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Nonlinear Determinants of Türkiye's Capital Goods Imports: Uncertainty, Industrial Production, and Real Exchange Rates

Barış Ülker[*]

Abstract

Capital goods are among Türkiye's main import items. In this study, the effects of world uncertainty, industrial production index, and real effective exchange rates (REER) on Türkiye's real capital goods imports over the 1994Q1-2025Q1 period are investigated with the Nonlinear Autoregressive Distributed Lag (NARDL) model to reveal asymmetries. Industrial production affects imports asymmetrically, surging during growth but exhibiting downward rigidity in recessions. Uncertainty confirms the Real Options Theory by affecting imports negatively in the short run, however it is ineffective in the long run. The asymmetric effect of the uncertainty is only directional. On the contrary, the REER has a symmetric effect on imports in the long-run. The results show Türkiye's high dependence on imported capital goods and the importance of domestic capital goods for growth. These findings suggest that policies aimed at straightening resilience to global uncertainty in the short run may help stabilize capital goods import demand, especially during downturn periods.

JEL Codes: F14, F41, C22

Keywords: Capital Goods Imports, World Uncertainty, Industrial Production, Exchange Rates, NARDL Model

[*] Department of Economics, Dicle University, Diyarbakır, Türkiye, https://orcid.org/0000-0002-6860-8210, barisulker.dr@gmail.com

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Türkiye'de Sermaye Malları İthalatının Doğrusal Olmayan Belirleyicileri: Belirsizlik, Sanayi Üretimi ve Reel Kur

Öz

Sermaye malları, Türkiye'nin başlıca ithalat kalemleri içinde yer almaktadır. Bu çalışmada, küresel belirsizliğin, sanayi üretim endeksinin ve reel efektif döviz kurunun (REDK), Türkiye'nin reel sermaye malı ithalatı üzerindeki etkileri, asimetrileri ortaya çıkarmak için Lineer Olmayan Otoregresif Dağıtılmış Gecikmeler (NARDL) modeli ile incelenmiştir. Çalışma 1994Q1-2025Q1 dönemini kapsamaktadır. Bulgular, sanayi üretiminin ithalat üzerinde güçlü bir asimetrik etkisini ve büyüme dönemlerinde ithalat hızla artarken, durgunluk dönemlerinde aşağı yönlü katılık gösterdiğini ortaya koymuştur. Kısa dönemde artan belirsizlik, ithalatı olumsuz etkileyerek Reel Opsiyon Teorisi'ni doğrularken, uzun dönemde etkisiz kalmıştır. Asimetrik etki sadece işaret açısından yönseldir. Buna karşın, REDK uzun dönemde ithalat üzerinde simetrik bir etkiye sahiptir. Sonuçlar, Türkiye'nin ithal sermaye mallarına olan yüksek bağımlığını ve büyüme için yerli sermaye mallarının önemini ortaya koymaktadır. Bu sonuçlar doğrultusunda, küresel belirsizliğe karşı dayanıklılığı güçlendirmek, özellikle durgunluk dönemlerinde sermaye malı ithalatının dengelenmesine yardımcı olacaktır.

JEL Kodları: F14, F41, C22

Anahtar Kelimeler: Sermaye Malı İthalatı, Dünya Belirsizliği, Sanayi Üretimi, Döviz Kurları, NARDL Modeli

Extended Summary

Capital goods imports is an important element for developing nations like Türkiye as they work as a mechanism for technology diffusion and capital formation. Unlike consumption goods, these imports directly influence the long-term productive capacity of the economy by augmenting the capital stock through investment. This study investigates the nonlinear determinants of Türkiye's real capital goods imports from 1994Q1 to 2025Q1. It specifically analysis the impacts of the World Uncertainty Index (WUI), industrial production index and the Real Effective Exchange Rate (REER). The primary object of this study is to reveal whether these economic drivers exert a symmetric or asymmetric effects on imported demand so more detailed understanding of investment behavior than traditional linear models allow can be provided. While existing literature acknowledges the influence of uncertainty, industrial activity and exchange rates on trade, most previous studies have employed linear models that assume economic variables respond identically to positive and negative shocks. This study differentiates itself by adopting a nonlinear approach, arguing that the reaction of importers to the changes in the selected economic variables may differ significantly in magnitude and speed compared to their reaction to increases or decreases.

To capture these potential asymmetries, the study utilizes the Nonlinear Autoregressive Distributed Lag (NARDL) model. This methodological choice allows for the decomposition of explanatory variables into partial sum processes of positive and negative changes to isolate the effects of increases and decreases in the independent variable. The analysis confirms that the variables are cointegrated and incorporates and endogenous structural break identified in the second quarter of 2005 to ensure robust estimation results. The theoretical framework rests on two main pillars: the Real Options Theory, which suggests uncertainty delays irreversible investment, and the Imports-as-Inputs Hypothesis, which posits a structural dependency on foreign machinery for production.

The empirical findings reveal a significant "ratchet effect" regarding industrial production, confirming that the relationship is highly asymmetric. The results demonstrate that capital goods imports respond strongly to expansions in industrial activity but adjust only modestly during contractions, indicating downward rigidity in import demand. This indicates that while Turkish firms aggressively import technology during expansions, they struggle to reduce these imports proportionally during recessions due to ongoing project commitments, maintenance needs, and the irreversibility of investment decisions.

Regarding global uncertainty, the study validates the Real Options Theory predominantly in the short run. Increased global uncertainty significantly dampens capital goods imports as firms adopt a "wait-and-see" strategy to avoid risks associated with irreversible costs. However, this effect is temporary, as the long-run impact of uncertainty is statistically insignificant, suggesting that firms eventually adjust to volatility and that the effect is only directional rather than permanent. Conversely, the Real Effective Exchange Rate demonstrates a long-run asymmetric effect. An appreciation of the domestic currency stimulates imports, while depreciation reduces them, but the magnitude differs across positive and negative movements. This finding implies that while price competitiveness is a factor, the structural need for machinery often dictates import levels regardless of currency fluctuations. In conclusion, the study highlights Türkiye's chronic dependence on imported investment goods, characterized by asymmetric sensitivity to growth and short-term vulnerability to global uncertainty. Policymakers are advised to incentivize domestic capital goods production to reduce this structural dependency and employ counter-cyclical measures to stabilize investment demand during periods of heightened global uncertainty.

1. Introduction

Capital goods are crucial for technology diffusion and capital formation, especially in emerging economies. As the number of countries is limited in the creation of new technologies, the pattern of the global production techniques is determined by international technology diffusion (Keller, 2004). Productivity growth is one of the key dimensions of long-run growth, and it is strongly tied with technology. As new technologies require new capital modalities, aggregate industrial output requires an increase in capital intensity (Long, Summers and Abel, 1992). Here, foreign trade plays a significant role. Imports of new capital goods help developing countries achieve technological catch-up when combined with human capital formation (Mayer, 2001). Capital goods imports also have a big share in Türkiye's total import basket. Over the last ten years (2015–2025), the share of capital goods in Türkiye's total imports averaged 11.67%, ranging from 8.47% to 15.11% across quarters (Turkish Statistical Institute, 2025). It is calculated according to the Broad Economic Categories (BEC) classification, which is a high-level product classification introduced by the United States Statistical Commission and was first published in 1971 (United Nations, 2018). Especially the sectors with higher capital and technology intensity have the highest import requirement (Erduman, Eren and Gül, 2020).

In recent years, the world economy has been subject to elevated levels of uncertainty. These global uncertainties strongly affect all economic activities, especially investment decisions. As the unpredictability in the economic environment increases, firms tend to delay, reduce, or even entirely abandon their investments, particularly those that are irreversible and require substantial capital commitments. These decisions of the firms are explained by Real Options Theory. According to this theory, when uncertainty rises, firms choose to wait for additional information before making new investments (Dixit and Pindyck, 1994). As the option value of waiting rises, total investment decreases. The theory is basically explained by the formula $I_t = I(V_t - V^*)$. Here, I_t refers to investment at time t, V_t is the expected value of the project and V^* is the threshold value of the investment under uncertainty. This expression is a simplified representation of the real options mechanism, highlighting the threshold nature of investment under uncertainty. Investment occurs only when $V_t > V^*$. An increase in uncertainty also raises V^*, so, in an economic environment where $V^* > V_t$, firms postpone their investments (Dixit and Pindyck, 1994). Earlier studies also emphasize that as policy and macroeconomic uncertainties increase, the perceived risk of long-term projects increases so private investments are discouraged (Bernanke, 1983; p. 90; Rodrik, 1991). Subsequent evidence also proves that uncertainty shocks cause dramatic falls in employment and investment because of an increase in the real-options value of timing due to higher uncertainty which leads firms to scale back their plans (Bloom, 2009). In open and developing countries, investments are highly sensitive to

uncertainties, particularly when capital formation depends on imported machinery and equipment. Policy uncertainty directly influences firms' investments and export decisions by affecting timing and scale of their entry to international markets (Handley and Limão, 2015). In this study, the uncertainty channel is captured by the World Uncertainty Index (WUI), which is expected to impose a negative effect on the capital goods imports through the Real Options Theory.

Industrial production is an important proxy for cyclical real activity in manufacturing sectors, where fluctuations in outputs often translate into changes in demand for machinery equipment. If the equipment is not produced domestically, it directly affects capital goods imports. Especially in developing economies, capital formation is often constrained by limited domestic production capacity and technological capabilities in investment goods. Translating domestic savings into domestically produced capital goods becomes difficult for these economies. Due to their technological lag and sectorally disarticulated structures, these economies are structurally compelled to import the majority of their intermediate and capital inputs (Stockhammer, 2023). These imported goods are often technologically advanced and not easily replaced by domestic production. Following Oulton (1997), the gross output production function is defined as $Q = F(K, L, M, t)$ and here, Q is gross output, K is capital, L is labor, M is intermediate inputs (materials, energy, business services, etc.) and t denotes time. In this setting, capital goods imports augment the capital stock through investment and imported intermediates enter production. It is particularly relevant for developing and semi-industrialized economies where reliance on foreign sources is typically higher. This condition is also referred to as the Imports-as-Inputs Hypothesis. The index of industrial production measures the volume changes in industrial output and serves as an indicator of economic activity (United Nations, 2013). Accordingly, the industrial production index also shows the scale of the economic activities in the sectors that use imported capital goods. So, as the capital stock is an increasing function of output, an expansion in industrial production should also increase the demand for capital goods. In Türkiye, this mechanism is particularly relevant as capital accumulation relies substantially on imported machinery. This pattern is consistent with input-output evidence showing that Türkiye's import dependency on intermediate inputs has increased markedly, especially in technology-intensive manufacturing sectors (Ünal, 2020). Therefore, a positive relationship between the industrial production index and capital goods imports is expected, and industrial production is included in the empirical model of the study as it is one of the key determinants of capital goods import demand.

The impact of global uncertainty is an important determinant of the capital goods imports; however, these imports are also governed by relative price signals. A key measure of the price levels is the real effective exchange rate (REER), a measure of the rate at which one country's goods trade against a number of relevant partners (Reinert,

2012). In this study, the REER index is defined such that an increase represents a real appreciation of the domestic currency. According to the standard mechanism, a real appreciation of the domestic currency increases the REER, makes foreign goods relatively cheaper, and stimulates import demand. Conversely, a real depreciation makes imported goods more expensive in domestic currency, which should dampen import demand (Goldstein and Khan, 1985; Hooper et al, 2000; Campa and Goldberg, 2005). In addition, according to the structuralist approach, in economies that depend on imported intermediate and capital goods for production, such as Türkiye, a real depreciation may also lead to contraction. In this case, higher costs of imported inputs raise production costs, reduce investment and amplify the decline in capital goods import demand (Krugman and Taylor, 1978; Bruno, 1979; Lizondo and Montiel, 1989; Agénor, 1991). It is important to note that these price and contractionary effects are mutually reinforcing, as both lead to a reduction in import demand during a real depreciation. On the other hand, a fall in the REER can also be expansionary through the competitiveness channel. It improves net exports and output, which may raise firms' profitability and stimulate investments (Edwards, 1985; Kamin and Rogers, 2000). If investment goods are largely imported in an economy, stronger investment demand also stimulates capital goods imports, which may offset the negative relative-price and cost channels to some extent. Thus, the magnitude and potential asymmetry of REER movements on capital goods imports remain as an important empirical question. Accordingly, the empirical analysis allows the impacts of REER appreciations and depreciations to differ.

In summary, the empirical model of the study connects Türkiye's capital goods imports to three key variables, global uncertainty, domestic industrial activity, and the REER as a proxy for the relative-price competitiveness. Based on the above theories, uncertainty is expected to have a negative effect via the real options channel, industrial production is expected to exert a positive effect through the imports-as-inputs mechanism, while the impact of the REER is expected to be asymmetric due to offsetting channels that may operate differently across appreciations and depreciations.

An asymmetric framework is particularly relevant for capital goods imports because these flows are closely tied to investment decisions that are often lumpy, partly irreversible and subject to adjustment costs. According to the real-options mechanism, increases in uncertainty can trigger a sharp wait-and-see response, whereas declines in uncertainty may not generate equally strong rebound because investment typically resumes only after profitability thresholds are crossed. Similarly, under the imports-as-inputs channel, expansion in industrial activity may require an immediate rise in imported capital goods, while contractions may not translate into proportional cuts due to fixed input needs, ongoing projects and replacement or maintenance requirements. Finally, REER appreciations and depreciations can have direction dependent net effects because relative price, cost and competitiveness channels may dominate differently across directions. A linear Autoregressive Distributed Lag (ARDL) model imposes

symmetry, however the nonlinear ARDL (NARDL) framework allows potential nonlinear responses dependent to direction responses. Theoretical and empirical work also emphasize that global financial and uncertainty conditions can be largely disconnected from country-specific macroeconomic fundamentals (Rey, 2015). Accordingly, global uncertainty shocks are largely external to domestic conditions and can be treated as exogenous from the perspective of an open economy such as Türkiye. This is also consistent with evidence that global uncertainty factors can be treated as exogenous for open economies and tend to have stronger real effects when trade openness is greater (Bonciani and Ricci, 2018).

The paper is organized as follows. Section 2 reviews the literature on imports (mainly capital goods), uncertainty, industrial production and the exchange rate nexus. Section 3 introduces the data, variables and presents the methodological framework and the NARDL specification used in the analysis. Section 4 reports empirical results, which include the long-run and short-run effects as well as the asymmetric impacts of the positive and negative changes in the explanatory variables which are captured through the decomposed partial-sum components in the NARDL framework. Section 5 discusses the main findings together with existing literature and summarizes the policy implications for an open and import dependent country such as Türkiye.

2. Literature Review

Capital goods imports have a crucial role for economic growth of developing countries as they serve as a primary channel for technology transfer and modernizing domestic production. Therefore, the determination of the factors affecting these imports is essential for policymakers to sustain industrial production capacities. Traditional trade literature focuses on relative prices and income levels to explain import demand; however, structural shifts in the global economy over the last two decades require a broader analytic framework. In this section, the empirical literature that uses three fundamental determinants of capital goods imports and their proxies. These are uncertainty, industrial production and exchange rate dynamics.

Following the 2008 Financial Crisis and the highly unstable period after 2016, traditional models that are based on price, income etc. have become inadequate to explain the volatility of trade volumes. This gap is mostly filled by the inclusion of an uncertainty variable in the models. Especially, the trade war between the United States and China started in 2018 and the Brexit process made uncertainty a fundamental determinant of imports. There are many studies regarding the relationship between total imports and uncertainty, however, here, we only focus on a limited body of literature analyzing the relationship between uncertainty and capital goods imports. Imbruno (2019) shows that reductions in trade policy uncertainty are associated with higher imports and higher quality in China. Sharma and Paramati (2020) find that uncertainty

may raise imports in the short run but dampens imports in the long run for India. Lanzilotta et al. (2023) report that higher uncertainty reduces Uruguay's capital goods import index, while Li and Zang (2024) show that trade-friction uncertainty mainly depresses imports of complete agricultural machinery in China. Besides direct indices, uncertainty is also proxied by financial market volatility such as the Chicago Board Options Exchange Volatility Index, also known as VIX (Ahir et al., 2025). Novy and Taylor (2020) document that higher VIX reduces U.S. imports, with particularly large declines in business equipment. Güney and Balkaya (2022) find that higher VIX reduces Türkiye's investment goods imports. Overall, the evidence suggests that, when uncertainty rises, countries tend to dampen investment-related imports although very short-run front-loading/stockpiling effects may occur.

Industrial production is a leading indicator of real sector activity and is expected to be positively linked to import demand through higher input requirements and investment needs during expansions. Although most empirical studies on capital goods import demand use broader activity proxies such as GDP or capital utilization, the limited evidence relating industrial production to import dynamics generally supports a positive association. For example, Osigwe and Obi (2015) show that higher capacity utilization increases raw material imports in Nigeria. Goicoechea (2017) finds that domestic industrial output has a long-run positive effect on capital goods imports in a panel of developed economies and Wahab et al. (2017) report a positive long-run relationship between imports of capital goods (machinery and equipment) and industrial output growth for Bangladesh. More recent evidence for Bangladesh also indicates a favorable long-term association between imported capital goods and manufacturing output (Islam, 2024). Evidence for Türkiye is more mixed; Erkişi and Tekin (2019) report no Granger causality from industrial production to capital goods imports, although both variables appear to raise intermediate goods imports. Overall, existing findings suggest that stronger production activity is typically associated with higher imports of production-related goods, including capital goods, while country-specific dynamics may weaken the direct link in some cases.

Real exchange rate (RER) movements affect capital goods imports by changing relative prices, but the magnitude and even the direction of the effect may vary according to factors such as import dependence in investment goods, production structure, exchange-rate regime, financial depth and exchange-rate volatility. Serven (1995) provides a theoretical framework for a small open economy that imports most investment goods and predicts a negative long-run relationship between the RER and the capital stock. Empirical evidence for Türkiye is mixed. Yamak and Korkmaz (2005) show that although there is no long-run relationship between the RER and the trade balance, short-run movements are largely driven by capital goods related trade. Some studies report a positive association between the RER/REER and capital goods imports (Akal, 2008; Akpiliç, 2025). The evidence can be specification sensitive as Oktay and Gozgor (2013) find a relationship under ARDL but an insignificant effect under DOLS.

Related evidence also indicates that higher exchange rate volatility tends to reduce machinery imports (Tarasenko, 2023). Overall, while theory often predicts a dampening effect of real depreciation on investment-related imports, empirical results for Türkiye frequently reveal a positive or insignificant relationship varying according to country-specific dynamics and model selection.

The existing results in the literature present a complex picture regarding the determinants of capital goods imports. There is consensus that as uncertainty increases, it significantly obstructs capital goods imports. However, industrial production and these imports are positively related in general although the study conducted on Türkiye did not find any causality between these variables. The results regarding the effects of exchange rates on capital goods imports are mixed. The theory suggests that a depreciation in REER should reduce imports, but the empirical analysis conducted for Türkiye shows positive or insignificant relationship. These divergences in the literature highlight the need for re-examination of the relationships with up-to-date data and econometric techniques. The key empirical question is not only whether uncertainty, activity and REER affect capital goods imports, but also whether increases and decreases in these drivers have quantitatively different effects in the short and long run, which is the aim of this study.

3. Dataset and Methodology

3.1. Dataset

The aim of this study is to estimate the effects of global uncertainty, industrial production and competitiveness via real exchange rates on capital goods imports in Türkiye over the period of 1994Q1-2025Q1. All datasets are quarterly. The dependent variable is Türkiye's capital goods imports (except transportation equipment) in USD according to the classification of goods by Broad Economic Categories (BEC) Rev. 4, denoted as BEC 41. This data is only available in nominal values, so it is converted to real terms by dividing each value by its corresponding import unit value index in USD (base year: 2015) and multiplying by 100. Both the nominal and index values are obtained from the Turkish Statistical Institute (TURKSTAT) database. The first independent variable is the World Uncertainty Index (WUI), obtained from the Economic Policy Uncertainty website (policyuncertainty.com) and compiled by Ahir et al. (2022). The second independent variable is Türkiye's industrial production index, which is obtained from TURKSTAT. This variable is seasonally and calendar adjusted (base year: 2021). The third independent variable is Türkiye's Consumer Price Index (CPI) based Real Effective Exchange Rate (REER). These data are obtained from Electronic Data Delivery System (EVDS) of the Central Bank of the Republic of Türkiye (TCMB). The endogenous structural break is determined via Zivot-Andrews (ZA) unit

root test, d1, is also added to the model which is identified as 0 from 1994Q1 to 2005Q1 and 1 from 2005Q2 to 2025Q1. Prior to analysis, all variables are transformed into natural logarithms. No additional normalization is applied beyond the original index base years reported by the data providers. After the transformations, the variables are denoted as CGI, WUI, IPI, and REER, respectively.

The definitions, data sources, and transformations of the variables are summarized in Table 1,

Table 1. Summary of variables used in the analysis

Abbreviation	Description	Source	Adjustment
CGI	Türkiye's Capital goods Imports in Real Terms and USD	TURKSTAT	Natural log
WUI	World Uncertainty Index	PolicyUncertainty.com (Ahir et al., 2022)	Natural log
IPI	Türkiye's Industrial Production Index	TURKSTAT	Natural log
REER	Türkiye's Real Effective Exchange Rate	EVDS of TCMB	Natural log
d1	2005Q2 Structural Break Dummy Variable	Determined by ZA Unit Root Test	No Adjustment

3.2. Methodology

First of all, unit-root properties should be examined to ensure that none of the variables is I(2), which is the only integration-order requirement for the Nonlinear Autoregressive Distributed Lag (NARDL) approach. Following the unit root tests, the cointegration relationship between the dependent and independent variables is analyzed with the NARDL developed by Shin et al. (2014). Similar to the Autoregressive Distributed Lag (ARDL) model, this approach allows the use of variables that have different degrees of stationarity, I(0) or I(1). However, the ARDL model analyses only symmetric models whereas the NARDL model allows testing an asymmetric cointegration relationship by separating variables into their positive and negative components (Mert and Çağlar, 2023). Following Shin et al. (2014), the explanatory variables are decomposed into positive and negative partial sum processes as follows where $x_t \in \{WUI_t, IPI_t, REER_t\}$:

$$x_t^+ = \sum_{j=1}^{t} max(\Delta x_j, 0), \qquad x_t^- \sum_{j=1}^{t} min\,(\Delta x_j, 0) \tag{1}$$

The existence of a long-run relationship is examined using the bounds testing approach of Pesaran et al. (2001). The empirical equation that captures both positive and negative shocks, including dynamic interactions between the dependent and independent variables with the asymmetric error correction framework of the NARDL is given below:

$$\begin{aligned}\Delta CGI_t = {} & \beta_0 + \beta_1 CGI_{t-1} + \beta_2^+ WUI_{t-1}^+ + \beta_3^- WUI_{t-1}^- + \beta_4^+ IPI_{t-1}^+ + \\ & \beta_5^- IPI_{t-1}^- + \beta_6^+ REER_{t-1}^+ + \beta_7^- REER_{t-1}^- + \gamma d1_t + \\ & \sum_{k=1}^{p-1} \delta_{1k} \Delta CGI_{t-k} + \sum_{k=0}^{q-1} (\delta_{2k}^+ \Delta WUI_{t-k}^+ + \delta_{2k}^- \Delta WUI_{t-k}^-) + \\ & \sum_{k=0}^{w-1} (\delta_{3k}^+ \Delta IPI_{t-k}^+ + \delta_{3k}^- \Delta IPI_{t-k}^-) + \sum_{k=0}^{z-1} (\delta_{4k}^+ \Delta REER_{t-k}^+ + \\ & \delta_{4k}^- \Delta REER_{t-k}^-) + \varepsilon_t\end{aligned} \quad (2)$$

In the above equation, β_i denotes the long-run coefficients, δ_{jk} denotes the short-run coefficients where j indexes the regressor group and k the lag order, γ is the structural break dummy coefficient and ε_t is the error term. Optimal lag lengths for the variables are indicated as p, q, w and z, which are determined by the AIC. Dynamic multipliers are also computed as in Shin et al. (2014). These short- and long-run calculations analyze the effects of the shocks in the explanatory variables on the explained variable. This model also assesses the error correction term (ECT), the extent of disequilibrium and the speed of reversion to its long-run equilibrium state. The coefficient of the ECT is expected to be negative and statistically significant, indicating adjustment towards the long-run equilibrium. The short and long-run asymmetries are tested via Wald tests on the equality of positive and negative coefficients. They are used to test linear restrictions on the coefficients (Greene, 2018). In addition, standard diagnostic tests for serial correlation, heteroskedasticity, normality and parameter stability are conducted for the selected NARDL model.

4. Results

Prior to the econometric analysis, descriptive statistics for the log-transformed variables are presented in Table 2:

Table 2. Descriptive statistics of the variables

	CGI	WUI	IPI	REER
Mean	22.199	9.744	3.955	4.508
Median	22.464	9.792	3.934	4.557
Maximum	23.091	10.92	4.696	4.849
Minimum	20.366	8.625	3.138	3.917
Std. Dev.	0.6705	0.472	0.466	0.218
Skewness	-0.8100	0.008	0.027	-0.644
Kurtosis	2.6079	2.692	1.668	2.545
Jarque-Bera	14.471	0.492	9.244	9.719

According to the above statistics, the highest variability is in CGI (sd=0.670) and the lowest in *REER* (sd=0.218). Consistent with skewness and kurtosis statistics, the Jarque-Bera test results indicate non-normality for CGI, *IPI* and *REER*.

Before conducting the Nonlinear Autoregressive Distributed Lag (NARDL) model, it should be ensured that none of the variables is integrated of order two, I(2). For this purpose, three different unit root tests are used in the analysis, Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Zivot-Andrews (ZA) unit root tests (Dickey and Fuller, 1981; Phillips and Perron, 1988; Zivot and Andrews, 1992). ZA is applied to check for structural breaks endogenously. All unit root tests are conducted with two different models, with an intercept only and with both an intercept and a trend. Akaike Information Criterion (AIC) is employed for all the tests to determine optimal lag lengths. The results are reported in Table 3:

Table 3. ADF, PP and ZA unit root test results

		Level				First Difference	
		ADF	PP	ZA	Break Date	ADF	PP
		With Intercept					
CGI	t-Stat.	-1.191	-1.966	-6.438***	2005Q2	-3.242***	-17.659***
WUI	t-Stat.	-3.026***	-3.863***	-5.620***	2000Q3	-6.085***	-23.266***
IPI	t-Stat.	-0.696	-0.260	-3.606**	2016Q4	-14.218***	-14.186***
REER	t-Stat.	-1.477	-1.633	-3.338***	2005Q1	-13.577***	-14.065***
		With Trend and Intercept					
CGI	t-Stat.	-2.023	-3.304*	-6.439**	2005Q2	-3.285*	-17.657***
WUI	t-Stat.	-5.039***	-6.151***	-5.772**	2000Q3	-6.0372***	-23.611***
IPI	t-Stat.	-3.823**	-3.907**	-3.852*	2003Q3	-14.159***	-14.131***
REER	t-Stat.	-2.064	-2.089	-3.969*	2006Q3	-7.109***	-15.363***

Notes: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%.

All the unit root tests confirm that none of the variables is integrated of order two (I(2)).

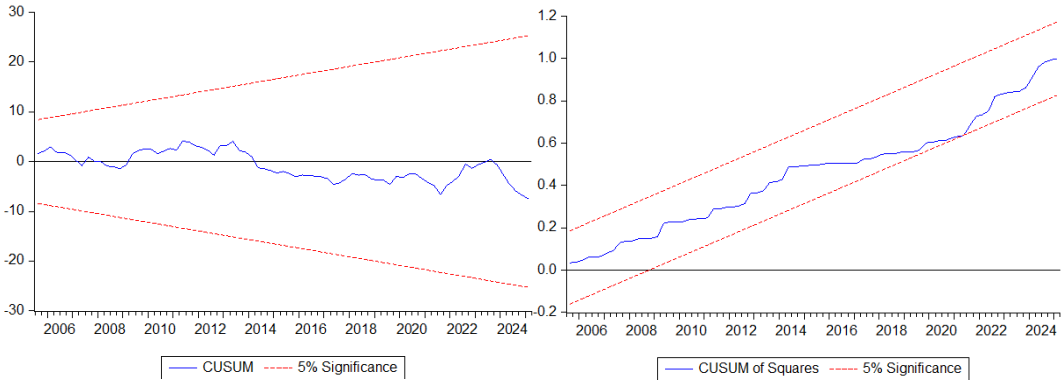
Prior to the bounds test, diagnostic tests were performed to ensure statistical reliability and robustness of the model and the results are summarized in Table 4. CUSUM and CUSUMSQ test graphics are also presented in Figure 1:

Table 4. Diagnostic Test Results

Test Statistic	Value
Adjusted R^2	0.76
F-Statistic	14.417***
Breusch-Godfrey LM Serial Correlation test (χ^2)	2.63
Breusch-Pagan-Godfrey Heteroskedasticity Test (χ^2)	20.51
Jarque-Bera Normality Test (χ^2)	3.34

Notes: *** denotes significance at the 1% level. Diagnostic tests (LM, BPG, Jarque-Bera) are reported as Chi-square statistics; none are significant, indicating that the model satisfies all diagnostic requirements for serial correlation, heteroskedasticity, and normality.

Figure 1. CUSUM and CUSUMSQ test results



Prior to applying the NARDL the Broock, Dechert and Scheinkman (BDS) independence test is utilized to detect potential nonlinear structures in the time series to provide a robust empirical justification for adopting a nonlinear methodology (Broock et.al., 1996). The results are presented in Table 5:

Table 5. BDS Independence test results

Variable	m=2 (z-stat)	m=3 (z-stat)	m=4 (z-stat)	m=5 (z-stat)	m=6 (z-stat)
CGI	29.43***	32.12***	36.42***	38.64***	43.78***
WUI	12.60***	14.04***	15.15***	16.32***	17.35***
IPI	52.96***	56.74***	61.40***	68.14***	77.33***
REER	29.23***	30.93***	32.62***	35.15***	38.64***

Notes: *** denotes significance at the 1% level. The parameter m represents the embedding dimension.

The BDS test results reject the null hypothesis of independent and identically distributed (i.i.d.) series at the 1% level across all dimensions. These results confirm the presence of significant non-linear dependencies in the data. It also validates the suitability of the NARDL model for capturing asymmetric effects. Following the confirmation of non-linear dependencies, the NARDL bounds test results are presented in Table 6:

Table 6. Bounds test results

Test Statistic	Value	k
F-statistic	10.068	6
Significance	I(0) Bound	I(1) Bound
10%	2.12	3.23
5%	2.45	3.61
1%	3.15	4.43

Notes: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%.

According to the bounds test results, the F-statistic value exceeds the I(1) bound across all significance levels. The results indicate that the dependent variable and the independent variables are cointegrated. Following the bounds test, short-run and error correction term coefficients are presented in Table 7:

Table 7. Short run coefficients and error correction term

Variable	Coefficient	Std. Error	t-Statistic
D(CGI(-1))	0.051	0.059	0.863
D(CGI(-2))	0.048	0.052	0.924
D(CGI(-3))	-0.103	0.054	-1.892*
D(CGI(-4))	0.468	0.052	8.911***
D(WUI_POS)	-0.087	0.039	-2.239**
D(WUI_POS(-1))	-0.059	0.041	-1.433
D(WUI_POS(-2))	-0.136	0.043	-3.111***
D(WUI_NEG)	0.009	0.043	0.211
D(WUI_NEG(-1))	-0.115	0.043	-2.644***
D(WUI_NEG(-2))	-0.020	0.043	-0.462
D(WUI_NEG(-3))	-0.038	0.039	-0.975
D(WUI_NEG(-4))	-0.109	0.039	-2.787***
D(IPI_POS)	0.845	0.246	3.434***
D(IPI_NEG)	0.470	0.312	1.506
D(REER_POS)	1.040	0.246	4.213***
D(REER_POS(-1))	-0.501	0.232	-2.159**
D(REER_POS(-2))	0.441	0.237	1.856*
D(REER_POS(-3))	0.506	0.217	2.325**
D(REER_NEG)	0.251	0.159	1.576
D(REER_NEG(-1))	0.479	0.165	2.895***
D(REER_NEG(-2))	-0.109	0.164	-0.666
D(REER_NEG(-3))	0.357	0.167	2.127**
D(D1)	0.099	0.078	1.267
C	12.004	1.372	8.743***
ECT	-0.571	0.065	-8.727***

Notes: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%. The optimal lag structure (5, 3, 5, 0, 0, 4, 4) is determined by the Akaike Information Criteria (AIC); the first parameter represents the dependent variable (CGI), while the following six denote the positive and negative partial sums of WUI, IPI, and REER, respectively.

According to the short-run results reported above, the fourth lag (one year) of the import variable exerts strong and positive inertia on the short-run change in imports. Specifically, a 1% change in the fourth lag of capital goods imports increases current imports by 0.468%. World uncertainty also significantly affects capital goods imports; a 1% positive shock to uncertainty decreases imports by 0.087% in the same quarter. The negative impact of increased uncertainty intensifies after two quarters, reducing current imports by 0.136%. Conversely, a 1% decrease in uncertainty leads to a 0.115% increase in capital goods imports one quarter later and 0.109% four quarters later. These findings confirm the validity of Real Options Theory for Türkiye in the short run. Regarding industrial production, a 1% increase raises the capital goods imports by

0.845% in the current quarter; however, negative shocks to industrial production are statistically insignificant. This asymmetry suggests that the acceleration mechanism operates only during growth periods; conversely, when industrial production tightens, capital goods imports do not decrease significantly, highlighting Türkiye's strong dependency on these imports in the short-run. Finally, when the Turkish Lira appreciates and the REER increases by 1%, the capital goods imports rise by 1.04% in the current quarter, although 0.501% of this increase is offset one quarter later. In the case of a 1% depreciation of the REER, imports decrease by 0.479% with a one-quarter lag as expected. Furthermore, the ECT is between 0 and -1 and is statistically significant, so 57% of the deviations from the long-run equilibrium are corrected within three months, implying a relatively fast adjustment towards the long-run equilibrium.

The Wald test result for the short-run coefficients, which determines the impacts of negative shocks in the independent variable, is statistically different and is given in Table 8:

Table 8. Wald tests results for short run coefficients

Variable	Null Hypothesis	F-statistic
WUI	POS = NEG	35.617***
IPI	POS = NEG	0.440
REER	POS = NEG	26.063***

Notes: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%.

The test results provide evidence in favor of the nonlinear specification. The symmetry null hypothesis is rejected for *WUI* and *REER*. For these variables, positive and negative changes exert statistically asymmetric effects on capital goods imports. However, the null hypothesis for *IPI* cannot be rejected, which implies a short-run symmetry. Although the positive component of IPI is individually significant while the negative component is not, the Wald test fails to reject equality. Hence, the evidence does not support short-run asymmetry for industrial production.

The long-run coefficients are given in Table 9:

Table 9. Long run coefficients

Variable	Coefficient	Std. Error	t-Statistic
WUI_POS	-0.070	0.075	-0.942
WUI_NEG	0.088	0.092	0.955
IPI_POS	1.671	0.248	6.724***
IPI_NEG	0.605	0.233	2.589**
REER_POS	1.066	0.213	4.996***
REER_NEG	0.767	0.148	5.177***
D1	0.178	0.080	2.201**

Notes: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%.

According to the long-run results reported above, in contrast to the short-run findings, world uncertainty shocks do not have a significant effect on capital goods imports. This suggests that uncertainty does not appear to have a permanent impact on capital goods imports in the long run. Secondly, there is a strong asymmetry between industrial production and capital goods imports. A 1% increase in the industrial production index increases imports by 1.671% whereas a 1% decrease in the index decreases imports only by 0.605%. The fact that the elasticity of capital goods imports with respect to industrial production exceeds unity highlights the import intensity of capital formation and reliance on imported capital goods within investment in Türkiye. However, the estimated asymmetry does not quantify the share of imported capital goods in total investments. Also, it does not rule out similar asymmetries for domestically supplied investment goods. Furthermore, the limited decrease in imports during downturns indicates downward rigidity, suggesting that import demand is maintained at a certain level even during crisis periods. Lastly, the REER coefficients confirm Türkiye's foreign dependency on capital goods imports. A 1% appreciation in the REER increases imports by 1.066% whereas a 1% depreciation decreases them by 0.767%. The stronger reaction to cost reductions compared to cost increases suggests that domestic substitution possibilities for imported capital goods are limited. Finally, the structural break coefficient is positive and statistically significant, indicating that following the 2005Q2 period, the capital goods imports experienced a permanent upward shift of about 18%.

The Wald test result for the long-run coefficients is presented in Table 10:

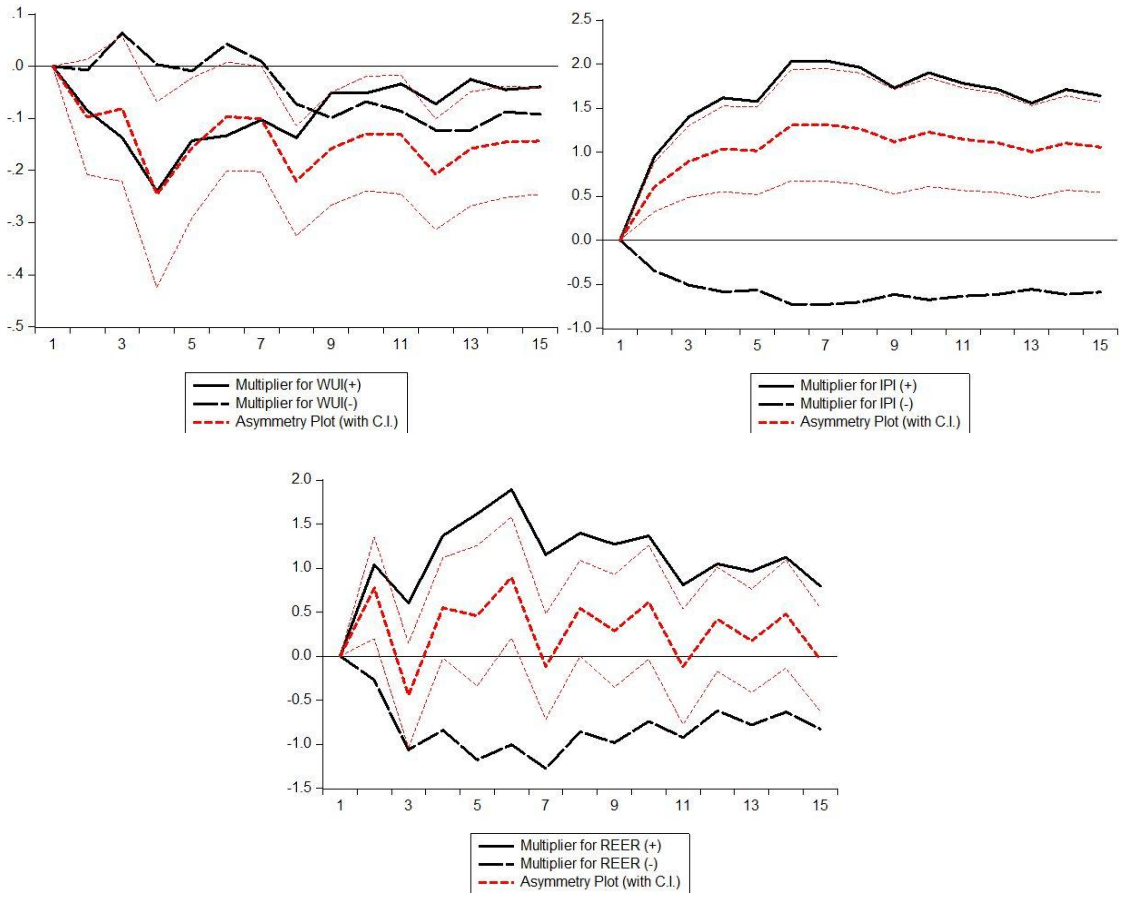
Table 10. Wald tests results for long run coefficients

Variable	Null Hypothesis	F-statistic
WUI	POS = NEG	0.856
IPI	POS = NEG	-2.970***
REER	POS = NEG	-2.144***

Notes: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%.

The results indicate that the long-run relationship is symmetric for *WUI* but asymmetric for *IPI* and *REER*. These results provide direct empirical support for the nonlinear structure of the import-demand function and strengthen the methodological justification for employing the NARDL framework as a linear ARDL would impose long-run symmetry that is not supported by the data for *IPI* and *REER*.

Figure 2. Cumulative dynamic multiplier graphs of *WUI*, *IPI* and *REER*



In addition to the Wald tests, cumulative dynamic multiplier graphs are used to illustrate the adjustment paths of positive and negative changes. These graphs are presented in Figure 2. The plots corroborate the asymmetric responses for industrial production and the REER, while the asymmetry for global uncertainty appears mainly at shorter horizons.

6. Conclusion

In this study, the relationship between Türkiye's capital goods imports and industrial production, global uncertainty and the real effective exchange rate (REER) is analyzed with the Nonlinear Autoregressive Distributed Lag (NARDL) model for the 1994Q1-2025Q1 period. Unlike standard symmetric models, this study contributes to the literature by taking the reactions of the positive and negative components of the variables to shocks into account. There are several empirical findings according to the results.

The main finding is the ratchet effect, as industrial production embodies a strong asymmetry. When Türkiye's industrial production increases, capital goods imports increase aggressively, however in case of a production reduction, imports do not diminish at the same speed. This pattern is consistent with Türkiye's downward rigidity in capital goods demand. A plausible interpretation is that investment-related imports adjust more slowly as firms may continue ongoing investment projects, face irreversibility and need maintenance or replacement to sustain their existing capacities. These results may also be interpreted as evidence of dependence on imported capital goods in a broader sense and the same type of asymmetry could also arise for domestically produced capital goods. At the same time, the asymmetry documented here is an import-based outcome, and the extent to which similar dynamics apply to domestically sourced capital goods is an avenue for future research. Moreover, the Wald tests and dynamic multiplier graphs show that the REER has a symmetric effect in the long run. Appreciation of the Turkish lira increases imports while depreciation decreases them at similar rates. However, short-term dynamics show that importers react instantly to exchange rate advantages while they adjust to negative shocks with a lag. Lastly, in the long-run, although the effect of global uncertainty is limited in magnitude, it is directionally asymmetric. However, in the short-run, especially an increase in uncertainty represses capital goods imports. Real Options Theory is supported by the evidence and companies postpone their capital goods investments in uncertain global environments and follow a wait-and-see strategy.

Several suggestions can be made to policymakers based on these results. First of all, the asymmetry in industrial production shows Türkiye's chronic dependency on imported investment goods. During growth periods, investment incentives should also focus on domestic capital goods, not only on capacity increases. From a policy perspective, these results highlight the importance of improving the resilience of capital formation to adverse cycles. Strengthening domestic capabilities may help to reduce vulnerability to external shocks and imported-input bottlenecks. Secondly, during periods of uncertainty, the investment appetite of Turkish companies declines in the short run. In such periods, counter-cyclical incentives should be implemented by the public authorities to break the wait-and-see effect of global shocks on the real sector. Thirdly, competitive exchange rate policies have a limited but symmetric effect on reducing imports. Considering the near-unitary price elasticity of capital goods imports, exchange rate volatility significantly elevates the cost of investment. Therefore, the Central Bank's price-stability-oriented policies are more critical than exchange rate levels for investment plans. Lastly, short-run evidence shows that industrialists cannot reduce imports immediately in response to negative shocks. This situation may disrupt companies' cash flows and cause challenges in foreign debt payments. For this reason, in periods of economic depression, it is essential to diversify the financial tools to support the working capital of companies.

In conclusion, Türkiye exhibits a structure in which capital goods imports are sensitive to global uncertainties, particularly in the short run, and respond symmetrically to exchange rate movements; however, capital goods imports increase asymmetrically during growth periods. The fundamental solution for the Turkish economy is to cleanse the industrial production pattern of import-intensive input dependence to achieve sustainable growth.

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