik bir çıktı değişkeni olarak kullanılmıştır.

Bu doğrultuda kurulan panel veri modeli aşağıdaki genel formda ifade edilmiştir:

$$SDG_{it} = \alpha_i + \beta_1 RE_{it} + \mu_{it}$$

SDG_{it} : Ülke i'nin yıl t'deki Sürdürülebilir Kalkınma Hedefleri (SKH) endeks puanı (SDSN & Bertelsmann Stiftung)

RE_{it} : Ülke i'nin yıl t'deki toplam yenilenebilir enerji kapasitesi (EUROSTAT)

α_i : Ülkeye özgü sabit etkiler

μ_{it} : Hata terimi (zaman ve ülke etkilerini içeren bileşen)

Model, yenilenebilir enerji üretim kapasitesinin ülkelerin sürdürülebilir kalkınma performansı üzerindeki uzun vadeli etkisini incelemektedir. Buradaki temel varsayım, maliye politikası araçlarının (örneğin yeşil teşvikler, enerji sübvansiyonları, kamu yatırımları) ülkelerin SDG performansına yansıyan makro sonuçlar üzerinden dolaylı olarak etkili olduğudur. Dolayısıyla SDG puanları, maliye politikasının “sonuç göstergesi” olarak değerlendirilmiştir. Panel veri analizi kapsamında şu sıralı ekonometrik test adımları uygulanmıştır:

- Pesaran CADF Panel Birim Kök Testi – serilerin durağanlığını incelemek için,
- Westerlund Durbin-H Panel Eşbütünleşme Testi – uzun dönem ilişkiyi tespit etmek için,
- Dumitrescu–Hurlin Nedensellik Testi – değişkenler arası yönlü etkiyi belirlemek için.

$$= T \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij}^2 \quad (1)$$

$$= \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \frac{(T-k)\hat{\rho}_{ij}^2 - \mu_{Tij}}{v_{Tij}} \quad (2)$$

Bunun ardından, yenilenebilir enerji kapasitesi ile SKH göstergeleri arasında uzun vadeli ilişkilerin olup olmadığını belirlemek için Westerlund Durbin-H Eşbütünleşme Testi uygulanmıştır. Eşbütünleşmenin varlığı veya yokluğu, yenilenebilir enerjiyi destekleyen mali politikaların daha geniş sürdürülebilir kalkınma sonuçlarına dönüşüp dönüşmediğine dair bilgiler sunmaktadır (Pesaran, 2007).

$$= N^{-1} \sum_{i=1}^N \text{CADF}_i \quad (3)$$

$$\begin{aligned} \Delta y_{it} = & \delta_i' d_t + \alpha_i (\Delta y_{it-1} - \beta_i' x_{it-1}) \\ & + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{it-j} \\ & + \sum_{j=0}^{p_i} \gamma_{ij} \Delta x_{it-j} + e_{it} \end{aligned} \quad (4)$$

Son aşamada Dumitrescu–Hurlin Panel Nedensellik Testi uygulanarak değişkenler arasındaki nedensellik yönü incelenmiştir. Yenilenebilir enerji yatırımlarının sürdürülebilir kalkınmayı yönlendirip yönlendirmediği veya bu iki değişkenin eşzamanlı olarak etkilendiği değerlendirilmiştir. Modelin sağlamlığını artırmak amacıyla, potansiyel içsellik sorunlarını azaltmak için Genelleştirilmiş Momentler Metodu (GMM) tahmincisi kullanılmıştır. GMM yöntemi, gecikmeli değerleri araç değişken olarak kullanarak tahmin sapmalarını en aza

indirir ve modelin güvenilirliğini artırır. Bu teknik, parametrelerin önyargısız tahmin edilmesine olanak tanımıştır (Pesaran, Shin ve Smith, 2001).

2.4. Ekonometrik Yaklaşım İçin Gerekçe

Panel veri ekonometrisi, hem ülkeler arası yapısal farklılıkları hem de zaman içindeki dinamik değişimleri eş zamanlı olarak analiz etme imkânı sunduğundan bu çalışmada tercih edilmiştir. Bu yöntem, yalnızca kesitsel verilerle yapılan analizlerin göz ardı ettiği zaman boyutunu dâhil ederek, maliye politikalarının sürdürülebilir kalkınma üzerindeki etkilerini hem ülke içi hem de ülke dışı karşılaştırmalarla değerlendirmeye olanak tanır. Panel veri yaklaşımı ayrıca, ülkelere özgü sabit özellikleri (gözlemlenmeyen heterojenlikleri) kontrol ederek, kurumsal yapı, mali disiplin, vergi sistemleri ve kamu harcama öncelikleri gibi farklılıkların sonuçları çarpıtmasını önler. Böylece elde edilen katsayılar, maliye politikalarının genel sürdürülebilir kalkınma performansı üzerindeki etkilerini daha güvenilir biçimde yansıtır (Costanza et al., 2016; OECD, 2022).

Çalışmada kullanılan Sürdürülebilir Kalkınma Hedefleri (SDG) Endeksi, maliye politikalarının sosyal, ekonomik ve çevresel boyutlarda yarattığı toplam etkinin ölçülmesine olanak sağlayan bütüncül bir göstergedir. Bertelsmann Stiftung ve SDSN (2023) raporlarında belirtildiği üzere SDG Endeksi; kamu bütçelemesi, vergi yapısı ve yeşil teşvikler gibi maliye politikası araçlarının ülkelerin sürdürülebilir kalkınma performansları üzerindeki yansımalarını bütüncül biçimde değerlendirmektedir. OECD (2022) de maliye politikalarının SDG performansını şekillendiren temel etkenlerden biri olduğunu ve bütçe çerçevelerinin bu hedeflerle uyumlu hale getirilmesi gerektiğini vurgulamaktadır.

Dolayısıyla bu çalışmada panel veri ekonometrisi kullanımı, maliye politikalarının yenilenebilir enerji yatırımları ve sürdürülebilir kalkınma endeksi üzerindeki dolaylı etkilerini eşzamanlı olarak analiz edebilme imkânı sağlamaktadır. Bu yaklaşım, literatürde önerilen “yeşil bütçeleme ve sürdürülebilir kalkınma ilişkisinin ampirik ölçümü”ne uygun bir metodolojik çerçeve sunar (Şentürk Ulucak, 2024; Yiğit Şakar & Aydın, 2023). Böylelikle elde edilen bulgular, maliye politikalarının genel sürdürülebilir kalkınma performansına katkısını dolaylı ancak istatistiksel olarak anlamlı biçimde ortaya koymaktadır.

3. Bulgular

Bulgular, yenilenebilir enerji ve bazı sürdürülebilir kalkınma hedefleri arasında eşbütünleşme eksikliği ile seçilmiş sürdürülebilir kalkınma hedefleriyle potansiyel eşbütünleşme şeklinde iki ana başlıkta ele alınacaktır.

3.1. Yenilenebilir Enerji ve Bazı Sürdürülebilir Kalkınma Hedefleri Arasında Eşbütünleşme Eksikliği

Ekonometrik analiz, yenilenebilir enerji kapasitesinin birkaç temel (SKH) ile istatistiksel olarak anlamlı bir uzun vadeli ilişki göstermediğini göstermektedir. Özellikle, Pesaran CADF Panel Birim Kök Testi (Tablo 1), yenilenebilir enerji kapasitesinin birçok ülkede olduğu gibi Türkiye'de de durağanlıktan yoksun olduğunu göstermektedir. Bu da zaman içinde SKH göstergeleriyle istikrarlı bir ilişkinin yokluğunu desteklemektedir.

Tablo 1. CADF Panel Birim Kök Testi (SKH) Sırası

Ülkeler	ADF Gecikmeleri	CADF		Kısaltılmış CADF	
		t-istatistiği	p-değeri	t-istatistiği	p-değeri
Avusturya	5	-1.80923	≥ 0.10	-1.80923	≥ 0.10
Belçika	5	-2.93057	≥ 0.10	-2.93057	≥ 0.10
Bulgaristan	5	1.55735	≥ 0.10	1.55735	≥ 0.10
Hırvatistan	5	1.38115	≥ 0.10	1.38115	≥ 0.10
Güney Kıbrıs	5	-1.00241	≥ 0.10	-1.00241	≥ 0.10
Çekya	0	-2.64289	≥ 0.10	-2.64289	≥ 0.10
Danimarka	5	-0.39251	≥ 0.10	-0.39251	≥ 0.10
Estonya	5	-1.11390	≥ 0.10	-1.11390	≥ 0.10
Finlandiya	5	-2.43954	≥ 0.10	-2.43954	≥ 0.10
Fransa	5	0.50477	≥ 0.10	0.50477	≥ 0.10
Almanya	5	-0.86639	≥ 0.10	-0.86639	≥ 0.10
Yunanistan	5	-0.56653	≥ 0.10	-0.56653	≥ 0.10
Macaristan	5	-6.00628	< 0.01	-6.00628	< 0.01
İrlanda	5	-4.61556	< 0.05	-4.61556	< 0.05
İtalya	5	-4.54893	< 0.05	-4.54893	< 0.05
Letonya	5	-0.84731	≥ 0.10	-0.84731	≥ 0.10
Litvanya	5	-1.85665	≥ 0.10	-1.85665	≥ 0.10
Lüksemburg	5	-1.34694	≥ 0.10	-1.34694	≥ 0.10
Malta	5	-1.05909	≥ 0.10	-1.05909	≥ 0.10
Hollanda	5	0.94559	≥ 0.10	0.94559	≥ 0.10
Polonya	5	-23.69580	< 0.01	-6.42000	< 0.01
Portekiz	5	-1.88475	≥ 0.10	-1.88475	≥ 0.10
Romanya	5	-2.21892	≥ 0.10	-2.21892	≥ 0.10
Slovakya	5	-1.68896	≥ 0.10	-1.68896	≥ 0.10
Slovenya	5	-0.53323	≥ 0.10	-0.53323	≥ 0.10
İspanya	5	-0.74727	≥ 0.10	-0.74727	≥ 0.10

İsveç	5	-4.43563	<0.05	-4.43563	<0.05
Türkiye	4	-0.61304	>=.10	-0.61304	>=.10

Ayrıca, Westerlund Durbin-H Eşbütünleşme Testi'nden (Tablo 2) elde edilen sonuçlar, yenilenebilir enerji kapasitesi ile SKH 8, 10, 15, 17 dahil olmak üzere temel sosyo-ekonomik hedefler arasında güçlü bir eşbütünleşme olmadığına dair ek kanıtlar sunmaktadır. Sırasıyla 0,921 ve 0,403'lük dh_g ve dh_p test değerleri, p değerleri 0,000'dir. Bu da eşbütünleşmenin reddedildiğini göstermekte ve bu sürdürülebilirlik hedeflerinin yenilenebilir enerji genişlemesiyle doğası gereği uyumlu olmadığını düşündürmektedir.

Tablo 2. Westerlund Durbin-H Eşbütünleşme Testi

	Değer
dh_g	0.921 (0.000)
dh_p	0.403 (0.000)

Tablo 2'deki bulgular önemli bir sınırlamayı vurgulamaktadır. Çünkü yenilenebilir enerji gelişimi çevresel sürdürülebilirlik ve karbon azaltımı için önemli olsa da otomatik olarak sosyoekonomik ilerlemeye dönüşmemektedir. Doğrudan eşbütünleşmenin olmaması, yenilenebilir enerji yatırımlarının tek başına istihdamı artırmak, toplumsal eşitsizlikleri azaltmak veya kurumsal ortaklıkları teşvik etmek için ayrıca yeterli olmadığını göstermektedir. Dolayısıyla tamamlayıcı mali ve sosyal politikalar (işgücü piyasası reformları, hedefli sosyal programlar ve ekonomik çeşitlendirme stratejileri gibi) yenilenebilir enerji yatırımlarının sosyoekonomik faydalarını en üst düzeye çıkarmak için gerekli olmaktadır.

3.2. Seçilmiş Sürdürülebilir Kalkınma Hedefleriyle Potansiyel Eşbütünleşme

Belirli SKH (1, 2, 3, 4, 7, 8, 10, 13, 14, 15, 16, 17)'ler yenilenebilir enerji yatırımlarıyla hiçbir eşbütünleşme göstermezken, panel eşbütünleşme analizi diğer sürdürülebilirlik göstergeleriyle potansiyel uzun vadeli bağlantılar ortaya koymaktadır. Panel eşbütünleşme testlerinden elde edilen sonuçlar, yenilenebilir enerji kapasitesi ile SKH 5 6, 9, 11 ve 12 arasında zayıf ancak olumlu eşbütünleşme eğilimleri göstermiştir.

Örneğin, SKH 5 için eşbütünleşme testi (Tablo 3) karışık sonuçlar sunmaktadır; Panel PP (Phillips-Perron t-istatistik: -1,359) ve Grup PP (t-istatistik: -0,8214)*¹ daha düşük bir istatistiksel önem seviyesinde olsa da potansiyel entegrasyonu göstermektedir. SKH 6 için de benzer örüntüler ortaya çıkmakta (Tablo 4), burada Panel PP (-2,117) ve Panel ρ (-0,7741)* değerleri temiz enerji genişlemesi ve su sürdürülebilirliği girişimleri arasında orta düzeyde bir uyum olduğunu göstermektedir.

Tablo 3. SKH 5 ve 6 için Eşbütünleşme Testi

<i>In-Group Statistics</i>	SKH 5	SKH 6
Panel v – (Rate of Variation)	-1.284	-0.2603
Panel ρ - (Phillips–Perron Tipi ρ)	-0.2168*	-0.7741*
Panel PP – (Phillips–Perron Tipi t)	-1.359*	-2.117*
Panel ADF (Dickey–Fuller Tipi t)	2.533	1.481
<i>Between Groups Statistics</i>		
Grup ρ - (Phillips–Perron Tipi ρ)	1.021	0.7219
Grup PP - (Phillips–Perron Tipi t)	-0.8214*	-1.543*
Grup ADF - (Dickey–Fuller Tipi t)	1.335	1.059

SKH 9 (Tablo 4'te) daha belirgin bir ilişki ortaya çıkıyor; burada Panel PP (-0,7564) ve Grup PP (-0,1032)* testleri yenilenebilir enerji büyümesinin endüstriyel inovasyona ve altyapı gelişimine katkıda bulunabileceğini göstermektedir. Benzer şekilde, SKH 11 ve SKH 12 (Tablo 4) zayıf ama olumlu entegrasyon kalıpları göstermekte, temiz enerji yatırımlarının kentsel sürdürülebilirliği ve sorumlu üretim modellerini dolaylı olarak etkileyebileceği fikrini güçlendirmektedir.

¹ Negatif değer ve yıldız işareti (*), eşbütünleşme olmadığına dair boş hipotezin %5 anlamlılık düzeyinde reddedildiğini gösterir. Bu da eşbütünleşmeyi göstermektedir.

Tablo 4. SKH 9, 11 ve 12 için Eşbütünleşme Testi

<i>In-Group Statistics</i>	SKH 9	SKH 11	SKH 12
Panel v – (Rate of Variation)	-2.137	-2.416	-1.526
Panel ρ - (Phillips–Perron Tipi ρ)	0.9974	0.8186	0.7882
Panel PP – (Phillips–Perron Tipi t)	-0.7564*	-0.4546*	-1.207*
Panel ADF (Dickey–Fuller Tipi t)	1.269	2.319	-0.6305*
<i>Between Groups Statistics</i>			
Grup ρ - (Phillips–Perron Tipi ρ)	2.57	2.082	2.15
Grup PP - (Phillips–Perron Tipi t)	-0.1032*	0.2956	-0.9261*
Grup ADF - (Dickey–Fuller Tipi t)	0.04462	2.941	-0.8492*

Bu olumlu eğilimlere rağmen, bu ilişkilerin hiçbirinin yüksek istatistiksel öneme ulaşmadığını ve gözlemlenen bağlantıların zayıf kaldığını ve daha fazla araştırma gerektirdiğini belirtmek gerekmektedir. Tüm göstergelerde tutarlı istatistiksel önemin olmaması, yenilenebilir enerji genişlemesinin belirli SKH'leri destekleme potansiyeline sahip olmasına rağmen, etkisinin sürdürülebilir kalkınmanın tüm boyutlarında tekdüze olmadığını da göstermektedir.

4. Tartışma

Bu çalışmanın bulguları, yenilenebilir enerji kapasitesi ile SKH arasındaki karmaşık ve tekdüze olmayan ilişkileri vurgulamaktadır. Önemli bir gözlem, yenilenebilir enerji yatırımları ile SKH 8, 10, 15 ve 17 arasındaki eşbütünleşmenin eksikliğidir. Bu yenilenebilir enerjinin, çevresel sürdürülebilirlikte kritik bir rol oynamasına rağmen, ekonomik ve sosyal sürdürülebilirlik üzerindeki doğrudan etkisinin sınırlı kaldığı anlamına gelmektedir. Bu sonuçlar, yenilenebilir enerji geçişlerinin önemli sosyo-ekonomik faydalar elde etmek için daha geniş ekonomik ve işgücü politikalarıyla tamamlanması gerektiğini belirten çalışmalarla uyumludur (Neverauskienė vd., 2025; Binsaeed vd., 2025, Nourenn vd., 2022, Apergis ve Payne, 2010).

Bazı SKH için doğrudan eşbütünleşmenin olmamasına rağmen, ekonometrik analiz yenilenebilir enerji genişlemesi ile SKH 5, 6, 9, 11 ve 12 arasında potansiyel dolaylı bağlantılar olduğunu göstermektedir. Bu ilişkiler istatistiksel olarak anlamlı olmasa da yenilenebilir enerjinin sürdürülebilir kentleşmeyi, endüstriyel yeniliği ve su koruma girişimlerini ilerletmek için bir temel oluşturabileceğini göstermektedir. Benzer bulgular, AB içinde yenilenebilir enerjinin uzun vadeli ekonomik büyümedeki rolünü değerlendiren çalışmalarda gözlemlenmiş, teknolojik ilerlemeleri ve yeşil altyapı yatırımlarını entegre eden tamamlayıcı politikalara olan ihtiyacı vurgulamıştır (Hiremath, Tadeipalli ve Nalina, 2024).

Literatürün daha geniş bir şekilde incelenmesi, yenilenebilir enerji yatırımlarını hedeflenen maliye politikası unsurlarıyla entegre etmenin, SKH odaklı sürdürülebilirlik hedeflerine ulaşmak için önemli olduğunu ortaya koymaktadır. Örneğin, Dong ve Akhtar (2022), Çin'de CO₂ emisyonları, teknolojik yenilik, finansal gelişme ve yenilenebilir enerji arasındaki uzun vadeli ilişkiyi analiz etmiş, teknolojik ilerlemelerin ve yeşil finans mekanizmalarının etkili yenilenebilir enerji geçişlerinin temel kolaylaştırıcıları olduğunu vurgulamıştır. Benzer şekilde, yeşil finans ve endüstriyel sürdürülebilirlikteki rolü üzerine yapılan araştırmalar, yeşil tahviller ve karbon fiyatlandırması gibi stratejik finansal araçların, temiz enerji teknolojilerine eşit erişimi garanti ederken yenilenebilir enerji projelerinin ekonomik uygulanabilirliğini artırdığını ifade etmişlerdir (Du, Zhang ve Hou, 2025). Khan vd. göre (2025), ekonomik büyüme, ticaret açıklığı ve endüstriyel rekabet gücü, çevresel kaliteyi ve sürdürülebilir kalkınma sonuçlarını önemli ölçüde etkilemektedir. Bulguları, yenilenebilir enerji ve insan sermayesi yatırımlarının çevresel sürdürülebilirliğe olumlu katkıda bulunurken, olumsuz sosyo-ekonomik sonuçları önlemek için ekonomik rekabet gücünün sürdürülebilirlik hedefleriyle dikkatlice dengelenmesi gerektiğidir. Bu bakış açısı, özellikle yenilenebilir enerji gelişiminin uluslararası ticaret ve endüstriyel modernizasyon çabalarına yakından bağlı olduğu ekonomilerde politika entegrasyonunun önemini vurgulamaktadır.

Chen vd. (2024)'ne göre sürdürülebilir kalkınmada enerji verimliliğinin sağlanması sera gazlarını yaklaşık %40 düzeyinde azaltmaktadır. Ekonomik büyüme hedeflerine ulaşmak için iklim değişikliğini azaltmak kritik bir zorluk gerektirmektedir. Bunun içinde yenilenebilir enerji imkanlarının geliştirilmesi SKH hedeflerine ulaşmak için önem arz etmektedir. Abbas vd. (2024) tarafından yapılan çalışmada SKH'ler ile yenilenebilir enerjiye geçiş arasındaki ilişkiyi 29 OECD ülkesi açısından incelemiştir. Çalışmada; çevre vergilendirmesi, karbon fiyatlandırma politikası, yenilenebilir enerji geliştirme ve gösterimi için bütçe, bölgesel yetki, finansal kalkınma ve küreselleşmeyi birleştirerek 1993-2019 yılları arası verileri kullanarak analizler yapılmıştır. Çalışma bulguları, çevre vergilendirmesinin artırılmasının ve karbon fiyatlandırma politikalarının güçlendirilmesinin çevresel inovasyonu

teşvik ettiğini ortaya koymaktadır. Bunun yanı sıra, yenilenebilir enerji geliştirme ve gösterimi için özel sektör bütçelerini teşvik eden politika yapımının gerekliliği vurgulanmıştır. Apergis ve Payne, (2010) tarafından yapılan çalışmada ise 1985-2005 dönemi için 20 OECD ülkesinden oluşan bir panel için yenilenebilir enerji tüketimi ile ekonomik büyüme arasındaki ilişkiyi çok değişkenli bir çerçevede incelenmiştir. Zaman serisi verilerinin nispeten kısa bir süreye sahip olması nedeniyle, nedensel ilişkiyi çıkarmak için bir panel eşbütünleşme ve hata düzeltme modeli kullanılmıştır. Heterojen panel eşbütünleşme testi, reel Gayri Safi Yurtiçi Hasıla (GSYH), yenilenebilir enerji tüketimi, reel brüt sabit sermaye oluşumu ve işgücü arasında ilgili katsayıların pozitif ve istatistiksel olarak anlamlı olduğu uzun vadeli bir denge ilişkisini ortaya koymaktadır. Granger nedensellik sonuçları, yenilenebilir enerji tüketimi ile ekonomik büyüme arasında hem kısa hem de uzun vadede çift yönlü nedensellik olduğunu göstermektedir.

Zaka vd. (2025), yenilenebilir enerji genişlemesinde yeşil finansın rolünü vurgulayarak, finansal katılımın ve teknolojilere yatırım, sürdürülebilirliğin temel itici güçleri olduğunu savunmaktadır. Araştırmaları, yenilenebilir enerji girişimlerinin gelişimsel etkisini en üst düzeye çıkarmak için hem çevresel hem de ekonomik boyutları içeren bütünsel politika çerçevelerinin gerekliliğini vurgulamaktadır. Benzer şekilde Chen vd. (2024), OECD ekonomilerinden, farklı ekonomik bağlamlarda yenilenebilir enerji teknolojilerine yapılan yatırımların sürdürülebilirlik politikalarının etkinliğini şekillendirdiğini gösteren kanıtlar sunmaktadır. Bu bulgular, küresel sürdürülebilirlik gündemlerini ilerletmede çok sektörlü iş birliğine duyulan ihtiyacın altını çizmektedir.

5. Sonuç

Çevresel, ekonomik ve sosyal alanlarda bugünkü neslin ihtiyaçlarını karşılarken, gelecek nesilleri tehlikeye atmayan yani dengeyi sağlayarak hem bugünü hem de geleceği koruyan, kalkınma anlayışı, sürdürülebilir kalkınmayı ifade etmektedir. Kalkınmanın sürdürülebilir olmasında ise yenilenebilir enerji önemli bir rol oynamaktadır. Birleşmiş Milletler Kalkınma Programında da ifade edildiği üzere enerji; geçim kaynakları, suya erişim, tarımsal üretkenlik, sağlık, nüfus seviyeleri, eğitim, cinsiyetle ilgili konular, yoksulluk da dâhil olmak üzere sosyal, ekonomik ve çevresel kalkınma alanlarının tamamını etkileme gücü vardır. Bu gücü nedeniyle de hem kalkınma hem de çevresel sürdürülebilirliğin temel taşlarından birisini oluşturmaktadır.

Yenilenebilir enerjinin sürdürülebilirlik üzerindeki bu gücü kaçınılmaz olarak ekonomi politikası araçlarıyla özellikle de maliye politikası araçlarıyla desteklenmesi gerektirmektedir. Maliye politikasının yenilenebilir enerji üzerindeki gücü ise hem yenilenebilir enerji kaynakları

teşvik edilmesinde hem de fosil yakıtlar, nükleer enerji gibi (yenilenemez) enerji kaynaklarının caydırılmasında önemli bir rol oynamaktadır. Literatürde de yenilenebilir enerji politikalarının sürdürülebilir kalkınmayı desteklemede önemli olduğu kabul edilmekle birlikte, ülkelerin uyguladıkları politikaların uygulama düzeyi, farklılıklar burada dikkat çekici bir araştırma alanı oluşturmaktadır.

Bu yüzden bu çalışmada belirli kriterlere göre belirlenen seçilmiş bazı AB ülkeleri ile Türkiye ele alınarak incelenmiştir. Ekonometrik analizler sonrasında ulaşılan bulgular değerlendirildiğinde; yenilenebilir enerji yatırımları ile belirli sürdürülebilir kalkınma hedefleri; 8, 10, 15 ve 17 arasında eşbütünleşme eksikliği olduğu tespit edilmiştir. Bunun anlamı yenilenebilir enerji genişlemesinin tek başına otomatik olarak ekonomik büyümeye, sosyal eşitliğe veya kurumsal iş birliğine yol açmadığı yönündedir. Sürdürülebilir kalkınma hedeflerinden 5, 6, 11 ve 12 arasında ise istatistiksel olarak anlamlı olmasa da potansiyel ilişkiler tespit edilmiştir. Bu ilişki ise yenilenebilir enerji yatırımlarının sosyo-ekonomik faydalarını tam olarak gerçekleştirmek için tamamlayıcı politikaların gerekli olduğunu göstermektedir. Bulgular, yenilenebilir enerji yatırımlarının iklim değişikliğini azaltmak için hayati önem taşımasına rağmen, daha geniş mali ve işgücü piyasası reformlarıyla bütünleştirilmediği sürece ekonomik büyüme, sosyal eşitlik ve kurumsal ortaklıklar üzerindeki etkilerinin sınırlı kalabileceğini göstermektedir.

Sonuç olarak yenilenebilir enerji kaynaklarının kullanım oranının artırılması; enerji politikalarında değişim, uygun destekleme önlemleri, uygun politikaları yaşama geçirme kararlılığı, yasal düzenlemeler, bilimsel çalışmalar ile var olan sorunların tespit edilmesi gibi önlemlerin bir bütün olarak ele alınması gerekmektedir. Yenilebilir enerji kaynaklarının yaygın kullanımını sağlamak için bu yollara başvurulurken aynı zaman bunun kadar değerli olan bir başka şey ise şirketlerin ya da ülkelerin kaliteye değil de fiyata önem vererek hareket ettiği, rekabeti öncelik haline getirerek sosyal ve çevresel maliyetleri göz ardı ettiği hem bugünkü hem de gelecek nesillere negatif dışsallıkları yüklediği alanlarda da zıt yönde benzer politikalar (cezalar, vergiler, yasalar, kararlılık gibi) uygulayarak iki yönlü bir çözümün birlikte düşünülmesi gerekmektedir. Bu çözüm yollarında ise maliye politikası anahtar rol oynamaktadır. Ancak maliye politikası bağlamında tek başına çözümler sunmak yeterli değildir. Çünkü uygulanan bütün politikaların ekonomik, sosyal ve çevresel hedefleri dengeleyici olması, bu önemlerin bir bütün olarak birbiriyle uyumlaştırılması gerekmektedir. Yoksa tek başına maliye politikası adına sübvansiyonlar, vergi teşvikleri ve yeşil finansman mekanizmaları kullanılması ya da yenilenemez enerjilerin caydırılması yeterli olmayacaktır. Olması gereken ekonomi, çevre ve sosyal alanda politikaların öncelikle kendi içinde sonra

birbiri ile uyumlaştırılması, eğer tarafların farklı istekleri çıkışıyor ise bu sefer de sürdürülebilirlik yönünde feragat edilerek ortak bir noktada buluşulması gerekmektedir.

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Turist Motivasyonu, Deneyimi ve Satın Alma Sonrası Davranışsal Niyet Arasındaki İlişki: Bodrum Örneği

The Relationship Between Tourist Motivation, Experience and Post-Purchase Behavioural Intentions: The Case of Bodrum

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Öz: Bu çalışma, Bodrum destinasyonunu ziyaret eden yerli turistlerin seyahat motivasyonları, deneyimleri ve satın alma sonrası davranışsal niyetleri arasındaki ilişkiyi incelemektedir. Araştırma kapsamında turistlerin seyahat motivasyonları ile turizm deneyimleri ve satın alma sonrası davranışsal niyetleri arasındaki ilişkiler ele alınmıştır. Veriler, 15 Haziran–15 Eylül 2025 tarihleri arasında Bodrum’da 397 yerli ve turiste uygulanan anket formları ile toplanmıştır. Araştırma yönteminde nicel veri analizi kullanılarak bu değişkenler arasındaki ilişkiler test edilmiştir. Analizler SPSS programında gerçekleştirilmiştir. Araştırma sonuçları, seyahat motivasyonunun (rahatlama ve sosyal) turistlerin deneyimleri ile satın alma sonrası davranışsal niyetleri üzerinde anlamlı ve pozitif bir etkiye sahip olduğunu ortaya koymuştur. Ayrıca, uygulamalı ve estetik deneyimlerin de davranışsal niyet üzerinde etkili olduğu belirlenmiştir. Bu bulgular, özellikle sosyal motivasyon ve estetik deneyim unsurlarının turistlerin destinasyona yönelik davranışsal niyetlerini güçlendiren temel belirleyiciler olduğunu göstermektedir.

Anahtar Kelimeler: Turist Motivasyonu ve Deneyimi, Satın Alma Sonrası Davranışsal Niyet, Bodrum

JEL Sınıflandırması: L83, M31, Z32

Abstract: This study investigates the relationship between travel motivation, tourist experience, and post-purchase behavioral intentions of domestic tourists visiting the Bodrum destination. Within the scope of the research, the relationships among these variables were examined. Data were collected from 397 domestic tourists in Bodrum through questionnaires administered between June 15 and September 15, 2025. Quantitative data analysis was employed to test the relationships among the variables. The analyses were conducted using SPSS software. The research findings reveal that travel motivation (relaxation and social) has a significant and positive effect on tourists' experiences and post-purchase behavioural intentions. Furthermore, it has been determined that practical and aesthetic experiences also influence behavioural intentions. These findings indicate that social motivation and aesthetic experience elements in particular, are key determinants that strengthen tourists' behavioural intentions towards the destination.

Keywords: Tourist Motivation and Experience, Post-Purchase Behavioral Intention, Bodrum.

JEL Classification: L83, M31, Z32

1. Giriş

Turizm olgusu, bireylerin farklı ihtiyaçlarını karşılamaya yönelik güçlü bir motivasyon süreci üzerine temellenmektedir. İnsanları seyahate yönelten güdüler tarihsel süreç içerisinde farklı kuramlarla açıklanmış özellikle itici (push) ve çekici (pull) motivasyon faktörleri alan yazında geniş kabul görmüştür (Tatık, 2024). İtici motivasyonlar; günlük rutinden uzaklaşma, sosyalleşme, yeni kültürleri tanıma ve kişisel gelişim gibi içsel dürtülere dayanırken; çekici motivasyonlar destinasyonun sahip olduğu doğal, kültürel ve sosyal çekiciliklerle ilgilidir. Bu

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bağlamda, turistlerin seyahat kararlarını yönlendiren motivasyonel unsurların doğru analiz edilmesi hem destinasyon pazarlaması hem de sürdürülebilir turizm politikaları açısından kritik önem taşımaktadır (Seyitoğlu, 2020).

Turist motivasyonu, bireylerin seyahat kararı vermelerinde etkili olan içsel ve dışsal faktörlerin bütünüdür ifade etmektedir. Yapılan araştırmalarda motivasyonun turistlerin destinasyon seçiminde belirleyici bir rol üstlendiği ve seyahat deneyiminin temel tetikleyicisi olduğu görülmektedir. Örneğin, Huang ve Hsu (2021) ve Biran vd. (2011) motivasyonu, bireyin ihtiyaçlarını, isteklerini ve hedeflerini karşılamak amacıyla çevresindeki fırsatlar ve zorluklarla etkileşim halinde şekillenen dinamik bir psikolojik süreç olarak tanımlamaktadır. İlgili çalışmalar, turizm motivasyonunun turist davranışlarını yönlendiren içsel bir güç olduğunu; doğrudan turistlerin ihtiyaç ve isteklerinden kaynaklandığını ve davranışsal niyetlerin oluşumunu teşvik ettiğini ortaya koymaktadır (Carreira, 2022). Baloglu'nun (2000) yaptığı araştırmada ise, turistlerin turizmle bağlantılı davranışsal niyetlerini etkileyen faktörler analiz edilmiş; psikolojik motivasyonların ve güven duyulan bilgi kaynaklarının, turistlerin davranışsal kararlarını şekillendirmede kritik bir rol üstlendiği vurgulanmıştır.

Bodrum sahip olduğu doğal güzellikler, tarihi miras, eğlence olanakları ve uluslararası marka değerine sahip konaklama tesisleriyle Türkiye'nin en önemli turizm destinasyonlarından biridir. Her yıl milyonlarca yerli ve yabancı turisti çeken Bodrum, farklı motivasyonlara sahip turist gruplarını kendine çekmektedir. Ancak bu turistlerin destinasyondaki deneyimlerinin nasıl algılandığı ve satın alma sonrası davranışsal niyetlere nasıl yansıdığına ilişkin çalışmalar sınırlıdır. Bu bağlamda, motivasyon, deneyim ve satın alma sonrası davranışsal niyet değişkenlerinin birlikte ele alınması turist davranışlarının yalnızca “ne yaptığını” değil neden ve nasıl şekillendiğini anlamak açısından önem taşımaktadır. Özellikle destinasyon rekabetinin arttığı günümüz turizm pazarında turistlerin deneyimsel tatmin yoluyla davranışsal sadakate nasıl yöneldiğinin ortaya konulması hem kuramsal gelişim hem de destinasyon yönetimi açısından araştırılmaya değer bir konudur. Bu nedenle, Bodrum özelinde yürütülecek bu araştırma, destinasyon yöneticileri için turistlerin motivasyonlarını ve deneyimlerini daha iyi anlamaya; elde edilen bulgular ise Bodrum'un sürdürülebilir turizm politikalarının geliştirilmesine, marka değerinin korunmasına ve tekrar ziyaret eden sadık turist kitlesinin güçlendirilmesine katkı sağlayacaktır.

2. Kavramsal Çerçeve

Turistlerin bir destinasyondaki deneyimleri yalnızca seyahat anında değil seyahatten sonraki davranışlarında da belirleyici rol oynamaktadır. Seyahat deneyimleri turistlerin

motivasyonlarını gerçekleştirme sürecinin ayrılmaz bir parçasıdır. Deneyim sürecinde yaşanan faaliyetler, karşılaşılan hizmetler ve destinasyona dair gözlemler, turistlerin zihninde bir imaj oluşturur. Bu imaj, destinasyon hakkındaki genel algıyı şekillendirirken aynı zamanda memnuniyet düzeyini de doğrudan etkilemektedir (Jiang vd., 2022). Turizm deneyimi, bireylerin seyahat süresince yaşadıkları duygusal, entelektüel ve fiziksel süreçleri kapsayan çok boyutlu bir yapıdır (Chen ve Rahman, 2018). Tung ve Ritchie (2011). Turizm deneyimini, seyahat öncesinden başlayan, seyahat esnasında devam eden ve sonrasında tamamlanan bir süreç olarak tanımlamaktadır. Bu nedenle, turistlerin seyahat boyunca edindikleri deneyimler, destinasyon imajlarının şekillenmesine ve uzun vadeli algıların tutarlılık kazanmasına katkı sağlamaktadır (Gallarza vd., 2023).

Özellikle satın alma sonrası davranışsal niyetler; destinasyonu yeniden ziyaret etme, başkalarına tavsiye etme veya olumlu/olumsuz geri bildirimlerde bulunma gibi unsurları kapsamaktadır (Albayrak ve Caber, 2018). Bu niyetler, turistin tatmin düzeyinin ve algıladığı değer bir yansımasıdır. Nitekim, tatil deneyimi sonrası oluşan davranışsal niyetlerin güçlü olması destinasyonların uzun vadeli başarısında kritik rol oynamaktadır (Tatık, 2024). Zhao vd. (2025) çalışmasında da vurgulandığı üzere motivasyon ve algılanan değer, turistlerin seyahat sonrasındaki niyetlerini şekillendiren başlıca unsurlardır. Dolayısıyla, satın alma sonrası davranışsal niyet sadece bireysel tercihler açısından değil aynı zamanda destinasyonların rekabet gücünü koruyabilmesi bakımından da stratejik bir öneme sahiptir.

Turist motivasyonu, yalnızca seyahat kararını şekillendiren bir unsur değil, aynı zamanda deneyimin algılanma biçimini de doğrudan etkileyen bir faktördür. Seyitoğlu'nun (2020) Kadadokya üzerine yaptığı çalışmada, yenilik ve öğrenme, kaçış ve rahatlama gibi motivasyonların turistlerin deneyimlerini zenginleştirdiği ve memnuniyet düzeylerini artırdığı vurgulanmaktadır. Benzer şekilde, Albayrak ve Caber'in (2018) rafting etkinliği üzerine gerçekleştirdikleri araştırmada, motivasyonun deneyim öncesi ve sonrası farklı biçimlerde tatmin üzerinde etkili olduğu özellikle deneyim sonrası motivasyon değerlendirmelerinin tatminin en güçlü belirleyicisi olduğu ortaya konmuştur. Tatık (2024) ise motivasyonel güdülerin, destinasyonda yaşanan deneyimi anlamlandırmada önemli rol oynadığını ve bunun davranışsal niyetlere doğrudan yansıdığını belirtmektedir. Bu bulgular, turistlerin motivasyonlarının yalnızca seyahat tercihlerinde değil deneyim kalitesini algılamalarında ve sonrasında ortaya çıkan davranışsal eğilimlerinde de belirleyici olduğunu göstermektedir. Satın alma sonrası davranışsal niyet, turistin gelecekte aynı ürün/hizmeti satın alma veya aynı sağlayıcıyla ilişki kurma konusundaki eğilimini ifade eder. Bu niyet, turistin önünde başka

alternatifler olsa bile aynı tercihi sürdürme bağlılığını içermektedir (Chen ve Chen, 2010; Rundle-Thiele, 2005).

Alanyazın incelendiğinde, turistlerin seyahat motivasyonlarını ya da davranışsal niyetlerini ele alan çok sayıda çalışmanın bulunduğu görülmektedir (Crompton, 1979; Yoon ve Uysal, 2005; Chen ve Chen, 2010; Zhao vd., 2025). Ancak hem motivasyon hem de deneyim ile satın alma sonrası davranışsal niyet arasındaki ilişkileri birlikte inceleyen araştırmaların oldukça sınırlı olduğu dikkat çekmektedir. Bu durum, söz konusu değişkenlerin bütüncül bir yaklaşımla ele alınmasının önemini ortaya koymakta ve mevcut çalışmanın literatüre katkısını vurgulamaktadır. Turist motivasyonu uzun yıllardır turizm araştırmalarında önemli bir değişken olarak ele alınmaktadır. Örneğin, Seyitoğlu (2020) tarafından Kapadokya örneğinde yapılan çalışmada öğrenme ve keşif gibi motivasyonların deneyim kalitesi ve destinasyon sadakati üzerinde anlamlı etkiler yarattığı ortaya konmuştur. Benzer şekilde Tatık (2024), motivasyonun destinasyon imajı ve davranışsal niyetleri şekillendirmedeki rolünü vurgulamıştır. Yabancı literatürde ise Chen ve Chen (2010), kültürel turizm bağlamında deneyim kalitesinin turist memnuniyeti ve davranışsal niyetler üzerinde doğrudan etkili olduğunu göstermiştir. Zhao vd. (2025) tarafından gerçekleştirilen araştırmada da seyahat motivasyonu ve algılanan değer, özellikle sağlık turizmi kapsamında, turistlerin davranışsal niyetlerini anlamlı biçimde etkilediği belirlenmiştir. Bu çalışmalar, motivasyon, deneyim ve davranışsal niyetlerin birbirinden bağımsız olarak önemli değişkenler olduğunu göstermektedir. Ancak bu değişkenlerin birlikte ele alınarak bütünsel bir çerçevede incelenmesi hem teorik katkı hem de destinasyon yönetimi açısından kritik bir gerekliliktir.

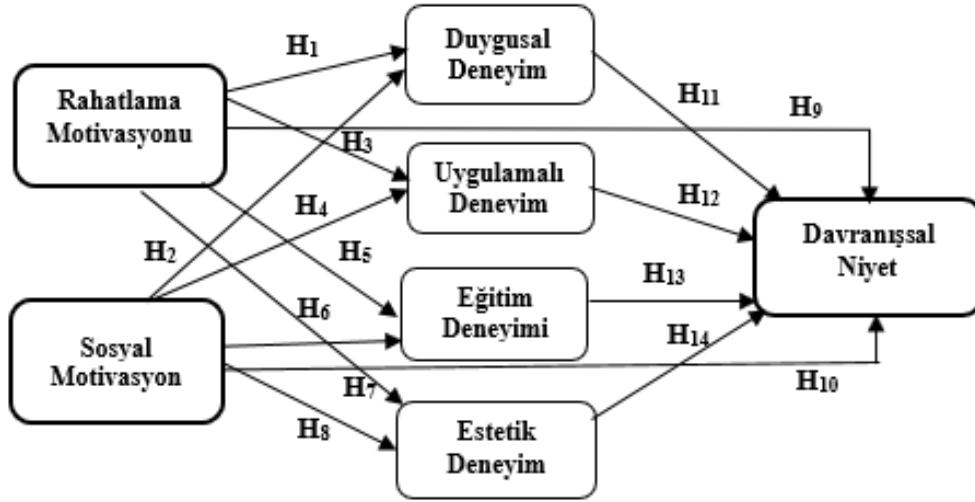
Genel olarak literatür turist motivasyonu, deneyim ve davranışsal niyet konularında önemli bulgular sunmaktadır. Ancak bu değişkenleri bütüncül bir yaklaşımla ele alan çalışmaların oldukça sınırlı olduğu görülmektedir (Bayar ve Ünal, 2025). Literatür, genellikle yeniden ziyaret etme ve tavsiye etme niyetine odaklanmış (Wang vd., 2012), turistik deneyim sonrası davranışsal niyetlere doğrudan odaklanan araştırmalar ise sınırlı kalmıştır. Bu bağlamda, mevcut çalışma motivasyon, deneyim ve satın alma sonrası davranışsal niyet arasındaki ilişkileri birlikte ele alarak literatürdeki bu boşluğu gidermeyi amaçlamaktadır. Böylelikle hem teorik düzeyde yeni bir katkı sunulmakta hem de destinasyon yöneticileri ve turizm işletmeleri için uygulanabilir stratejik çıkarımlar sağlanmaktadır. Araştırmanın temel amacı, turistlerin seyahat motivasyonları ve deneyimlerinin, satın alma sonrası davranışsal niyetleri nasıl şekillendirdiğini ortaya koymak ve bu yolla turizm alanındaki bilgi birikimine katkı sağlamaktır.

3. Yöntem

Bu araştırmada, Bodrum destinasyonunu ziyaret eden yerli turistlerin seyahat motivasyonları, deneyimleri ve satın alma sonrası davranışsal niyetleri arasındaki ilişkileri incelemek amacıyla nicel bir araştırma yaklaşımı benimsenmiştir.

Verilerin toplanmasında anket tekniği kullanılmıştır. Ankette, turistlerin motivasyon, deneyim ve satın alma sonrası davranışsal niyet ölçümlerinde kullanılacak maddelerin oluşturulmasında iki aşamalı bir yaklaşım izlenmiştir. İlk aşamada, ilgili değişkenlerin ölçümüne yönelik ifadeler kapsamlı literatür taraması sonucunda belirlenmiş ve önceki çalışmalarda geçerliliği kanıtlanmış ölçeklerden uyarlanmıştır. İkinci aşamada, hazırlanan taslak formun görünüş ve içerik geçerliliğini değerlendirmek amacıyla alan uzmanlarından oluşan bir panel görüşüne başvurulmuştur. Bu bağlamda, araştırmada kullanılan seyahat motivasyonu, turizm deneyimi ve satın alma sonrası davranışsal niyet ölçekleri, Adam ve Amuquandoh'un (2019) ve Adam vd., (2019) çalışmalarından uyarlanmıştır. Ölçekler araştırmanın amacına uygun olacak şekilde Türkçeye çevrilmiş ve dil geçerliliği sağlanmıştır. Tüm ifadeler 5'li Likert tipi ölçek ile ölçülmüştür. Veriler 15 Haziran–15 Eylül 2025 tarihleri arasında toplanmış olup bu süreçte toplam 430 anket dağıtılmış, 415 anket geri dönmüş ve eksik ya da hatalı doldurulan 18 anketin elenmesiyle birlikte analizlere 397 geçerli anket dâhil edilmiştir. Bu çalışmada, verilerin elde edilmesinde kolayda örnekleme yöntemi benimsenmiş olup analizler SPSS programı aracılığıyla gerçekleştirilmiştir.

Test edilecek yapısal model Şekil 1'de sunulmaktadır. Bu modelde, turistlerin seyahat motivasyonlarının, destinasyonda yaşadıkları deneyimlerin ve satın alma sonrası davranışsal niyetlerinin birbirleriyle olan ilişkileri incelenmektedir. Modelin oluşturulmasındaki temel amaç, Bodrum destinasyonunu ziyaret eden yerli turistlerin seyahat güdülerinin, destinasyondaki deneyimlerini nasıl şekillendirdiğini ve bu deneyimlerin de satın alma sonrası davranışsal niyetlerine (örneğin destinasyonu tekrar tercih etme ve başkalarına önerme eğilimi) nasıl yansıdığını ortaya koymaktır.



Şekil 1. Araştırmanın Yapısal Modeli

Bu bağlamda, motivasyonun deneyim ve davranışsal niyet üzerindeki etkilerini, ayrıca deneyimin davranışsal niyet üzerindeki rolünü açıklığa kavuşturmak amacıyla hipotezler geliştirilmiş ve modelle test edilmiştir

3.1. Motivasyon Boyutları ile Deneyim Boyutları Arasındaki İlişkiler

Turistleri seyahate yönelten motivasyonlar genellikle iki grupta ele alınır:

İtici (push) faktörler, bireyin içsel psikolojik ihtiyaçlarından doğan; kaçış, dinlenme, sosyalleşme, prestij, kişisel gelişim ve macera arayışı gibi nedenleri kapsar. Çekici (pull) faktörler ise destinasyonun doğal, kültürel, eğlence veya hizmet olanakları gibi dışsal çekiciliklerini ifade eder (Allan M., 2025; Yoon ve Uysal, 2005).

Bu iki faktör birlikte ele alındığında, turistin seyahat kararı ve destinasyona ilişkin algılarının daha bütüncül biçimde anlaşılmasına katkı sağlamaktadır. Çünkü turistlerin motivasyonları ile önceki seyahat deneyimleri, destinasyon imajının oluşumunda etkili olan temel bireysel faktörler arasında yer almaktadır (Baloglu ve McCleary, 1999). Turistik deneyim ise turistin bir destinasyonda yaşadığı duygusal, bilişsel ve fiziksel süreçlerin bütünüdür (Pine ve Gilmore, 2011).

Bu bağlamda turist motivasyonu, deneyim türlerini şekillendiren temel belirleyicilerden biridir. Özellikle rahatlama ve sosyal motivasyon unsurları bireylerin destinasyondan elde ettikleri deneyim biçimlerini anlamada kritik rol oynamaktadır (Poria vd., 2004; Biran vd., 2011). Turistlerin gevşeme, stres atma ve huzur bulma yönündeki rahatlama motivasyonu, destinasyondaki duygusal, uygulamalı ve estetik deneyimlerini güçlendirmektedir (Kim vd., 2012). Motivasyon ile deneyim arasındaki ilişki karşılıklı ve dinamik bir yapı sergiler.

Motivasyon, deneyimin türünü, derinliğini ve algılanan değerini belirleyen bir başlangıç noktasıdır; buna karşılık deneyim, bireyin sonraki motivasyonlarını ve davranışsal niyetlerini şekillendiren geri besleyici bir unsurdur. Dolayısıyla turizm literatüründe turist motivasyon deneyimin öncülü olarak; seyahat deneyim ise motivasyonun çıktısı ve gelecekteki seyahat davranışlarının belirleyicisi olarak görülmektedir (Prebensen vd., 2013). Bu kuramsal yaklaşımlar ışığında aşağıdaki hipotezler geliştirilmiştir:

H₁: Rahatlama motivasyonu, duygusal deneyimi pozitif ve anlamlı şekilde etkilemektedir.

H₂: Sosyal motivasyon, duygusal deneyimi pozitif ve anlamlı şekilde etkilemektedir.

H₃: Rahatlama motivasyonu, uygulamalı deneyimi pozitif ve anlamlı şekilde etkilemektedir.

H₄: Sosyal motivasyon, uygulamalı deneyimi pozitif ve anlamlı şekilde etkilemektedir.

H₅: Rahatlama motivasyonu, eğitim deneyimini pozitif ve anlamlı şekilde etkilemektedir.

H₆: Sosyal motivasyon, eğitim deneyimini pozitif ve anlamlı şekilde etkilemektedir.

H₇: Rahatlama motivasyonu, estetik deneyimi pozitif ve anlamlı şekilde etkilemektedir.

H₈: Sosyal motivasyon, estetik deneyimi pozitif ve anlamlı şekilde etkilemektedir.

3.2. Motivasyon Boyutları ile Davranışsal Niyet Arasındaki Doğrudan İlişkiler

Motivasyon, yalnızca deneyim türlerini değil, aynı zamanda turistlerin tekrar ziyaret etme, başkalarına önerme veya destinasyona yönelik olumlu davranışsal eğilimlerde bulunma niyetlerini doğrudan etkileyen önemli bir psikolojik değişkendir (Yoon ve Uysal, 2005). Özellikle rahatlama motivasyonu, turistlerin zihinsel tatmin düzeyini artırarak gelecekteki niyetleri güçlendirirken; sosyal motivasyon, grup aidiyeti ve paylaşım isteği yoluyla destinasyona yönelik bağlılığı artırmaktadır (Chen ve Chen, 2010; Prayag vd., 2013). Bu kuramsal temeller doğrultusunda aşağıdaki hipotezler geliştirilmiştir:

H₉: Rahatlama motivasyonu, davranışsal niyeti pozitif ve anlamlı şekilde etkilemektedir.

H₁₀: Sosyal motivasyon, davranışsal niyeti pozitif ve anlamlı şekilde etkilemektedir.

3.3. Deneyim Boyutları ile Davranışsal Niyet Arasındaki İlişkiler

Turizm literatüründe “deneyimsel tüketim” yaklaşımı, turistlerin destinasyonlardaki duygusal, uygulamalı, eğitimsel ve estetik deneyimlerinin, onların gelecekteki davranışsal niyetlerini (tekrar ziyaret, tavsiye etme, sadakat vb.) önemli ölçüde etkilediğini vurgulamaktadır (Pine ve Gilmore, 2011; Oh vd., 2007). Özellikle duygusal ve estetik deneyimlerin turistlerin destinasyona karşı duygusal bağını güçlendirdiği, uygulamalı ve eğitimsel deneyimlerin ise algılanan değeri ve öğrenme memnuniyetini artırdığı belirtilmektedir (Hosany ve Gilbert,

2010; Kim vd., 2012; Zhou, M., ve Wang, X., 2024). Bu kuramsal temeller doğrultusunda aşağıdaki hipotezler geliştirilmiştir:

H₁₁: Duygusal deneyim, davranışsal niyeti pozitif ve anlamlı şekilde etkilemektedir.

H₁₂: Uygulamalı deneyim, davranışsal niyeti pozitif ve anlamlı şekilde etkilemektedir.

H₁₃: Eğitim deneyimi, davranışsal niyeti pozitif ve anlamlı şekilde etkilemektedir.

H₁₄: Estetik deneyim davranışsal niyeti pozitif ve anlamlı şekilde etkilemektedir.

4. Bulgular

Katılımcılara ilişkin tanıtıcı özellikleri belirlemek amacıyla yapılan frekans analizi sonucunda, araştırmaya katılanların %54'ünün erkek, %46'sının ise kadın olduğu görülmüştür. Yaş dağılımına bakıldığında, katılımcıların yaklaşık yarısının 27–48 yaş aralığında yer aldığı; çoğunluğunun evli ve önemli bir kısmının üniversite mezunu olduğu tespit edilmiştir.

4.1. Değişkenlere Yönelik Açıklayıcı Faktör Analizi

Seyahat motivasyonu, seyahat deneyimi ve davranışsal niyet ölçeklerinin boyutsal yapılarının belirlenmesi ile bu ölçeklerin güvenilirlik ve geçerlilik düzeylerinin tespiti amacıyla açıklayıcı faktör analizi uygulanmıştır. Öncelikle ölçeklerin güvenilirliğini ölçmek üzere yapılan analizde, Cronbach Alfa katsayısı seyahat motivasyonu ölçeği için ,854; seyahat deneyimi ölçeği için ,852 ve davranışsal niyet ölçeği için ,838 olarak bulunmuştur. Nunnally (1978) belirttiği üzere bu değerlerin 0,70'in üzerinde olması ölçeklerin güvenilir ve geçerli olduğunu göstermektedir.

Tablo 1. Ölçeklere Yönelik Faktör Analizi ve Ortalamalar

Seyahat Motivasyonu	Faktör Yükleri	Varyans %	C. Alfa
Rahatlama Motivasyonu			
Fiziksel olarak yenilendim	,898	35,80	0,931
Duygusal olarak yenilendim	,881		
Dinlendim	,863		
Hayatımın sıkıntılarını ve endişelerini unuttum.	,858		
Günlük rutinlerimden uzağım.	,844		
İçsel bir uyum / barış hissine sahibim	,842		
Güzel havanın tadını çıkardım	,698		
Sosyal Motivasyon			
Arkadaşlarla vakit geçirdim.	,832	29,12	0,877
Kendimi Bodrum insanlarıyla ilişkilendiriyorum.	,810		
Benzer ilgi alanlarına sahip insanlarla etkileşime girdim.	,791		
Bodrumda yerel insanlarla tanıştım.	,764		
Ait olma hissine sahibim.	,729		
Ailemle zaman geçirdim.	,686		
Başkaları ile arkadaş oldum.	,682		
Cronbach Alfa: 0,854 Çıkarım Yöntemi: Temel Bileşenler Analizi, Döndürme Yöntemi: Kaiser Normalleştirme ve Varimax, İterasyon Sayısı: 3; KMO Uygunluk Ölçütü: 0,859. Barlett Küresellik Testi x2: 3200,713 p: 0,000			

Seyahat Deneyimi	Faktör Yükleri	Varyans %	C. Alfa
Eğitim Deneyimi			
Bodrum kalesi hakkında bilgi sahibi oldum.	,813	20,07	0,842
Bodrum mirasını öğrendim.	,803		
Bodrum bana yeni deneyimler sağlamadı.	,759		
Bu cazibe beni hayatım hakkında düşündürdü	,652		
Bodrum tarihi hakkında bilgi edindim.	,572		
Duygusal Deneyim			
Bodrum bendeki mutluluğa ilham kaynağı oldu.	,826	17,65	0,806
Bodrum hakkındaki düşüncem olumlu yönde değişti	,817		
Bodrum rahatlamama yardımcı oldu	,794		
Uygulamalı Deneyim			
Çalışanlar bize karşı duyarlıydı	,698	13,73	0,709
Gezi deneyimim iyiydi.	,667		
Bodrumun bendeki hikâyesi tamamlandı.	,629		
Bodrum gezilerinin tamamı ilginçti	,599		
Estetik Deneyim			
Bodrumda sağlık önlemleri iyiydi	,869	12,60	0,714
Bodrum çevresinde temizlik işleri iyiydi	,783		
Bodrumdaki çekicilikler iyi durumda idi.	,667		
Cronbach Alfa: 0,852 Çıkarım Yöntemi: Temel Bileşenler Analizi, Döndürme Yöntemi: Kaiser Normalleştirilmesi ve Varimax, İterasyon Sayısı: 8; KMO Uygunluk Ölçütü: 0,766. Barlett Küresellik Testi x2: 2330,264 p: 0,000			
Davranışsal Niyet	Faktör Yükleri	Varyans %	C. Alfa
Bodrumu arkadaşlarıma / akrabalarıma önereceğim.	,928	77,48	0,838
Gelecekte tekrar Bodrumu ziyaret edeceğim.	,883		
Başka cazibe merkezleri yerine Bodrumu ziyaret edeceğim.	,827		
Cronbach Alfa: 0,838 Çıkarım Yöntemi: Temel Bileşenler Analizi, Döndürme Yöntemi: Kaiser Normalleştirilmesi; KMO Uygunluk Ölçütü: 0,677. Barlett Küresellik Testi x2: 495,979 p: 0,000			

Öncelikle seyahat motivasyonu ölçeğine yapılan faktör analizi sonucunda, Kaiser Normalleştirilmesinde, özdeğeri 1’den büyük faktörler dikkate alınmış ve ölçeğin 2 faktörden oluştuğu belirlenmiştir. Bu faktörler orijinal ölçekte olduğu gibi, rahatlatma motivasyonu ve sosyal motivasyon olarak isimlendirilmiştir. Ölçeğin toplam açıklanan varyans oranı %64,92 olarak hesaplanmıştır. Bu oran %50’nin üzerinde olduğundan, analiz sonuçlarının açıklayıcılık düzeyi yeterli ve modelin geçerli olduğu kabul edilmektedir (Hair vd., 2019). Ölçeğin Cronbach’s Alfa değerinin de 0,85 olduğu görülmektedir. Nunnally (1978) 0,70 ve üzeri Cronbach katsayısının iyi düzeyde içsel güvenilirliğe işaret ettiğini belirtmektedir. Diğer yandan seyahat deneyimine ilişkin yapılan açıklayıcı faktör analizinde ölçeğin 4 faktörden oluştuğu tespit edilmiştir. Bu faktörler orijinal ölçekte olduğu gibi, eğitim deneyimi, duygusal deneyim, uygulamalı deneyim ve estetik deneyim olarak isimlendirilmiştir. Motivasyonu ve sosyal motivasyon olarak isimlendirilmiştir. Ölçeğin varyans yüzdesi toplamı 64,92 çıkmıştır. Cronbach’s Alfa değerinin de; 0,85 olduğu görülmektedir.

Açıklayıcı faktör analizinde ortak varyans (communality) değerleri ile ölçekteki maddelerin değerlerinin 0,4’ten düşük olmaması gerekmektedir (Field, 2000). Yapılan bu faktör analizinde, bir ifade binişik olarak yüklendiği için, çıkarılmış ve faktör analizi tekrar

yapılmıştır. Son olarak davranışsal niyet ölçeğine açıklayıcı faktör analizi yapılmış ve ölçeğin tek faktörden oluştuğu belirlenmiştir. Ölçeğin varyans yüzdesi toplamı 64,05 çıkmıştır. Cronbach's Alfa değerinin de; 0,84 olduğu görülmektedir.

4.2. Değişkenler Arası İlişkiler

Korelasyon analizine geçilmeden önce, verilerin dağılımının normalliği çarpıklık (skewness) ve basıklık (kurtosis) değerleri kullanılarak test edilmiştir. Tabachnick ve Fidell'e (2013) göre, çarpıklık ve basıklık değerlerinin -1.5 ile +1.5 aralığında olması verilerin normal dağıldığını göstermektedir. Bu kriter doğrultusunda, araştırmada elde edilen verilerin normal dağılım gösterdiği belirlenmiş ve buna bağlı olarak Pearson korelasyon testi uygulanmıştır.

Tablo 2. Değişkenler Arasındaki Korelasyon Analizi

Boyutlar	DD	UD	ED	ESD	DN
Rahatlama	,177**	,187**	,101	,040	,179**
Sosyal Motivasyon	,182**	,242**	,258**	,190**	,380**
Duygusal Deneyim (DD)	1	,370**	,459**	,198**	,218**
Uygulamalı Deneyim (UD)	,370**	1	,455**	,265**	,368**
Eğitim Deneyimi (ED)	,459**	,455**	1	,273**	,272**
Estetik Deneyim (ESD)	,190**	,265**	,273**	1	,467**

** $p < 0.01$, DN: Davranışsal Niyet

Değişkenler arasındaki ilişkiyi tespit etmek için yapılan Pearson korelasyon testi Tablo 2'de yer almaktadır. Pearson Korelasyon kat sayılarına bakıldığında, seyahat motivasyonlarında biri olan Rahatlama boyutu ile duygusal deneyim ($r=0,177$; $p<0,01$), uygulamalı deneyim ($r=0,187$; $p<0,01$) ve davranışsal niyet ($r=0,179$; $p<0,01$) arasında pozitif yönde zayıf seviyede bir ilişki belirlenmiştir. Bir diğer seyahat motivasyon boyutu olan sosyal motivasyon ile duygusal deneyim ($r=0,182$; $p<0,01$), uygulamalı deneyim ($r=0,242$; $p<0,01$), eğitim deneyimi ($r=0,258$; $p<0,01$), estetik deneyim ($r=0,190$; $p<0,01$) ve davranışsal niyet ($r=0,380$; $p<0,01$) arasında pozitif bir ilişki saptanmıştır. Bununla birlikte, seyahat deneyiminin bütün faktörleri ile davranışsal niyet arasında pozitif ilişkiler tablo da görülmektedir.

4.3. Hipotezlerin Testi

Tablo 3'te verilen modelin test edilebilmesi için yukarıda geliştirilen hipotezler için çoklu regresyon analizleri gerçekleştirilmiştir.

Tablo 3. Değişkenler Arasındaki Regresyon Analizine İlişkin Modeller

<i>Model 1 (Bağımlı Değişken: Duygusal Deneyim)</i>			
<i>Bağımsız Değişken</i>	<i>Beta</i>	<i>t</i>	<i>P</i>
<i>Rahatlama</i>	,161	3,017	,003
<i>Sosyal Motivasyon</i>	,166	3,112	,002
R=,242; R ² =,059; Düzeltilmiş R ² =,053; F=10,39; p= 0.000; Tolerans=0,991; VIF= 1, 009; DW: 1,591			
<i>Model 2 (Bağımlı Değişken: Uygulamalı Deneyim)</i>			
<i>Bağımsız Değişken</i>	<i>Beta</i>	<i>t</i>	<i>P</i>
<i>Rahatlama</i>	,165	3,137	,002
<i>Sosyal Motivasyon</i>	,227	4,305	,000
R=,293; R ² =,086; Düzeltilmiş R ² =,080; F=15,63; p= 0.000; Tolerans=0,991; VIF= 1, 009; DW: 1,588			
<i>Model 3 (Bağımlı Değişken: Eğitim Deneyimi)</i>			
<i>Bağımsız Değişkenler</i>	<i>Beta</i>	<i>t</i>	<i>P</i>
<i>Rahatlama</i>	,077	1,445	,149
<i>Sosyal Motivasyon</i>	,251	4,725	,000
R=,269; R ² =,072; Düzeltilmiş R ² =,067; F=12,98; p= 0.000; Tolerans=0,991; VIF= 1, 009; DW: 1,244			
<i>Model 4 (Bağımlı Değişken: Estetik Deneyim)</i>			
<i>Bağımsız Değişkenler</i>	<i>Beta</i>	<i>t</i>	<i>P</i>
<i>Rahatlama</i>	,022	,414	,679
<i>Sosyal Motivasyon</i>	,188	3,479	,001
R=,191; R ² =,037; Düzeltilmiş R ² =,031; F=6,34; p= 0.000; Tolerans=0,991; VIF= 1, 009; DW: 1,738			
<i>Model 5 (Bağımlı Değişken: Davranışsal Niyet)</i>			
<i>Bağımsız Değişkenler</i>	<i>Beta</i>	<i>t</i>	<i>P</i>
<i>Rahatlama</i>	,104	2,047	,041
<i>Sosyal Motivasyon</i>	,370	7,306	,000
R=,393; R ² =,155; Düzeltilmiş R ² =,150; F=30,50; p= 0.000; Tolerans=0,991; VIF= 1, 009; DW: 1,647			
<i>Model 6 (Bağımlı Değişken: Davranışsal Niyet)</i>			
<i>Bağımsız Değişkenler</i>	<i>Beta</i>	<i>t</i>	<i>P</i>
<i>Duygusal Deneyim</i>	,035	,648	,517
<i>Uygulamalı Deneyim</i>	,233	4,321	,000
<i>Eğitim Deneyimi</i>	,045	,793	,429
<i>Estetik Deneyim</i>	,386	7,866	,000
R=,534; R ² =,285; Düzeltilmiş R ² =,277; F=33,06; p= 0.000; Tolerans=0,680-0,898; VIF= 1, 114-1,471; DW: 1,697			

Öncelikle ayrı ayrı regresyon tabloları oluşturmamak için, bağımsız değişkenlerin bağımlı değişkenler üzerindeki etkisini yönelik olarak tek bir tabloda ayrı ayrı çoklu regresyon modelleri kurulmuştur.

1. modelde seyahat deneyimlerinden biri olan duygusal deneyim üzerinde rahatlama ($\beta=,161$; $p=,003$) ve sosyal motivasyon ($\beta=,166$; $p=,002$) değişkenlerinin pozitif ve anlamlı bir etkisinin olduğu yönündedir 2. modelde uygulamalı deneyim üzerinde rahatlama ($\beta=,165$;

$p=,002$) ve sosyal motivasyon ($\beta=,227$; $p=,000$) değişkenlerinin pozitif ve anlamlı etkisi saptanmıştır. 3. modelde eğitim deneyimi üzerinde rahatlama değişkeninin ($\beta=,077$; $p=,149$) anlamlı bir etkisi olmadığı; sosyal motivasyon ($\beta=,251$; $p=,000$) değişkeninin ise pozitif ve anlamlı etkisi olduğu tespit edilmiştir. 4. modelde estetik deneyimi üzerinde rahatlama değişkeninin ($\beta=,022$; $p=,679$) anlamlı bir etkisi olmadığı; sosyal motivasyon ($\beta=,188$; $p=,001$) değişkeninin ise pozitif ve anlamlı etkisi olduğu belirlenmiştir. 5. modelde ise davranışsal niyet üzerinde seyahat motivasyon boyutlarından rahatlama ($\beta=,101$; $p=,041$) ve sosyal motivasyon ($\beta=,370$; $p=,000$) değişkenlerinin pozitif ve anlamlı etkisi olduğu tespit edilmiştir. 6. modelde yine davranışsal niyet üzerinde seyahat deneyimi boyutlarından duygusal uygulamalı deneyim ($\beta=,233$; $p=,000$) ve estetik deneyim ($\beta=,386$; $p=,000$) değişkenlerinin pozitif ve anlamlı etkisi belirlenirken; duygusal deneyim ($\beta=,035$; $p=,517$) ve eğitim deneyimi ($\beta=,045$; $p=,429$) değişkeninin anlamlı bir etkisi saptanmamıştır.

Ayrıca kurulan tüm modellerde çoklu bağıntı ve oto-korelasyon (multicollinearity) olup olmadığı test edilmiştir. Tüm VIF, Tolerans ve Durbin Watson değerleri değişkenler arasında çoklu bağıntı ve oto-korelasyon olmadığını göstermektedir (Field, 2000). Bu bölümde araştırma hipotezlerinin test edilmesi sonucunda elde edilen sonuçları sunulmaktadır.

Tablo 4. Yapısal Modele İlişkin Hipotez Testi Sonuçları

<i>Hipotezler</i>				<i>Standardize Edilmiş Değerler</i>	<i>t-değeri</i>	<i>P Değeri</i>	<i>Sonuç</i>
H_1	Rahatlama Motivasyonu	→	Duygusal Deneyim	,161	3,017	,003	Kabul
H_2	Sosyal Motivasyon	→	Duygusal Deneyim	,166	3,112	,002	Kabul
H_3	Rahatlama Motivasyonu	→	Uygulamalı Deneyim	,165	3,137	,002	Kabul
H_4	Sosyal Motivasyon	→	Uygulamalı Deneyim	,227	4,305	,000	Kabul
H_5	Rahatlama Motivasyonu	→	Eğitim Deneyimi	,077	1,445	,149	Ret
H_6	Sosyal Motivasyon	→	Eğitim Deneyimi	,251	4,725	,000	Kabul
H_7	Rahatlama Motivasyonu	→	Estetik Deneyim	,022	,414	,679	Ret
H_8	Sosyal Motivasyon	→	Estetik Deneyim	,188	3,479	,001	Kabul
H_9	Rahatlama Motivasyonu	→	Davranışsal Niyet	,104	2,047	,041	Kabul
H_{10}	Sosyal Motivasyon	→	Davranışsal Niyet	,370	7,306	,000	Kabul

H_{11}	Duygusal Deneyim	→	Davranışsal Niyet	,035	,648	,517	Ret
H_{12}	Uygulamalı Deneyim	→	Davranışsal Niyet	,233	4,321	,000	Kabul
H_{13}	Eğitim Deneyimi	→	Davranışsal Niyet	,045	,793	,429	Ret
H_{14}	Estetik Deneyim	→	Davranışsal Niyet	,386	7,866	,000	Kabul

Yapısal modelin sonuçları, önerilen 14 hipotezden 10'unun kabul, 4'ünün ise reddedildiğini göstermektedir. Öncelikle, rahatlama motivasyonunun duygusal deneyim (H_1 : $\beta=,161$; $p=,003$) ve uygulamalı deneyim (H_3 : $\beta=,165$; $p=,002$) üzerindeki etkileri pozitif ve anlamlı bulunmuş, bu nedenle her iki hipotez kabul edilmiştir. Ancak rahatlama motivasyonunun eğitim deneyimi (H_5 : $\beta=,077$; $p=,149$) ve estetik deneyim (H_7 : $\beta=,022$; $p=,679$) üzerindeki etkileri anlamlı çıkmamış, bu hipotezler reddedilmiştir.

Sosyal motivasyon açısından değerlendirildiğinde, bu değişkenin duygusal (H_2 : $\beta=,166$; $p=,002$), uygulamalı (H_4 : $\beta=,227$; $p=,000$), eğitim (H_6 : $\beta=,251$; $p=,000$) ve estetik deneyim (H_8 : $\beta=,188$; $p=,001$) boyutları üzerinde anlamlı ve pozitif etkilerinin olduğu belirlenmiş, dolayısıyla bu dört hipotez de kabul edilmiştir. Bu sonuç, sosyal etkileşim ve aidiyet duygusunun turistlerin deneyimlerinin tüm boyutlarında önemli bir belirleyici olduğunu göstermektedir.

Davranışsal niyet üzerindeki etkiler incelendiğinde, rahatlama motivasyonu (H_9 : $\beta=,104$; $p=,041$) ve sosyal motivasyonun (H_{10} : $\beta=,370$; $p=,000$) davranışsal niyet üzerinde pozitif ve anlamlı etkileri olduğu tespit edilmiştir; bu nedenle her iki hipotez de kabul edilmiştir. Buna karşılık, duygusal deneyim (H_{11} : $\beta=,035$; $p=,517$) ve eğitim deneyiminin (H_{13} : $\beta=,045$; $p=,429$) davranışsal niyet üzerindeki etkileri anlamlı bulunmamış, dolayısıyla bu hipotezler reddedilmiştir. Öte yandan, uygulamalı deneyim (H_{12} : $\beta=,233$; $p=,000$) ve estetik deneyim (H_{14} : $\beta=,386$; $p=,000$) değişkenlerinin davranışsal niyet üzerindeki etkileri pozitif ve anlamlı bulunmuş, her iki hipotez de kabul edilmiştir.

Genel olarak değerlendirildiğinde, model sonuçları turistlerin sosyal motivasyon ve estetik deneyim unsurlarına verdikleri önemi, destinasyona yönelik davranışsal niyetleri güçlendirdiğini göstermektedir. Bu bulgular, destinasyon yöneticileri ve turizm işletmeleri açısından, sosyal etkileşimi destekleyen ve estetik deneyim unsurlarını zenginleştiren stratejilerin ziyaretçi memnuniyeti ve tekrar ziyaret niyetini artırmada kritik bir rol oynayabileceğini ortaya koymaktadır.

5. Sonuç ve Tartışma

Bu araştırma, Bodrum destinasyonunu ziyaret eden yerli turistlerin seyahat motivasyonları, deneyimleri ve satın alma sonrası davranışsal niyetleri arasındaki ilişkileri incelemiştir. Bulgular, seyahat motivasyonunun turistlerin deneyimlerini ve davranışsal niyetlerini anlamlı biçimde etkilediğini; aynı zamanda deneyimin de davranışsal niyet üzerinde doğrudan etkili olduğunu göstermektedir. Bu bulgu, motivasyon, deneyim ve satın alma sonrası davranışsal niyet arasındaki ilişkilerin birbirini tamamlayan yapılar olduğunu ortaya koymaktadır. Araştırmada elde edilen sonuçlar, rahatlama motivasyonunun turistlerin duygusal ve uygulamalı deneyimleri üzerinde anlamlı ve pozitif bir etkiye sahip olduğunu göstermiştir. Bu durum, Bodrum destinasyonunu ziyaret eden turistlerin gündelik yaşamın stresinden uzaklaşma, dinlenme ve yenilenme arzusu taşıdıklarını göstermektedir. Benzer biçimde Adam ve Amuquandoh'un (2019) çalışmasında da rahatlama motivasyonunun tüm etnik gruplar arasında duygusal deneyimi güçlendirdiği belirtilmiştir. Bu bağlamda, Bodrum'un turistik çekiciliğinin önemli bir kısmının "rahatlama ve huzur" teması etrafında şekillendiği söylenebilir.

Araştırmanın bir diğer önemli sonucu, sosyal motivasyonun turist deneyiminin tüm boyutları (duygusal, uygulamalı, eğitimsel ve estetik) üzerinde anlamlı bir etkiye sahip olduğudur. Sosyal motivasyon özellikle yerel halkla etkileşim kurma, ait olma hissi geliştirme ve diğer turistlerle sosyal bağ kurma isteği ile açıklanabilir. Bu bulgu, Cajiao vd. (2022) Antarktika örnekleminde elde ettiği sonuçlarla da örtüşmektedir. Söz konusu çalışmada, "sosyal bağ kurma" (social bonding) motivasyonunun, ziyaretçilerin hem öğrenme hem de duygusal tatmin düzeylerini anlamlı biçimde artırdığı ve genel deneyim kalitesine katkı sağladığı belirlenmiştir. Dolayısıyla sosyal motivasyonun, turistlerin deneyimsel çıktıları üzerindeki bu çok boyutlu etkisi, destinasyon yönetiminde ve pazarlama stratejilerinde dikkate alınması gereken önemli bir faktör olarak değerlendirilebilir. Sosyal etkileşimi ve topluluk hissini destekleyen turizm uygulamaları, turistlerin duygusal ve bilişsel tatminini güçlendirerek, daha sürdürülebilir ve katılımcı bir turizm deneyiminin oluşmasına katkı sağlayacaktır.

Araştırma sonuçları, turistlerin estetik ve uygulamalı deneyimlerinin davranışsal niyet üzerinde anlamlı ve pozitif etkiler yarattığını ortaya koymuştur. Bu bulgu, destinasyonda geçirilen deneyimlerin, özellikle görsel estetik unsurlar ve katılımcı etkinliklerle zenginleştirilen uygulamalı faaliyetlerin, turistlerin yeniden ziyaret etme ve destinasyonu başkalarına tavsiye etme eğilimlerini artırdığını göstermektedir. Buna karşılık, duygusal ve eğitimsel deneyimlerin davranışsal niyet üzerinde anlamlı bir etkisi olmadığı tespit edilmiştir.

Bu sonuçlar, Huddin vd. (2024)'ün müşteri deneyiminin güven ve sadakat üzerindeki pozitif etkisini vurgulayan bulgularıyla örtüşmekte; olumlu deneyimlerin destinasyona yönelik güveni ve uzun vadeli bağlılığı güçlendirebileceğini desteklemektedir. Dolayısıyla Bodrum'un estetik değerleri (tarihi dokusu, doğal çevresi, mimarisi vb.) ve ziyaretçilerin etkin katılımını sağlayan deneyimsel unsurların destinasyonun sürdürülebilir rekabet gücüne katkı sağladığı söylenebilir. Bu sonuç, Rasoolimanesh vd. (2021) tarafından miras turizmi bağlamında yürütülen çalışmayla da paralellik göstermektedir. Söz konusu araştırmada, turist deneyiminin çok boyutlu yapısının (duygusal, bilişsel, estetik) davranışsal niyet üzerinde doğrudan ve güçlü bir etkisi olduğu kanıtlanmıştır.

Araştırma sonuçları genel olarak, rahatlama motivasyonunun ve sosyal motivasyonun turistlerin davranışsal niyetleri üzerinde anlamlı ve pozitif etkiler yarattığını göstermektedir. Bu bulgu, seyahat motivasyonlarının yalnızca destinasyon seçimini değil, aynı zamanda ziyaret sonrası davranışsal eğilimleri de şekillendirdiğini ortaya koymaktadır. Elde edilen sonuçlar, Coşkuner ve Kozak (2025) tarafından termal turizm bağlamında gerçekleştirilen çalışmanın bulgularıyla örtüşmektedir. Söz konusu çalışmada da turistlerin rahatlama ve sosyal etkileşim temelli motivasyonlarının, yeniden ziyaret etme ve tavsiye etme niyetleri üzerinde belirleyici olduğu vurgulanmaktadır. Özellikle sosyal motivasyonun yüksek etki düzeyi, turistlerin destinasyonda kurdukları sosyal ilişkiler, aidiyet duygusu, yerel halk ve diğer turistlerle etkileşim gibi faktörlerin, destinasyona yönelik bağlılığı ve tekrar ziyaret etme niyetini güçlendirdiğini göstermektedir. Rahatlama motivasyonunun anlamlı etkisi ise, turistlerin stres ve gündelik yaşamdan uzaklaşma arzusunun, seyahat sonrası memnuniyetlerini artırarak destinasyona yönelik olumlu tutum geliştirmelerine katkıda bulunduğunu göstermektedir. Dolayısıyla hem sosyal hem de rahatlama temelli motivasyonların turistlerin davranışsal niyetlerinin oluşumunda temel belirleyiciler olduğu söylenebilir. Bu sonuç, turistlerin deneyimlerinde sosyal bağ kurma, huzur ve yenilenme gibi duygusal unsurların destinasyon sadakati ve olumlu ağızdan ağıza iletişimi destekleyen önemli bileşenler olduğunu ortaya koymaktadır.

5.1. Pratik ve Sektörel Katkılar

Bu araştırmadan elde edilen bulgular, Bodrum destinasyonunda faaliyet gösteren turizm paydaşları için önemli pratik ve yönetsel çıkarımlar sunmaktadır. Bu doğrultuda, huzur ve yenilenme temalı turistik ürünlerin geliştirilmesi, sosyal etkileşimi teşvik eden yerel etkinlikler ve deneyimsel faaliyetlerin artırılması, turist memnuniyetini ve tekrar ziyaret niyetini güçlendirecektir. Ayrıca, estetik değerler ve ziyaretçilerin aktif katılımını sağlayan

uygulamalı deneyimlerin ön plana çıkarılması destinasyonun rekabet gücünü ve olumlu ağızdan ağıza iletişimi destekleyecektir. Sonuç olarak bu çalışmada, Bodrum destinasyonunda turizm sektörünün geleceğine yönelik olarak deneyimi merkezine alan, sosyal etkileşimi güçlendiren ve rahatlama temelli değer önerileri sunan bütüncül bir destinasyon yönetimi anlayışının geliştirilmesi gerektiğini ortaya koymaktadır. Bu yönüyle araştırma, yalnızca akademik literatüre değil aynı zamanda turizm planlamacıları, destinasyon yöneticileri ve işletmeler için uygulanabilir ve stratejik yol haritaları sunmaktadır.

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The Relationship Between Human Development and Selected Macroeconomic Variables: The Case of Türkiye

İnsani Gelişme İle Seçilmiş Makroekonomik Değişkenler Arasındaki İlişki: Türkiye Örneği

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Abstract: Human development is a concept expressing the richness of human life rather than the richness of the economy in which people live. It is a multidimensional approach that puts the individual at the centre, provides opportunities worthy of human dignity, and incorporates numerous social and economic components. Human Development Index is an important indicator measuring the socio-economic development levels of countries. This study investigates the relationship between the human development index and selected macroeconomic variables in Türkiye for the period 2000 -2024 by employing annual time series and statistical analyses. The results indicate that, in the long term, only GDP per capita has a statistically significant relationship with the Human Development Index. The study found that a 1% increase in GDP per capita leads to an approximate 0.23% increase in the HDI. No other variables were found to have a significant effect in the long term.

Keywords: Human Development Index, Economic Development, Income Inequality, Time Series

JEL Classification: D30, O10, O11

Öz: İnsani gelişme bireylerin içinde bulundukları ekonominin zenginliğinden öte insan hayatının zenginliğini ifade eden bir kavramdır. İnsanı merkezine alan, insan onuruna yakışır imkânlar sunan, sosyal ve ekonomik birçok unsuru bünyesinde barındıran çok boyutlu bir yaklaşımdır. İnsani Gelişme Endeksi ülkelerin sosyoekonomik gelişmişliklerini ölçen önemli bir endekstir. Bu çalışmada Türkiye’de 2000-2024 dönemi için insani gelişme endeksi ve seçilmiş makroekonomik değişkenler arasındaki ilişki yıllık zaman serileri kullanılarak istatistiksel analiz yardımıyla incelenmiştir. Çalışma sonucunda, uzun dönemde yalnızca kişi başına düşen gelirin İnsani Gelişme Endeksi ile istatistiksel açıdan anlamlı bir ilişkiye sahip olduğunu göstermektedir. Çalışma sonucunda, kişi başına gelirdeki %1’lik bir artışın İGE’de yaklaşık %0,23 oranında artışa neden olacağı belirlenmiştir. Diğer değişkenlerin ise uzun dönemde anlamlı bir etkisi tespit edilmemiştir.

Anahtar Sözcükler: İnsani Gelişme Endeksi, Ekonomik Kalkınma, Gelir Eşitsizliği, Zaman Serisi

JEL Sınıflandırması: D30, O10, O11

1. Introduction

It is mentioned in the United Nations development programs that the concepts of development and growth are not identical, and that the concept of development must be handled in a much broader dimension including multiple factors. A human-oriented development model and the sustainability of such a model are among the essential objectives of countries. While economic

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growth contributes to development, it is not sufficient on its own to ensure improvements in human well-being.

When the human development reports dealing with socio-economic development in Türkiye between 2011 and 2023 within the framework of HDI are analyzed, it is revealed that human development has tended to increase over the years. Türkiye, which had an index score of 0.699 in 2011, managed to raise its index score to 0.853 in 2023. With this score, Türkiye was classified as a country with very high human development, ranking 51st among 193 countries.

This study consists of three parts. In the first part of the study, the theoretical framework related to the topic will be explained. In the second part of the study, the literature review will be presented. As for the third part of the study, the relationship between socio-economic development and selected macroeconomic variables will be examined using statistical analysis. In the conclusion, the findings derived from the analysis will be discussed and recommendations will be presented.

2. Theoretical Framework

2.1. Human Development Index (HDI)

The Human Development Index (HDI) is a measure created by taking into account a number of basic indicators that will improve human welfare, emphasizing that economic growth is not the only criterion for the development of a country, but is based on the human factor. Since its introduction, the HDI has been an index that has the ability to shift the benchmark of progress in issues related to economic development from economic growth to human-centered strategies (Ul Haq, 1995). This perspective is rooted in Amartya Sen's capability approach, which provides the historical and intellectual underpinning of the human development concept. (Sen, 1999). The index is formed by combining a set of criteria necessary for human development. The measurement of human development is determined through assessing these three dimensions using four basic indicators. As a result of taking the geometric mean of these three dimensions, the Human Development Index has a value between 0 and 1. The closer the score is to 1, the higher the level of human development, and the further it is from 1, the lower the level. HDI values determine the socio-economic development of all countries and evaluate the changes of countries over time.

This turning point underscored the vulnerability of human development to wide-ranging global shocks. It also showed that progress in HDI cannot be viewed separately from the strength

of health systems, the continuity of education, and overall socio-economic resilience. The years following 2019 highlighted the need for stronger social protection mechanisms, more equitable access to health and education, and policies capable of helping countries absorb and recover from multidimensional crises.

Table 1. The Top 10 Countries With Very High HDI and Their HDI Values

		Human Development Index (HDI)								Change in HDI Rank
Country		Value								
HDI rank	Very High Human Development	1990	2000	2010	2015	2020	2021	2022	2023	2015-2023
1	Iceland	0.841	0.902	0.935	0.956	0.965	0.967	0.964	0.972	2
2	Norway	0.856	0.924	0.947	0.959	0.969	0.969	0.967	0.970	-1
3	Switzerland	0.858	0.892	0.945	0.957	0.963	0.968	0.966	0.970	0
4	Denmark	0.844	0.896	0.920	0.943	0.954	0.968	0.966	0.962	2
5	Germany	0.844	0.897	0.936	0.948	0.955	0.958	0.955	0.959	-1
6	Sweden	0.818	0.912	0.918	0.945	0.951	0.958	0.959	0.959	0
7	Australia	0.867	0.897	0.929	0.938	0.950	0.961	0.950	0.955	1
8	Hong Kong	0.755	0.839	0.912	0.937	0.950	0.961	0.950	0.955	2
9	Netherlands	0.855	0.900	0.925	0.940	0.945	0.951	0.953	0.955	-1
10	Belgium	0.824	0.894	0.921	0.933	0.939	0.948	0.945	0.951	3

Source: UNDP Report, 2025

The first 10 countries with very high HDI values and their index values are listed in Table 1. In 2023, the ranked number one was Iceland with a value of 0.972 in the Socio-Economic Development Index (SEGE). Iceland ranked first by increasing its HDI value, which was 0.956 in 2015, by advancing 2 steps in 2023. Norway (0.970), Switzerland (0.970), Denmark (0.962),

Germany (0.959) and Sweden (0.959) are listed among the countries with very high human development. While Iceland topped among the countries with very high levels of human development, Somalia ranked last with an index value of 0.380. In the 2025 Human Development Report, HDI values have been categorised as very high, high, medium and low. The threshold values are reported as 0.902 for very high HDI value, 0.760 for high HDI value, 0.640 for medium HDI value, and 0.517 for low HDI value.

Table 2. Türkiye's HDI Value and Ranking for 2013–2023

Türkiye	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
HDI Rank	69	69	71	65	64	64	68	48	48	45	51
HDI Value	0.759	0.759	0.767	0.787	0.791	0.791	0.820	0.838	0.838	0.855	0.853
Number of Countries	187	187	188	188	189	188	189	191	191	193	193

Source: Compiled from United Nations Development Reports

Türkiye's Human Development Index (HDI) values and human development rankings between 2013 and 2023 have been presented in Table 2. The results indicate a general upward trend in Türkiye's HDI over the period. According to the 2025 United Nations Human Development Report, Türkiye ranks 51st among 193 countries with an HDI value of 0.853.

The factors that shape the Human Development Index influence people's living conditions through several transmission channels that operate on income, education and health outcomes. An increase in exports supports economic growth, raises public revenues and helps strengthen spending on education and health. This process also promotes employment and technology transfer, which can improve human development. Higher income per capita makes it easier for individuals to access education, nutrition, and health services, leading to improvements across all HDI components.

Inflation weakens household welfare by reducing purchasing power and limiting access to basic services, which tends to lower human development. Rising income inequality narrows the opportunities of low income groups, especially in health and education and becomes a barrier to overall human development. Unemployment has similar negative effects, as loss of income and social exclusion reduce people's quality of life.

From a theoretical perspective, human development is closely related to a country's macroeconomic conditions. Income levels affect access to education and health services, while inflation and unemployment affect living standards and social stability. Income inequality reflects how economic gains are distributed within society and therefore shapes overall human development outcomes. Based on these connections, the empirical model examines the relationship between the HDI and key macroeconomic indicators.

For these reasons, exports and income per capita are theoretically expected to be positively associated with HDI, while inflation, income inequality and unemployment are expected to have negative relationships.

3. Literature Review

3.1. The Relationship Between HDI and Exports

Davies and Quinlivan (2006) analysed the effects of HDI on international trade by using the generalized method of moments with data from 154 countries for the period 1975-2004. As a result of the study, it was found that growth in trade will increase social welfare in the future.

Asongu (2013) examined the effects of trade and financial liberalization on inequality-adjusted HDI for 52 African countries for the period 1996-2010. As a result of the study, it was pointed out that while trade liberalization has a positive effect on human development, financial liberalization has a negative effect on human development.

Hamid and Amin (2013) explored the relationship between trade activities and development for 24 member countries of the Organization of Islamic Cooperation for the period 1980-2005. In the study, the Generalised Method of Moments was used. On the basis of the study's results, it has been indicated that trade activities have a positive impact on human development across all countries.

Similarly, Jawaid and Waheed (2017) analyzed the impact of international trade on human development in Pakistan for the period 1980-2013. In the study carried out by applying time series method, they demonstrated that trade has positively influenced human development.

The literature generally finds a positive relationship between exports and human development through growth and income effects. However, empirical evidence for Türkiye, particularly in the long run, remains limited. Therefore, exports are included in the empirical analysis.

3.2. The Relationship Between HDI and GDP per Capita

Uçan and Koçak (2018) examined the relationship between human development and economic growth in selected countries with high HDI values, including Türkiye, using panel data methods for the period 1990-2015. As a result of the study, a long-run relationship was observed between HDI and economic growth.

Aydın (2019) investigated the causal relationship between economic growth and human development in Türkiye for the period 1990-2017. The results of the study indicated that a bidirectional causal relationship existed between the variables in the long run.

Sezgin and Budak (2022) explored the relationship between HDI and economic growth in developed and developing countries for the period 2010-2020 using the panel regression model. They established that a one-unit increase in HDI would increase growth by 38.7% in developed countries and by 17.4% in developing countries.

Overall, the literature suggests a long-run relationship between GDP per capita and human development. However, evidence for Türkiye is mostly based on earlier periods. This study re-examines this relationship using more recent time-series data.

3.3. The Relationship Between HDI and Inflation

Yolanda (2017) concluded that inflation had a significant and positive effect on human development, based on a study employing multiple regression analysis using inflation, HDI and poverty data in Indonesia for the period 1997-2016.

Runtunuwu (2020) demonstrated that inflation had a negative and insignificant effect on the Human Development Index (HDI) in his study analyzing the impact of inflation on human development using multiple linear regression for the period 2009–2019.

Koyuncu and Koyuncu (2022) analyzed the effects of inflation on HDI in Türkiye for the period 1990-2021 by utilizing the time series method for the short and long run. They reported that inflation and HDI moved together in the long run and that there was a statistically significant and negative relationship between inflation and human development.

Overall, the literature suggests that inflation tends to hinder human and economic development by weakening purchasing power and creating economic uncertainty. However, evidence for Türkiye remains limited and is mostly based on earlier periods. This study re-examines the relationship between inflation and HDI using more recent time-series data.

3.4. The Relationship Between HDI and Gini

Durgun and Durgun (2023) analyzed the relationship between income distribution and HDI in Türkiye by employing the time series method for the period 1990-2019 and concluded that there was a long-run relationship between the variables, as well as a unidirectional causality running from the Human Development Index to income inequality.

Öztürk and Oktar (2017) indicated that the inverse of the inverted U hypothesis was valid and there was a positive relationship between human development and income inequality in their study on the relationship between HDI and income distribution in Türkiye during the period 1990-2015 with the ARDL bounds test method.

Bucak and Saygılı (2022) analyzed the relationship between income inequality and HDI in 15 OECD countries during the period 2004-2016 by conducting the panel cointegration test. As a result of the study, they observed that the increase in human development reduced income inequality and that there was a unidirectional causality from human development towards income inequality.

Kılıç (2024) examined the effect of the HDI on income distribution in Brazil and Ireland for the period 1990-2020 using the ARDL bounds test approach and concluded that the HDI had an equity-enhancing effect on income distribution only in Brazil in the short run, while it reduced income inequality in both countries in the long run.

Theyson and Heller (2015) analyzed the relationship between the HDI and income inequality by considering 147 countries during the period 1992-2007. In the study, the OLS method and the fixed effects model were used. They concluded that there was an S-shaped relationship between the HDI and income distribution.

Overall, the literature suggests that income inequality, as measured by the Gini coefficient, is closely related to human development outcomes. Most studies indicate that higher inequality tends to constrain human development. This study re-examines the relationship between HDI and income inequality in Türkiye using recent time-series data.

3.5. The Relationship Between HDI and Unemployment

Özmen (2016) analyzed the relationship between the HDI and female employment in Türkiye during the period 1990-2010 with the OLS method. Based on the results of the study, he concluded that there was a significant regression relationship between the two variables, as well as a unidirectional causal relationship between them.

Kartal and Zanbak (2019) explored the relationship between female unemployment and the HDI in BRICS-TM countries from 1991 to 2017 using the panel ARDL approach. In light of the study's findings, it was seen that every 10% decline in female unemployment rates increased the HDI by 4% in the analyzed countries and accelerated development.

Ağırkaya (2022) in her study on the relationship between female employment and the HDI in E7 countries for the period 1995-2019 determined that female labour force in the service sector had a positive effect on human development for all countries, whereas in the industrial sector, it had a negative impact in Brazil, Indonesia, Russia, and Türkiye.

Hoş (2023) analyzed the relationship between the HDI and income distribution in seven developing countries for the period 1996-2017 using the causality and panel cointegration methods. As a result of the study, it was concluded that there was a long-term relationship between the HDI and the Gini coefficient in these countries, as well as one way causality between these variables.

Studies in the literature generally show that exports and income per capita support human development, while inflation, income inequality and unemployment tend to have negative effects on HDI. However, many of these studies focus on a single variable or examine relatively short time periods. In addition, there are only a few studies that analyse all five macroeconomic variables together for Türkiye and cover a more recent period.

This study aims to address this gap. Overall, the existing literature indicates that human development is shaped by both growth-enhancing factors such as exports and income per capita and by socio-economic constraints related to inflation, inequality and unemployment. Although these studies differ in terms of country groups, sample periods and estimation strategies, their findings generally point to similar long-run patterns: improvements in economic capacity tend to raise human development, while macroeconomic instability and distributional imbalances weaken it. Despite these common results, the literature remains fragmented, as most studies focus on a limited set of variables or narrow time frames, making it difficult to form an integrated picture for Türkiye.

This study contributes to the existing research by examining all five major macroeconomic variables together exports, income per capita, inflation, income inequality and unemployment over an extended period for Türkiye. Unlike previous studies that analyse only one or two indicators or use shorter samples, this paper employs both Johansen cointegration and FMOLS methods to provide complementary long-run evidence. By combining these approaches, the study

offers a more comprehensive empirical assessment of the macroeconomic factors that shape human development in Türkiye and fills a gap in the literature where multi-variable, long-horizon analysis are limited.

4. Data Set and Methodology

The study attempts to explain the relationship between the HDI and selected macroeconomic variables in Türkiye for the period 2000-2024 using statistical analysis and annual time series data. The period 2000–2024 is chosen due to data availability and to capture the long-term macroeconomic and human development trends in Türkiye after the structural changes of the early 2000s.

Annual data are used because the Human Development Index is produced on a yearly basis and the related macroeconomic indicators are consistently available at annual frequency. Data used for the HDI were obtained from the United Nations Development Programme (UNDP), the Gini index was collected from the data set of TURKSTAT (Turkish Statistical Institute) and DİE (formerly known as the State Institute of Statistics), unemployment (UNEMP), inflation (INF), gross domestic product per capita (GDP), and exports (EXP) were retrieved from the World Bank's World Development Indicators database. In the study, the HDI was employed as the dependent variable, while EXP, GDP, INF, GINI and UNEMP were used as independent variables. In order to ensure linearity, some variables were included in the study by applying logarithmic transformation.

The study first introduces the variables and their sources, followed by unit root tests to determine the stationarity properties of the time series. Depending on the integration orders of the variables, Johansen's cointegration framework is applied to identify long run relationships. When cointegration is confirmed, a Vector Error Correction Model (VECM) is estimated to capture both short run adjustments and long-run dynamics. In addition, a Fully Modified Ordinary Least Squares (FMOLS) estimator is employed as a robustness check to obtain consistent long-run coefficients.

The variables used in the study are as follows:

HDI: Human Development Index

EXP: Exports (as a percentage of GDP)

GDP: Gross Domestic Product per capita (constant 2015 US dollars)

INF: Consumer Price Index (Annual)

GINI: Gini Coefficient

UNEMP: Unemployment

In this study covering the 2000-2024 period, the graphs of the series are presented in Figure 1.

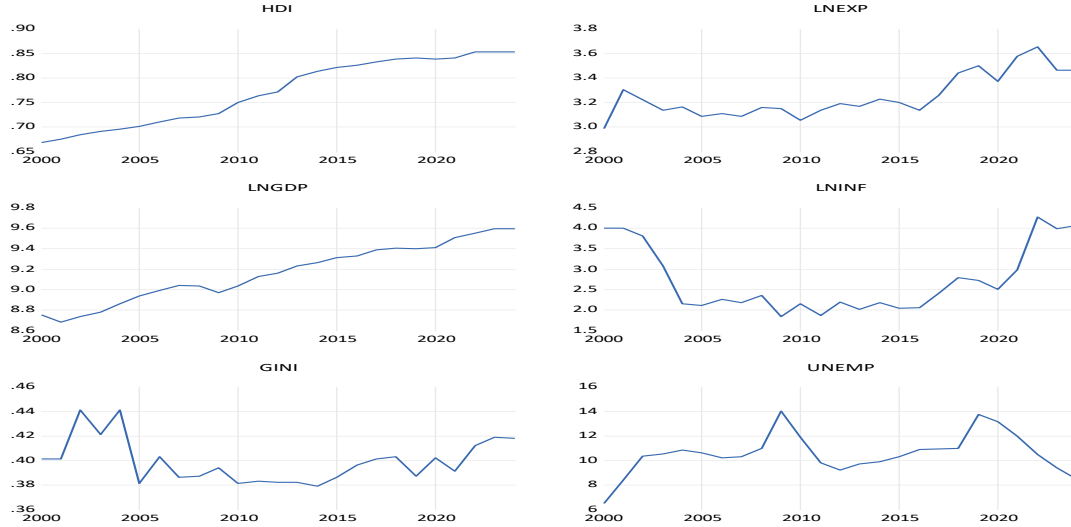


Figure 1. The Graphs of The Series

5. Empirical Findings

In line with the econometric framework described in the methodology section, this part presents the empirical results. The analysis begins with the cointegration findings and then reports the VECM estimates that capture both short-run adjustments and long-run dynamics. Finally, the FMOLS results are provided as a robustness check for the long-run coefficients. The findings are discussed in accordance with the structure outlined in the methodology.

In the empirical model, the Human Development Index (HDI) is the dependent variable, while Exports (EXP), GDP per capita (GDP), Inflation (INF), Income inequality (GINI), and Unemployment (UNEMP) are used as independent variables. In the model, exports, GDP per capita and inflation are used in logarithmic form, while HDI and GINI are included in their original levels.

The model is specified as follows:

$$HDI_t = \beta_0 + \beta_1 \ln EXP_t + \beta_2 \ln GDP_t + \beta_3 \ln INF_t + \beta_4 GINI_t + \beta_5 UNEMP_t + \varepsilon_t \quad (1)$$

The macroeconomic variables included in the model are used as control variables to examine the relationship between the main variables and human development. These variables aim to isolate the effect on the HDI from other economic conditions.

Table 3 reports the descriptive statistics of the variables.

Table 3. Descriptive Statistics

	HDI	LNEXP	LNGDP	LNINF	GINI	UNEMP
Mean	0.771760	3.249965	9.162777	2.718850	0.399120	10.53888
Median	0.772000	3.192978	9.161131	2.346040	0.396000	10.46500
Maximum	0.853000	3.652843	9.596525	4.280946	0.441000	14.02600
Minimum	0.669000	2.989775	8.680618	1.832738	0.379000	6.495000
Std. Dev.	0.066494	0.174820	0.283931	0.812557	0.017796	1.634197
Skewness	-0.158581	0.791624	-0.100030	0.818978	0.990156	0.075858
Kurtosis	1.411514	2.598381	1.841446	2.107880	3.210788	3.769629
Jarque-Bera	2.733209	2.779135	1.439865	3.623724	4.131324	0.640986
Probability	0.254971	0.249183	0.486785	0.163350	0.126734	0.725791
Number of Observations	25	25	25	25	25	25

An important prerequisite for applying the Johansen cointegration test is that the series are stationary. Series that contain a unit root should be differenced before inclusion in the analysis. There are multiple methods for testing stationarity. One of the most widely used conventional tests is the Augmented Dickey and Fuller (ADF) test (Dickey&Fuller,1981).

For the ADF unit root test, the following equation (2) is estimated;

$$Y_t = \alpha + \rho Y_{t-1} + \varepsilon_t \quad (t = 2, 3, \dots, n) \quad (2)$$

Accordingly, if the series becomes stationary in a trending (trend-included) process, this value is taken as the basis without following the other processes. Unless the series becomes stationary, the test with constant term is performed, and if stationarity still cannot be achieved in this process, the test without constant term is applied and as a result of this process, the value making the series stationary is taken as the reference (Enders, 1995).

The ADF test results for the levels and first differences of the variables are presented in Table 4.

Table 4. ADF Test Results

Variables	ADF (Trend)	At level I(0)	ADF (Trend)	First difference I(1)
HDI, d(HDI)	t statistic	-0.5172	t statistic	-3.7280
	Prob.	0.9751	Prob.	0.0406**
LNEXP, d(LNEXP)	t statistic	-1.7903	t statistic	-4.8547
	Prob.	0.6746	Prob.	0.0042***
LNGDP, d(LNGDP)	t statistic	-3.7464	t statistic	-4.8466
	Prob.	0.0692	Prob.	0.0040***
LNINF, d(LNINF)	t statistic	-1.8741	t statistic	-5.4001
	Prob.	0.6318	Prob.	0.0015***
GINI, d(GINI)	t statistic	-2.5796	t statistic	-6.7823
	Prob.	0.2915	Prob.	0.0001***
UNEMP, d(UNEMP)	t statistic	-2.9526	t statistic	-3.8930
	Prob.	0.1657	Prob.	0.0293**

Note: "d" represents the first difference of the series. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

ADF results indicate that all variables are I(1). Since all variables are integrated of order one, a multivariate cointegration approach is required to examine their long-run relationship. For this reason, the Johansen method is employed, as it is suitable for systems where multiple I(1) variables interact simultaneously. Therefore, Johansen cointegration analysis is deemed appropriate. It is necessary to determine the optimal lag length for the cointegration analysis.

Table 5. Selection of The Optimal Lag Length İn The VAR Model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	112.216	NA	5.77e-12	-8.851334	-8.556821	-8.773200
1	233.443	171.7394*	5.27e-15*	-15.9536*	-13.89206*	-15.40671*

Table 5 presents the optimal lag length applied through the VAR analysis.

Table 6. Roots of Characteristic Polynomial

Root	Modulus
0.969092 - 0.102526i	0.974500
0.969092 + 0.102526i	0.974500
0.623672 - 0.127465i	0.636564
0.623672 + 0.127465i	0.636564
-0.246207	0.246207
-0.033132	0.033132

The information criteria indicate that the optimal lag length is 1. Accordingly, the inverse root unit circle of the VAR model estimated with 1 lag is shown in Table 6 above. As illustrated in the table, the stability condition is provided in the model.

Table 7. Breusch-Godfrey Serial Correlation LM Test Results

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	54.5713	36	0.0243	1.832153	(36, 29.1)	0.059

Table 8. Heteroskedasticity Test

Heteroskedasticity Test	
Chi-square	262.1722
df	252
P-value	0.3168

Table 9. Normality Test Results

Test	Chi-sq	df	Prob.
Skewness	8.204002	6	0.2235
Kurtosis	4.866420	6	0.5611
Jarque-Bera	13.07042	12	0.3639

The diagnostic test results show that the main econometric assumptions of the model are met. The Breusch–Godfrey LM test indicates that the model does not suffer from serial correlation, and the Breusch–Pagan test suggests that there is no heteroskedasticity. In addition, the residuals were examined for normality and the multivariate normality test results confirm that they follow a normal distribution. These findings support the reliability of the FMOLS estimates and indicate that the model is properly specified. Johansen cointegration test performed to find the number of cointegrating vectors and test results are shown in Table 10.

Table 10. Johansen Cointegration Test Results

Null (H_0) Hypothesis	Trace Statistic	Critical Value %5	p-value	Max-Eigen Statistic	Critical Value %5	p-value
$r=0$	147.3782***	83.93712	0.0000	72.84658***	36.63019	0.0000
$r\leq 1$	74.63165***	60.06141	0.0019	36.97941***	30.43961	0.0067
$r\leq 2$	37.55224	40.17493	0.0886	22.00572	24.15921	0.0953

$r \leq 3$	15.54652	24.27596	0.4132	8.283186	17.79730	0.6821
$r \leq 4$	7.236366	12.32090	0.2935	6.263240	11.22480	0.3508
$r \leq 5$	1.066127	4.129906	0.3508	1.066127	4.129906	0.3508

Note: ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

Johansen's cointegration method is used because it allows for identifying more than one long-run relationship among the variables. This approach is appropriate for multivariate systems where several macroeconomic indicators may jointly influence the long-run dynamics. Its ability to test multiple cointegrating vectors makes it more suitable than single-equation techniques for the structure of this study.

According to table 10, it has been realised that both the trace statistic and the maximum eigenvalue statistic are greater than the critical values for the first two hypotheses and lower for the third. The null hypothesis, which states that there are at most 2 cointegration vectors, is accepted since both the trace and maximum eigenvalue statistics are smaller than their respective critical values. In other words, it has been determined that there are 2 cointegrating vectors in the model according to both trace statistic and the maximum eigenvalue tests.

At this stage of the study, the results of ADF unit root test and the Johansen cointegration tests have been evaluated and it has been indicated that there is a cointegration relationship between the independent variables and the HDI. When cointegration is present, estimating a Vector Error Correction Model (VECM) becomes necessary because it incorporates the long-run equilibrium relationship identified by the cointegration tests. The VECM framework allows short-run dynamics to adjust toward the long-run path through the error-correction term. This structure prevents the loss of long-run information that would occur if a standard VAR model were used after confirming cointegration, making the VECM the appropriate specification for the empirical analysis.

Table 11. Vector Error Correction Model (VECM)

Variable	Co-integ Eq1	t-statistic	Co-integ Eq2	t-statistic
HDI(-1)	1.000000	–	0.000000	–
LNEXP(-1)	0.000000	–	1.000000	–
LNGDP(-1)	-0.340352	-16.4215	-0.242347	-11.9724
LNINF(-1)	0.056571	4.26987	-0.335209	-25.9057
GINI(-1)	-3.218449	-5.48309	8.681870	15.4143
UNEMP(-1)	-0.014939	-5.55290	-0.042639	-16.2285
C	3.640433	–	-3.152650	–

Table 12. Short-Run Dynamics and Error Correction Terms

Error Correction Term	d(HDI)	d(LNEXP)	d(LNGDP)	d(LNINF)	d(GINI)	d(UNEMP)
COINTEQ1	0.026243 (0.07515) [0.34921]	-1.412727 (0.94264) [-1.49689]	-0.216267 (0.29636) [-0.72974]	-7.344057 (3.89340) [-1.91281]	0.131473 (0.07861) [1.67234]	23.09984 (10.9524) [2.10911]
COINTEQ2	0.039167	0.634477	0.461403	-2.266408	-0.167434	5.409352

The obtained VECM results confirm the presence of two long-run cointegrating relationships within the system, indicating a strong long-term link between HDI and the economic variables included in the model. The long-run coefficients show that LNEXP, LNGDP, and LNINF have significant effects on HDI, supporting the presence of a meaningful long-term equilibrium relationship. In the short run, the negative and statistically significant error-correction term indicates that deviations from the long-run equilibrium are corrected over time, confirming that the system adjusts back toward its long-term balance. Overall, the results demonstrate that the model has a consistent dynamic structure and that changes in economic indicators play both short-run and long-run roles in shaping HDI. In the VECM estimation, the error-correction term is statistically significant and carries the expected negative sign, indicating that deviations from

the long-run equilibrium are corrected over time. The VECM results for the short term show that short-term fluctuations in the variables have no significant or strong effect on the HDI. This indicates that human development produces limited effects in the short term, while the long-term adaptation process is decisive.

Table 13. FMOLS Coefficient Estimation Results

Variables	Coefficient	Standard Error	t-Statistics	Level of Significance
FMOLS				
Exports	0.076	0.054	1.391	0.1811
Gdp	0.229	0.023	9.911	0.0000***
Inflation	-0.028	0.015	-1.903	0.0731
Gini	0.674	0.493	1.366	0.1885
Unemployment	-0.002	0.003	-0.783	0.4436
Constant term	-1.736	0.303	-5.720	0.0000***

Note: ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

Furthermore, in order to provide robustness to the study, the long-run cointegration relationship between Exports, GDP per capita, Inflation, Gini coefficient and Unemployment and the HDI was also examined with FMOLS (Fully Modified Ordinary Least Squares) tests and presented in Table 13.

The FMOLS estimator is used as a robustness check to obtain reliable long-run coefficients. While the VECM framework captures both short-run adjustments and the long-run equilibrium relationship, FMOLS provides fully modified estimates that correct for serial correlation and endogeneity. Using FMOLS alongside the VECM strengthens the empirical results and ensures that the long-run findings are not dependent on the specific structure of the error-correction model.

According to the FMOLS analysis, GDP per capita is the only variable that exhibits a statistically significant long-run relationship with the HDI, and the estimated coefficient (0.229) indicates that a 1% increase in GDP per capita leads to approximately a 0.229% increase in the

HDI. The coefficient of 0.229 obtained indicates that the increase in income has had a significant impact on human development, considering that the HDI is a slowly changing index. Although the coefficients of exports, inflation, the Gini coefficient, and unemployment preserve their expected theoretical signs, they are statistically insignificant in the long run. These results suggest that, within the examined period, improvements in GDP per capita constitute the primary long-run driver of human development.

6. Discussion and Conclusion

HDI is an important index that measures development in social and economic dimensions. It is used as a basic indicator in United Nations development programs. The change in HDI values can be monitored in these reports published every year since 1990, and it provides the opportunity to observe long-term social and economic progress.

In this study, the long-run relationship between HDI and selected macroeconomic variables in Türkiye was examined for the period 2000–2024. The FMOLS estimation results indicate that GDP per capita is the only variable that has a statistically significant and positive long run effect on HDI. This finding is consistent with the theoretical expectation that higher income levels improve access to education, health services and overall living standards, thereby enhancing human development outcomes. These results are consistent with the theoretical view that variables such as exports, inflation, income inequality, and unemployment affect human development indirectly and more slowly. Furthermore, a more general look at the empirical literature also shows that similar long-run findings have been reported in previous studies. This interpretation is supported by studies cited in this paper, such as Hoş (2023) and Ağırkaya (2022), which show that the effects of income inequality and unemployment dynamics on the HDI emerge in the long term.

Exports, inflation, income inequality, and unemployment show the expected signs, but the coefficients are statistically insignificant in the long run. This indicates that income levels played a more decisive role than other macroeconomic indicators included in the model over the examined period. The weak and insignificant effect of inflation indicates that price movements alone are not a strong factor determining HDI. Similarly, the insignificant coefficients of exports, Gini and unemployment imply that these factors may influence human development through more complex and possibly indirect channels that are not captured in the long-run cointegration framework.

The results highlight that policies aimed at raising income levels such as productivity enhancing investments, employment creation and long term growth strategies may generate more substantial improvements in human development. While other variables remain important from a policy perspective, their long run statistical impact on HDI appears limited in this empirical setting.

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