Research Article

Economic Determinants of E-Commerce: A Frequency-Domain Causality Analysis of CPI and Personal Loans in Türkiye

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Abstract: This study explores the relationship between e-commerce volume, the Consumer Price Index (CPI), and personal loan rates in Türkiye, focusing on the period from 2015 to 2024. By employing time series analysis and frequency-domain causality tests, the research aims to identify the factors influencing the growth of e-commerce in Türkiye, particularly in response to economic fluctuations. Traditional unit root tests, including the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, were used alongside the Zivot-Andrews test to account for structural breaks in the data. The findings suggest a significant positive impact of personal loans on e-commerce volume, while CPI fluctuations show a nuanced effect, with short-term inflation dampening consumer activity and long-term inflation promoting price-sensitive shopping behaviors. Frequency-domain tests further reveal that personal loans have a stronger long-term causal impact on e-commerce than CPI. These results underline the crucial role of digital finance mechanisms and consumer credit in supporting the expansion of Türkiye's digital economy. The study contributes to the literature by highlighting the interplay between economic indicators and e-commerce dynamics in emerging markets.

Keywords: e-commerce, Consumer Price Index, personal loans, frequency-domain causality, Türkiye
Jel Codes: C32, E44, L82

E-Ticaretin Ekonomik Belirleyicileri: Türkiye'de TÜFE ve İhtiyaç Kredileri Üzerine Frekans Alanı Nedensellik Analizi

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Öz: Bu çalışma, 2015-2024 dönemi boyunca Türkiye'deki e-ticaret hacmi, Tüketici Fiyat Endeksi (TÜFE) ve ihtiyaç kredisi oranları arasındaki ilişkiyi incelemektedir. Zaman serisi analizi ve frekans alanı nedensellik testleri kullanılarak, ekonomik dalgalanmalara yanıt olarak Türkiye'de e-ticaretin büyümesini etkileyen faktörler belirlenmeye çalışılmıştır. ADF ve Phillips-Perron (PP) gibi geleneksel birim kök testlerinin yanı sıra yapısal kırılmaları hesaba katmak için Zivot-Andrews testi de kullanılmıştır. Bulgular, ihtiyaç kredilerinin e-ticaret hacmi üzerinde olumlu bir etkiye sahip olduğunu, TÜFE dalgalanmalarının ise kısa vadede tüketici faaliyetlerini azalttığını, uzun vadede ise fiyat hassasiyetine dayalı alışveriş davranışlarını teşvik ettiğini göstermektedir. Frekans alanı testleri ayrıca, ihtiyaç kredilerinin e-ticaret üzerinde uzun vadede TÜFE'den daha güçlü bir nedensel etkiye sahip olduğunu ortaya koymaktadır. Bu sonuçlar, Türkiye'nin dijital ekonomisinin genişlemesinde dijital finans mekanizmalarının ve tüketici kredilerinin önemli rolünü vurgulamaktadır. Çalışma, gelişmekte olan piyasalarda ekonomik göstergeler ile e-ticaret dinamikleri arasındaki etkileşimi vurgulayarak literatüre katkı sağlamaktadır.

Anahtar Kelimeler: e-ticaret, Tüketici Fiyat Endeksi, ihtiyaç kredileri, frekans alanı nedensellik, Türkiye
Jel Kodları: C32, E44, L82

1. Introduction

In recent years, with the acceleration of digitalization, one of the most notable changes in the structure of commerce has been the growing significance of e-commerce in global economies. E-commerce, which emerged in the early 1990s alongside the rise of internet usage, has since transformed commercial processes on a fundamental level. Unlike traditional commerce, e-commerce removes geographical boundaries, effectively reducing the distance between consumers and producers in the digital realm. This development enables businesses and consumers from various parts of the world to interact swiftly and seamlessly. Particularly in the United States and European Union, e-commerce has experienced significant growth since the early 2000s within the framework of digital transformation policies, allowing not only large corporations but also small and medium-sized enterprises (SMEs) to establish a strong presence in the sector (Aydın, 2020).

The rapid global expansion of e-commerce is progressing in parallel with technological advancements. Factors such as the widespread availability of internet access, the evolution of digital payment systems, and the increasing use of mobile devices in everyday life have all contributed to strengthening the role of e-commerce in economic growth. In this context, China has emerged as a leader, particularly in the development of mobile commerce. The rapid growth of China's mobile commerce sector accounts for a significant portion of global e-commerce volume and plays a pivotal role in shaping future trends (Aydın, 2020). Growth patterns in e-commerce vary across countries; while this growth is swift in developed nations, developing countries are also gaining momentum through digitalization policies and economic reforms.

Türkiye began taking steps towards developing e-commerce in the early 2000s and has reinforced its digital transformation strategies since the 2010s. One of the main drivers behind the growth of e-commerce in Türkiye has been the enhancement of internet infrastructure and the increasing use of mobile devices. According to data from the Turkish Statistical Institute (TÜİK), the proportion of households with internet access in Türkiye rose from 42.9% in 2011 to nearly 90% by 2020. This sharp increase has had a considerable impact on consumers' habits of engaging in commerce through digital platforms. While the e-commerce volume in Türkiye was relatively modest in the early 2010s, it has grown rapidly in subsequent years, capturing a significant share in both domestic and international trade channels (Acilar, 2016).

Another crucial factor driving the development of e-commerce in Türkiye has been innovations in payment systems and the increasing use of personal credit. The digitalization of the banking sector has made online payments more accessible for consumers, and the widespread use of credit cards has significantly boosted e-commerce spending. Between 2011 and 2016, domestic credit card transactions in Türkiye increased by 283%, while international transactions rose by 123% (Keleş, 2018). The development of mobile payment systems, in particular, has heightened consumer interest in e-commerce platforms in Türkiye, and during this period, personal loans have become a key factor supporting consumer spending.

Among the key economic indicators influencing e-commerce volume, one of the most important is the Consumer Price Index (CPI). As an indicator that tracks changes in the overall price level of goods and services, the CPI directly impacts consumers' spending behaviors. Higher inflation rates can dampen consumer demand and subsequently reduce e-commerce spending, whereas lower inflation rates typically bolster consumer confidence and spending. In Türkiye, fluctuations in inflation rates between 2011 and 2020 have played a pivotal role in the growth of the e-commerce sector. The price comparison tools and competitive pricing offered by e-commerce platforms have encouraged consumers to continue shopping online, even during periods of high inflation (Eryüzlü, 2020).

This study conducts a comprehensive analysis of the relationship between e-commerce volume, the Consumer Price Index (CPI), and personal loan rates in Türkiye.

While various studies in the literature explore the relationship between e-commerce and economic indicators (Dikkaya & Aytekin, 2018; Kayahan & Hepaktan, 2016), this research aims to provide a detailed analysis of the current situation in Türkiye, offering valuable insights from both theoretical and practical perspectives. The analysis is geographically focused on Türkiye, providing a context-specific understanding that reflects the unique structural and digital characteristics of its economy. Additionally, the time frame of the data, spanning January 2015 to July 2024, establishes a robust basis for examining the dynamics of e-commerce and economic indicators, though it may not fully capture the long-term effects of rapidly evolving technologies and consumer trends. By employing frequency-domain causality tests, this study ensures a nuanced exploration of these relationships across different time horizons, paving the way for future research to build on these findings with alternative modeling techniques or expanded scopes.

2. Literature Review

This section addresses studies conducted on e-commerce in Türkiye. The research focuses on analyses of the development of e-commerce, digital infrastructure, and its economic contributions within the country.

The study by Altuparmak & Avcı (2011) examines the impact of international trade on the ecological footprint, with a particular focus on Türkiye. The research employs a time series analysis covering the period from 1990 to 2010. In the study, international trade volume, energy consumption, and industrial production are considered as independent variables, while the ecological footprint is used as the dependent variable. The findings reveal that the increase in Türkiye's international trade volume has negatively impacted its ecological footprint, with energy consumption and industrial production contributing to environmental degradation. The study concludes that sustainable development policies need to be implemented to mitigate these effects.

Osman Değer & Mesut Demie (2015) explored the causal link between the real effective exchange rate and foreign trade volume in Türkiye, utilizing data spanning from 1990 to 2015. Employing the Granger causality test and Johansen cointegration analysis, the study assessed both short- and long-term relationships between the two variables. In this analysis, the real effective exchange rate served as the independent variable, while foreign trade volume was treated as the dependent variable. The findings revealed that fluctuations in the real effective exchange rate had substantial impacts on foreign trade volume in both the short and long run. This research underscores the pivotal role that exchange rate variations play in shaping foreign trade performance.

In his study examining the development of e-commerce in Türkiye between 2011 and 2015, Acilar (2016) utilized data from the Interbank Card Center (BKM), the Turkish Statistical Institute (TÜİK), and Eurostat statistics. The research evaluated the effects of internet infrastructure development and the increase in the number of internet users on e-commerce volume in Türkiye. It was noted that both the number of transactions and the transaction amounts of online card payments showed significant growth during this period. The study emphasized that, while Türkiye's e-commerce volume increased each year, it remained at lower levels compared to European Union countries. The findings indicate that e-commerce in Türkiye has strong growth potential, but further improvements in legal regulations and infrastructure investments are necessary to realize this potential.

Kayahan & Hepaktan (2016) utilized a Vector Autoregression (VAR) analysis to investigate the factors affecting e-commerce volume in Türkiye between 2005 and 2015. The independent variables in this study encompassed the number of internet users, personal loan volume, inflation rate, and Gross Domestic Product (GDP), with e-commerce volume as the dependent variable. The findings showed that both the number of internet users and the volume of personal loans had positive effects on e-commerce growth, while rising inflation rates had a negative impact. The study emphasizes that

improvements in digital infrastructure and greater access to personal credit have been key drivers in the expansion of e-commerce in Türkiye.

Demirdöğmez et al. (2018) analyzed the development of Türkiye's e-commerce sector over the years, with a focus on the period from 2000 to 2018. Through a descriptive analysis approach, the study assessed the growth rates of e-commerce volume, user numbers, and sectoral investments in Türkiye. Independent variables such as the number of internet users, e-commerce infrastructure, and payment systems were evaluated, while the dependent variable was e-commerce volume. The results demonstrated that advancements in internet infrastructure and innovations in payment systems played a crucial role in fostering the growth of Türkiye's e-commerce sector. The study highlights the growing importance of e-commerce in Türkiye's economy and its strong potential for future expansion.

Dikkaya & Aytekin (2018) analyzed the development of global e-commerce and Türkiye's role in this process, focusing on data from 2005 to 2018. Using a descriptive analysis method, the study assessed the growth of global e-commerce volume and the developments in Türkiye's e-commerce infrastructure. Independent variables included internet penetration, mobile commerce usage, and digital payment systems, while e-commerce volume was used as the dependent variable. The results indicated that Türkiye's share in the global e-commerce market is increasing, but further improvements are needed in areas such as infrastructure and security. The study emphasizes that Türkiye has the potential to grow in line with global e-commerce trends.

Keleş (2018) analyzed the developments in Türkiye's e-commerce transaction volume between 2011 and 2016. The study highlighted that the domestic e-commerce transaction volume through local credit cards increased by 283 %, while international transactions grew by 278 %. Additionally, card transactions from abroad to Türkiye saw a 123 % increase. This growth was attributed to advancements in internet and communication technologies, along with the widespread use of computers and mobile devices. Data from TÜİK's "Household Information Technologies Usage Survey" further supported these growth trends. The study projected that Türkiye's e-commerce volume would continue its upward trend in the future. Considering the economic contributions of e-commerce, the study emphasized the strategic necessity for countries to support e-commerce activities, strengthen technological infrastructure investments, and implement legal regulations. It also stressed that Türkiye needs to take steps to support e-commerce in order to remain competitive on a global scale.

Eryüzlü & Kurtoğlu (2020) examined the multifaceted relationships between e-commerce and personal loans in Türkiye in their study covering the period from 2010 to 2020. Using cointegration and Granger causality tests, the study analyzed the connections between e-commerce volume and the use of personal loans. Various types of personal loans (such as consumer, housing, and vehicle loans) were considered as independent variables, while e-commerce volume was treated as the dependent variable. The results showed that the increase in personal loan usage had a positive impact on e-commerce spending, highlighting the significant role of credit access in shaping consumer behavior. The study emphasized that the expansion of personal loans contributes to the growth of the digital economy.

Eryüzlü (2020) analyzed the impact of e-commerce on inflation in Türkiye using data spanning from 2005 to 2020. The study applied time series analysis along with the ARDL model to explore the relationship between e-commerce volume and inflation rates. In this research, e-commerce volume was treated as the independent variable, while the Consumer Price Index (CPI) served as the dependent variable. The findings revealed that an increase in e-commerce volume had a positive effect on inflation in the short run, but a constraining impact over the long term. The study concluded that e-commerce helps to ease inflationary pressures by intensifying price competition.

Yılmaz & Bayram (2020) examined the development of e-commerce and e-export in Türkiye during the COVID-19 pandemic, using data from 2019 to 2020. Through a

descriptive analysis method, the study assessed the growth in e-commerce volume and the state of e-export during the pandemic. Independent variables included the restrictions imposed during the pandemic, internet usage rates, and the effectiveness of digital infrastructure, while the dependent variables were e-commerce volume and e-export performance. The results revealed that e-commerce experienced rapid growth during the pandemic, while e-export saw a limited but notable increase. The study highlighted the importance of digital transformation in ensuring the continuity of trade during the pandemic.

This section includes studies conducted on global e-commerce. The research focuses on developments in the global e-commerce market, digitalization, and the economic impacts of e-commerce.

Nagy (2016) analyzed the development of e-commerce in Hungary using data from 2010 to 2016. Through a descriptive analysis, the study assessed the growth trends of Hungary's e-commerce market, consumer behavior, and digital infrastructure. Independent variables included the number of internet users, digital payment systems, and mobile commerce usage, while e-commerce volume was examined as the dependent variable. The findings revealed that e-commerce in Hungary grew rapidly, but there were shortcomings in the development of digital payment systems and consumer security. The study emphasized that for e-commerce to further develop in Hungary, improvements in digital infrastructure are necessary.

Kantarcı et al. (2017) analyzed the impact of e-commerce on economic growth on a global scale in their study covering the period from 2008 to 2017. Using a descriptive analysis method, the study evaluated the role of e-commerce in economic growth, particularly as digitalization accelerated. Independent variables included internet penetration, digital infrastructure, and mobile device usage rates, while economic growth was treated as the dependent variable. The results showed that digitalization and e-commerce made significant contributions to economic growth, with mobile commerce spreading rapidly during this period. The study emphasized that e-commerce acts as a driving force in digitalizing economies.

Aydın (2020) examined the global growth trends of e-commerce and its projected future direction during the period from 2010 to 2020. The study, employing a descriptive analysis approach, highlighted key drivers of e-commerce, including the rise of mobile applications, the expansion of internet infrastructure, and the increasing adaptation of younger generations to technology. The research primarily focused on the surge in e-commerce volumes in the United States and European countries, along with China's expanding role in the global e-commerce market, particularly through mobile commerce. The study forecasted that global e-commerce volume would reach 4 trillion dollars by 2020 and offered insights into the development of B2B and B2C e-commerce models.

Ivanova et al. (2021) focused on the development of e-commerce within the context of the digital economy, examining the period from 2010 to 2020. The study utilized descriptive analysis and multiple regression analysis to assess the effects of digitalization on e-commerce. Independent variables included digital infrastructure, mobile technology usage, and data security, while the dependent variable was e-commerce volume. The results revealed that the development of digital infrastructure and the widespread adoption of mobile technologies supported the growth of e-commerce, but challenges related to data security limited this growth. The study emphasized the necessity of improving security and infrastructure for the sustainable development of e-commerce in the digital economy.

Jain et al. (2021) provided a comprehensive evaluation of electronic commerce in their study, covering the period from 2010 to 2020. Using a descriptive analysis method, the study examined the historical development of e-commerce, business models, and its global economic impacts. Independent variables such as internet usage rates, digital infrastructure development, and mobile commerce applications were assessed, while the dependent variable was e-commerce volume. The results indicated that e-commerce has

rapidly expanded worldwide, with significant growth potential particularly in developing countries. The study emphasized the critical role of digital infrastructure and secure payment systems in ensuring the sustainable growth of e-commerce.

Gedik (2021), in her study exploring the theoretical foundations of e-commerce, reviewed the literature from 2000 to 2020, assessing the operation, conceptual framework, and development of e-commerce. The study discussed e-commerce business models, its role within the digital economy, and the impact of technological advancements. Independent variables included digital infrastructure, internet access rates, and mobile commerce applications, while the dependent variable was the theoretical dimensions of e-commerce. The findings demonstrated that e-commerce is a crucial component of digital transformation within economic systems, and sustainable business models have evolved on this basis. The study emphasized the critical role e-commerce plays in shaping the theoretical framework of a digitalized economy.

Siregar et al. (2023), in their study examining the effects of digital marketing on e-commerce customers, focused on the period between 2015 and 2023. Using a causal research method and regression analysis, the study evaluated the impact of digital marketing strategies on e-commerce customer behavior. Independent variables included social media marketing, digital advertising, and email marketing, while the dependent variables were customer satisfaction and purchase rates. The results showed that digital marketing strategies positively influenced e-commerce customers' purchasing decisions and enhanced customer loyalty. The study emphasized that effective digital marketing strategies play a critical role in the success of e-commerce.

3. The Development of E-commerce in Türkiye

As digitalization accelerates globally, the growth of e-commerce has become an inevitable outcome. Türkiye, one of the countries embracing this trend, has made notable progress, particularly since the early 2000s, in terms of digital transformation and enhancing its internet infrastructure. The expansion of e-commerce in Türkiye is closely tied to the increasing availability of internet access, the rising use of mobile devices, and the adoption of digital payment systems. Initially, large corporations capitalized on the benefits of online commerce, but by the mid-2010s, small and medium-sized enterprises (SMEs) also became active players in the e-commerce sector. In Türkiye, e-commerce not only presents a new shopping alternative for domestic consumers but also opens up opportunities to engage with international markets (Acilar, 2016).The COVID-19 pandemic accelerated the adoption and expansion of e-commerce not only in Türkiye but also worldwide. During the pandemic, the closure of physical stores and the enforcement of social distancing measures in many countries drove consumers to turn to online shopping. This global shift allowed e-commerce companies to quickly adapt, contributing to a significant increase in digital sales across the World (Barışık & Kasap, 2024).

The growth of e-commerce in Türkiye has been driven by several factors closely associated with economic development. Chief among these are the enhancement of internet infrastructure and the widespread integration of mobile commerce, both of which have played pivotal roles in shifting consumer behavior toward digital platforms. Data from the Turkish Statistical Institute (TÜİK) shows that household internet usage rose sharply between 2005 and 2020, significantly contributing to the rapid expansion of the e-commerce sector. Additionally, the proliferation of mobile devices and advancements in internet speeds have greatly improved consumers' online shopping experiences. In 2011, Türkiye experienced a notable increase in online card payment transactions, and by 2016, this growth had accelerated dramatically. Data from the Interbank Card Center (BKM) indicates that Türkiye's e-commerce transaction volume grew by 283% between 2011 and 2016 (Keleş, 2018).

Another crucial factor influencing the growth of e-commerce in Türkiye has been the use of personal credit. In particular, consumer loans have increased purchasing power, contributing to the expansion of e-commerce volume. The early 2010s saw a rapid rise in

the use of personal credit cards, which supported consumer spending. The widespread adoption of e-commerce in Türkiye can be attributed to consumers' ability to make secure payments online, alongside the digitalization of the banking sector. According to TÜİK's "Household Information Technology Usage Survey," the mid-2010s witnessed a significant increase in online shopping, indicating a shift in consumer demand towards online platforms (Keleş, 2018).

In addition, the development of the e-commerce sector in Türkiye is directly linked to innovations in digital payment systems. Türkiye has made significant progress in digital payment technologies, making it easier for consumers to engage in online shopping. The volume of transactions carried out via both domestic and international credit cards has increased rapidly, with e-commerce activities aimed at international markets gaining considerable momentum. Card transactions from abroad to Türkiye rose by 123% between 2011 and 2016 (Keleş, 2018). During this period, Türkiye's efforts to strengthen its digital infrastructure supported the growth potential of e-commerce and enhanced its global competitiveness.

In conclusion, the development of e-commerce in Türkiye has accelerated alongside the successful implementation of digital transformation policies, the strengthening of internet infrastructure, and changes in consumer behavior. Economic indicators, such as the increase in personal credit usage and the impact of inflation rates, have played a direct and decisive role in shaping e-commerce volume. Since the mid-2010s, Türkiye has made significant progress in the field of e-commerce and continues to hold strong potential for further growth in this area (Acilar, 2016).

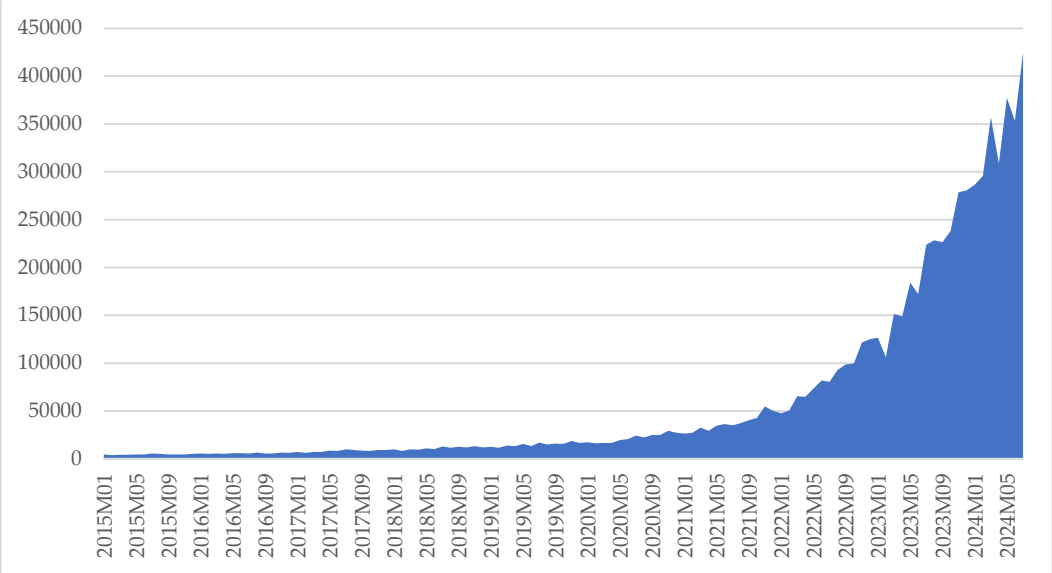

Figure 1. E-Commerce Volume (Million TL)

In Graph 1, illustrates the change in e-commerce volume (in million Turkish Liras) in Türkiye between 2015 and 2024. From 2015 to 2020, the e-commerce volume remained at relatively low levels and displayed a stable trend. These low volumes indicate a period when digitalization had not yet become widespread, consumer habits were still focused on physical retail, and internet infrastructure was not fully developed. This period can also be seen as a time when e-commerce in Türkiye faced infrastructural and regulatory challenges.

However, by the end of 2020, a significant increase in e-commerce volume began, spurred by the global COVID-19 pandemic. The pandemic led to the closure of physical stores worldwide and forced people to shop from home, contributing to the rapid growth of e-commerce in Türkiye, as it did globally. By 2021, the e-commerce volume in Türkiye

gained momentum due to the pandemic, and the graph shows a marked rise during this period. This increase is closely tied to changes in consumer habits, with online shopping becoming increasingly preferred and digital platforms expanding to meet this demand.

By 2022, the e-commerce volume showed a strong growth trend. The key factors behind this growth include the rising internet penetration rate in Türkiye, increased use of mobile devices, and the widespread adoption of digital payment systems. Additionally, the development of logistics capabilities offered by e-commerce platforms, fast delivery solutions, and the increased variety available to consumers further contributed to the rise in e-commerce volume during this period. Türkiye accelerated its digitalization process, making significant improvements in internet infrastructure, which facilitated the increase in online transactions. Furthermore, the growing trust consumers had in online shopping, along with the widespread use of credit cards and digital payment methods, played a pivotal role in this growth.

By 2023 and especially in 2024, the e-commerce volume experienced a significant surge, reaching a peak in the graph. During this period, the increase in public and private sector investments in digitalization in Türkiye, the expansion of major e-commerce platforms, and the entry of new players into the market are likely some of the key reasons behind this substantial growth. At the same time, the rapid growth of online shopping in Türkiye, coupled with the integration of small and medium-sized enterprises (SMEs) into digital platforms, became a noteworthy development. The integration of SMEs into e-commerce platforms not only contributed to local economies but also provided consumers with more choices, further driving the growth in e-commerce volume.

This dramatic increase in e-commerce volume reflects the rapid transformation of the Turkish economy during the digitalization process. It also indicates that Türkiye's digital economy holds great potential for the future. Especially considering the young population's adaptability to technological innovations and the ongoing rise in mobile device usage, e-commerce growth in Türkiye is expected to continue. The graph clearly shows that e-commerce has become more than just a sales channel, evolving into a crucial component of economic growth. In conclusion, e-commerce volume in Türkiye is likely to continue growing in the coming years, driven by investments in digitalization, the adoption of new technologies, and changes in consumer habits.

This rapid growth trend also suggests that Türkiye has the potential to become a more significant player in the global e-commerce market. In terms of the future of e-commerce, both consumers and businesses are expected to further adapt to this digital transformation, and the strengthening of the e-commerce ecosystem is anticipated.

3.1 The Impact of CPI and Personal Loans on E-commerce Volume

The rapid growth of e-commerce in Türkiye is closely related to various economic indicators, chief among them being the Consumer Price Index (CPI) and personal loans. CPI, which measures the general price level of goods and services in an economy, directly affects consumers' purchasing power. As inflation rates rise, consumers' spending capacity may decrease, which can also be reflected in their online shopping habits. During periods of high inflation in Türkiye, consumers have tended to rely more on personal loans to meet their needs, creating a complex set of effects on e-commerce volume (Eryüzlü, 2020).

While rising CPI typically leads to reduced consumer spending, e-commerce platforms often leverage competitive advantages by offering lower prices. Features such as price comparison tools and discount campaigns can attract consumers to online shopping even during inflationary periods. The price fluctuations seen in Türkiye since the mid-2010s have led to shifts in consumer behavior. Notably, during major sales events, the price flexibility of e-commerce platforms has played a mitigating role, softening the impact of rising CPI on consumer spending (Eryüzlü, 2020).

Additionally, personal loans significantly impact e-commerce volume by increasing consumers' purchasing power. In Türkiye, the widespread use of personal credit cards

and the availability of personal loans with low interest rates have strengthened consumers' inclination toward online shopping. Between 2011 and 2020, the rise in personal loans affected a substantial portion of consumer spending in Türkiye, contributing to the growth of e-commerce volume. Personal loans provide consumers with easy access to financial resources, and their effect on consumer behavior is clearly observed in online shopping trends (Keleş, 2018).

The relationship between e-commerce and personal loans in Türkiye has developed in direct correlation with the increase in consumers' spending capacity. Consumers are able to make large purchases more easily through credit cards and personal loans, a trend supported by the various payment options offered by e-commerce platforms. The expansion of digital payment systems and the growing habit of making online payments in Türkiye have further strengthened this connection between personal loans and e-commerce (Eryüzlü & Kurtoğlu, 2020).

The influence of personal loan rates on the growth of e-commerce volume is also directly linked to advancements in payment systems. Since the early 2010s, the strengthening of digital banking systems and mobile payment infrastructure in Türkiye has led to an increase in loan usage, making online shopping more accessible. This positive impact of personal loans on e-commerce is particularly evident when consumers make large purchases without the concern of exceeding their credit card limits, enabling them to shop with confidence (Kayahan & Hepaktan, 2016).

In conclusion, CPI and personal loans are two significant economic factors that directly affect consumer behavior and e-commerce volume in Türkiye. During periods of rising CPI, the competitive pricing strategies of e-commerce platforms increase consumers' willingness to shop online, while personal loans facilitate easy access to financial resources, supporting e-commerce spending. These two indicators play a critical role in the growth dynamics of e-commerce in Türkiye.

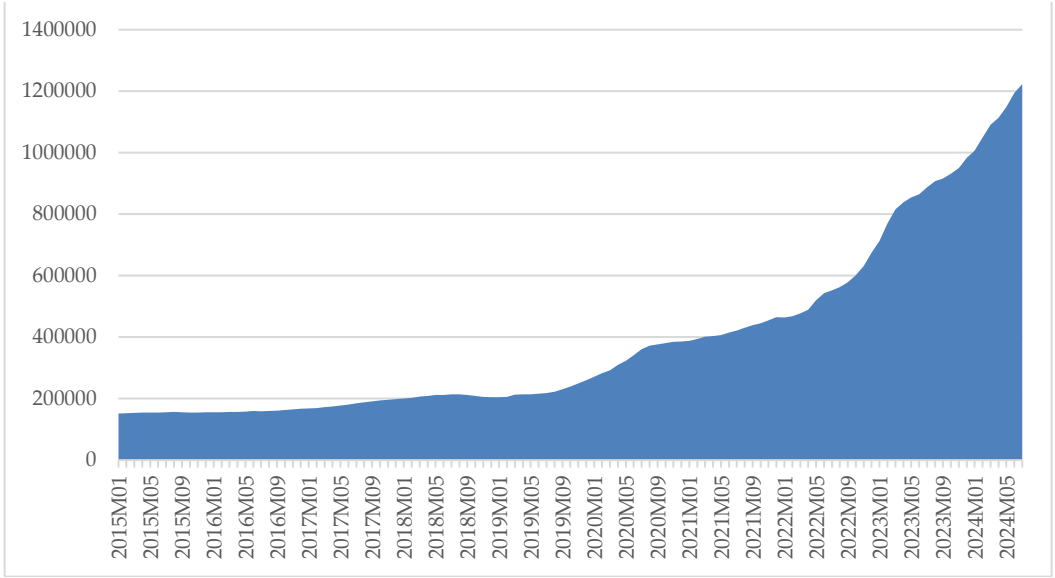

Figure 2. Consumer Loan Usage in Türkiye (Million TL)

In Graph 2, which illustrates the amount of consumer loans in millions of Turkish Lira (TL), a significant upward trend in loan usage in Türkiye from 2015 to 2024 is observed. Between 2015 and 2019, the usage of consumer loans exhibits a relatively slow and steady increase. This period indicates a stable macroeconomic environment, with limited fluctuations in household incomes and a moderate demand for credit. The gradual rise in consumer loan usage can be attributed to a relatively stable economy where households did not face significant financial pressure, and borrowing remained contained.

However, towards the end of 2019, there is a notable acceleration in the usage of consumer loans. The sharpest increase occurs in 2020, coinciding with the economic impact of the COVID-19 pandemic. During this period, the global health crisis led to economic uncertainties, job losses, reduced incomes, and increased liquidity needs for households, driving a surge in demand for consumer loans. In addition to this, expansionary monetary policies, low-interest rates, and government stimulus packages aimed at supporting households likely contributed to the rising loan usage during this time.

From 2021 onward, the trend becomes steeper, showing a rapid escalation in consumer loan usage. By 2024, the amount of consumer loans exceeds 1.2 million TL, marking a historical peak. This sharp increase can be linked to persistent inflationary pressures, rising borrowing needs, and households facing greater economic challenges. As inflation eroded real incomes, individuals increasingly turned to borrowing to meet their consumption and liquidity needs. Additionally, fluctuations in credit interest rates and more flexible lending policies in the banking sector further fueled the demand for consumer loans.

Overall, Graph 2 reflects the increasing reliance of Turkish households on consumer loans, particularly in the face of economic instability and financial pressures. The sustained upward trend underscores the growing financial risks faced by households as they resort to borrowing to cope with economic uncertainty. This trajectory is closely aligned with broader macroeconomic indicators, highlighting the rising demand for consumer loans as a financial coping mechanism.

3.2 The Relationship Between E-commerce Volume and Economic Indicators: Theoretical Framework

As a key indicator of economic growth and consumer behavior, e-commerce volume is directly linked to various economic factors. Indicators such as inflation rates, consumer confidence, and personal loan usage play a decisive role in shaping e-commerce. At this point, the Consumer Price Index (CPI) and personal loan rates have a direct impact on consumer behavior, and it is essential to explain theoretically how digital commerce is affected by these economic conditions.

The CPI measures changes in the general price level of goods and services in an economy and directly affects consumers' purchasing power. From a Keynesian perspective, it is widely accepted that price increases (inflation) reduce consumer demand and limit spending. During periods of inflation, as consumers' purchasing power weakens and a significant portion of their income is allocated to essential needs, the volume of online shopping may decline. However, e-commerce often offsets this effect by offering price advantages and promotional campaigns. In developing countries like Türkiye, e-commerce platforms have the potential to attract consumer demand by adopting more competitive pricing strategies in response to inflationary pressures (Eryüzlü, 2020).

In addition to CPI, personal credit usage is another significant economic factor influencing e-commerce volume. Within the framework of the Quantity Theory of Money, it is evident that the financial resources provided by credit expansion increase spending capacity. Personal loans, in particular, are an important financial tool that individuals use to expand their consumption expenditures. Increased access to credit facilitates consumers' ability to purchase more products, positively impacting e-commerce platforms. Friedman's consumption function theory also suggests that individuals' spending tendencies increase based on their future income expectations. In this context, the widespread use of personal loans has enhanced consumers' tendency to shop online, contributing to the expansion of e-commerce volume in Türkiye (Keleş, 2018).

In the context of Türkiye, the impact of personal loans on e-commerce should be evaluated alongside digital payment systems and the banking sector, which make consumers' shopping habits more flexible. Particularly, the integration of credit cards and

personal loans into online commerce allows consumers to prefer credit when purchasing high-value products. This aligns with the Neo-Classical Consumption Theory, which posits that consumers optimize their income and expenditures based on available credit facilities and market conditions. The strong correlation between personal credit usage and e-commerce volume in Türkiye can be explained by consumers' increased capacity to expand their purchasing decisions (Kayahan & Hepaktan, 2016).

Based on economic theories, understanding how e-commerce volume in Türkiye responds to inflation and credit rates sheds light on the role of digital commerce in economic growth. Both the impact of CPI and how credit rates shape consumer behavior are critical for understanding the growth dynamics of the e-commerce sector. The price advantages offered by e-commerce increase consumers' interest in online platforms, while the expansion of personal loans provides the financial capacity to meet this demand. Thus, e-commerce volume in Türkiye grows in strong relation to economic indicators (Dikkaya & Aytekin, 2018).

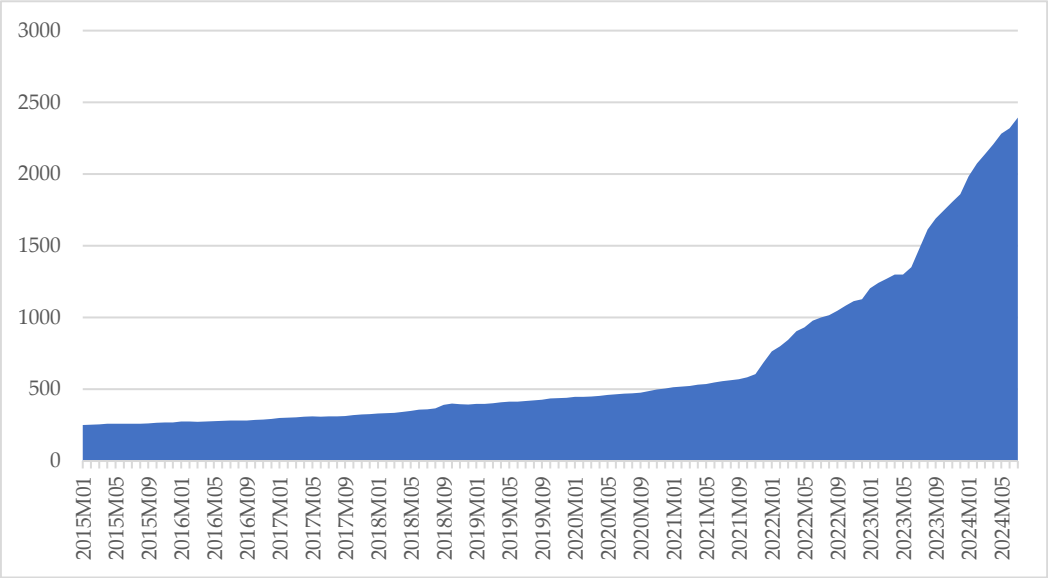

Figure 3. Consumer Price Index (CPI) in Türkiye

Graph 3 shows the Consumer Price Index (CPI) in Türkiye from 2015 to 2024, highlighting the changes in the general price level of goods and services consumed by households during this period. The CPI is a crucial measure of inflation, reflecting how prices have shifted over time, and this graph demonstrates a continuous rise in the cost of living for Turkish households. The upward trend throughout the years indicates that Türkiye has experienced sustained inflationary pressures over the last decade.

Between 2015 and 2019, the graph exhibits a gradual and relatively stable increase in CPI, suggesting that inflation was kept under control during this period. The modest rise in CPI can be attributed to a more stable macroeconomic environment where inflation management policies, such as those of the central bank, were likely effective. Economic stability and limited external shocks contributed to a manageable inflationary trend, keeping price levels in check, and thereby, the impact on household purchasing power remained moderate.

However, towards the end of 2019, an acceleration in CPI is observed, which becomes more pronounced by 2020. The onset of the COVID-19 pandemic had a significant economic impact globally, and this sharp rise in CPI can be closely linked to the pandemic-induced supply chain disruptions, which led to increased production costs that were passed on to consumers. Furthermore, the depreciation of the Turkish Lira exacerbated the inflationary pressures by increasing the cost of imported goods and services, driving up the CPI further.

From 2021 onwards, the CPI growth becomes steeper, reflecting a rapid rise in consumer prices. The escalation of inflation during this period can be attributed to various global and domestic economic factors. The depreciation of the Turkish Lira, combined with the volatility in commodity prices and disruptions in global supply chains, contributed to rising import costs and a surge in domestic prices. Expansionary monetary and fiscal policies, such as increased money supply and low-interest rates, also played a role in fueling inflation. As consumer expectations for inflation worsened, it became increasingly difficult to contain price hikes.

The most noticeable spike in CPI occurs between 2022 and 2024, a period marked by severe inflationary pressures in Türkiye. Rising energy prices, increased food costs, and higher import expenses are among the main factors driving this inflation surge. The worsening of inflation expectations further amplified the problem, causing prices to rise more persistently. By 2024, CPI levels have exceeded 2,500, indicating a dramatic increase in the cost of living for households and reflecting the severity of Türkiye's inflation problem.

By 2024, the CPI surpasses the 2,500 mark, signaling a significant erosion in household purchasing power. The persistent and sharp rise in CPI during this period indicates that inflation has become a critical issue for the Turkish economy, posing risks not only for consumer welfare but also for broader economic stability. If inflation remains uncontrolled, it could negatively impact investment decisions, production costs, and overall economic growth.

Overall, **Graph 3** underscores the increasing inflationary pressures faced by Türkiye in recent years, particularly after 2020. The sustained rise in CPI highlights the broader challenges of inflation management in an environment of economic instability, rising production costs, and external shocks. As inflation becomes a long-term concern, its implications for households and the broader economy are becoming increasingly apparent, making it one of the most pressing economic issues in Türkiye today.

4. Data and Model

The econometric model in this study has been constructed using monthly data from January 2015 to July 2024. The primary objective is to examine the causal relationship between the volume of e-commerce in Türkiye and consumer loans, specifically personal loans (a subcategory of consumer loans), as well as the Consumer Price Index (CPI). The dependent variable is the spending amount (in Turkish Lira) made with domestic cards both within Türkiye and abroad, while the independent variables included in the model are the Consumer Price Index (2003=100) and personal loans (in Turkish Lira). The analysis, conducted using a total of 115 observations, was performed with the help of Gauss 21 and Stata14 econometrics software. Descriptive statistics for the data used in the study are presented in Table 1.

Table 1. Descriptive Statistics for Variables

Variables	Notation	Definition	Usage Method	Source
ETH	lneth	The Domestic and International Usage of Local Cards (Mn TL)	Logarithmic	Interbank Card Center (BKM)
TUFE	lntufe	Consumer Price Index (2003=100).	Logarithmic	Turkish Statistical Institute (TÜİK)
İHKRE	lnihkre	Personal Loans (Mn TL)	Logarithmic	Turkish Statistical Institute (TÜİK)

All variables were subjected to a natural logarithmic transformation to ensure that observation values expressed in different units convey the same type of meaning. The "ln" notation indicates that the logarithm of the series has been taken. When the natural logarithms of the variables are used, the estimated parameters will be equal to elasticity, which facilitates the interpretation of the parameters. The model under analysis is provided in Equation (1). In the econometric model presented in Equation (1), the

notations β0 and εt represent the constant term and the error term, respectively. The parameters from β0 to β2 denote the coefficients of the explanatory variables included in the function:

$$lneth_t = \beta_0 + \beta_1 lnihkre_t + \beta_2 lntufe_t + \varepsilon_t \quad (1)$$

5. Method

In the first stage of the study, traditional unit root tests, namely the Augmented Dickey-Fuller (ADF) test (1981) and the Phillips & Perron (1988), along with the Zivot & Andrews (2002) unit root test, which allows for structural breaks, were employed to determine the stationarity levels of the series. In the second stage, symmetric and frequency-domain causality tests were conducted.

For the causality analysis, the Hacker & Hatemi-J (2006) and Breitung & Candelon (2006) frequency-domain causality tests were applied, and the results were interpreted. While the Hacker and Hatemi-J causality test examines the entire period as a whole and performs a causality test from a single point, it does not take into account the cyclical fluctuations that can occur in every economy. On the other hand, frequency-domain causality tests provide the opportunity to investigate the causality relationship at different time intervals. This method allows for the generation of test statistics at different frequencies and the distinction between temporary and permanent causality relationships between the variables.

5.1 Traditional and Structural Break Unit Root Tests

In this study, the ADF and PP unit root tests, which are traditional unit root tests, as well as the Zivot & Andrews (2002) test, which allows for structural breaks, were applied to examine the unit root and stationarity of the series. Stationarity is defined as a time series having a constant mean, variance, and autocorrelation structure over time Enders & Granger (1998).

The Dickey & Fuller (1981) stationarity test aims to assess a first-order autoregressive (AR) process. The Augmented Dickey & Fuller (1981) test, on the other hand, works on the AR(p) model with a lag order of p, evaluating the null hypothesis as an ARIMA(p,1,0) autoregressive integrated moving average process, and the alternative hypothesis as a stationary ARIMA(p+1,0,0) model (Cheung & Lai, 1995). In the test, it is assumed that the error terms are independently and identically distributed [ε_t ~WN(0,σ^2)].

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-1+1} + \varepsilon_t \quad (2)$$
$$\Delta y_t = c + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \quad (3)$$
$$\Delta y_t = c + \gamma y_{t-1} + \delta_2 t + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \quad (4)$$

The first model (Model 1) has a regression structure without a constant term and trend variable. The second model (Model 2) includes only the constant term, excluding the trend variable. The third model (Model 3) reflects a model that incorporates both the constant term and the trend. In these models, the coefficient of the dependent variable's previous period value, y_(t-1), denoted as "γ", is tested to determine whether it is less than one. The acceptance of the alternative hypothesis leads to the conclusion that the series is stationary.

The Dickey-Fuller test is based on constant variances and independent error terms, assuming no autocorrelation. However, Phillips & Perron (1988) reexamined the assumptions of the Dickey & Fuller (1979) test and introduced a different approach to account for random shocks (Sevüktekin & Nargeleçekenler, 2010). This new approach offers more flexible solutions, particularly for cases involving autocorrelation and heteroscedasticity. The equations describing the constant and constant-trend models used in the PP test are as follows:

$$Y_t = \alpha_0 + \beta_1 Y_{t-1} + \varepsilon_t \quad (5)$$
$$Y_t = \alpha_0 + \beta_1 Y_{t-1} + \beta_2 \left(t - \frac{T}{2}\right) + \varepsilon_t \quad (6)$$

The equations numbered (4) and (5) mentioned above represent models that include the constant term and those that incorporate both the constant term and the trend, respectively. In these models, Y_t denotes the tested variable, α_0 represents the constant term, t stands for the trend, and T symbolizes the number of observations, while the error term reflects the uncertainty component of the model. The coefficient estimation is conducted through this method. As in the Augmented Dickey-Fuller (ADF) test, the test results are compared with MacKinnon critical values to determine whether the series is stationary (Tarı, 2010).

Although the ADF and PP unit root tests provide valuable insights into stationarity analysis, they disregard structural breaks. However, the presence of structural changes in econometric models can influence the stationarity properties of the series. Therefore, after applying traditional stationarity tests, the Zivot-Andrews test, which accounts for structural breaks, was employed to examine the presence of such breaks. The Zivot & Andrews (2002) study explains structural breaks as endogenous and allows for only one break point through the following three models:

$$Model\ A: Y_t = \mu + \beta_t + \delta Y_{t-1} + \theta_1 DU(\lambda) + \sum_{i=1}^{k} \delta_i \Delta Y_{t-i} + \varepsilon_t \quad (7)$$
$$Model\ B: Y_t = \mu + \beta_t + \delta Y_{t-1} + \theta_2 DT(\lambda) + \sum_{i=1}^{k} \delta_i \Delta Y_{t-i} + \varepsilon_t \quad (8)$$
$$Model\ C: Y_t = \mu + \beta_t + \delta Y_{t-1} + \theta_1 DU(\lambda) + \theta_2 DT(\lambda) + \sum_{i=1}^{k} \delta_i \Delta Y_{t-i} + \varepsilon_t \quad (9)$$

The null hypothesis for Model A, Model B, and Model C is that the series contains a unit root under the presence of a structural break. DU represents the dummy variable for a break in the level of the series, while DT represents the dummy variable for a break in the slope.

$$DU(\lambda) = \begin{cases} 1, & t \geq T_B \\ 0, & t \leq T_B \end{cases} ve\ DT(\lambda) = \begin{cases} t - T\lambda, t > T\lambda \\ 0, \quad t \leq T_B \end{cases} \quad (10)$$

t = 1,2,3,…,T represents time, while T_B denotes the break date, and λ = T_B/T represents the break time.

5.2 Hacker and Hatemi-J (2006) Symmetric Causality Test

The symmetric causality analysis by Hacker & Hatemi-J (2006) is based on and serves as a continuation of the causality analysis by Toda and Yamamoto (1995). In both analyses, the cointegration status and the stationarity order of the series are not considered; however, the main difference is that the Hacker & Hatemi-J (2006) analysis employs the leveraged bootstrap method (Özer & Kırca, 2018).

Hacker and Hatemi-J (2006) have thoroughly examined the dimensional properties of the Toda and Yamamoto (1995) analysis and pointed out that the asymptotic χ^2 distribution performs inadequately in small sample sizes. Findings from the Monte Carlo simulation demonstrate that in the Toda and Yamamoto (1995) analysis, based on the bootstrap method, dimensional distortions caused by the asymptotic distribution are less prominent. Therefore, it is recommended to use the leveraged bootstrap method to reduce dimensional distortions (Hacker & Hatemi-J, 2006). In the Toda and Yamamoto (1995) based analysis proposed by Hacker and Hatemi-J (2006), the estimated VAR (p+dmax) model is expressed as follows (Hacker & Hatemi-J, 2006):

$$y_t = v + A_1 y_{t-1} + A_p y_{p-1} + \cdots + A_{p+d} y_{t-(p+d)} + \varepsilon_t \quad (11)$$

In equation (11), y_t represents the vector of k independent variables, v denotes the constant term, A represents the parameter matrix, and ε_t stands for the error term vector. (p) indicates the maximum lag length, while dmax represents the maximum degree of

integration. Unlike the Toda and Yamomoto (1995) causality analysis, the bootstrap distribution has been preferred. The bootstrap method estimates the distribution of the test statistic by resampling the dataset. This approach yields more accurate critical values and reduces distortions. To conduct the bootstrap simulation, each simulation first generates K* data by assuming the null hypothesis (H0) of no Granger causality (Hacker & Hatemi-J, 2006).

$$K^* = \check{E}Z + \psi^* \tag{12}$$

According to equation (12), Z represents the independent variables, $\check{E}$denotes the estimated parameter values, and ψ∗ signifies the bootstrap error terms. The parameters are determined by the equation $\check{E} = KZ'^{(ZZ')^{-1}}$. Bootstrap error terms are randomly drawn T times and used in place of the error terms. These terms are selected with a probability of 1/T, and by taking their averages and differences, the issue of varying variance is eliminated. Before the bootstrap error terms, the matrix of independent variables must be constructed. The T×1leverage vectors are represented as X_{1t} ve X_{jt} in equations (13) and (14), respectively (Hatemi-J & Roca, 2006):

$$h_1 = diag\ (X_1(X_1'X_1)^{-1}X_1' \tag{13}$$
$$h_2 = diag\ (X(X'X)^{-1}X' \tag{14}$$
$$j = i - 1\ , i = 1,2,3,4 \dots, j$$

In Equations (13) and (14), $X = (W'_{-1}, \dots, W'_{-P})$ ve $X_i = (W'_{i,-1}, \dots, W'_{i,-P})$ where W represents the lagged values of X_{1t}, and in the equation determining X_{1t}, X1 represents the matrix of independent variables. Similarly, in the model determining Xjt,X is the matrix of independent variables. This equation is subject to the Granger causality restriction, and the null hypothesis H_0 is formulated as " Xjt is not the Granger cause of X_{1t}". The error term matrix is represented by Equation (15), where h_{it} represents the t-th component of h_i, and εit denotes the unmodeled error term.

$$\varepsilon_{it}^m = \frac{\varepsilon_{it}}{\sqrt{1-h_{it}}} \tag{15}$$

5.3 Breitung and Candelon (2006) Frequency Domain Causality Test

Granger (1969) introduced the concept of causality to the literature, which refers to the inclusion of the lagged values of one variable in the equation of another variable. Various causality tests have been developed in the literature to examine causal relationships between variables. These traditional tests operate in the time domain, providing a test statistic that measures causality between variables in only a single time dimension (Aydın, 2020).

Granger (1969), Geweke (1982), and Hosoya (1991) are notable contributors to the development of frequency-based causality tests and their application methods in the literature. Geweke and Hosoya offered a causality measurement in the frequency domain by decomposing spectral density functions into specific frequency intervals. Building on these approaches, Breitung & Candelon (2006) proposed the use of a Vector Autoregression (VAR) model, as shown in Equations (16) and (17), to evaluate potential causality relationships in their frequency-based causality test (Breitung & Candelon, 2006).

$$Y_t = \theta_{11,1}Y_{t-1} + \theta_{11,2}Y_{t-2}, \dots, +\theta_{11,p}Y_{t-p} + \theta_{12,1}X_{t-1} + \theta_{12,2}X_{t-2}, \dots, \theta_{12,p}X_{t-p} \tag{16}$$
$$X_t = \theta_{21,1}Y_{t-1} + \theta_{21,2}Y_{t-2}, \dots, \theta_{21,p}Y_{t-p} + \theta_{22,1}X_{t-1} + \theta_{22,2}X_{t-2}, \dots, \theta_{22,p}X_{t-p} \tag{17}$$

The model presented in Equations (16) and (17) is expressed in matrix form using the lag operator (L) as follows:

$$\varphi(L) = \begin{pmatrix} Y_t \\ X_t \end{pmatrix} = \begin{pmatrix} \varphi_{11}(L) & \varphi_{12}(L) \\ \varphi_{21}(L) & \varphi_{21}(L) \end{pmatrix} \begin{pmatrix} X_t \\ Y_t \end{pmatrix} = \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix} \quad (18)$$

$\varphi(L) = I - \varphi_1 L - \varphi_2 L^2 - \cdots - \varphi_p L^p$ represents the 2x2 lag polynomial, while denotes $\varphi_1 - \varphi_2 - \varphi_3 - \cdots - \varphi_p$ the 2x2 autoregressive parameter matrix. Breitung & Candelon (2006) specified that ε_{1t} and ε_{2t} represent the error vector, which corresponds to white noise. The moving average representation of the VAR model, shown through Cholesky decomposition, is:

$$\begin{pmatrix} Y_t \\ X_t \end{pmatrix} = \psi(L)\eta_t = \begin{pmatrix} \psi_{11}(L) & \psi_{12}(L) \\ \psi_{21}(L) & \psi_{22}(L) \end{pmatrix} \begin{pmatrix} \eta_{1t} \\ \eta_{2t} \end{pmatrix} \quad (19)$$

$\psi(L) = \varphi(L)^{-1}G^{-1}, E(\eta_t, \eta_t) = I$ ve $\eta_t = G\varepsilon_t$ represents. Based on this equation, the spectral density function of x_t is expressed as follows:

$$f_x(\omega) = \frac{1}{2\pi}\left\{\left|\psi_{11}(e^{-i\omega})\right|^2 + \left|\psi_{12}(e^{-i\omega})\right|^2\right\} \quad (20)$$

The causality measure proposed in the studies of Geweke (1982) and Hosoya (1991) has been reformulated as shown in Equation (21):

$$M_{x\to y}(\omega) = \log\left[1 + \frac{\left|\psi_{12}(e^{-i\omega})\right|^2}{\left|\psi_{11}(e^{-i\omega})\right|^2}\right] \quad (21)$$

In Equation (21), the test examines whether Y_t is not the Granger cause of X_t at frequency ω. The approach by Breitung and Candelon (2006) is expressed with the following linear restrictions:

$$\sum_{k=1}^{p} \theta_{12,k} \cos(k\omega) = 0,\ \sum_{k=1}^{p} \theta_{12,k} \sin(k\omega) = 0 \quad (22)$$

In line with these restrictions, a standard F-test can be conducted to test the null hypothesis, which implies the absence of Granger causality at frequency ω. The F-statistic is distributed as F(2,T−2p) where $\omega \in (0,\pi)$ representing 2 restrictions. T denotes the number of observations, while p represents the order of the VAR model.

6. Findings

Using a monthly data set for the period from January 2015 to July 2024, this study examines the causal relationship between e-commerce volume in Türkiye, personal loans, and inflation. Both symmetric and frequency-based causality tests were employed. For the time domain causality test, the Hacker and Hatemi-J (2006) Symmetric Causality Test was utilized, while the Breitung and Candelon (2006) Frequency Domain Causality Test was applied for frequency-based causality analysis. Given the Turkish economy's experience of numerous structural breaks during the observed period, alongside traditional unit root tests such as the Augmented Dickey-Fuller (ADF) (1981) and Phillips-Perron (PP) (1988) tests, the Zivot-Andrews (1992) unit root test, which is effective at detecting endogenous breaks and allows for a single structural break, was also employed. The descriptive statistics for the variables are as follows:

Table 2. Descriptive Statistics of the Data Set

	Lneth	**Lnihkre**	**lntufe**
Average	10.049	12.656	6.260
Median	9.695	12.386	6.076
Maximum	12.959	14.017	7.780
Minimum	8.229	11.927	5.523
Standard Deviation	1.343	0.644	0.651
Skewness	0.642	0.611	0.901
Kurtosis	2.234	2.070	2.611
Jarque-Bera	10.710	11.318	16.315
Probability	0.004	0.003	0.000

When examining the descriptive statistics of the variables in the data set, it can be observed that the median values are close to the means, indicating that the distributions of the variables are largely symmetrical, albeit with some small deviations. Considering the minimum and maximum values, it is particularly notable that the e-commerce volume variable exhibits a wider range of distribution and shows more fluctuations compared to other variables. This highlights that the variability in e-commerce volume is greater than that of other variables such as personal loans and inflation. The standard deviation values support this finding, showing that the e-commerce volume variable has higher volatility and a broader distribution range.

When skewness values are examined, all variables exhibit positive skewness, indicating that the distributions are skewed to the right, or shifted toward higher values. The kurtosis values are lower compared to a normal distribution, indicating that the distributions are flatter and that extreme values are relatively limited. According to the Jarque-Bera test results, the probability values for all variables are below 0.05, indicating significant deviations from normal distribution. In particular, when considering the skewness and kurtosis values of the variable representing inflation (lntufe), it can be said that it shows a more pronounced deviation from normal distribution.

These findings emphasize the need to consider the distribution characteristics of the variables during the modeling process and highlight the necessity of making corrective adjustments, particularly regarding outliers and skewness issues. Additionally, the variability differences between e-commerce volume and other variables suggest that frequency-based causality analyses could produce meaningful results, indicating that e-commerce volume has a more dynamic structure compared to other variables.

In terms of the methodological sequence of the study, the results of the unit root tests on the series are reported first, followed by the results of the symmetric causality and frequency-domain causality tests. The results of the traditional unit root tests, ADF and PP, are presented in Table 3:

Table 3. ADF and PP Unit Root Test Results

				Augmented Dickey-Fuller (1979, ADF)
		Level I(0)		
		LNETH	LNTUFE	LNIHKRE
Constant	t-Statistic	3.696	2.925	1.689
	Prob.	0.999	0.999	0.999
Constant and Trend	t-Statistic	-0.048	-0.075	-1.558
	Prob.	0.995	0.994	0.803
No Constant and No Trend	t-Statistic	7.179	3.669	2.801
	Prob.	0.999	0.999	0.998
		First Difference I(1)		
		d(LNETH)	d(LNTUFE)	d(LNIHKRE)
Constant	t-Statistic	-20.358	-4.859	-3.618
	Prob.	0.000***	0.000***	0.006***
Constant and Trend	t-Statistic	-9.563	-6.016	-4.339
	Prob.	0.000***	0.000***	0.003***
No Constant and No Trend	t-Statistic	-0.072	-2.024	-2.353
	Prob.	0.000***	0.000***	0.000***
				Phillips ve Perron (1988, PP)
	Level I(0)			
		LNETH	LNTUFE	LNIHKRE
Constant	t-Statistic	4.071	4.654	2.968
	Prob.	0.999	0.999	0.999
Constant and Trend	t-Statistic	-1.102	0.400	-1.153
	Prob.	0.923	0.998	0.914
No Constant and No Trend	t-Statistic	7.451	5.541	5.095
	Prob.	0.999	0.999	0.999
		First Difference I(1)		
		d(LNETH)	d(LNTUFE)	d(LNIHKRE)
Constant	t-Statistic	-20.858	-4.859	-3.583
	Prob.	0.000***	0.000***	0.007***
Constant and Trend	t-Statistic	-29.489	-5.917	-4.410
	Prob.	0.000***	0.000***	0.000***
No Constant and No Trend	t-Statistic	-14.985	-3.055	-2.068
	Prob.	0.000***	0.000***	0.000***

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. The "d" notation signifies that the first difference of the series has been taken.

As a result of the unit root test, it was determined that all variables exhibit unit roots at their level values (I(0)) in both unit root tests. However, when first differences (I(1)) were taken, the series became stationary at a high significance level of 1%. After determining the stationarity levels of the series, the Zivot & Andrews (2002) unit root test was applied to identify the break dates. The results are reported in Table 4:

Table 4. Zivot-Andrews (ZA) (1992) Unit Root Test

	Model A		Model C	
Değişken	Min T-stat	Breakage	Min T-stat	Breakage
LNETH	-2.344	March 2022(3)	--3.995	December 2020(3)
dlneth	*-7.215*	*March 2020(4)****	*-7.460*	*March 2022(4)****
LNTUFE	-3.939	December 2021(4)	-4.713	February 2021(4)
dlntufe	*-6.409*	*November 2021(3)****	*-7.140*	*December 2021(3)****
LNIHKRE	-2.824	September 2022(1)	-3.904	August 2018(1)
dlnihkre	*-4.762*	*August 2020(0)**	*-4.743*	*August 2019(0)*

Note: The values in parentheses indicate the number of lags selected by the Akaike Information Criterion. The critical values for the models taken from Zivot and Andrews (1992) are as follows: for Model A, at the 1%, 5%, and 10% significance levels, the critical values are -5.34, -4.80, and -4.58, respectively. For Model C, at the 1%, 5%, and 10% significance levels, the critical values are -5.57, -5.08, and -4.82, respectively.

The results of the ZA unit root test, which determines the structural break endogenously in the series, are reported in Table 4. The results obtained are consistent with the ADF and PP tests. When the calculated t-statistic exceeds the critical values provided in Zivot-Andrews (1992) in absolute terms, the null hypothesis indicating the

presence of a unit root without a structural break is rejected. Conversely, if the t-statistic falls below the Zivot-Andrews (1992) critical values in absolute terms, the alternative hypothesis indicating trend stationarity with a single structural break in the trend function is rejected. Since the test statistic values for all variables in the model at the level values, for both Model A and Model C, are smaller than the critical values in absolute terms, no statistical significance was found.

In the empirical analysis, after the stationarity tests, the next step was to examine causality. For this purpose, the Hacker and Hatemi-J (2006) Symmetric Causality Test, which provides reliable results in small sample sizes and detects causality in the time domain, was utilized. The results are presented in Table 5:

Table 5. Hacker and Hatemi-J (2006) Symmetric Causality Test

Direction of Causality	Test Statistic	Critical Values		
		%1	%5	%10
Eth≠>ihkre	0.373	12.495	8.253	6.469
ihkre≠>eth	10.789**	12.067	8.091	6.491
eth≠>tufe	4.078	13.474	8.492	6.449
tufe≠>eth	4.613	11.558	8.066	6.422

Note: The optimal lag length was determined using the HJC criterion. Critical values were generated via bootstrap. The number of bootstrap replications is 10,000.

Upon examining Table 5, it can be seen that the WALD statistic values are smaller than the critical values in all pairwise tests, except for the relationship between ihkre≠>eth. In other words, in each pairwise group where the test statistic is smaller than the critical values, there is no symmetric causality relationship between the variables. However, a unidirectional causality relationship from personal loans to e-commerce was detected at the 5% significance level. After the symmetric causality test, which was conducted to detect causality in the time domain, the Breitung and Candelon (2006) Frequency Domain Causality Test was applied, which allows for testing causality in the frequency domain. One of the key advantages of the frequency domain causality test is that it investigates time in more detail, rather than treating it as a single dimension like other causality tests. The results are reported in Table 6:

Table 6. Breitung and Candelon (2006) Frequency Domain Causality Test

	Long Term (Permanent)		Medium Term		Short Term (Temporary)	
Variables	ω= 0.01	ω= 0.05	ω= 1.00	ω= 1.50	ω= 2.00	ω= 2.50
Eth≠>ihkre	3.9861	3.9862	4.0127	4.0362	3.9476	3.7507
	(0.1363)	(0.1363)	(0.1345)	(0.1329)	(0.1389)	(0.1533)
ihkre≠>eth	9.1610**	9.1293**	1.3106	5.6313*	8.4083**	9.5565
	(0.0102)	(0.0104)	(0.5193)	(0.0599)	(0.0149)	(0.0084)***
eth≠>tufe	8.0435**	8.0437**	8.0150**	7.2795**	3.4458	0.2238
	(0.0179)	(0.0179)	(0.0182)	(0.0263)	(0.1785)	(0.8941)
tufe≠>eth	7.2292**	7.2441**	10.8254***	5.9360*	3.3530	2.5470
	(0.0269)	(0.0267)	(0.0045)	(0.0514)	(0.1870)	(0.2798)

Note: For ω (frequency) between 0 and π ω∈(0,π) with degrees of freedom (2, T-2p), the F table value is approximately 2.49 at the 10% significance level. * Indicates that the null hypothesis is rejected at the 10% significance level. The values in parentheses represent the p-values of the F statistics.

The results of the frequency domain causality test reveal causal relationships between the variables over different frequency ranges in the long, medium, and short terms. Upon examining Table 6, no significant causality relationship was found from e-commerce to personal loans, as the p-values across all frequency ranges remained above

the threshold for statistical significance. This finding indicates that the e-commerce variable does not have any causal effect on personal loans.

On the other hand, a strong causality relationship from personal loans to e-commerce was identified at the 1% significance level in the long term (ω=0.01 and ω=0.05) and the short term (ω=2.00 and ω=2.50). Additionally, in the medium term (ω=1.50), a weak causality relationship was found at the 10% significance level. These results suggest that personal loans have a significant causal impact on e-commerce, particularly in the long term.

When examining the causality relationship between e-commerce and the Consumer Price Index (CPI), it was observed that e-commerce had a causal effect on CPI at the 5% significance level in the long and medium terms (ω=0.01, ω=0.05, ω=1.00, and ω=1.50). However, this causality relationship loses significance in the short term (ω=2.00 and ω=2.50). Similarly, a strong causality relationship from CPI to e-commerce was found in the long and medium terms, with a 1% significance level at the ω=1.00 frequency. In the short term, no significant impact of CPI on e-commerce was detected.

Overall, these findings indicate that personal loans and CPI have strong causality relationships with e-commerce in the long and medium terms, but this effect diminishes or disappears in the short term. The causality test graphs are provided in the appendix.

Table 7 presents a heat map visualizing the results of the Frequency Domain Causality Test. This map illustrates the causality relationships between variables at different frequencies (ω) and the magnitude of statistical values using a color scale. Higher values are represented by darker colors, highlighting the areas where statistically significant relationships are stronger.

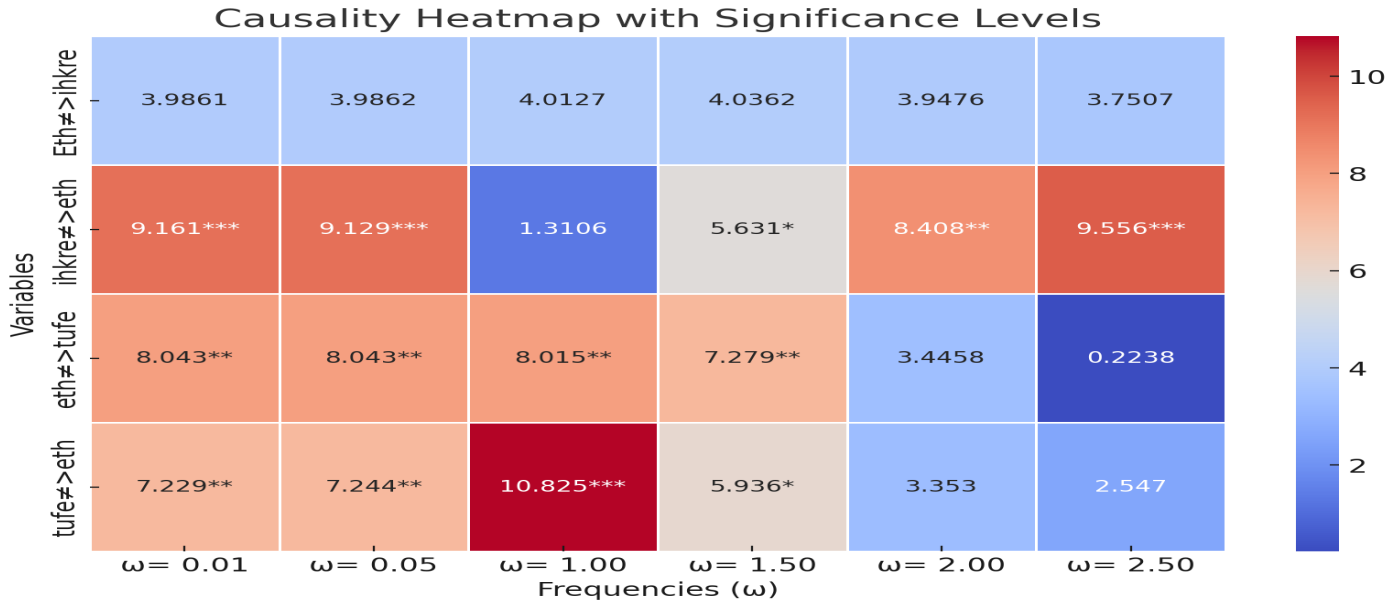

Figure 4. Frequency Domain Causality Test Heat Map

7. Conclusion

This study aims to examine the causality relationship between e-commerce volume, personal loans, and the Consumer Price Index (CPI) in Türkiye using frequency-based methods. The frequency domain causality test employed in this study allows for a more detailed analysis of the relationships between variables over short, medium, and long terms, compared to traditional causality tests. By using this method, the study distinguishes itself from previous works and contributes to the relatively limited literature on e-commerce.

During the sample period considered in this study (2015:01–2024:07), the detailed empirical analysis reveals that the interactions between e-commerce volume, personal loans, and the Consumer Price Index (CPI) could have significant implications for both the financial sector and consumer behavior. First, when examining the impact of personal loans on e-commerce, the strong causality relationship between credit expansion and e-commerce volume is noteworthy. Personal loans are seen as a key tool for financing consumer spending and boosting consumer demand. The rapid growth of e-commerce in Türkiye has been supported by the liquidity provided by consumer loans. In this context, it was concluded that increases in personal loans could positively affect e-commerce volume. From an economic perspective, credit expansions can stimulate consumer demand and, consequently, promote the growth of e-commerce, while also supporting short-term economic growth. However, uncontrolled growth in credit could lead to rising debt levels and pose risks to financial stability.

The absence of a direct causal effect from e-commerce on personal loans suggests that consumers' use of credit is more dependent on other factors, such as general economic conditions, interest rates, and income expectations. Economically, this indicates that there is no direct relationship between the growth of the e-commerce sector and credit demand, but personal loans can contribute to increased consumer spending.

Secondly, when examining the causality relationship between CPI and e-commerce, it is evident that inflation has a significant impact on e-commerce, particularly in the long and medium terms. General increases in consumer prices can directly affect households' purchasing power, shaping their consumption habits. As inflation rises, consumers may increasingly turn to digital platforms to compare prices and seek more affordable products. Economically, this suggests that e-commerce could become a more competitive and preferred channel during inflationary periods. E-commerce platforms' ability to adapt quickly to price changes and offer a wide range of products could demonstrate their resilience against inflationary pressures.

On the other hand, the lack of a significant causality relationship from CPI to e-commerce in the short term may indicate that consumer behavior does not immediately respond to short-term inflation changes. This suggests that a certain period may need to pass for inflation pressures to have a sustainable effect. The limited impact of price increases in the short term may also imply that businesses operating in the digital environment could show some resistance to inflation.

In conclusion, e-commerce volume in Türkiye, shaped by the spending amounts of domestic cards used both domestically and abroad, exhibits strong causality relationships with macroeconomic variables such as personal loans and inflation. The expansion of personal loans positively influences e-commerce volume by increasing consumer spending, with this effect becoming more pronounced in the long term. Inflation, on the other hand, drives consumer behavior towards digital platforms, increasing price sensitivity in e-commerce and having a noticeable impact on e-commerce volume, particularly in the long and medium terms. However, in the short term, the effect of inflation on e-commerce is limited. These findings indicate that e-commerce in Türkiye plays a significant role in economic activities through domestic and international spending and is directly influenced by credit expansions and inflation dynamics.

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Yazar Katkısı: Mehmet Mert TÜRK (%100)

APPENDIX

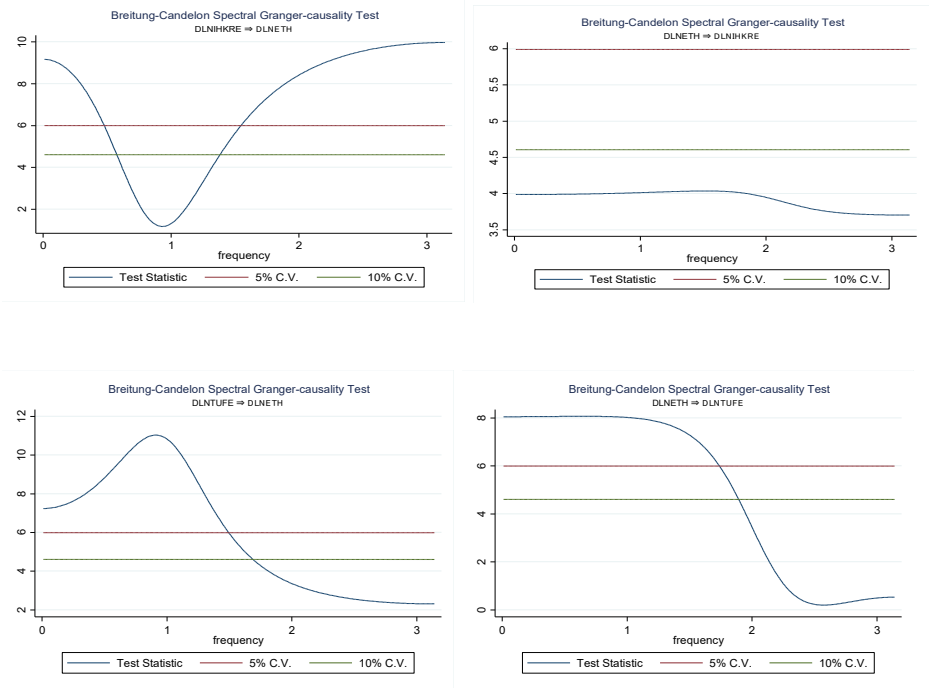

Figure 5. Breitung and Candelon (2006) Frequency Domain Causality Test Graphs Between Variables