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Aslı Güler[1]
İbrahim Al[2]

WHEN STABILITY MATTERS: LONG-RUN AND DYNAMIC EFFECTS OF PUBLIC AND PRIVATE FIXED-CAPITAL INVESTMENTS ON ECONOMIC GROWTH IN TURKEY[3]

This study investigates the cointegration and causality relationships between public and private fixed capital investments and economic growth in Turkey during the 1988-2023 period, taking into account structural breaks in the cointegration relationship among the variables and allowing for time-varying causal relationships. The findings from the sharp-break Augmented ARDL approach confirm a long-term relationship between public and private fixed capital investments and economic growth. On the other hand, the positive impact of private fixed capital investments on growth tends to be more pronounced and permanent compared to public investments. The findings from the time-varying causality technique reveal that the causal relationships between public and private fixed capital investments and economic growth tend to fluctuate over time. Accordingly, the causal effect of public investments on growth is more pronounced in periods of macroeconomic stability. Besides, the causality from private investments to growth is more stable and persistent.
Keywords: Public fixed capital investment; Private fixed capital investment; Economic growth; Augmented ARDL; Time-varying causality test
JEL: E22; O40; C32

1. Introduction

Economic growth, defined as the real increase in production or the expansion of production capacity, is generally examined within a production function framework where capital and labour are considered the main factors of production. In this context, capital consists of both physical and human capital; however, the capital generally referred to in production is typically physical capital. When the theoretical literature on economic growth is examined, it is observed that in many models, the source of growth is emphasised as capital investment or capital accumulation. Capital investments largely consist of fixed capital investment (FCI)

[1] *Aslı Güler, Assoc. Prof., PhD, Ordu Unye Faculty of Economics and Administrative Science, Türkiye, e-mail: asliguler24@hotmail.com, https://orcid.org/0000-0002-2900-1184.*
[2] *İbrahim Al, Assoc. Prof., PhD, Karadeniz Technical University Faculty of Economics and Administrative Science, Türkiye, e-mail: ibrahimal@ktu.edu.tr, https://orcid.org/0000-0002-2653-4663.*
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aimed at increasing production capacity, while stock and housing investments make up a relatively smaller share of capital investments. FCI refers to expenditures on machinery, equipment, and structures made by the public and private sectors. Along with FCI, on one hand, production capacity expands, while on the other hand, labour productivity increases, thereby leading to an increase in production quantity.

In empirical literature, researchers have examined the relationship between economic growth and a number of variables for particular countries or groups of countries, including monetary, fiscal, trade, and exchange rate policies, as well as institutional, legal, and political characteristics. Levine, Renelt (1991) analysed the empirical growth literature and discovered that over 50 variables had statistically significant relationships with economic growth. In another study, Levine, Renelt (1992) tested the robustness and fragility of the relationship between economic growth and over 50 variables, given small changes in the information set. The researchers concluded that there was a strong and positive correlation between economic growth and investments, but a weak correlation with almost all other variables.

There are three primary justifications that FCI in machinery and equipment has a bigger effect on growth than other kinds of investments (De Long, Summers, 1991): First, historical studies on economic growth have always emphasised the central role of mechanisation. Economic historians have viewed the wealthiest countries as those that were the first to invent and implement capital-intensive technologies. These technologies incorporate the most advanced levels of technological knowledge. Second, in some sectors, the spillover effects and externalities may be larger compared to other sectors. For example, according to Summers (1990), 95% of private-sector R&D in the U.S. is concentrated in manufacturing, and more than half of that comes from the equipment sector, making it plausible that equipment investment generates substantial externalities. Third, there is the claim that many countries have rapidly grown by adopting the "developmental state" approach. The rationale behind this policy is that less-developed countries that adopt the market structure of wealthier countries tend to grow faster than other poor countries. In this approach, the state initiates the industrialisation process more quickly than private entrepreneurs could. If the developmental state approach is correct, countries that invest more in machinery and equipment are likely to experience faster growth. Rapid growth leads to more savings and investment, creating a feedback loop, implying potential bidirectional causality (Ghali, Al-Mutawa, 1999).

The identification of the impact of FCI made by the public and private sectors on economic growth is crucial for the efficient use of limited resources. If public FCI affects economic growth, a state-led development model might be preferred, or the state could play a more significant role in the economy. This situation also closely influences public debt, budget management, and tax policies. On the other hand, if public FCI does not affect economic growth, the state's role in the economy might be limited, and resources could be allocated to the private sector, with more support for private sector growth.

Several studies have investigated the relationship between FCI and growth for Turkey. Bayraktutan, Aslan (2008), Arısoy (2011), and Gövdere, Can (2016) have not identified a cointegration or causality between the variables. But, Şimşek, Kadılar (2005), Altıntaş,

Çetintaş (2010), Karataş, Çankaya (2011), Çetinkaya, Türk (2014), Teyyare (2018), Teyyare, Sayaner (2018) and Eşsiz, Durucan (2023) have found evidence of such relationships.

This study offers a multi-layered contribution to the literature by addressing the effects of public and private investments on economic growth, not only with the level effect but also with both persistence (co-integration/AARDL analysis) and temporal dynamism (time-varying causality test). While existing studies mostly examine the investment-growth relationship with fixed parameter models, this study also shows how the effect of investments on growth evolves over time. The findings reveal that private investments create both a more persistent and stronger growth effect, while public investments become significant only under conditions of macroeconomic stability. In this context, the study provides an important roadmap not only for the empirical literature but also for policymakers on the timing and effectiveness of public investment decisions. It also offers an alternative framework to deterministic approaches by revealing that public investments are not ineffective but conditionally effective.

This study aims to examine the existence of cointegration and causality relationships between public and private fixed capital investments and economic growth in Turkey over the 1988-2023 period by employing the Augmented Autoregressive Distributed Lag (AARDL) model with sharp structural breaks and the Lag-Augmented VAR (LA-VAR) time-varying causality tests. The remaining sections of this manuscript are organised as follows: The next section delves into the theoretical framework and the relevant literature. The third section details the research methodology. The fourth section presents the findings along with commentary on the results. The final section concludes by offering a comprehensive discussion and policy recommendations based on the key insights.

2. Theoretical Framework and Literature

It is clear from economic growth theories that one of the key drivers of growth is capital. In classical theory, Smith (1776) considered capital accumulation, division of labour, and free trade as the fundamental sources of growth. According to Smith, capital accumulation leads to new investments that increase production capacity, and, through new machines and equipment, it also boosts labour productivity, allowing for greater production and thus enabling economic growth. In the Keynesian growth model, Harrod (1939) and Domar (1946) explain economic growth through the capital-output ratio, which is determined by the savings rate, the marginal efficiency of capital, and the depreciation rate. This model states that more savings lead to more investment, more capital stock, and ultimately higher economic growth. In neoclassical growth theory, Solow (1956) and Swan (1956) explain growth through the Cobb-Douglas production function. In this context, the key factors affecting production are capital and labour, while technological advancements increase factor productivity, thereby enabling higher production. Although capital accumulation raises growth in the short term, it does not affect long-term growth rates. The only factor that can increase long-term growth is technological progress. In endogenous growth models, Romer (1986) identified technological development and innovation as the sources of growth. At the core of technological progress lies human capital and knowledge. In this model, physical

capital alone cannot sustain long-term economic growth; however, with technological advancement and knowledge accumulation, it becomes more efficient and contributes to sustainable growth. Therefore, investments in research and development are critical for long-term growth. Lucas (1988) based the foundation of growth on human capital. Physical and human capital are the basic production factors, and the development of human capital enhances the productivity of physical capital, thereby accelerating economic growth.

In their study covering the period 1950-1977 for 47 countries, Kormendi, Meguire (1985), stated that capital investments influence economic growth through the investment rate and capital return. In this context, more capital investment typically leads to higher growth. Additionally, higher returns on investment promote greater capital accumulation, which can further boost growth. Barro (1991) found that the growth rate of real GDP per capita was negatively correlated with its starting level and positively correlated with initial human capital in his analysis, which covered 98 countries over the years 1960–1985. According to the study, nations with greater levels of human capital typically have lower fertility rates and higher rates of physical investment in relation to GDP. Mankiw et al. (1992) examined 98 countries from 1960 to 1985 using an enhanced Solow model that incorporates both human and physical capital to test the validity of the convergence hypothesis among nations. The researchers found that there were no significant externalities from physical capital accumulation. However, they demonstrated that physical capital accumulation had a larger effect on increasing income per capita than predicted by the classical Solow model. De Long, Summers (1991), in their analysis covering 61 nations over the years 1960–1985, found a high positive correlation between fixed capital formation, which is defined as the ratio of investment to GDP, and economic growth. They concluded that one of the key factors influencing economic growth is the accumulation of physical capital. Additionally, the researchers discovered a one-way causality. Podrecca, Carmeci (2001), in their study of 104 countries over the period 1960-1990, discovered that, in contrast to previous research, there is a bidirectional causality between the investment ratio and growth, although the effect from investments to growth was found to be negative. This result suggests that the view of capital fundamentalism, which implies that fixed investments are the key to long-term economic growth, as proposed by Romer (1986) in his endogenous growth models, is not supported. This finding aligns with the predictions of Solow-type standard neoclassical growth models. According to the Solow model, an increase in the investment ratio boosts the growth rate in the short term, but as the economy approaches a steady-state value over time, this effect diminishes gradually. As a result, growth is determined solely by technological progress. Therefore, during the transition period, a negative relationship between lagged investment and current growth is expected (Podrecca, Carmeci, 2001). However, Blomström et al. (1996), in a study conducted for 101 countries over the period 1960-1985, aimed to determine the direction of the effect between growth rate and capital formation, as well as the timing of the interaction. According to their findings, the growth of GDP per capita in one period is more closely related to future capital accumulation than to current or past capital accumulation. Moreover, causality tests showed that growth triggers capital accumulation in later periods, while capital accumulation has less of an effect on triggering growth. Therefore, no evidence was found to support the claim that FCI is the key to growth. Chow (1993) discovered cointegration between variables. He came to the conclusion that long-term growth is significantly impacted by FCI. Çetin (2012) discovered that only in Malaysia was

cointegration; however, no causality was found between the variables. This indicates that FCI doesn't have the same effect on growth in every country. Kanu, Ozurumba (2014) found that in the long run, gross fixed capital formation has a positive impact on growth and a one-way causality from GDP to total fixed capital formation. Şahbaz (2014), Esen, Farahmand (2020), Emirkadı (2022) concluded that there is no cointegration, but a one-way causality from FCI to growth in the long term. Boamah et al. (2018), Abbas et al. (2020), and Kong et al. (2020) found that gross fixed capital formation has a positive impact on economic growth. Additionally, Kong et al. (2020) discovered that there is a bidirectional causality between variables.

Several studies have examined the relationship between public investments and economic growth using cointegration or causality analysis for Turkey. Şimşek, Kadılar (2005) analysed the relationship between Turkey's private sector manufacturing output and public FCI from 1963 to 2002. Public fixed capital investments had a positive effect on output, and the results show a cointegration between these variables. Altıntaş, Çetintaş (2010) analysed the relationship between human capital, fixed capital, exports, and growth by using cointegration and causality tests based on annual data from 1970 to 2007. Their findings indicate a long-term, positive, and statistically significant relationship among variables. However, Karataş, Çankaya (2011), in their study covering the period 1981-2006, concluded that physical capital has a greater impact on growth than human capital. Çetinkaya, Türk (2014) examined the relationship between domestic savings, FCI, and growth for the 1975–2012 period. They concluded that there is cointegration, with causality running from savings and investments to economic growth. However, there is no causality in the short run. Teyyare (2018) studied the sectoral FCI and growth for the 1963- 2014 period. The results indicate that fixed investments in energy, tourism, and other sectors exert a negative influence on growth, while those in manufacturing, agriculture, health, and transportation have a positive impact. Teyyare, Sayaner (2018) examined the effects of FCI, public borrowing, and institutional quality on growth for the 1984-2014 period. Their findings indicate that increases in FCI and institutional quality have a positive influence on economic growth, whereas higher public borrowing has a negative impact on economic growth. Eşsiz, Durucan (2023) used the ARDL approach to examine the relationship between gross FCI and growth from 1974 to 2021. The results indicate that these variables have a negative short-term and positive long-term relationship. However, Bayraktutan, Aslan (2008), Arısoy (2011), and Gövdere, Can (2016) tested the relationship between FCI and growth for Turkey in various periods, but were unable to identify any cointegration or causal relationship between the variables.

3. Data and Methodology

3.1. Model Specification and Data

This section outlines the model and additional explanatory variables used to assess the relationship between fixed capital investments and economic growth in Turkey. Although the model emphasises fixed capital investments, other factors should also be considered to fully explain changes in output. Therefore, by following the theoretical and empirical literature, this study incorporates control variables with critical potential effects on different

aspects of growth in the framework of country-specific conditions and structural characteristics. The model used in this study can be expressed as Equation (1):

$$\Delta GDP_t = \beta_0 + \beta_1 PUBI_t + \beta_2 PRIVI_t + \beta_3 FDI_t + \beta_4 TRADE_t + \beta_5 DEBT_t + \beta_6 HCAP_t \quad (1)$$

where:

GDP_t is the gross domestic product at time t;

$GPUBI_t$ is public fixed capital investments at time t;

$GPRIVI_t$ is private fixed capital investments at time t;

FDI_t is foreign direct investments at time t;

$TRADE_t$ is openness at time t;

$PUBI_t$ is the public debt service ratio at time t;

$HCAP_t$ is human capital at time t.

Table 1 and Table 2 present the abbreviations, explanations, data sources, and descriptive statistics.

Table 1. Variable Definitions and Sources

Variables	Definition	Sources
GDP	Economic growth (real GDP growth per capita), constant 2015 US$	WDI
PUBI	Gross Public Fixed Investment (Percentage Change)	Presidency of Strategy and Budget
PRIVI	Gross Private Fixed Investment (Percentage Change)	Presidency of Strategy and Budget
FDI	Foreign Direct Investment (% of GDP)	WDI
TRADE	Trade (% of GDP)	WDI
DEBT	Total debt service (% of GNI)	WDI
HCAP	Human Capital (School enrollment, tertiary (% gross)	WDI

Source: Compiled by the authors.

Table 2. Descriptive Statistics

	GDP	PUBI	PRIVI	FDI	TRADE	DEBT	HCAP
Mean	3.106960	2.602778	4.600000	1.183569	48.91033	7.896920	53.76951
Median	4.291655	2.350000	4.100000	1.171092	48.54553	7.495219	35.26638
Maximum	10.42940	38.60000	44.90000	3.623382	81.17013	12.10540	128.0000
Minimum	-7.138251	-43.40000	-27.70000	0.305387	30.47601	4.841835	9.799290
Std. Dev.	4.405545	15.72884	14.97632	0.839801	11.34423	1.955451	40.90030
Skewness	-0.772565	-0.430104	0.289802	1.110272	0.580737	0.638810	0.689839
Kurtosis	2.972377	4.473185	3.587150	3.884245	3.565167	2.588039	1.900933
Jarque-Bera	3.582289	4.365346	1.021029	8.331023	2.502651	2.627952	4.667186
Probability	0.166769	0.112740	0.600187	0.015522	0.286125	0.268749	0.096947
Observations	36	36	36	36	36	36	36

Source: Author's Calculation, 2025.

The dataset begins in 1988 to effectively capture Turkey's economic transformations following the structural reforms of the 1980s. The choice of this period was influenced by

several important developments that can be considered milestones in the Turkish economy. Firstly, the "January 24th Decisions of 1980" are considered the starting point of the transition from a closed economic model to an outward-oriented free market economy, emphasising export-led industrialisation. Despite these reforms, achieving economic stabilisation remained a challenge in the following years. By the late 1980s, critical policy changes, including the "1989 Decree on the Protection of the Value of the Turkish Currency", helped further liberalise trade and introduced new incentives for foreign investments. Moreover, capital flows gained more flexibility, as the Turkish lira became convertible in 1989. Given that the dataset includes key indicators, such as public and private FCIs, foreign direct investment (FDI), and trade openness, 1988 as a starting point ensures that the analysis captures the effects of these economic shifts while maintaining data consistency.

For better econometric consistency and a stronger foundation for policy research, the model's dependent variable is GDP. Since some of the explanatory variables are expressed as ratios to GDP, using the total GDP growth rate as the dependent variable may lead to measurement errors and spurious correlations. In this case, the relationships observed between the variables may stem from mechanical connections rather than genuine economic linkages, which could lead to misleading results. Additionally, the total GDP growth incorporates the effects of population growth, making it a less precise measure for analysing the fundamental drivers of economic expansion. By contrast, real GDP per capita growth filters out the direct impact of population growth and allows for a more accurate assessment of the true determinants of economic growth. This, in turn, enables a clearer evaluation of how factors such as investment, foreign trade, and debt influence economic performance.

PUBI and PRIVI, used as annual percentage changes, are key independent indicators of the model. PUBI covers government expenditures on socioeconomic infrastructure and development projects that support private sector growth and contribute significantly to overall economic expansion. In contrast, PRIVI covers expenditures made by the private sector on infrastructure, facilities, technology, and other productive assets. These investments are generally focused on expanding production capacity, enhancing efficiency, and gaining a competitive edge. Both indicators are typically analysed to assess their relative potential impacts on GDP.

In this study, TRADE and FDI (% of GDP) serve as proxies for the impact of technology and technical change on GDP. TRADE reflects the extent of a country's integration into global markets. International trade facilitates the diffusion of new technologies and production techniques, acting as a key channel for both embodied and disembodied technical change. Similarly, FDI represents the role of international capital flows in technology transfer and the development of managerial capabilities (Khan, Kumar, 1997). These variables are not limited to one-time increases in production capacity but also enable sustained growth through dynamic economies of scale and learning-by-doing mechanisms (Grossman, Helpman, 1991; Edwards, 1992).

Macroeconomic instability adversely affects economic growth. One of the key indicators of such instability is public debt. Public finance theories generally suggest that government expenditures are primarily directed toward areas with little or no wealth-generating potential, such as social assistance, unemployment compensation, and government transfer payments, rather than investment spending necessary for a country's growth (Amamou, Hellara, 2016).

Therefore, an excessive increase in public spending leads to a budget deficit, which in turn increases the public sector's borrowing requirements. The excessive accumulation of public debt undermines confidence in public finance, worsening risk perceptions. Accordingly, total debt service (% of GNI) is included in the model as an additional explanatory variable.

Education, particularly higher education, enhances individual skills and workforce productivity, making it a key driver of economic growth. As education levels rise, individuals can more effectively absorb new knowledge and technologies transmitted via foreign investment and trade, further contributing to economic expansion. A highly skilled labour force fosters technological progress, innovation, and productivity growth. Therefore, the tertiary enrollment rate is included in the equation as a representative indicator of human capital, aimed at capturing its long-term impact on economic growth.

3.2. Empirical Strategy

This study adopts a two-stage analytical approach. In the first stage, the short- and long-term relationships between public and private FCIs, control variables, and growth are evaluated using the Augmented Autoregressive Distributed Lag (AARDL) model with sharp breaks. After validating the long-term association between the variables using the AARDL approach, the dynamic causation between variables is examined using the lag-augmented VAR (LA-VAR) time-varying Granger causality test.

3.2.1. AARDL with Sharp Structural Breaks

The AARDL test is an extended version of the linear ARDL bounds test developed by Pesaran et al. (2001). This extension, introduced by McNown et al. (2018) and Sam et al. (2019), incorporates an additional F-test to assess the significance of the explanatory variables' coefficients. By including this supplementary test, the AARDL method enhances the robustness of cointegration analysis, addressing limitations in the standard ARDL approach.

The selection of the AARDL methodology is driven by its numerous advantages over the linear ARDL, particularly its ability to explore cointegration relationships among variables of mixed integration orders (I(0) and I(1)). Its ability to overcome the standard ARDL test method's weak size and power constraints is one of these benefits. Additionally, the bootstrap ARDL procedure's supplementary F-test applied to the independent variables' lagged levels enhances the F- and t-tests already included in the standard ARDL. This enhancement strengthens the power of the F-test and, consequently, offers more robust insights into the cointegration status of the system. Building on Pesaran et al. (2001), McNown et al. (2018), and Sam et al. (2019), the model in Equation (2) is restructured as follows:

$$GDP_t = \alpha_0 + \alpha_1 Dum + \beta_1 GDP_{t-1} + \beta_2 PUBI_{t-1} + \beta_3 PRIVI_{t-1} + \beta_4 FDI_{t-1} + \beta_5 TRADE_{t-1} + \beta_6 DEBT_{t-1} + \beta_7 HCAP_{t-1} + \sum_{i=1}^{p-1} \partial_i' \Delta GDP_{t-i} + \sum_{i=1}^{p-1} \emptyset_i' \Delta PUBI_{t-i} + \sum_{i=1}^{p-1} \varpi_i' \Delta PRIVI_{t-i} + \sum_{i=1}^{p-1} \varphi_i' \Delta FDI_{t-i} + \sum_{i=1}^{p-1} \delta_i' \Delta TRADE_{t-i} + \sum_{i=1}^{p-1} \sigma_i' \Delta DEBT_{t-i} + \sum_{i=1}^{p-1} \vartheta_i' HCAP_{t-i} + e_t \quad (2)$$

where:

α_1 is the coefficient of the dummy variable; $\beta_1, \dots, \beta_7$ are the coefficients of the lagged levels of all variables; ∂, $\emptyset$, ϖ, φ, δ, σ, ϑ are the parameters of the lagged differenced regressors; t is time, and $t = 1, \dots, T$; Δ is the first difference operator; p is the lag length operator; e_t is the independently distributed error term that has a finite variation and zero mean.

Ignoring structural discontinuities may produce biased results, as they can significantly affect cointegration relationships. Dummy variables are incorporated into the ARDL by Goh et al. (2017), Cai et al. (2018), and Lin et al. (2018) to account for these structural discontinuities in the long-run relationship. The dummy variable is defined as follows:

$$dum_t = \begin{cases} 1 \; if \; t > TB \\ 0 \quad else \end{cases}$$

According to Pesaran et al. (2001), the presence of cointegration in the standard ARDL test is determined if the overall F-test statistic ($F_{Overall}$) exceeds the upper critical values. However, McNown et al. (2018) and Sam et al. (2019) argue that since ($F_{Overall}$) tests the joint significance of the coefficients of all variables; its statistical significance may stem solely from the lagged dependent variable or the lagged independent variables. This leads to two potential degenerate cases: Degenerate Case 1, which occurs when the lagged levels of the dependent variable are insignificant, and Degenerate Case 2, which arises when the lagged levels of the independent variables are insignificant.

To partially address this ambiguity, the t_{IDV}, which evaluates the significance of the lagged dependent variable, can be employed. However, for a definitive conclusion on cointegration, it is also necessary to test whether the lagged values of the explanatory variables are statistically significant. To address this limitation, McNown et al. (2018) and Sam et al. (2019) proposed an additional F test (F_{IDV}) to examine the significance of the lagged values of the explanatory variables.

Thus, in the AARDL framework, which incorporates the additional F test, the existence of a cointegration relationship is determined by jointly rejecting three null hypotheses based on the three test statistics ($F_{Overall}, F_{IDV}$ *and* t_{IDV}) :

$H_{0A}: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = 0$, based on the *overall F-test* on all lagged variables ($F_{Overall}$)

$H_{0B}: \beta_1 = 0$, based on the *t-test* on the lagged dependent variable (t_{IDV})

$H_{0C}: \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = 0$ based on the *F-test* on the lagged independent variable(s) (F_{IDV})

The critical values for the tests are obtained by the bootstrap resampling method. This approach effectively addresses two key issues: endogeneity and the case where the dependent variable is $I(0)$. In addition, these critical values are appropriate for small datasets (Sam et al., 2019). The use of bootstrap resampling helps mitigate these limitations and ensures more reliable statistical inferences within the AARDL framework.

Depending on the significance of the test statistics, four possible cointegration scenarios can be identified.

Case 1: Cointegration occurs when $F_{Overall}$, F_{IDV} and t_{IDV} are significant

Case 2: No cointegration occurs when $F_{Overall}$, F_{IDV} and t_{IDV} are insignificant

Case 3: Degenerate case #1 occurs when $F_{Overall}$, F_{IDV} are significant but t_{IDV} is not significant.

Case 4: Degenerate case #2 occurs when $F_{Overall}$ and t_{IDV} are significant, but F_{IDV} is not significant.

Among the four scenarios, only Case 1 provides evidence of a cointegration relationship. In contrast, Case 2, Case 3, and Case 4, indicate no cointegration, as a valid conclusion requires the joint rejection of all three null hypotheses. This method enhances clarity in detecting degenerate cases (#1 and #2) and addresses the issue of inconclusive, misleading inferences that may arise when using the standard ARDL method (McNown et al., 2018; David et al., 2023).

3.2.2. LA-VAR Time-Varying Granger Causality Test

The LA-VAR time-varying Granger causality test, proposed by Shi et al. (2020), is used in this section of the study to examine the dynamic causality effect of public and private FCIs on growth. Since the Granger causality test is sensitive to the selected VAR model period, the identified causal relationships are considered valid only for the specific period analysed. This is particularly relevant for developing economies, where macroeconomic conditions frequently fluctuate. Structural breaks, driven by changes in economic or government policies as well as financial and political turbulence, can substantially alter VAR parameters, necessitating the consideration of time-varying coefficients (Tümtürk, 2023; Erer, 2023). As a result, assuming that VAR parameters remain constant may lead to misleading conclusions regarding causality relationships (Balcılar, Özdemir, 2013).

To take into consideration potential shifts in causal links, time-varying causality tests have been created. The most important feature of these tests is that they are based on different window types. In these approaches, structural break effects are mitigated since the estimation window is shifted over the sample period. Since the liberalisation of capital movements in 1989, Turkey has faced crises in 1994, 2000-2001, 2008-2009, and most recently in 2018-2022. In addition, the Gezi Park events of May 28, 2013, the coup d'état of July 15, 2016, the Brunson Crisis of 2018, several international political tensions involving Russia, Europe, and

the United States, and wars in neighbouring countries in Syria and Iraq have also put Turkey in economic difficulties. Therefore, using moving window causality tests instead of explicitly modelling structural breaks allows for a more nuanced, visual analysis of how the dynamic causal relationship between public and private FCIs and growth changes during turbulent periods.

Recursive estimation methods enable the tracking of changes in Granger causality over time by computing test statistics separately for each sub-period, allowing for inferences about causal relationships. Among the methods used in the literature for this purpose are the expanding window Granger causality test (Thoma, 1994) and the rolling window Granger causality test (Swanson, 1998; Balcilar et al., 2010; Arora, Shi, 2015, among others). Additionally, the recursive-rolling window procedure, proposed by Shi et al. (2018), has emerged as a prominent approach for time-varying Granger causality analysis. Later, Shi et al. (2020) proposed the LA-VAR model, which incorporates non-stationary variables into the VAR framework. Developed by Shi et al. (2020), this approach is particularly useful for tracking the evolution of causal relationships with greater flexibility and reliability, especially in complex datasets such as economic data and time series. In this context, three algorithms are available to produce a series of test statistics:

- The Forward Expanding Window (FEW),
- The Rolling Window (ROW), and
- The Recursive Evolving Window (REW)

The choice among these depends on the research focus: FEW is suited for long-term trends, ROW for short-term fluctuations, and REW for balancing both perspectives.

4. Findings

4.1. The Results of Unit Root Tests

The AARDL procedure is a test that allows explanatory variables to be $I(0)$ or $I(1)$. However, since it is based on the standard ARDL procedure developed by Pesaran et al. (2001), it is essential to ensure that none of the variables are $I(2)$. In this study, three different tests were employed to determine the stationarity levels. Firstly, the widely used Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test were applied. However, since these tests exhibit low power and size distortions when structural breaks are present, to account for structural breaks under the null hypothesis, the stationarity properties of the series were also examined using the Lee-Strazicich (LS) (2003) unit root test, which explicitly includes structural breaks[4].

[4] According to Lee, Strazicich (2013), as the magnitude of structural breaks increases, the Zivot-Andrews (1992) test, one of the most frequently preferred structural break unit root tests, suffers from power loss, spurious rejections of the null hypothesis, and incorrect identification of breakpoints.

Table 3. ADF and PP Unit Root Test Results

Variable	ADF		PP		ADF		PP	
	Level				First Difference			
	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept
GDP	-6.13*	-4.28**	-6.41*	-8.34*	-	-	-	-
PUBI	-3.05**	-2.73	-5.63*	-5.54*	-	-	-	-
PRIVI	-5.07*	-4.98*	-3.83*	-3.74**	-	-	-	-
FDI	-2.28	-2.59	-2.17	-2.47	-5.42*	-4.59*	-9.43*	-9.50*
TRADE	0.15	-2.31	-0.86	-3.22***	-6.08*	-5.90*	-7.09*	-6.67*
DEBT	-3.07**	-3.52***	-2.52	-2.91	-2.07	-2.01	-5.44*	-5.32*
HCAP	-1.39	-0.26	-1.39	-1.90	-5.96*	-6.26*	-4.75*	-5.14*

*Note: ***, **, * represent %1, %5, and % 10 significance level, respectively.*
Source: Author's Calculation, 2025.

The results of the ADF and PP unit root tests are presented in Table 3. According to both tests, for both constant and trend specifications, the GDP, PUBI, and PRIVI variables are found to be stationary at levels. In contrast, the FDI, TRADE, and HCAP variables become stationary after first differencing. For the DEBT variable, while the ADF test indicates stationarity at the level, the PP test suggests that it becomes stationary after first differencing. Since the PP test is generally considered a more robust unit root test compared to the ADF, the DEBT variable is classified as I(1).

The results of the LS test are presented in Table 4, which was performed to determine the structural break dates. The results obtained for the model that allows two breaks in both the constant and the trend are consistent with the results obtained from the ADF and PP tests. Accordingly, while the variables GDP, PUBI, and PRIVI are stationary at their levels with two breaks, the other variables become stationary after first differencing. The break dates coincide with the years of major events in Turkey.[5]

Table 4. The Results of LS Unit Root Tests

Series	k	$TB1$	$TB2$	$\lambda 1$	$\lambda 2$	Min. Test Statistic
GDP	8	2001	2006	0.3889	0.5278	-6.52**
PUBI	3	1999	2013	0.3333	0.7222	-7.05*
PRIVI	4	1999	2005	0.3333	0.5000	-7.30*
FDI	3	2004	2010	0.4857	0.6571	-5.02
ΔFDI	8	1999	2012	0.5000	0.7059	-8.54*
TRADE	7	2016	2019	0.3889	0.8889	-5.22
ΔTRADE	1	2008	2018	0.4722	0.7778	-6.71**
DEBT	9	2002	2018	0.4286	0.8857	-5.14
ΔDEBT	5	2001	2010	0.3889	0.8889	-6.69**
HCAP	4	2000	2013	0.5294	0.6471	5.24
ΔHCAP	5	2007	2019	0.5556	0.8889	-9.28*

Note. $TB1$ and $TB2$ are the break dates, k is the lag length. ***,**,*, denote statistical significance at 1%, 5% and 10% respectively.
Source: Author's Calculation, 2025.

[5] The 1999 IMF Standby Agreement, the November 2000 and February 2001 financial crises, the 2008 Global Financial Crisis, the 2013 Gezi Park protests, the 2016 coup attempt, the 2018 Pastor Brunson crisis, and the sanctions imposed on Turkey.

4.2. The Results of AARDL and Long-Term and Short-Term Estimations

After confirming that all variables are integrated of order one, the AARDL results examining the cointegration relationship are presented in Table 5. As noted earlier, cointegration is confirmed in the AARDL procedure when the $F_{Overall}, F_{IDV,}$ and t_{IDV} test statistics should exceed the upper critical values. S shown in Table 5, the $F_{Overall}$ test statistic exceeds the 1% upper critical value provided by Narayan (2005). Moreover, both F_{IDV} and t_{IDV} statistics exceed the 1% upper critical, thereby avoiding the degenerative situations pointed out by McNown et al. (2018) and Sam et al. (2019) and allowing for a more precise inference on cointegration. Accordingly, all three null hypotheses are rejected, confirming the existence of a long-run relationship among the variables. This result suggests that changes in PUBI and PRIVI, together with other variables, significantly affect economic growth in Turkey. These findings are consistent with those of Chow (1993) and Çetin (2012) but contradict the result reported by Bayraktutan, Aslan (2008), Arısoy (2011), and Gövdere, Can (2016).

Table 5. AARDL Cointegration Results

			Lag-Length		Test Statistics		Results
			(1, 1, 2, 1, 2, 1, 2)		$F_{Overall}$=12.57366***		Cointegrated
					$t_{DV=}$-8.19***		
					F_{IDV} =7.89***		
Table CVs		%1		%5		%10	k=6
Tests	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	Sources
$F_{Overall}$	3.6	4.9	2.87	4	2.53	3.59	Narayan (2005)
t_{DV}	-3.96	-5.31	-3.41	-4.69	-3.13	-4.37	Pesaran et al. (2001)
F_{IDV}	2.81	4.79	2.11	3.75	1.78	3.27	Sam et al. (2019)

Note: *** denotes statistical significance at 1%. Optimal lag length was determined by AIC.
Source: Author's Calculation, 2025.

After confirming the cointegration among the variables, the short-run and long-run coefficients estimated using the AARDL procedure are presented in Table 6. As shown in the table, the coefficients for PUBI are positive and statistically significant at the 1% level in both the short and long run. Specifically, a one-unit increase in PUBI leads to a 0.077-unit rise in GDP in the long run, and a 0.09-unit increase in the short run. These results indicate that PUBI strongly and positively supports GDP in both the short and long run. Similarly, the coefficients for PRIVI are also positive and significant at the 1% level in both the short and long run. A one-unit increase in PRIVI increases GDP by 0.096 units in the long run and approximately 0.08 units in the short run. Furthermore, the fact that the lagged effect of PRIVI remains significant, albeit relatively weaker, suggests that the impact of PRIVI on GDP is positive and persistent over time. These findings are consistent with those of Altıntaş, Çetintaş (2010), Teyyare, Sayaner (2018), Boamah et al. (2018), Abbas et al. (2020), and Kong et al. (2020), who also report a positive and significant relationships between fixed capital investment and growth.

An important aspect of the findings warrants particular emphasis. Analysing the long-run coefficients reveals that, in terms of marginal contribution, PRIVI exerts a stronger impact on GDP compared to PUBI over the examined period. Additionally, the significance of the lagged effect of private investments in the short run further underscores their long-lasting influence on growth.

Regarding the other variables, the coefficients for FDI, TRADE, DEBT, and HCAP are statistically significant in both the short and long run. Among them, FDI emerges as the variable with the strongest positive long-run effect, with a coefficient of 1.20, implying that a one-unit increase in FDI leads to a 1.20-unit increase in GDP. In the short run, although increases in FDI still have a positive effect on growth, their impact is more limited compared to the long-run effects. This finding suggests that FDI contributes more significantly to growth over time.

Similarly, TRADE is found to have a positive and significant effect on GDP in both the short and long run. The coefficient for TRADE is estimated at 0.14 in the long run and 0.16 in the short run, indicating that an increase in trade volume supports economic growth. In contrast, the coefficients for DEBT are negative and statistically significant in both the short (-1.57) and long run (-1.26). These findings suggest that an increase in total debt service has a significant negative impact on economic growth. This result can be interpreted as an indication that government borrowing is allocated to expenditures that do not contribute to growth.

Table 6. The Results of AARDL

Variables	Coefficient	t-Statistic	Prob.
Panel A. Short-Run Coefficients			
C	0.077	0.144	0.8878
@TREND	0.221***	3.884	0.0022
Δ(PUBI)	0.091***	8.493	0.0000
Δ(PRIVI)	0.076***	4.662	0.0005
Δ(PRIVI (-1))	0.028*	2.135	0.0540
Δ(FDI)	0.704*	-2.138	0.0538
Δ(FDI(-1))	0.448***	-3.864	0.0023
Δ(TRADE)	0.164***	4.790	0.0004
Δ(DEBT)	-1.570***	-11.845	0.0000
Δ (HCAP)	0.198**	2.272	0.0423
Δ (HCAP(-1))	-0.315**	-2.554	0.0253
D2001	-1.629*	-2.122	0.0553
D2006	-4.988***	-5.023	0.0003
ECT(-1)*	-1.778***	-11.490	0.0000
Panel B. Long-Run Coefficients			
PUBI	0.077***	7.347831	0.0000
PRIVI	0.096***	3.417134	0.0051
FDI	1.206**	2.661517	0.0207
TRADE	0.146***	3.574388	0.0038
DEBT	-1.263***	-6.386129	0.0000
HCAP	0.545***	4.706326	0.0005
R			0.96
R^2			0.92
F-statistic			95.60601***

Note: ***, **, and * denote statistical significance at 1%, 5% and 10% respectively.
Source: Author's Calculation, 2025.

Finally, HCAP emerges as one of the strongest determinants of long-run GDP growth. The coefficients for HCAP are positive and statistically significant in both the short and long run, indicating that a one-unit increase in human capital leads to a 0.54-unit increase in GDP in

the long run and a 0.19-unit increase in the short run. These results reaffirm the well-established positive relationship between educational attainment and economic growth.

Another noteworthy finding is the negative and significant impact of the dummy variables representing structural breaks in 2001 and 2006. The economic downturns during these years, likely triggered by financial crises, are associated with substantial declines in economic growth. Furthermore, as shown in Table 6, the error correction term (ECT) is negative and significant, with a coefficient of -1.77, which aligns with expectations. According to Narayan, Smyth (2006), if the absolute value of this coefficient is less than one, the convergence process toward equilibrium is considered stable. However, when the absolute value exceeds one, the convergence process is expected to fluctuate but gradually stabilise over time. In this case, the absolute value of the ECT being greater than one suggests that the adjustment process toward long-run equilibrium follows a prolonged and volatile path.

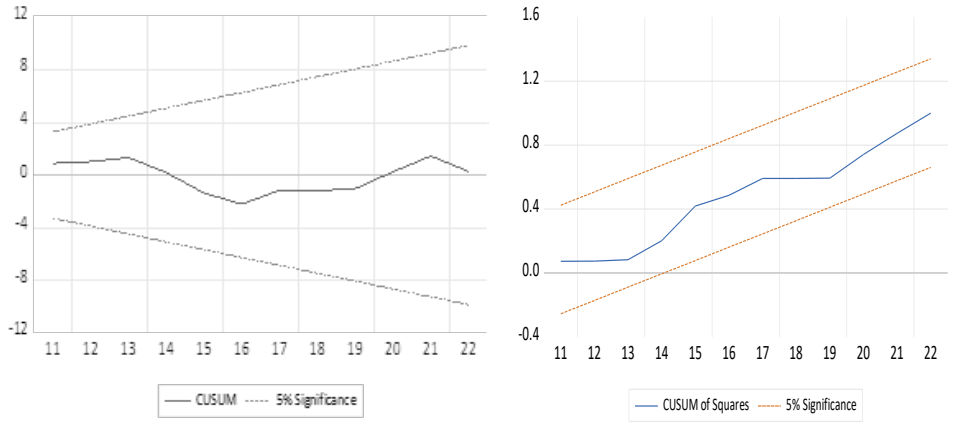
Although the R and R-squared values in Table 6 (0.96 and 0.92, respectively) appear quite high, this is consistent with the inclusion of strong theoretical predictors and macroeconomic variables that tend to co-move with economic growth. The model specification was tested for multicollinearity and robustness to ensure the validity of the estimations. The diagnostic test statistics presented in Table 7 indicate that the model is free from issues of autocorrelation, heteroscedasticity, and model specification errors, while the residuals follow a normal distribution.

Table 7. Diagnostic Test Results

Diagnostic Test	Test Statistics	p-value	Decision
Breusch–Godfrey serial correlation LM Test	0.10	0.90	No serial correlation
Breusch-Pagan-Godfrey Test	1.46	0.26	No heteroscedasticity
Jarque-Bera Test	0.62	0.73	Error terms are normally distributed
Ramsey RESET test	0.22	0.82	The model is correctly specified

Source: Author's Calculation, 2025.

Figure 1. The Plot of CUSUM and CUSUM of Squares



To investigate the stability of the estimated AARDL model, the CUSUM and CUSUMSQ tests were applied, and the corresponding results are presented in Figure 1. As observed, both the CUSUM and CUSUMSQ statistics remain within the critical bounds at the 5% significance level. This suggests that the model coefficients are stable over time, affirming the robustness of estimated relationships.

4.3. The Results of LA-VAR

Table 8 summarises the full-sample results of the LA-VAR, which is employed to capture the dynamic causality between PUBI, PRIVI, and GDP. In Panel A, the null hypothesis of no Granger causality from PUBI to GDP is rejected at the 5% level when the FEW algorithm is applied, and at the 1% level in the other windows. In Panel B, the null hypothesis of no Granger causality from PRIVI to GDP is rejected at the 10% level in the FEW algorithm, and at the 5% level in the ROW and REW algorithms. In Panel C, the null hypothesis of no Granger causality from GDP to PUBI is rejected at the 5% level in the FEW algorithm, and at the 1% level in both ROW and REW models. In Panel D, the null hypothesis of no Granger causality from GDP to PRIVI is not rejected in FEW but is rejected at the 10% level in ROW and at the 5% level in REW. This strong rejection of the null hypothesis indicates the presence of Granger causality among all the variables in the system.

In the LA-VAR, a large series of Wald statistics from the FE, RO and RE windows is used to assess whether the causal relationship exists or changes at specific points along the time series are plotted on the same graphical plane as the 90% and 95% percentiles of the empirical distribution of the bootstrap statistics derived by Shi et al. (2018) and Shi et al. (2020). In the LA-VAR, the null hypothesis states that there is no Granger causality between the variables. To reject the null hypothesis, the test statistics obtained from FE, RO, and RE algorithms must exceed the bootstrap critical values. The estimated start date of a change in causality is determined as the moment when the test statistic first exceeds the critical value, and subsequent changes are tracked similarly. In this way, periods when Granger causality relationships change significantly can be identified.

When the test statistic (solid line) exceeds the empirical critical values (dashed lines) derived from the bootstrap distribution, Granger causality is confirmed. Overall, these graphical results underscore the dynamic nature of Granger causality relationships and reveal that the specific iterative algorithm employed, namely FE, RO, or RE plays a significant role in shaping the observed causality patterns over time.

The Granger causality test results between PUBI, PRIVI and GDP over time are displayed in the graphs in Figures 2-7. Several noteworthy findings emerge from the analysis. First, the estimates obtained using the FE, RO, and RE windows in Figures 2, 3, and 4, respectively, show that the Granger causality from PUBI to GDP has significantly changed over time during the analysis period. Specifically, the statistics from all three algorithms reveal that Granger causality from PUBI to GDP was active between 2005 and 2010, but weakened in the subsequent periods. This indicates that the impact of PUBI on growth was more pronounced in the earlier years, while the influence of PUBI weakened after 2010.

Table 8. Time-varying Granger Causality Test Results, All Sample

	FEW	ROW	REW
Panel A: PUBI→GDP			
Maximal Wald Test Statistic	21.413**	119.469***	119.469***
Critical Values			
%1	28.170	26.732	28.170
%5	16.303	15.731	16.303
%10	11.562	11.138	11.562
Panel B: PRIVI→GDP			
Maximal Wald Test Statistic	17.967*	21.854**	24.737**
Critical Values			
%1	29.523	27.864	29.523
%5	19.019	17.123	19.019
%10	12.788	12.464	12.788
Panel C: GDP →PUBI			
Maximal Wald Test Statistic	29.537 **	85.523***	85.523***
Critical Values			
%1	53.794	49.184	53.494
%5	31.463	30.765	31.463
%10	24.294	23.533	24.294
Panel D: GDP →PRIVI			
Maximal Wald Test Statistic	13.913	17.636*	25.873**
Critical Values			
%1	45.257	40.611	45.257
%5	22.297	21.286	22.297
%10	16.825	15.646	16.825

Notes: Time-varying Granger causality analysis based on the LA-VAR model with p=2, d=0, m=1, and includes a trend. The minimum window size is set at 15 observations. Sub-Window Length is determined by the Caspi (2017) formula ($(0.01+1.8/\sqrt{T})$). The 99th, 95th, and 90th percentiles of the empirical distribution of the bootstrap test statistics are based on 599 replications. Maximal Wald test statistics are robust to heteroscedasticity.

Source: Author's Calculation, 2025.

This finding can be attributed to the economic stability and structural reforms in Turkey during the period between 2005 and 2010[6]. This period encompasses a time of strengthened public discipline, increased confidence, inflation decreasing to single-digit levels after a prolonged period, the reduction of the budget deficit relative to GDP from 12% to 2%, and the implementation of crucial infrastructure investments for development. These factors reinforced the impact of PUBI on growth and laid the foundation for the prominence of causal relationships.

[6] The average inflation rate is 8%, the budget deficit-to-GDP ratio is approximately -2.26%, and the public debt-to-GDP ratio is around 41%.

Figure 2. Time-Varying Granger Causality Tests for PUBI→GDP (FE Algorithm)

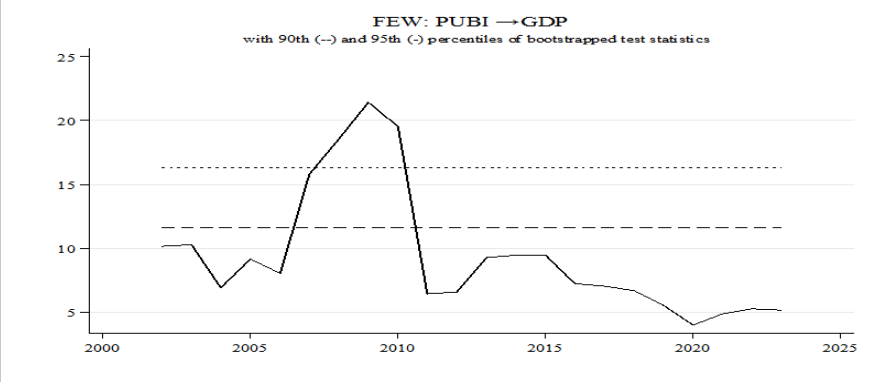


Figure 3. Time-Varying Granger Causality Tests for PUBI→GDP (RO Algorithm)

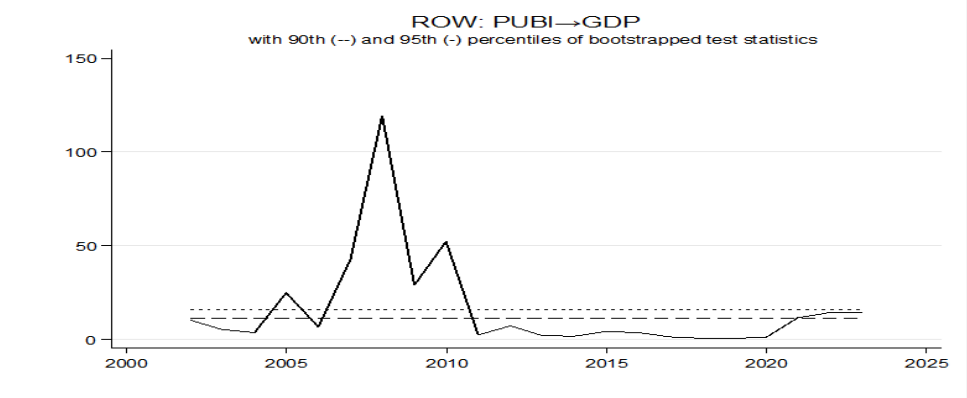
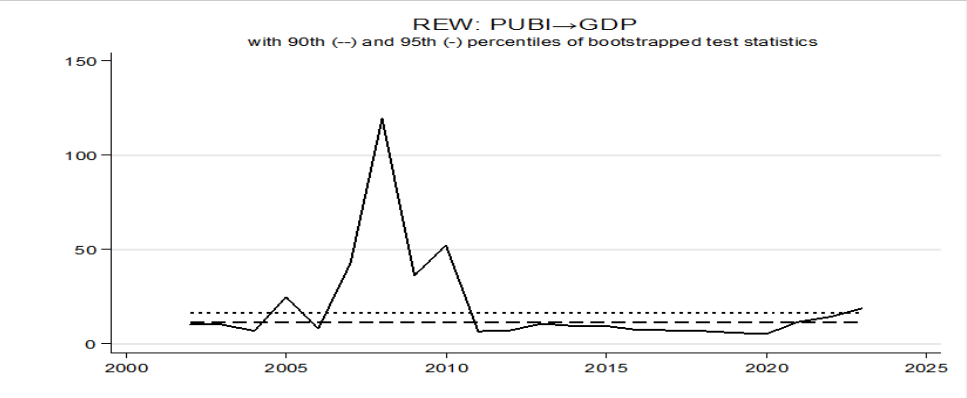


Figure 4. Time-Varying Granger Causality Tests for PUBI→GDP (RE Algorithm)



In Figures 5, 6, and 7, the estimates obtained using FE, RO, and RE windows show a strong causal relationship from PRIVI to GDP. A few important points should be emphasised here. The graphs indicate that, according to the RO algorithm, there is Granger causality from PRIVI to GDP throughout most of the period, and according to the REW algorithm, this causality holds for the entire period after 2005. However, the FE algorithm fails to capture this causal relationship in the latter part of the sample period. This confirms the fact that the FE algorithm is not sensitive to changes at the end of the sample (Baum et al., 2022). Since the RE algorithm integrates both the FE and RO recursions, it can be concluded that the causality between PRIVI and GDP is more comprehensive when using the RE algorithm.

Figure 5. Time-Varying Granger Causality Tests for PRIVI→GDP (FE Algorithm)

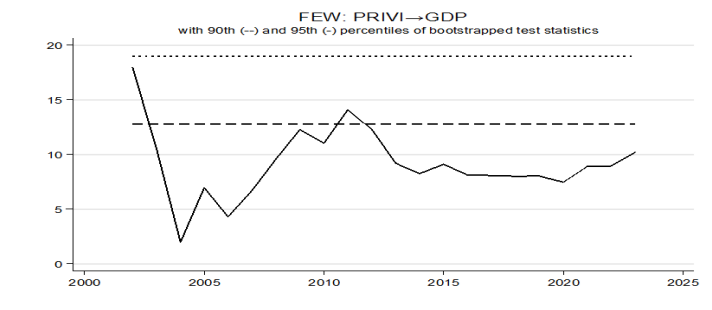


Figure 6. Time-Varying Granger Causality Tests for PRIVI→GDP (RO Algorithm)

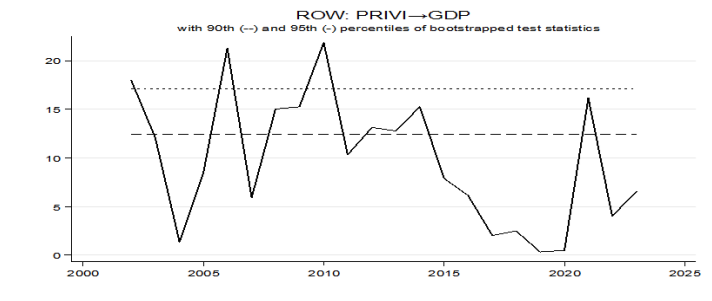
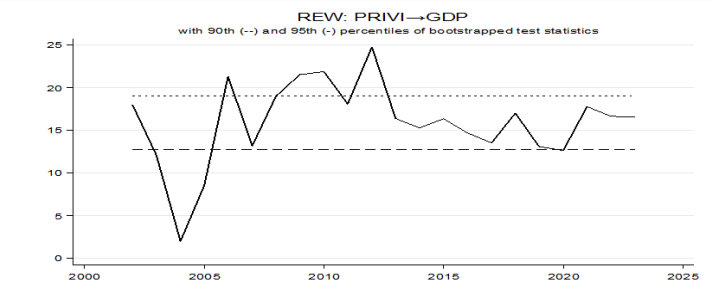


Figure 7. Time-Varying Granger Causality Tests for PRIVI→GDP (RE Algorithm)



Finally, in Table 9, the causal periods determined based on the 90th percentile of the bootstrap test statistics for the REW method are presented. Upon reviewing the table, it is observed that the Granger causality from both PUBI to GDP persisted during the periods from1988-2001, while the causality from PRIVI to GDP continued until 2002. However, in the post-2002 period, the Granger causality from PUBI to GDP, although intermittently active, gradually disappeared during the period from 2010 to 2021. The causal effect of PRIVI on GDP remained largely consistent throughout the entire examined period.

Table 9: Identified Causal Periods for REW for the 90th Percentile of Bootstrapped Test Statistics

	Active Causality Periods
PUBI→GDP	1988-2001, 2005, 2007-2010, 2021-2023
PRIVI→GDP	1988-2002, 2006-2019, 2021-2023

Source: Data Processed, 2025.

5. Conclusion

This study confirms the existence of a long-run cointegration relationship between economic growth and various explanatory variables, including public and private fixed capital investments, FDI, trade openness, debt service, and human capital. While both public and private investments contribute positively to growth, private investments stand out with their consistent and enduring impact. Additionally, FDI emerges as the most influential driver of growth, and trade openness and human capital also play significant supportive roles. On the contrary, debt service has a persistently negative effect on growth, highlighting the need for careful fiscal management.

The time-varying Granger causality results complement these findings by demonstrating that the strength and direction of causality between investment types and growth have shifted over time. The causal link from public investments to growth was particularly strong during the 2005–2010 period, a time of macroeconomic stability in Turkey. Meanwhile, private investments exhibit a more stable and lasting causal influence on growth over time.

These findings underscore the importance of accounting for structural and temporal dynamics in growth strategies. In light of this, the following policy recommendations are proposed to enhance the effectiveness and sustainability of growth-oriented interventions:

1) Since the impact of public investments on growth is more pronounced under strong macroeconomic conditions, ensuring macroeconomic stability is essential for public investments in energy, infrastructure, technology, and R&D to effectively support private sector investment. In this context, priority should be given to stabilisation policies such as maintaining fiscal discipline, keeping the budget deficit under control, and ensuring price stability.
2) Private sector investments are vital for sustainable growth. Therefore, emphasis should be placed on policies that enhance the private sector productivity, including structural reforms to improve the investment climate, accelerate the digital transformation process,

effectively implement regional and sector-based support and incentive mechanisms, and facilitate access to finance.

3) Foreign direct investment (FDI), the strongest determinant of growth, deserves greater incentives. In this context, a transparent and stable legal framework should be established, and tax incentives, exemptions, subsidies, and financial support mechanisms should be activated. In addition, broad policy perspectives, supported by infrastructure and logistics improvements, are essential to increase the country's attractiveness for foreign investors.
4) Policies that support trade openness should be prioritised. Turkey's export-oriented growth model makes this even more important. In this context, encouraging exports through wide-scale incentives such as tax exemptions, cheap inputs, and credit enhances competitiveness and integration into global markets. Additionally, training exporters and reducing bureaucratic barriers may multiply the impact of economic incentives.
5) Effective debt management and fiscal discipline must be maintained. To mitigate the adverse effects of debt service burdens on economic growth, sustainable fiscal policies should be implemented, and public debt management should be strengthened.
6) Policies aiming to expand access to quality education and improve workforce skills should be prioritised for long-term sustainable growth.

As a final remark, considering that economic conditions fluctuate over time and may require different policy approaches, it is essential to emphasise the importance of adopting dynamic and flexible policy frameworks to sustain economic growth. Given that fixed capital investments are key drivers of economic growth dynamism, these findings are critical in shaping policy preferences and priorities in Turkey's development and growth strategies.

Contribution of individual authors

Aslı Güler: AG: Idea, supervision, design, data collection, analysis, interpretation, and critical review.

İbrahim Al: Idea, supervision, literature review, formatting.

Conflict of Interests

There is no conflict of interest between the authors.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used [ChatGPT] in order to [assist language editing]. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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