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The impact of FinTech on economic growth in Türkiye: A novel FinTech index approach

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Abstract

Aim/purpose – This study aims to explore the impact of FinTech developments on Türkiye’s economic growth from 2012:Q2 to 2024:Q1. While FinTech offers faster, cheaper, and more flexible financial services, its rapid evolution may pose risks, such as economic instability and growth limitations, stemming from digital credit and speculative investments.

Design/methodology/approach – An index representing FinTech developments is constructed using the PCA method, incorporating eight distinct variables. Gross fixed capital formation, labor force, government expenditure, and inflation are included as control variables. The study employs the ARDL bounds testing approach to examine long-run relationships, and robustness checks are performed using FMOLS, DOLS, and CCR methods. Finally, causality relationships are investigated using the Toda–Yamamoto test.

Findings – The analysis reveals that FinTech developments and economic growth are closely linked in the long run, exhibiting a strong bidirectional causality relationship. However, FinTech has a dampening effect on economic growth, emphasizing its disruptive potential in Türkiye. These findings are consistent across alternative estimation methods.

Research implications/limitations – The study highlights the importance of regulating FinTech innovations to mitigate their adverse effects on economic stability. However, the research faces limitations, including the lack of comprehensive data that better captures the FinTech ecosystem and the inability to use panel data due to the single-country focus. Future studies could address these limitations by incorporating richer datasets or conducting cross-country analyses for broader insights.

Originality/value/contribution – This research contributes to the literature by developing a unique FinTech index and providing empirical evidence on its impact on economic growth in a developing economy. It underscores the critical role of effective regulation and the development of an inclusive financial ecosystem in ensuring sustainable growth.

Keywords: financial technology, FinTech, economic growth, ARDL.

JEL Classification: G00, O40, C22.

1. Introduction

The term financial technology (FinTech) encompasses a network of start-ups and innovations that heavily rely on technology in the financial services sector (Arner et al., 2015). FinTech has become increasingly prominent in the post-Global Financial Crisis (GFC) period, and interest in this concept is growing daily within the academic community (International Monetary Fund [IMF], 2018). Although the concept of “FinTech” emerged conceptually in the post-GFC period, the combination of the terms “finance” and “technology” and the meaning it conveys has a notable historical background.

According to the taxonomy developed by Arner et al. (2017), the historical roots of finance and technology interaction can be traced back to the 19th century. FinTech developments can be examined in three different periods. In 1866, the introduction of transatlantic cables connecting two continents marked the beginning of the FinTech 1.0 era. The use of credit cards and the subsequent introduction of automated teller machines (ATMs), which revolutionized payment services in 1967, led to the FinTech 2.0 period. Indeed, the transition from the FinTech 2.0 period to the 3.0 period was triggered by the GFC. This has led to a decline in trust in traditional banking, a rise in sanctions and regulations, and a growing emphasis on the stability of the financial system. However, artificial intelligence (AI), machine learning, software, cloud computing, and blockchain technologies have rapidly developed and found applications in financial services through FinTechs (Arner et al., 2017).

FinTechs, utilizing technologies such as blockchain, AI, and cloud computing, have emerged in the post-GFC era, offering a range of products and services, including crypto assets, data analytics, and peer-to-peer payments (Kömürçüoğlu & Kömürçüoğlu, 2025). In addition to their economic applications, digital technologies such as AI are being increasingly integrated into broader sustainability strategies, promoting energy efficiency and reducing carbon emissions (Wang et al., 2024a, 2025a). This signals the wider transformative potential of digital innovation, including FinTech, on socio-economic systems.

By providing cost-effective and accessible financial solutions via mobile platforms, they reduce transaction costs and enhance convenience outside traditional institutional frameworks (Ozili, 2018). However, their disruptive role – particularly through alternative payment methods – may also introduce risks to macroeconomic stability in the early stages of development (Jiang et al., 2025).

FinTech developments offer both opportunities and threats due to their rapid progress and wide application. The literature extensively discusses their structure, interaction with institutions, and future in the developing sector (Goldstein et al., 2019; Murinde et al., 2022). Econometric analyses have examined their effects on monetary policy (Kömürçüoğlu & Akyazı, 2024), retail banking (Varma & Nijjer, 2022), unemployment (Elmasmari & Amaghous, 2024), and inflation (Romdhane et al., 2023). Most importantly, empirical studies on the impact of FinTech on economic growth are quite limited.

The impact of FinTech on economic growth is closely linked to the structural transformation of financial systems and the implementation of technological innovations. FinTech fosters growth primarily by increasing financial inclusion, expanding access to financial services, and reducing costs. Innovations such as mobile banking, digital lending, and crowdfunding encourage broader economic participation, particularly among populations underserved by traditional financial institutions (Bu et al., 2023). Furthermore, FinTech enhances financial efficiency by accelerating transactions, reducing costs, and mitigating information asymmetry through the use of big data, AI, and cloud computing. However, without adequate regulation and supervision, FinTech can introduce new financial risks, potentially undermining stability through rapid digital credit expansion and speculative activities (Mashamba & Gani, 2023). Additionally, disparities between developed and developing regions may widen, as FinTech-driven growth tends to concentrate in regions with more advanced digital and educational infrastructures (Song & Appiah-Otoo, 2022). Therefore, understanding the mechanisms through which FinTech affects economic growth is essential for designing policies that maximize its benefits while minimizing its potential risks.

Against this background, the question of whether FinTech developments promote or inhibit economic growth has become particularly critical for Türkiye, where this relationship remains largely unexplored. In light of this gap, the present study aims to empirically examine the short and long-run effects of FinTech developments on economic growth in Türkiye over the period 2012:Q2–2024:Q1. While existing studies frequently focus on financial innovation, development, or inclusion, these concepts do not fully capture the multidimensional nature of FinTech. To this end, a novel FinTech index has been constructed using Principal Component Analysis (PCA), incorporating eight variables that

represent key components of the contemporary FinTech ecosystem. Unlike previous indexes in the literature, this index provides a more comprehensive, inclusive, and methodologically rigorous representation of FinTech developments, with particular emphasis on payment services, which dominate the FinTech ecosystem in Türkiye. Moreover, the selected period reflects the FinTech 3.0 era, characterized by the post-GFC expansion of digital financial services. In line with the stated aim, this study employs the Auto Regressive Distributed Lag (ARDL) bounds testing approach to analyze the short and long-run effects of FinTech developments on economic growth in Türkiye. The findings are expected to provide policymakers with valuable insights aiming to leverage technological advancements for sustainable economic development.

This study makes several contributions to the literature. First, it provides one of the earliest empirical investigations into the relationship between FinTech developments and economic growth in the Turkish context. Second, while the determinants of economic growth have been widely analyzed, the role of FinTech as a driver of growth remains underexplored, particularly in emerging economies. Third, the construction of a comprehensive FinTech index based on multiple indicators enables a more nuanced understanding of how financial technological innovations influence growth dynamics.

The remainder of the paper is structured as follows: Section 2 reviews the literature, Section 3 outlines the methodology and dataset, Section 4 presents the results, Section 5 discusses the findings, and Section 6 concludes with policy implications.

2. Literature review

The relationship between financial system development and economic growth has been a focal point in economic growth theories, with pioneering works by Bagehot (1873/1920) and Schumpeter (1912). Bagehot (1873/1920) highlighted the efficient functioning of the financial system in funding entrepreneurs and supporting growth, while Schumpeter (1912) emphasized the role of financial systems in financing innovations that drive economic progress. Later works, including those by Gurley and Shaw (1955), Hicks (1969), Goldsmith (1969), McKinnon (1973), and Shaw (1973), further deepened this understanding. Hicks (1969) focused on financial structures in the growth process, while Goldsmith (1969) linked financial development to higher growth rates. McKinnon (1973) and Shaw (1973), however, argued that financial repression limits growth, advocating for financial liberalization to enhance resource allocation and investment opportunities.

Before the GFC, financial development was seen mainly as a catalyst for economic growth, influencing financial reforms in developing countries (Bu et al., 2023). However, the GFC disrupted trust in traditional banking, paving the way for FinTechs to emerge as key players in the financial system. Technologies such as AI, robotics, and cloud computing have made FinTech products more efficient and affordable, granting them an advantage over traditional banking (Gomber et al., 2018). Following the GFC, FinTechs have experienced significant growth, reshaping financial systems and becoming increasingly relevant to economic growth (Jiang et al., 2025). This change has led to the role of FinTech in the economic development process being the subject of academic research. Recent studies also demonstrate that AI has transformative potential beyond financial systems, as it contributes to ecological sustainability by facilitating energy transitions and reducing ecological footprints (Wang et al., 2024b). These insights reinforce the narrative that disruptive technologies can simultaneously serve economic and environmental objectives.

For example, Narayan (2019) examined FinTech's impact on financial services and economic growth in Indonesia from 1998 to 2018 using the ordinary least squares. The study found that while FinTech upstart-ups initially caused disruptive effects, they later significantly contributed to growth. Key factors, such as capital per labor force, foreign direct investment, stock market development, and trade openness, were also critical. To sustain Indonesia's growth, the study emphasized the need to support FinTech through improved infrastructure and regulations.

Song and Appiah-Otoo (2022) examined FinTech's impact on economic growth across 31 Chinese provinces, focusing on subcomponents such as third-party payments, credit, and insurance, using the generalized method of moments (GMM) with data from 2011 to 2017. The results indicated that FinTech significantly enhances growth, with a 10% increase in FinTech boosting growth by 8%, third-party payments by 4%, credit by 5%, and insurance by 16%. Regionally, the eastern provinces benefited most. Moreover, the analysis revealed unidirectional causality between third-party payments, credit, and growth, whereas FinTech and growth were found to have a bidirectional relationship. The study recommended institutional reforms to foster FinTech's sustainable development.

Bu et al. (2023) examined the non-linear effects of FinTech on economic growth in China from 2011 to 2019. The findings revealed U-shaped relationship between FinTech development and economic growth. Accordingly, while FinTech may limit economic growth in the initial stage, it makes a substantial contribution to growth once a certain development threshold is exceeded. However, these effects are characterized by diminishing marginal returns over time.

Moreover, the impact of FinTech on economic growth varies depending on the region's specific economic circumstances. Therefore, it is emphasized that strategies should be developed to harmonize technology and economic development by considering local conditions.

Mashamba and Gani (2023) examined the impact of FinTech on bank financing and economic growth in 19 Sub-Saharan African countries for the period 2010-2020, particularly from the perspective of competition between FinTech and traditional banks. It has been found that FinTech has increased equity financing for banks but has not had a significant impact on deposits and long-run debt financing. The relatively limited size of the FinTech sector in the region also limits the overall impact of these technologies on economic growth. Moreover, FinTech has not significantly affected the relationship between bank financing and economic growth. Nevertheless, it is stated that FinTech investments should be maintained and their impact on financial stability should be monitored in order to achieve long-run economic growth targets.

Nenavath and Mishra (2023) analyzed the effects of green finance and FinTech on sustainable growth across Indian states with data between 2010 and 2021. According to the results of the study, which included cointegration, GMM, and causality analyses, green finance stands out as an important factor for sustainable growth by strengthening both the financial system's structure and environmental protection efforts. While FinTech enhances the efficiency of financial services, it also contributes to the support of green projects and further strengthens this process. In this context, the necessity of developing regulations that encourage investment in environmentally friendly projects and support the integration of FinTech with green finance is emphasized.

Cevik (2024) examined FinTech's impact on economic growth in 198 countries during 2012-2020. The results indicated that FinTech has a positive impact on gross domestic product (GDP) per capita growth, with digital lending playing a key role. While FinTech's growth effect is stronger in developed economies, it is statistically more significant in developing countries, attributed to differences in FinTech infrastructure, regulatory frameworks, and financial ecosystems. In developing nations, FinTech innovations enhance growth by boosting financial inclusion. However, establishing robust regulatory frameworks and integrating technology with these frameworks is critical for maximizing long-run growth impacts.

Liu and Chu (2024) focused on the contribution of the FinTech sector to economic growth during the COVID-19 pandemic. It was observed that FinTech supported economic performance positively in the economic stagnation process during the pandemic, especially in countries with widespread internet usage. It

was also revealed that FinTech played a role in mitigating the unfavorable economic conditions created by the pandemic. In this context, it is emphasized that countries should increase their investments in internet infrastructure and the FinTech sector to create a more resilient structure against economic fluctuations.

The literature review reveals that the impact of FinTech innovations on economic growth has been examined from diverse perspectives across different countries. A common aspect of these studies is that they emphasize the pivotal role FinTech plays in economic growth and the substantial advantages it provides over traditional financial systems. Narayan (2019) and Song and Appiah-Otoo (2022) disclose that FinTech contributes to economic growth and that countries tend toward a more innovative and digitalized structure in this process. Cevik (2024) highlighted that the effects of FinTech differ from one country to another. Similarly, Mashamba and Gani (2023) revealed the limited impact of FinTech development on growth in Sub-Saharan Africa.

Although studies analyzing the relationship between FinTech and economic growth are limited, their number has increased significantly in recent years. Nevertheless, to understand the nature of the relationship between FinTech and economic growth, this relationship should be analyzed from different aspects. While existing studies provide valuable insights into the FinTech-growth nexus, many of them focus on broader or cross-country settings and often overlook country-specific dynamics. Moreover, they tend to neglect the multidimensional structure of FinTech ecosystems and rarely address potential long-run structural risks associated with rapid digital transformation. This study aims to fill these gaps by empirically investigating the impact of FinTech developments in a single emerging economy – Turkish – using a novel FinTech index constructed via PCA. The index uniquely captures both traditional and modern dimensions of financial technology, offering a more comprehensive and context-sensitive measure. Additionally, the study distinguishes between the short and long-run effects of FinTech on economic growth, thereby contributing to a more nuanced understanding of the opportunities and risks posed by financial digitalization in developing economies.

3. Research methodology

In this section of the study, the model, dataset, and methodology used for the analysis are presented.

3.1. Model

This study aims to analyze the short and long-run effects of FinTech developments on economic growth. According to the literature, gross fixed capital formation, labor force, consumer price index, and government expenditures are included in the model as control variables following the literature (Adaramola & Dada, 2020; Islam & Biswas, 2023; Pandusetya et al., 2021). In particular, government expenditures are added to mitigate potential bias due to omitted variables. As an explanatory variable, the index representing FinTech developments is added to the model. The basic model used in the analysis is as in equation 1.

$$GDP_t = \beta_0 + \beta_1 GFCF_t + \beta_2 LABOR_t + \beta_3 CPI_t + \beta_4 GE_t + \beta_5 Findex_t + \varepsilon_t \quad (1)$$

Here, GDP represents gross domestic product, GFCF represents gross fixed capital formation, LABOR represents the labor force, CPI represents the consumer price index, GE represents government expenditures, and Findex represents the FinTech index.

3.2. Dataset

This study investigates the relationship between FinTech developments and economic growth in Türkiye from 2012:Q2 to 2024:Q1. “FinTech Index” was constructed to represent FinTech developments and eight different variables were used for this purpose. These variables include the number of ATMs, the number of point-of-sale (POS) devices, the total number of cards, the number of contactless cards, contactless card usage, the number of mobile banking customers, the number of internet banking customers, and confidence in financial services. Table 1 presents explanatory information regarding the variables used in the index.

Table 1. Variables used in the index

Variables	Description	Database
Number of ATMs	Total number of ATMs	The Interbank Card Centre (BKM)
Number of POS devices	Total number of POS and cash register devices	
Total number of cards	Total number of credit, debit, and prepaid cards	
Number of contactless cards	Number of contactless cards in total cards	
Contactless card usage	Number of transactions of contactless cards in domestic and cross-border usage	
Internet banking	Number of customers registered in internet banking	The Banks Association of Türkiye (BAT)
Mobile banking	Number of customers registered in mobile banking	Central Bank of the Republic of Türkiye (CBRT–EVDS)
Financial services	Financial services confidence index from survey results	

Source: Authors' own compilation.

These variables, shown in Table 1, are frequently used in the literature to represent the FinTech sector and its developments. The variables for the number of ATMs and POS devices were included in the analyses as representative of FinTech developments by Kredina (2021), and Dermaku et al. (2023); the variables related to the number and features of cards by Wasiaturrahma (2019) and Muslikhati and Aprilianto (2022); the mobile banking variable by Karaçayır and Afşar (2021); the internet banking variable by Feng et al. (2024); and the variables related to confidence in financial services by Mainardes et al. (2023) and Roh et al. (2024). These variables collectively demonstrate that financial services are increasingly being provided through technology. In the 20th century, ATMs, POS, and credit cards, which are symbols of the transition from analog to digital applications, can be considered the most traditional FinTech variables. The number of contactless cards and the use of contactless cards in transactions are also important elements of the technologies offered by the FinTech ecosystem. Additionally, it worth noting that the internet's adaptation to banking services in recent years has been complemented by increasing access to banking services via mobile phones (Arner et al., 2015). Finally, the confidence in financial services variable is included in the index as an indicator of the level of trust in innovative financial services during the FinTech 3.0 period, particularly among economic agents whose trust in traditional finance was shaken in the post-GFC period. Meanwhile, some other FinTech variables are also used in the literature. Crypto assets, a key FinTech element, are excluded from the index due to their daily high frequency and volatility. Additionally, since there is limited access to data on FinTech startup investments and loans on a country-by-country basis, as well as data on FinTech segments (such as investment, insurance, and loans), the FinTech index constructed is limited to the variables mentioned.

The Financial Services Confidence Index has been published by the CBRT since 2012:Q2, and the availability of this and other relevant data was a decisive factor in determining the sample period. In addition, the selection was influenced by the historical trajectory of FinTech developments, specifically the transition to the FinTech 3.0 era (post-2008), as classified by Arner et al. (2017). The past decade, in particular, marks a significant phase in the evolution of FinTech. Therefore, considering both data availability and the momentum of technological advancement in the FinTech 3.0 period, the study focuses on the timeframe between 2012:Q2 and 2024:Q1.

Information on the dependent and explanatory variables used in the analysis is presented in Table 2.

Table 2. Variables used in the analysis

Variables	Description [units of measurement] – references	Database
Finindex	FinTech index	Author's own calculation
GDP	GDP chain-linked volume [thousand TRY – level – 2009 = 100]	CBRT-EVDS
GFCF	Gross fixed capital formation [Thousand TRY – level – 2009 = 100] (Eşsiz & Durucan, 2023)	
CPI	Consumer price index [2003 = 100] (Khan & Hanif, 2020)	
GE	Primary government expenditures [Thousand TRY – Level] (Kutasi & Marton, 2020)	
LABOR	Labor force [thousand person] (Alam et al., 2013)	Turkish Statistical Institute (TurkStat)

Source: Authors' own compilation.

Before proceeding with the analysis, a seasonality test is applied using the Census X-12 method, as quarterly data are utilized for the variables shown in Table 2. Accordingly, GDP, GFCF, and LABOR variables are seasonally adjusted. Then, a logarithmic transformation is applied to the variables. Except for the FinTech index, which has negative values, the natural logarithm of all variables is taken and denoted by “L.” Accordingly, LGDP and LCPI are considered as proxies for economic growth and inflation, respectively. LGFCF stands out in terms of its positive contribution to growth, as it determines the country's production capacity and its impact on employment. This indicator is based on physical investments. The future production potential of the economy depends on the size of fixed capital investments (Eşsiz & Durucan, 2023). Inflation is widely regarded in academic studies as a significant factor influencing economic growth, although its effects vary (Khan & Hanif, 2020). Labor force quantity and productivity are among the factors that directly affect the growth potential of an economy (Alam et al., 2013). Government expenditure is considered a key determinant of income levels (Kutasi & Marton, 2020).

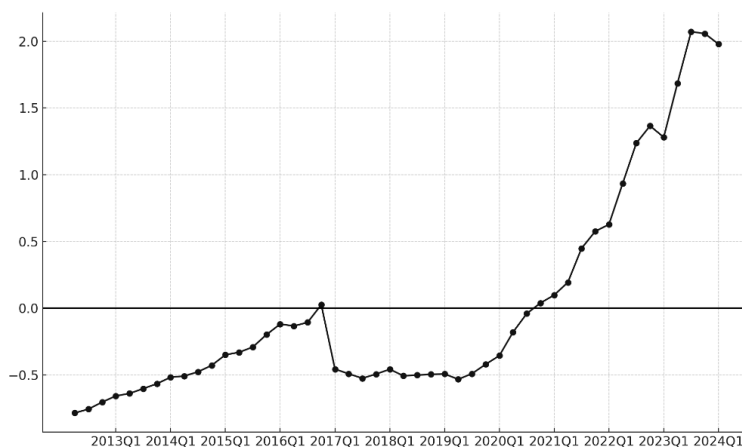
3.3. Estimation methods

First, the study constructs the “FinTech Index” using PCA. Next, the ARDL bounds testing method is applied to analyze both the short- and long-run relationships between the FinTech Index and economic growth. Then, the robustness of the findings is tested through the application of Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and Canonical Cointegrating Regressions (CCR) methods (Olorogun, 2024). Finally, the short-run causality relationship between the variables is investigated using the Granger-based Toda-Yamamoto causality test (Mert & Çağlar, 2019).

PCA is a basic mathematical method used in variable reduction. PCA transforms correlated variables into uncorrelated variables through orthogonal transformation (Lamichhane et al., 2021). The PCA method preserves most of the information carried by the data set and enables representation with fewer variables (Asbahi et al., 2019). The index constructed by PCA should be statistically significant and consistent (Kömürçüoğlu & Artan, 2024). The primary indicator of this is the high variance of the first component (70%). The first two principal components are used, capturing 84% of the total variance. The index is derived as a weighted combination of these two components. The PCA is performed on the standardized variables, meaning it is based on the sample correlation matrix rather than the covariance matrix. This ensures that variables with different scales do not disproportionately influence the index. Nevertheless, the Kaiser–Meyer–Olkin consistency test score is 75% and the probability value of the chi-square test statistic (1022.6) according to Bartlett’s Test of Sphericity is less than 5%, confirming the validity of the index. Therefore, the FinTech index is considered suitable for use in the model.

The time graph of the FinTech index is shown in Figure 1. Negative values indicate periods below the long-run average of the index. FinTech developments have been rapidly propelled by the COVID-19 pandemic, leading to a greater adoption of digital payments. Accordingly, it can be roughly stated that FinTech developments gained significant momentum in Türkiye after the mid-2020 period.

Figure 1. Time graph of Findex



Source: Authors' own computations

Developed by Pesaran et al. (2001) and based on Pesaran and Shin (1999), the ARDL method is widely used in econometric analyses due to its flexibility and ability to deliver robust results even with small sample sizes. As long as the stationarity level of the series is not I(2), the analysis can be performed regardless of whether the series is stationary at the level and/or first difference. This is because Pesaran's F-statistics and critical values are determined in accordance with I(0) and/or I(1) levels of stationarity (Kocak et al., 2025; Kripfganz & Schneider, 2023; Wegari et al., 2023). Equation (2) shows the basic model used in the analysis for the ARDL bounds test.

$$\Delta LGDP_t = \alpha_0 + \sum_{i=1}^n b_i \Delta LGDP_{t-i} + \sum_{i=0}^n c_i \Delta LGFCF_{t-i} + \sum_{i=0}^n d_i \Delta LLABOR_{t-i} + \sum_{i=0}^n e_i \Delta LCPI_{t-i} + \sum_{i=0}^n f_i \Delta LGE_{t-i} + \sum_{i=0}^n g_i \Delta Findex_{t-i} + \vartheta_0 LGDP_{t-1} + (2) \vartheta_1 LGFCF_{t-1} + \vartheta_2 LLABOR_{t-1} + \vartheta_3 LCPI_{t-1} + \vartheta_4 LGE_{t-1} + \vartheta_5 Findex_{t-1} + \varepsilon_t$$

Δ denotes the first difference operator, and ε denotes the error term. While b_i , c_i , d_i , e_i , f_i and g_i parameters represent short run dynamic coefficients, the parameters $-\frac{\vartheta_1}{\vartheta_0}$, $-\frac{\vartheta_2}{\vartheta_0}$, $-\frac{\vartheta_3}{\vartheta_0}$, $-\frac{\vartheta_4}{\vartheta_0}$, and $-\frac{\vartheta_5}{\vartheta_0}$ denotes the long run coefficients respectively for $LGFCF_{t-1}$, $LLABOR_{t-1}$, $LCPI_{t-1}$, LGE_{t-1} , and $Findex_{t-1}$.

FMOLS, DOLS, and CCR methods, like ARDL analysis, are also successful in producing reliable results in small samples. FMOLS, developed by Phillips and Hansen (1990), DOLS, developed by Stock and Watson (1993), and CCR methods, developed by Park (1992), offer an important advantage in that they allow for the interpretation of the obtained coefficients (Erdoğan et al., 2018).

While the ARDL approach, applicable to variables integrated at different levels, provides both short- and long-run estimates, it does not indicate the direction of causality. For this purpose, the Toda and Yamamoto (1995) causality test is preferred. Unlike the Granger causality test, it does not require stationarity and performs well in small samples, as in this study (Pata & Aydın, 2020). The test involves estimating a VAR model in levels with a lag length of $(k+d_{\max})$, where k is the optimal lag ensuring model stability, and d_{\max} is the maximum integration order of the variables.

4. Research findings

The variables in the study were tested for unit roots using the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests, with the results presented in Table 3.

Table 3. ADF and PP unit root test results

Variables		ADF		PP	
		Constant	Constant-Trend	Constant	Constant-Trend
Level	LGDP	-0.636	-2.762	-0.619	-3.223
	LGFCF	-1.879	-2.794	-1.803	-2.784
	LLABOR	-1.423	-2.309	-1.428	-2.220
	LCPI	7.222	2.738	6.111	2.178
	LGE	5.181	2.704	4.497	0.987
	Findex	1.920	0.096	1.920	-0.008
First difference	Δ LGDP	-10.829***	-10.708***	-12.212***	-12.057***
	Δ LGFCF	-8.349***	-8.278***	-8.329***	-8.315***
	Δ LLABOR	-6.758***	-6.739***	-6.777***	-6.740***
	Δ LCPI	-2.695**	-4.078**	-2.700*	-4.180***
	Δ LGE	0.358	-9.597***	-7.631***	-9.205***
	Δ Findex	-5.128***	-5.595***	-5.080***	-5.608***

Note: ***, **, and * denote 1%, 5%, and 10% significance level, respectively.

Source: Authors' own computations.

According to the unit root test results in Table 3, it was observed that all variables became stationary at their first difference at the 1% level of statistical significance. Therefore, these variables may exhibit a long-run trend or structural change, indicating that the series could have persistent effects in response to shocks, which should be carefully considered in economic analyses. Based on these results, no integration order higher than I(1) was found, and the ARDL bounds testing procedure was initiated.

A valid cointegration relationship is essential for interpreting the short- and long-run coefficients in ARDL analysis. The corresponding bound test results are displayed in Table 4.

Table 4. Bound test results

Model: k = 5				Models
Test statistics	Critical values	I(0)	I(1)	
F-statistic	5%	3.532	4.800	Long-run estimation model
7.967	1%	4.715	6.293	
t-statistic	5%	-3.410	-4.520	
-6.568	1%	-3.960	-5.130	
t-statistic	5%	-3.410	-4.520	Error correction model
-7.600	1%	-3.960	-5.130	

Source: Authors' own computations.

In the bound tests for the long run estimation shown in Table 4, the F-statistic ($7.967 > 6.293$) and t-statistic ($6.568 > 5.130$), as well as the t-statistic ($7.600 > 5.130$) in the bound test for the error correction model, exceed the upper critical values (I(1)) at the 1% significance level. The results confirm cointegration, a valid relationship, a significant error correction term, and a functioning model.

Although the variables in the model are non-stationary at levels, the presence of a cointegration relationship is confirmed through the bounds testing approach within the ARDL framework. Therefore, the estimated long-run coefficients can be interpreted as statistically meaningful despite the non-stationarity of the individual series. Table 5 shows the long-run coefficient estimation results of the ARDL (1, 3, 4, 2, 0, 3) model.

Table 5. Long-run estimation results

Dependent variable: LGDP				
Independent var.	Coeff.	Std. error	t-stat.	Prob.
LGFCF	0.155	0.044	3.507	0.002
LLABOR	0.468	0.105	4.474	0.000
LCPI	0.101	0.030	3.404	0.002
LGE	-0.033	0.023	-1.490	0.149
Findex	-0.035	0.011	-3.167	0.004

Source: Authors' own computations.

According to Table 5, the long-run coefficient results indicate that LGFCF, LLABOR, LCPI, and Findex have 1% statistical significance level. However, LGE was statistically insignificant. Changes in LGFCF, LLABOR, and LCPI have a positive impact on LGDP, while changes in Findex have a negative impact on it. 1% increases in LGFCF, LLABOR, and LCPI result in increases of 0.155%, 0.468%, and 0.101% in LGDP, respectively. A 1-unit increase in Findex decreases LGDP by 0.035%. After the long-run estimation, the Error Correction Model results are presented in Table 6.

Table 6. Error correction model estimation results

Variables	Coeff.	Std. error	t-stat.	Prob.
C	15.885	2.090	7.599	0.000
Δ LGFCF _t	0.793	0.043	7.926	0.000
Δ LLABOR _t	2.715	0.149	7.661	0.000
Δ LGE _t	0.093	0.021	1.917	0.063
Δ Findex _t	0.076	0.015	1.954	0.062
ECT _{t-1}	-1.324	0.174	-7.600	0.000

Source: Authors' own computations.

The error correction model requires the ECT_{t-1} coefficient to be both negative and statistically significant. If the coefficient is between -1 and -2, this indicates that the deviation from equilibrium will return to balance not linearly but through oscillations (Alam & Quazi, 2003). As shown in Table 6, the error correction coefficient was calculated to be -1.324. Therefore, it can be said that a short-run shock or deviation from equilibrium will return to its long-run balance with dampened oscillations. Based on the findings of the error correction

model, LCPI does not have a short-run effect on LGDP. However, the variables LGFCF, LLABOR, LGE, and Findex have a statistically significant and positive impact on LGDP in the short run.

The diagnostic test results and parameter stability of the model are presented in Table 7 and Figure 2, respectively.

Table 7. Diagnostic test results

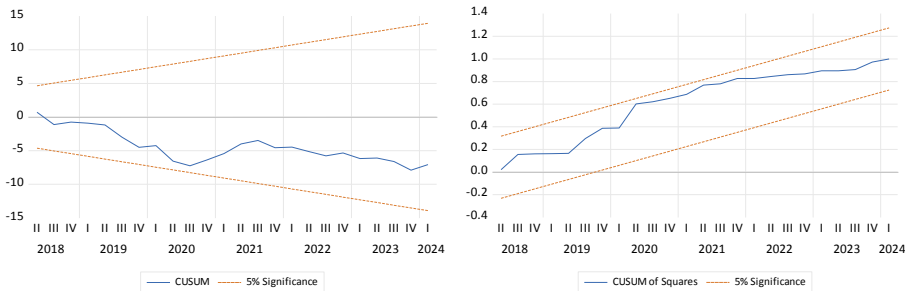
Tests	Test statistic
Serial correlation test	0.170 (0.844)
Heteroscedasticity test	0.715 (0.770)
Specification error test	1.961 (0.462)
Normality test	0.302 (0.859)

Note: Parentheses indicate probability values.

Source: Authors' own computations.

As seen in Table 7, it was determined that the p-values of the diagnostic tests were greater than the 5% significance level. Therefore, it was found that there is no heteroskedasticity, serial correlation, or specification error in the model, and the series are normally distributed.

Figure 2. Cusum and Cusum-Q graphs



Source: Authors' own computations.

According to Figure 2, the blue lines representing the parameter estimates fall within the dashed red lines, indicating 95% confidence intervals. Thus, the estimated parameters were found to be stable.

To test the predictive power of the ARDL model, we perform an out-of-time forecast evaluation. The model is re-estimated by excluding the last five quarters (2023Q1-2024Q1). Then, forecasts are generated for the excluded period, and the forecast accuracy is evaluated using Mean Absolute Percentage Error (MAPE) and Root Mean Squared Error (RMSE). The results (MAPE = 0.036, RMSE = 0.009) suggest that the model performs reasonably well in predicting the dependent variable in an out-of-sample context.

The bounds test results validated the existence of a cointegration relationship among the variables, and long-run coefficients were obtained as a result of ARDL analysis. To enhance the robustness of the obtained results, long-run coefficient estimates were also performed with FMOLS, DOLS, and CCR methods (Table 8).

Table 8. Long-run coefficient estimation results of FMOLS, DOLS, and CCR

Variables	Dependent variable: LGDP					
	FMOLS		DOLS		CCR	
	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.
LGFCF	0.374***	3.701	0.379***	2.988	0.379***	3.627
LLABOR	0.626***	3.064	0.595**	2.506	0.618***	3.118
LCPI	0.224**	2.042	0.300**	2.166	0.244**	2.136
LGE	-0.024	-0.314	-0.078	-0.605	-0.039	-0.340
Findex	-0.063**	-2.671	-0.072**	-2.662	-0.064***	-2.738
C	5.578***	3.993	6.365***	3.981	5.720***	4.081

Note: ***, **, and * denote 1%, 5%, and %10 significance level, respectively.

Source: Authors' own computations.

As shown in Table 8, the FMOLS, DOLS, and CCR models yield results that are consistent with those of the ARDL analysis. Although the LGE variable has a negative sign in all models, it is found to be statistically insignificant. For all other variables in the models, a 1% level of statistical significance was found. In all the FMOLS, DOLS, and CCR models, it was concluded that an increase in the LGFCF, LLABOR, and LCPI variables has a positive effect on LGDP, while an increase in Findex reduces LGDP. Similar and mutually supportive results were found across the ARDL, FMOLS, DOLS, and CCR analyses. Following the estimation of the long-run coefficients, the Toda–Yamamoto causality test was applied to determine the existence and direction of the causality relationship between the variables. The test results are presented in Table 9.

Table 9. Toda–Yamamoto causality test

H ₀ Hypothesis	χ^2 values	Probability	Decision
Findex \nrightarrow LGDP	13.371	0.009	Findex \leftrightarrow LGDP
LGDP \nrightarrow Findex	14.092	0.007	
LGFCF \nrightarrow LGDP	21.602	0.000	LGFCF \leftrightarrow LGDP
LGDP \nrightarrow LGFCF	29.659	0.000	
LLABOR \nrightarrow LGDP	11.967	0.017	LLABOR \leftrightarrow LGDP
LGDP \nrightarrow LLABOR	22.538	0.000	
LCPI \nrightarrow LGDP	3.086	0.543	LGDP \rightarrow LCPI
LGDP \nrightarrow LCPI	35.133	0.000	
LGE \nrightarrow LGDP	4.652	0.325	LGDP \rightarrow LGE
LGDP \nrightarrow LGE	8.262	0.082	

Note: According to AIC, the lag (k) is selected as 4, and thus k + dmax = 5.

Source: Authors' own computations.

According to Table 9, there is a bidirectional causality relationship between the *Findex* and *LGDP* variables, which is statistically significant at the 1% level. Similarly, a bidirectional causality relationship was found between *LGFCF* and *LGDP*. There is also a bidirectional causality relationship between *LLABOR* and *LGDP*, but the causality relationship is statistically stronger from *LGDP* to *LLABOR*. In addition, *LGDP* was found to be the Granger cause of *LCPI* and *LGE* at 1% and 10% statistical significance levels, respectively.

5. Discussion

Identifying the factors that influence economic growth is crucial, as one of the most important macroeconomic indicators will significantly impact the success of the economic policies implemented by countries. Enhancing the impact of factors that contribute positively to growth, while analyzing and mitigating or reversing the effects of those that contribute negatively, is crucial. Analyzing the impact of FinTech on economic growth can provide valuable insights for the design of effective economic policy. The key findings derived from the empirical analysis in this study are as follows:

- In the long run, increases in *LGFCF*, *LLABOR*, and *LCPI* positively affect *LGDP*, aligning with theoretical literature. Gross fixed capital formation fosters economic growth by enhancing productivity, driving innovation, and creating employment, with a multiplier effect on the economy (Soava et al., 2020; Öztürk et al., 2023). Similarly, labor force participation boosts growth by expanding production capacity, improving human capital through skill development, and encouraging innovation, as a skilled workforce enhances productivity and consumer demand (Hanushek & Kim, 1995; Lai & Yip, 2022). However, increased central bank efforts to curb inflation may reduce welfare by constraining production and government spending, with the net effect depending on fiscal and societal welfare priorities (Debelle, 1996). While Alper and Kök (2023) found inflation hampers growth, this study supports Yilmazkuday (2022), who noted inflation fosters growth in countries with weak institutional structures.
- According to the ARDL error correction model, *LCPI* was found statistically insignificant. In other words, the short-run impact of *LCPI* on economic growth is insignificant. The relationship between inflation and economic growth is generally evaluated in the long run. The uncertainty of the effects of inflation in the short run in Türkiye can be explained by the rapid adaptation of companies and households in response to inflation expectations (Andrés & Hernando, 1997; Attari & Javed, 2013).

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- In each of the long-run coefficient estimates from the ARDL, FMOLS, DOLS, and CCR models, the effect of FinTech on economic growth was found statistically significant and negative. In other words, FinTech developments in Türkiye have a constraining effect on economic growth. The negative long-run effect of FinTech on economic growth observed in this study diverges from the majority of existing literature, which often reports positive or mixed outcomes. For instance, Song and Appiah-Otoo (2022) and Cevik (2024) found significant positive effects of FinTech on growth, especially in regions with mature digital infrastructures and strong regulatory frameworks. In contrast, our findings align more closely with those of Narayan (2019) and Bu et al. (2023), who argue that in the early phases of FinTech development – particularly in emerging economies – disruptive effects such as market volatility, lack of trust, and uneven access can outweigh potential growth benefits. This divergence suggests that contextual factors, such as regulatory maturity, digital literacy, and the stage of FinTech adoption, play a critical role in shaping its economic impact. Consequently, rising social inequalities may further constrain economic growth. Moreover, advancements in payment systems driven by FinTech could reduce profitability in some regions of the traditional banking sector (Vives, 2019). Additionally, the rapid growth of the FinTech sector, particularly in areas where regulatory frameworks are not yet fully established, may create market uncertainty. Some FinTech companies may operate without being subject to financial regulations, which could lead to market instability. These uncertainties and loss of confidence could negatively impact consumer and investor behavior, leading to a slowdown in growth (Arner et al., 2017).
 - The ARDL error correction model revealed that the short-run FinTech coefficient is positive. As of August 2024, 870 FinTech companies are operating in Türkiye The Presidency of the Republic of Türkiye Finance Office [CBFO], 2024). The 278 FinTechs providing services in the payments sector are far ahead of the 115 FinTechs offering banking technology services, which ranks second. FinTech, particularly through digital payment systems, can increase consumer spending in the short run. The ease of payment for consumers may lead to higher spending, thereby boosting economic growth in the short run. However, in the long run, unsustainable spending or excessive borrowing could negatively impact economic growth. Household indebtedness rates in Türkiye could be an important indicator in this regard. According to data from the CBRT, the ratio of total household liabilities to GDP was 0.85 in the fourth quarter of 2012, rising to 4.93 in the fourth quarter of 2023. In this context, the positive short-run effects of FinTech developments in Türkiye may be expected to turn negative in the long run due to the debt burden. This increase in household debt may be a significant

explanation for the negative long-run effects on economic growth. In addition to the rapid development trend observed in the sector, The Banks Association of Türkiye [BAT] (2021) emphasized in its report that FinTechs act more quickly than banks and suggested that legislation to regulate the sector should support FinTechs to enter cooperation with banks without harming their potential. However, the BAT stated that due to FinTech developments, “Law No. 6493 on Payment and Securities Settlement Systems, Payment Services, and Electronic Money Institutions” should be updated and improved by the CBRT in light of these recommendations. In line with the global trend, the CBRT has recently accelerated its efforts to introduce the “Digital Turkish Lira” and completed the first phase of the process. In the related report, the Central Bank of the Republic of Türkiye [CBRT] (2023) emphasized the importance of utilizing the FinTech ecosystem in the process of developing the digital lira.

The distinction between short and long-run impacts of FinTech lies in the sustainability of its rapid gains. While FinTech technologies boost economic activity in the short run, factors such as structural transformations, costs, financial stability concerns, and external dependencies can hinder long-run growth. Similar to the dual impacts of AI technologies – where initial efficiency gains can be followed by systemic risks if not managed properly – FinTech developments also require robust regulatory responses to balance innovation and sustainability (Wang et al., 2025b). This study examines these dynamics, highlighting that in developing countries like Türkiye, FinTech’s rapid expansion—driven by digital payment systems – stimulates short-run growth but raises long-run sustainability concerns. Rising household indebtedness in Türkiye suggests debt-financed spending, threatening financial stability. Moreover, structural and regulatory gaps, as well as social inequalities, amplify risks, as inadequate oversight may deepen economic vulnerabilities and financial shocks. The results of the Toda–Yamamoto causality analysis further reinforce these findings, indicating a strong bidirectional causal relationship between FinTech developments and economic growth in Türkiye. The observed bidirectional causality suggests that while FinTech influences economic growth, the level and quality of economic growth may also shape the development trajectory of the FinTech sector. This mutual interaction highlights the dynamic nature of the FinTech-growth nexus and underscores the importance of supportive regulatory and institutional frameworks. Therefore, robust regulations and an inclusive financial ecosystem are needed to ensure that FinTech supports sustainable long-term growth in developing economies. It can be stated that the results can provide applicable insights for developing countries with similar characteristics.

6. Conclusions

This study investigates the long-run relationship between FinTech developments and economic growth in Türkiye utilizing quarterly data from 2012:Q2 to 2024:Q1. The findings suggest that while gross fixed capital formation, inflation, labor force, and FinTech developments are cointegrated with economic growth, FinTech developments are found to reduce economic growth during the analyzed period. This negative relationship may be attributed to the risks associated with rapid FinTech innovations, including financial instability, speculative investments, and inadequate regulation. These results were further validated by FMOLS, DOLS, and CCR estimators, as well as the Toda–Yamamoto causality test.

Based on the identified negative long-run impact, several targeted policy actions are warranted. First, regulatory frameworks should be updated to ensure that FinTech firms are subject to the same prudential standards as traditional financial institutions, particularly in areas such as consumer protection and credit risk monitoring. The CBRT could adopt a regulatory sandbox model to test new FinTech products in a controlled environment. Second, promoting financial inclusion is essential to reducing inequalities that may arise from unequal access to digital financial services. This can be achieved through targeted subsidies or tax incentives for FinTech firms operating in underserved regions. Third, establishing a centralized FinTech oversight committee under the CBFO could improve coordination among regulators and foster a balanced innovation ecosystem. Lastly, public awareness campaigns and school curricula should integrate digital financial literacy to ensure that consumers engage with FinTech responsibly and knowledgeably. In addition, to harness the short run economic benefits of FinTech while avoiding long run structural risks, regulators may: (1) establish a clear licensing framework for non-bank FinTech firms, (2) mandate interoperability standards among digital payment platforms, (3) implement credit risk monitoring for peer-to-peer lending services, and (4) integrate consumer protection protocols directly into digital finance regulations. These steps would ensure that the benefits of rapid digitalization are channeled into sustainable economic outcomes.

The originality of this study lies in the construction of a comprehensive FinTech index, which provides a more nuanced view of FinTech's impact on economic growth in Türkiye. By addressing the theoretical gaps in the literature and employing a robust econometric approach, this research provides valuable insights into the ongoing discussions about the role of financial technologies in economic development. However, the study's limitations include the lack of comprehensive, panel-level data to analyze the regional and sector-specific impacts of FinTech developments in greater detail. Furthermore, future research

could examine the nonlinear effects of FinTech developments and conduct comprehensive analyses with access to more detailed data (e.g., FinTech investments, FinTech adoption, FinTech share in the financial system), as well as panel-level data.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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