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Drivers of Yarn Exports in Turkiye: Anti-fragility and Stability in the Synthetic and Cotton Sectors

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This study investigates the asymmetric and non-linear impacts of the real effective exchange rate (REER), inflation (INF), industrial production index (IPI), and credit default swap (CDS) premiums on Turkiye's synthetic (SYN) and cotton yarn (CTN) exports. Covering data from January 2015 to August 2025, the research employs novel quantile-on-quantile kernel regularized least squares (QQKRLS) and quantile-on-quantile Granger causality (QQGC) methodologies to capture regime-dependent dynamics. Empirical results reveal a profound structural divergence: SYN exhibit 'anti-fragile' resilience during economic stress, whereas cotton yarns appear 'stability-dependent,' suffering from high inflation and risk uncertainty. QQKRLS analysis indicates that while REER enhances synthetic competitiveness, its impact on cotton yarn is threshold-dependent. Furthermore, QQGC findings confirm that causal relationships are highly sensitive to export regimes, with CDS premiums exerting dominant pressure during extreme risk periods. These findings suggest that the Turkish textile industry requires product-specific industrial strategies to effectively mitigate global economic volatility. By introducing the 'anti-fragility' framework to sectoral export analysis, this study highlights the necessity for product-specific, state-dependent strategies rather than a 'one-size-fits-all' approach to enhance industrial resilience in emerging markets.

Keywords: *Cotton Yarn Export; Synthetic Yarn Export; Real Effective Exchange Rate; Credit Default Swap; Quantile on Quantile Analysis; Türkiye.*

Introduction

Global textile product exports amounted to USD 319 billion in 2023 and increased to USD 350.8 billion in 2024, indicating an upward trend (Lu, 2024). The concept of textiles encompasses a very broad field, covering an extensive range of products from raw materials to final textile goods. Based on this scope, when textiles are examined by product groups, technical textile products constitute the largest share of global exports, followed respectively by woven fabrics, home textiles, and yarn. Global yarn exports reached USD 46.8 billion in 2024. Within this export volume, synthetic yarns accounted for 61.5 %, while cotton yarn represented 29.8 % (Turkish Statistical Institute [TUIK], 2025).

The export value of textile and apparel products has doubled since the early 2000s, reflecting the sector's structural growth within the national economy (Ministry of Trade of Turkiye, 2024). As of today, textile sector exports accounted for 10.5 % of Turkiye's total exports in 2024, ranking third after the automotive and chemical sectors (TUİK, 2025). Textile products, which hold a substantial share in Turkiye's exports, also position the country prominently in the global textile market. According to international trade statistics, Turkiye's share in global textile exports reached 3.3 %, making it the world's fifth-largest textile exporter (International Trade Centre [ITC], 2025). Furthermore, when analyzed on a product basis, Turkiye ranked fifth among the world's largest yarn-exporting countries, increasing its market share to 4.92 % in 2024. Within yarn exports, synthetic yarns held the largest share at 61 %, followed by cotton yarn with a share of 32.9 % (ITC, 2025)

Macroeconomic variables significantly affect countries' synthetic and cotton yarn sectors export performance. In the long run, instabilities in inflation and gross domestic product (GDP) have a measurable impact on export volume (Tuyen *et al.*, 2024). Fluctuations in exchange rates, GDP, and inflation rates are associated with firms' export performance (Chander, Tanya, & Chand, 2019). From the perspective of the textile sector, depreciation of the exporting country's currency may lead to an increase in textile exports, as it provides a price-based competitive advantage in international markets (Chen *et al.*, 2023). Additionally, interest rates and inflation rates have also been shown to influence textile exports (Ullah, Noreen, Rehman, & Shinwari, 2020). High inflation increases input costs such as raw materials, labor, and energy, thereby raising production costs and weakening firms' export capacity in the long term. At the same time, increases in industrial production tend to support export growth, as higher production levels encourage firms to expand into foreign markets (Putra & Djinar, 2022).

In addition to macroeconomic indicators, credit default swap (CDS) premiums, which reflect countries' risk perceptions, constitute a crucial determinant of export performance. An increase in CDS premiums signals a higher perception of financial risk, which may lead to increased

foreign trade costs, restricted access to finance, and reduced investor confidence (Longstaff, Pan, Pedersen, & Singleton, 2011). Conversely, declining CDS levels indicate enhanced economic stability and growing confidence in the country, thereby positively influencing foreign trade flows (Galil & Soffer, 2011).

Research Motivation

In this paper, Turkiye's export performance in the yarn sector is examined on the basis of synthetic and CTNs, analyzing the impacts of selected macroeconomic variables-namely interest rates, inflation, industrial production index, and Credit Default Swap (CDS) premiums. While Turkiye holds a significant share in global textile exports, this performance exhibits substantial heterogeneity across product groups, necessitating a disaggregated, product-specific analysis rather than an aggregate sectoral approach.

A primary motivation of this paper lies in the structural divergence between cotton and synthetic yarn production. Cotton yarn is deeply tied to agricultural cycles and natural raw material supply, whereas synthetic yarn is inherently dependent on petroleum-based chemical inputs. This distinction suggests that the two sub-sectors may exhibit asymmetric and non-linear responses to macroeconomic shocks. To capture these complexities, this paper employs the QQKRLS and QQGC methods. Unlike traditional linear models that focus on average impacts, these advanced econometric techniques allow for a granular examination of how macroeconomic variables influence exports across different market conditions (quantiles). This is particularly crucial for understanding how extreme volatility in inflation or CDS premiums affects export performance differently during periods of high versus low export growth. Furthermore, the inclusion of CDS premiums serves as a vital proxy for financial risk and capital costs. Given that synthetic yarn production relies heavily on imported intermediates, it is expected to be more sensitive to country-risk fluctuations, while cotton yarn's sensitivity may manifest through credit access and overall production costs.

The choice of QQKRLS and QQGC is directly tied to the study's objective of capturing regime-dependent asymmetries. Unlike traditional linear models, these advanced non-linear approaches allow us to observe how variables interact at the extreme tails of the distribution-such as during periods of peak country risk-thereby providing the necessary empirical granularity to test for 'anti-fragile' versus 'stability-dependent' patterns in yarn exports

The contribution of this paper to the literature is threefold:

- ✓ **Product-Specific Depth:** It moves beyond aggregate data to reveal the unique dynamics of cotton and synthetic yarn.
- ✓ **Methodological Novelty:** By utilizing QQKRLS and QQGC, it addresses the limitations of linearity and provides a more robust framework for capturing tail-risk dependencies and causal links across various quantiles.
- ✓ **Strategic Insight:** It offers empirical evidence for firms and policymakers to develop state-dependent strategies that account for the non-linear nature of economic fluctuations.

Crucially, this disaggregated investigation bridges the gap between advanced econometric modeling and applied engineering economics. In modern manufacturing systems, yarn spinning and extrusion processes involve highly specialized asset specificity, meaning capital expenditures and production capacities cannot be easily reconfigured in the short term. Therefore, examining how macroeconomic volatility dynamically transmits into product-specific export channels provides essential empirical insights for industrial policy formulation and strategic operational scheduling within the textile supply chain.

The remainder of the paper is organized as follows: a review of the relevant literature, a detailed explanation of the dataset and the advanced quantile-based methodology, the presentation of empirical findings, and finally, a discussion of the results and policy implications.

Despite the extensive literature on the macroeconomic determinants of international trade, a significant knowledge gap persists regarding how sovereign credit risks directly influence sectoral export dynamics. While traditional studies heavily focus on exchange rates and price stability, no empirical research has yet consolidated the role of Credit Default Swap (CDS) premiums within textile or yarn export models. This oversight is critical because country-risk perceptions directly dictate external financing costs and foreign trade liquidity. Consequently, rather than scattering this conceptual novelty across subsequent sections, this study consolidates this vital knowledge gap directly at the outset by investigating how CDS premiums act as a regime-dependent catalyst or constraint for asymmetric product-specific exports. To rigorously address this consolidated gap, this study seeks to answer the following formal research questions.

Based on the identified gaps in the literature and the structural differences between the two sub-sectors, this study seeks to answer the following formal research questions:

* RQ1: How do macroeconomic drivers, specifically the real effective exchange rate, inflation, and industrial production, asymmetrically influence Turkiye's synthetic and cotton yarn exports across different market conditions?

* RQ2: To what extent do country-specific financial risk perceptions, proxied by CDS premiums, exert a regime-dependent causal impact on yarn export performance?

Theoretical Framework

The theoretical foundation of this study is grounded in international trade theory and the concept of economic resilience under volatility. The relationships between macroeconomic variables and yarn exports are examined through four primary theoretical lenses:

a) The Price Competitiveness and Exchange Rate Channel: The impact of the REER is rooted in the Marshall-Lerner Condition (Lerner, 1944), which suggests that currency depreciation enhances export volumes by lowering the relative price of domestic goods in foreign markets. For SYN, which relies heavily on imported petroleum-based inputs, the exchange rate acts as a double-edged sword: while depreciation boosts price competitiveness, it simultaneously increases production costs. For CTN, the domestic nature of raw materials allows for a more direct

gain from exchange rate-based competitiveness, provided that volatility remains within manageable thresholds.

b) The Supply-Side and Domestic Absorption Theory: The IPI reflects the country's productive capacity. According to the Capacity Pressure Hypothesis (Goldstein & Khan, 1985), increases in IPI should support export growth through economies of scale and surplus production. However, the theory of Domestic Absorption (Alexander, 1952) suggests that during periods of high domestic economic activity, intermediate goods (like synthetic yarn) are prioritized for the domestic industrial chain rather than being exported, leading to a negative relationship between IPI and exports for certain sub-sectors.

c) Financial Risk and the Concept of Anti-fragility: A core theoretical contribution of this study is the application of Nassim Taleb's (2012) Anti-fragility theory to trade dynamics. Unlike "resilience" (which merely resists shocks) or "robustness" (which remains neutral), Anti-fragility describes systems that actually gain or thrive from disorder, volatility, and stress.

- ✓ Anti-fragile Resilience (SYN): Synthetic yarn exports exhibit anti-fragile characteristics because they leverage domestic market collapses and currency shocks (represented by high CDS and Inflation) to pivot aggressively toward external markets, turning systemic stress into an export opportunity.
- ✓ Stability-Dependent (CTN): Conversely, cotton yarn follows a more traditional economic path where predictability and low financial risk (low CDS) are prerequisites for performance, as high-risk premiums lead to financing constraints that suppress growth.

d) The Cost-Push and Uncertainty Framework: INF is integrated through the Cost-Push Theory (Bronfenbrenner & Holzman, 1963). High inflation levels create uncertainty in input pricing and supply chains, potentially weakening firms' long-term export capacity. The quantile-based approach allows us to test if this relationship shifts from "uncertainty-driven export propensity" at moderate levels to "cost-driven withdrawal" at extreme levels.

Following the theoretical considerations and research motivations, the following testable hypotheses are formulated for empirical investigation:

* H1: The REER has a significant negative impact on synthetic yarn exports through the price competitiveness channel, whereas its impact on cotton yarn exports exhibits a threshold-dependent non-linear structure.

* H2: INF exerts a non-linear and quantile-dependent impact on synthetic and cotton yarn exports, where the effect transitions from an uncertainty-driven export propensity at moderate levels to a cost-push constraint at extreme inflationary quantiles.

* H3: An increase in the IPI positively influences cotton yarn exports due to capacity expansion, while it negatively affects synthetic yarn exports due to the "domestic absorption" of intermediate inputs.

* H4: High CDS premiums suppress cotton yarn exports by increasing financial uncertainty, but trigger "anti-fragile" resilience in synthetic yarn exports as firms shift toward external markets during domestic stress.

* H5: The causal relationships between macroeconomic variables and yarn exports are regime-dependent and vary significantly across the different quantiles of the export distribution.

Conceptual Framework

The conceptual model of this study links macroeconomic volatility and sovereign risk to sectoral export performance through a non-linear lens. As illustrated in Figure 1, the model posits that financial risks (CDS) and economic indicators (REER, IPI, INF) do not affect yarn exports uniformly. Instead, these relationships are moderated by the anti-fragility of the sectors, where the impact varies across different quantiles of both independent and dependent variables.

The arrows on the right side of the conceptual framework illustrate the hypothesized directions of the relationships between macroeconomic determinants and sectoral export performance. Specifically, green arrows signify positive impacts, while red arrows denote negative influences. Gray arrows represent indeterminate or mixed associations, highlighting that the relationship is non-linear and varies significantly across different quantiles and time horizons.

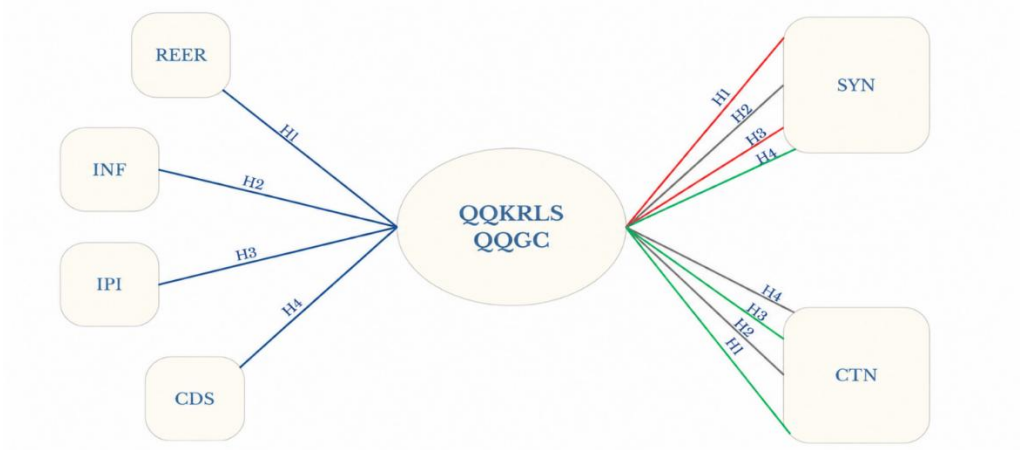

Figure 1. Conceptual Framework

Literature Review

Textile exports have been examined as a significant dependent variable in the economics and international trade literature, and their relationship with various macroeconomic and policy variables has been extensively investigated. Chan and Au (2007), in one of the earliest empirical articles focusing on textile products, laid an important foundation for the field by identifying the key factors affecting export performance. Their article particularly emphasized that variables such as exchange rates and import opportunities play a decisive role in determining export outcomes.

Puspitasari and Fachrudin (2020), as a result of their empirical analysis conducted in the Indonesian textile sector, revealed that fluctuations in the exchange rate and inflation rates have a negative impact on exports; in particular, they demonstrated that short-term exchange rate volatility adversely affects export performance. This finding indicates that exchange rate stability plays a critical role in export strategies. In contrast, Basak et al. (2025) found in their articles that increases in the exchange rate and inflation positively affect exports in the Bangladesh textile sector. This result, contrary to previous articles, suggests that the impacts of macroeconomic variables may vary depending on the country, sector, and time period.

The findings of other articles in the literature regarding the impacts of macroeconomic variables on textile product exports are comparatively presented in Table 1. This table systematically illustrates the role of key variables-such as exchange rates, inflation, and external demand-on export performance by bringing together the results of articles conducted across different countries and time periods.

Table 1

Literature Review

Author	Data Set	Method [+]	Variables [#]	Findings[^]
Chan & Au **(2007)**	1985-2004 (annual)	GM	PCCGDP, GDP, REER, D, GRW, FTA	PCCGDP (+)EXP, GDP (+)EXP, FTA(+)EXP, REER(-)EXP, GRW(-)EXP, D()EXP
Hatırlı & Onder **(2010)**	1998-2008 (monthly)	ADF, GARCH; VECM	REER, VOL, IPI,	REER(-)EXP, IPI(+)EXP, VOL (-) EXP
Hatırlı et al. **(2012)**	1998-2011 (montly)	ADF, VECM	RER	RER→EXP
Chaudhry & Bukhari **(2013)**	1980-2011 (annual)	SVAR	REER, FGDP	REER(-)UFEXP, REER(+)FEXP, GDP(+)UFEXP, FGDP(-)FEXP
Ozer **(2014)**	2007-2012 (annual)	GM	RER, GRW, CD	RER(+)EXP, GRW(+)EXP, CD(+)EXP
Puspitasari & Fachrudin **(2020)**	2016-2018 (annual)	PDR	ER, INF,	ER(-)EXP, INF(-)EXP
Yanar & Marangoz **(2022)**	2004-2020 (annual)	Panel GMM	REER, FGDP	REER(-)EXP, FGDP(+)EXP
Basak et. al. **(2025)**	1994-2022 (annuals)	ARDL	EV, ER, INF,	EV(-)EXP, ER(+)EXP, INF=EXP

Notes: [+] GM: Gravity model, ADF: Augmented Dickey-Fuller Unit Root Test, GARCH: Generalized Autoregressive Conditional Heteroskedasticity Voladite Modeli, VECM: Vector Error Correction Model, SVAR: Structural Vector Autoregression PDR: Panel Data Regression, Panel GMM: Panel Generalized Method of Moments, Autoregressive Distributed Lag, ARDL: Autoregressive Distributed Lag Bound Test

[#] PCCGDP: Gross Domestic Product per capita, GDP: Gross Domestic Product, REER: Real Effective Exchange Rate, FGDP: Foreign Gross Domestic Product, GRW: Population Growth, FTA: Free Trade Agreement, VOL: Real Effective Exchange Rate Volatility, IPI: Industrial Production Index, RER: Real Exchange Rate, CD: Customs duty, D: Distance, ER: Exchange rate, INF: Inflation Rate, EV: Exchange Rate Volatility, EXP: Textile Export, UFEXP: Unfinished Product Export, FEXP: Finished Product Export

[^]A= B: Long-term cointegration exists between the two variables, A(+)B: Variable A has a positive impact on variable B, A(-)B: Variable A has a negative impact on variable B. A()B: Variable A has no significant impact on variable B, A→B: There is a one-way causality between the variables.

An examination of Table 1 indicates that in the vast majority of papers in the literature, exchange rate and real exchange rate variables are treated as the primary determinants. This finding suggests that textile and apparel exports are highly sensitive to fluctuations in exchange rates. The exchange rate variable has generally been considered a factor that directly affects export revenues and price competitiveness. In particular, the papers conducted by Chan and Au (2007) and Ozer (2014) reveal that changes in exchange rates influence countries' textile export performance in both the short and long run.

In addition, macroeconomic indicators such as the inflation rate and gross domestic product (GDP) have been incorporated into certain papers as control variables (Chan & Au, 2007; Ozer, 2014; Puspitasari & Fachrudin, 2020; Basak et al., 2025). Through these variables, attempts have been made to measure the impact of countries' internal economic stability on export performance. The findings suggest that inflation exerts an indirect impact on exports mainly through cost structures and price competitiveness, while GDP functions as a supportive factor for exports by reflecting overall economic growth and production capacity.

Overall, while the majority of articles in the literature focus on exchange rates and macroeconomic stability variables, sectoral production indicators and firm-level dynamics have been examined relatively less. In order to address this gap, this article separately analyzes SYN and CTNs-two subcomponents of the textile sector—together with the selected macroeconomic variables. In doing so, the direction and magnitude of macroeconomic impacts at the product level will be identified, and a new product-based perspective will be introduced into the literature on textile exports. Finally, no empirical article has been found that directly examines the impact of credit default swap (CDS)

premiums on the textile sector or yarn exports. This absence strengthens the originality of the present article and supports the need to examine, for the first time, the potential impacts of the CDS variable on sectoral exports at the product level.

In contrast to aggregate textile research, recent high-impact scholarship has increasingly shifted its focus toward the specific dynamics and price transmission mechanisms of the cotton yarn sector. For instance, Muhammad et al. (2021) explored the significant disruptions in cotton import demand caused by the COVID-19 pandemic, emphasizing the vulnerability of the global supply chain. Ridley & Devadoss (2023) provided a rigorous analysis on how international trade policies and competition specifically shape the global cotton and yarn markets. Most recently, Gui et al. (2025) synthesized these perspectives by examining vertical linkages within the yarn supply chain. Their findings demonstrate that while external shocks like trade wars and pandemics weaken overall price co-movements, they simultaneously foster the independence and pricing influence of the cotton yarn sector during crisis phases.

Methodologically, in the economic and trade literature, the use of Quantile-on-Quantile (QQ) based methods has gained central importance for capturing the non-linear and quantile-dependent relationships between macroeconomic variables. For instance, Ozkan et al. (2025b) investigated the effects of macroeconomic uncertainties (VIX, EPU, and GPR) on green growth using QQ correlation techniques, revealing that these effects exhibit significant heterogeneity across different quantiles and time horizons. Addressing the impact of trade and monetary policies on sustainability, Adebayo & Olanrewaju (2024) incorporated Wavelet Quantile-on-Quantile Regression (WQQR) and Wavelet Quantile-on-Quantile Granger Causality (WQQGC) approaches into the literature, demonstrating that the predictive power of independent variables varies across different time-scales and quantiles. Furthermore, Dogan & Zeren (2025) analyzed the relationship between geopolitical risks and sustainability uncertainty in G7 economies through Wavelet Kernel-Based Regularized Least Squares (WKRLS) and Quantile-on-Quantile Connectedness (QQCON) methods, emphasizing that this relationship is non-stationary and shaped by market conditions. In this framework, the inclusion of CDS premiums as a primary proxy for sovereign risk is justified by their ability to capture the financial dimensions of macroeconomic turbulence, which exerts asymmetric and regime-dependent pressures on sectoral performance. Finally, the present study extends the literature by transferring these advanced techniques (WKRLS, QQKRLS, and QQGC) to the field of trade economics, testing the impact of CDS premiums on textile sub-sectors (cotton and synthetic yarn) *within an 'anti-fragility' framework and across the entire distribution.*

Data

All variables used in the study and forming the basis of the main model, along with their definitions and data sources, are listed in Table 2.

Table 2

Data Definitions

Data	Abbreviation	Unit	Variable	Sources
Real Effective Exchange Rate	REER	Index (2003=100)	Independent	TCMB[+]
Inflation Rate	INF	Percentage (%)	Independent	TURKSTAT
Industrial Production Index	IPI	Index	Independent	TURKSTAT[*]
Credit Default Swap	CDS	Basis Points (bps)	Independent	Investing.com
Synthetic Yarn Exports	SYN	US Dollar	Dependent	TradeMap[#]
Cotton Yarn Exports	CTN	US Dollar	Dependent	TradeMap

*Turkish Statistical Institute, +Central Bank of the Republic of Turkiye, # International Trade Center Marketing International Business Development Trade Statistics

The data period extends from January 2015 to August 2025 to capture the most recent post-pandemic and high-inflation recovery trends, providing a comprehensive coverage of varying economic regimes in Turkiye. All data points were retrieved at a monthly frequency after being officially finalized by TURKSTAT and the ITC TradeMap, ensuring that the analysis is based on actual realized trade volumes rather than projections.

To ensure empirical robustness and data validation, all monthly series were checked for missing values and seasonal anomalies. Independent macroeconomic indicators (REER, INF, IPI, and CDS) were synchronous with the dependent trade volumes (SYN and CTN) without requiring statistical interpolation. Prior to estimation, all variables were transformed into their natural logarithmic forms to reduce heteroskedasticity and stabilize variance across different economic regimes.

Figure 2 presents time series plots of the dependent and independent variables used in the study, These graphs illustrate the volatility and trends of the time series.

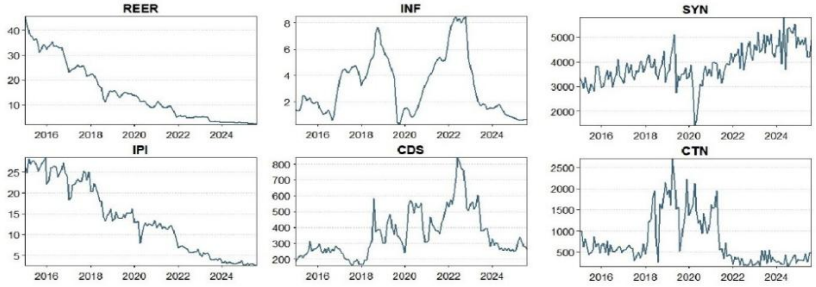

Figure 2. Time Series Plots

When the time series graphs presented in Figure 2 are examined, it is observed that the general trend of the IPI and REER variables has been downward since 2015. CDS appears as a variable with high volatility. INF exhibits cyclical fluctuations, reaching notable peaks in 2019 and 2022, followed by sharp declines in 2020 and 2023. SYN displayed an upward trend until 2020, experienced a sharp decline in that year, and then rapidly recovered, reaching record levels with strong increases. CTN, on the other hand, lost the sharp increase it experienced starting in 2018 due to a sudden decline toward the end of 2021, and no subsequent increase of similar magnitude has been observed.

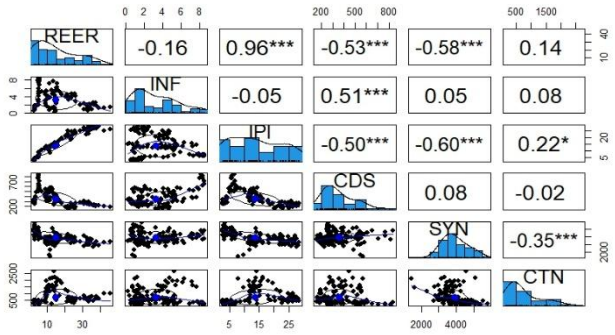

Figure 3. Correlation Matrix

Figure 3 illustrates the correlations among the variables. A very high correlation is observed between the independent variables IPI and REER (r = 0.96, p < 0.01). Credit CDS exhibits a significant and strong relationship with the other independent variables, namely IPI, INF, and REER. There is a negative and statistically significant correlation between SYN and both IPI and REER. Additionally, a negative and significant relationship is observed between CTN and SYN. The economic rationale for this inverse correlation, rooted in the contrasting regime-dependent behaviors of the two sub-sectors, is analyzed in detail in the Discussion section.

Methodology

BDS Linearity Test

The BDS Nonlinearity test was introduced by Brock et al. (1996). The BDS test is a nonlinearity test that examines the dependence among past values in time series data (Akgul & Ozdemir, 2018). The test is calculated based on the correlation integral and examines whether the time series is independently and identically distributed (Sezgin Alp & Kırkbesoglu, 2015). The BDS nonlinearity test statistic is calculated using the following Equation (1).

$$BDS_{\varepsilon,m} = \frac{\sqrt{N\left[C_{\varepsilon,m}-(C_{\varepsilon,1})^{m}\right]}}{\sqrt{V_{\varepsilon,m}}} \sim N(0,1) \quad (1)$$

The test is two-sided, and if the test statistic falls outside the critical values of ±1.96 at the 5 % significance level, the null hypothesis H_0 is rejected. Rejection of the null hypothesis indicates that the series contains nonlinear serial dependence (Akgul & Ozdemir, 2018).

QADF Unit Root Test

The first quantile-based unit root test in the literature was developed by Koenker and Xiao (2004), who emphasized that traditional unit root tests may have weak explanatory power for time series with heavy-tailed distributions. This approach allows testing not only stationarity in the conditional mean but also stationarity at different selected quantiles (Pata & Yılancı, 2021). The QADF unit root test statistic is calculated as shown in Equation (2) below.

$$QADF(\tau) = \frac{\hat{\rho}(\tau)-1}{\widehat{SE}(\rho(\tau))} \quad (2)$$

QQKRLS

In this paper, the QQKRLS method developed by Adebayo et al. (2024) is employed. This method enables the examination of the tail impacts of the quantiles of an independent variable on the quantiles of a dependent variable (Ozkan *et al.* 2025a). The impact of the independent variable on the dependent variable is computed using the following equation (3) of the QQKRLS methodology:

$$E_N\left[\frac{\beta QY_\tau}{\beta QY_{\theta k}}\right] = \frac{-2}{\sigma^2 N}\sum_k \sum_i j_i e^{\frac{\|x_{\theta i}-x_{\theta k}\|^2}{\sigma^2}} (X_{\theta i} - X_{\theta k}) \quad (3)$$

In the equation above, the expression $E_N\left[\frac{\beta QY_\tau}{\beta QY_{\theta k}}\right]$ represents the average pointwise marginal impact of the θ-th conditional quantile of the independent variable X on the τ-th conditional quantile of the dependent variable Y. In addition, QY_τ and QY_θ denote the τ-th conditional quantile series of the dependent variable Y and the θ-th conditional quantile series of the independent variable X, respectively (Adebayo *et al.*, 2024).

The KRLS method has some fundamental limitations in the analysis process. In this approach, the primary focus is generally placed solely on the distribution of the dependent variable, while the distributional properties of the explanatory (independent) variables are largely neglected (Emir et al., 2026). Moreover, KRLS evaluates nonlinear impacts only at the level of individual observations, within a relatively restricted framework. The QQKRLS method was developed to overcome these limitations (Somoye & Ayobamiji, 2026). The QQKRLS approach enables the capture of nonlinear and heterogeneous relationships that emerge across different quantile levels, thereby allowing for a more in-depth examination of the underlying relationships (Zeng *et al.*, 2025).

QQGC

In this article, following the QQKRLS test, the QQGC test developed by Adebayo & Ozkan (2024) was applied to the variables. While conventional causality tests developed in the literature examine median relationships under average conditions in a unidirectional manner, this quantile-based test also provides information on the direction of shocks and the evolution of relationships over time (Chishti, Dogan, & Binsaeed, 2024). In particular, this test enables the examination of causality relationships running from the

quantiles of the independent variable to the quantiles of the dependent variable, thereby allowing for a more detailed causality analysis compared to the GC and QGC methods (Adebayo & Ozkan, 2024). The formulation of the method is presented in Equation (4) below.

$$QY_{\tau,t} = \gamma_{\tau,\theta,0} + \sum_{i=1}^{p} \gamma_i QY_{\tau,t-i} + \sum_{i=1}^{p} \beta_i QX_{\theta,t-i} + \varepsilon_{\tau,\theta,t} \qquad (4)$$

In this model, $\gamma_{\tau,\theta,0}$ epresents the constant term specific to the quantiles τ and θ. The coefficients γ_i measure the impact of the lagged values of variable Y at the τ quantile on $QY_{\tau,t}$ Meanwhile, the coefficients $\beta_i$indicate the impact of the lagged values of variable X at the θ quantile on $QY_{\tau,t}$ Accordingly, $\varepsilon_{\tau,\theta,t}$ denotes the error term that captures the interaction between the τ and θ quantiles at time t (Zeng *et al.*, 2025). This method has certain limitations, such as sensitivity to model specification, which may lead to biased findings depending on the selection of quantiles (Li *et al.*, 2025; Bediroglu & Zeren, 2026).

In the estimation process, a Gaussian kernel was employed to ensure a smooth transition between quantiles, and the bandwidth was determined using Silverman's Rule of Thumb (set at 0.05) to minimize estimation bias. Furthermore, since the QQKRLS and QQGC models are estimated in a pairwise (one-on-one) fashion, the high correlation between certain independent variables does not induce multicollinearity issues in the resulting coefficients.

The empirical analysis procedure followed in this article is presented in Figure 4. First, the datasets were defined, and then the linearity and stationarity of the time series were examined using the BDS nonlinearity test and the QADF unit root test. Subsequently, the QQKRLS test was employed to identify the relationships between the independent and dependent variables. Finally, the robustness of the findings was verified using the QQGC test.

From an engineering economics perspective, the mathematical rigors of the QQKRLS and QQGC frameworks are not treated merely as methodological novelties. Instead, they serve as non-linear decision-making algorithms that map tail-risk dependencies. By computing marginal impacts across the entire distribution, these techniques function as analytical toolkits for industrial managers to perform robust scenario analyses and optimize resource allocation under varying regimes of macroeconomic stress.

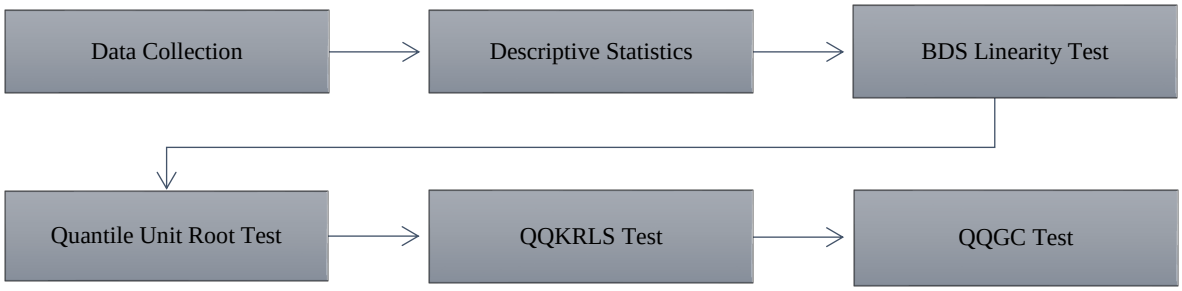

Figure 4. Methodological Pathway

Empirical Findings

In this article, the impacts of the REER, inflation rate, industrial production index, and CDS on SYN and CTN are examined.

BDS Linearity Test

In the first stage of the article, the linearity of the series to be used for the variables was tested. To investigate the nonlinear dynamics within the series, the BDS linearity test was employed. Table 3 presents the results of the linearity tests for the dependent and independent variables. The BDS nonlinearity test results presented in Table 3 reveal that all six variable series used in the studies are non-linear at the 99 % confidence level ($p < 0.01$).

Table 3

BDS Non-linearity Test Outputs

Dimensions	REER	INF	IPI	CDS	SYN	CTN
2	0.197511* (0.0000)	0.171236* (0.0000)	0.179764* (0.0000)	0.144787* (0.0000)	0.068110* (0.0000)	0.126792* (0.0000)
3	0.337189* (0.0000)	0.280535* (0.0000)	0.302889* (0.0000)	0.236363* (0.0000)	0.136866* (0.0000)	0.211641* (0.0000)
4	0.435544* (0.0000)	0.347063* (0.0000)	0.389769* (0.0000)	0.288818* (0.0000)	0.182960* (0.0000)	0.272560* (0.0000)
5	0.503943* (0.0000)	0.383735* (0.0000)	0.448118* (0.0000)	0.314916* (0.0000)	0.203101* (0.0000)	0.318967* (0.0000)
6	0.551535* (0.0000)	0.399883* (0.0000)	0.488974* (0.0000)	0.323576* (0.0000)	0.215982* (0.0000)	0.346437* (0.0000)

Note: * denotes statistical significance at the 99 % confidence level.

QADF Unit Root Test

The stationarity of the dependent and independent variables examined in the article was tested using the QADF unit root test developed by Koenker and Xiao (2004). Figure 5 presents the stationarity graphs of the variables.

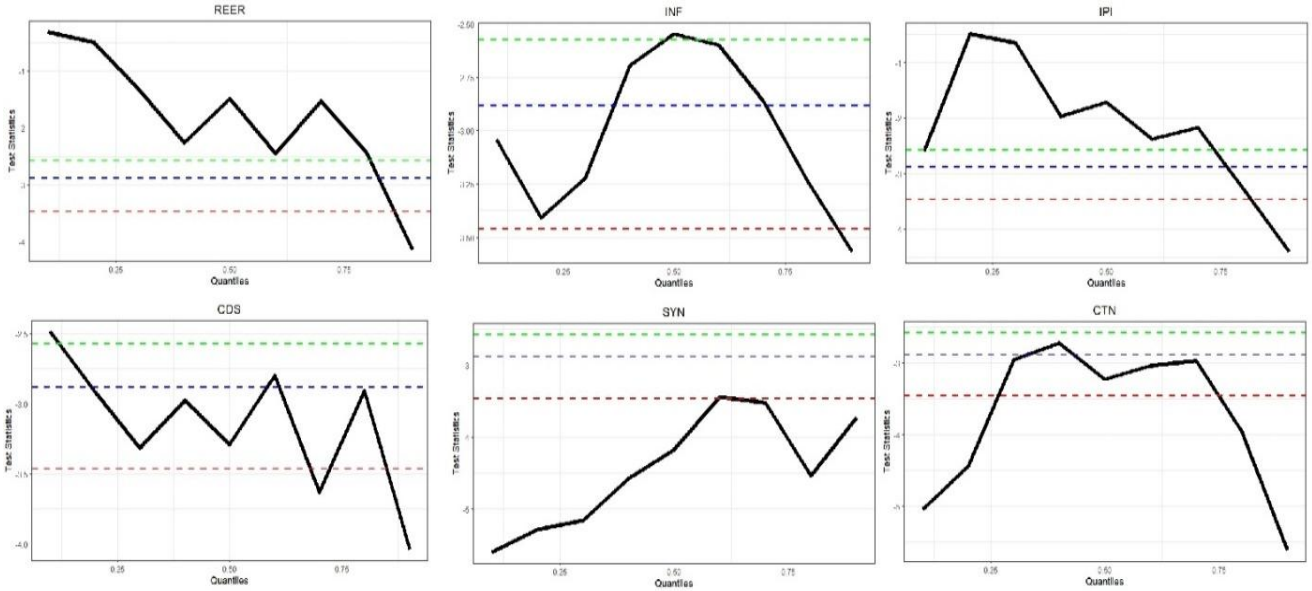

Figure 5. Quantile ADF Unit Root Test Results (Level)

Note: In the figure, the red, blue, and green lines indicate the 99 %, 95 %, and 90 % confidence levels, respectively, providing a visual reference for statistical significance.

Due to the non-stationary nature of the series, first differences were taken and the QADF unit root test was re-applied. It was observed that the series became stationary after taking their first differences. The stationarity graphs of the first-differenced series of the independent variables REER, INF, IPI, and CDS, as well as the dependent variables SYN and CTN, are presented in Figure 6.

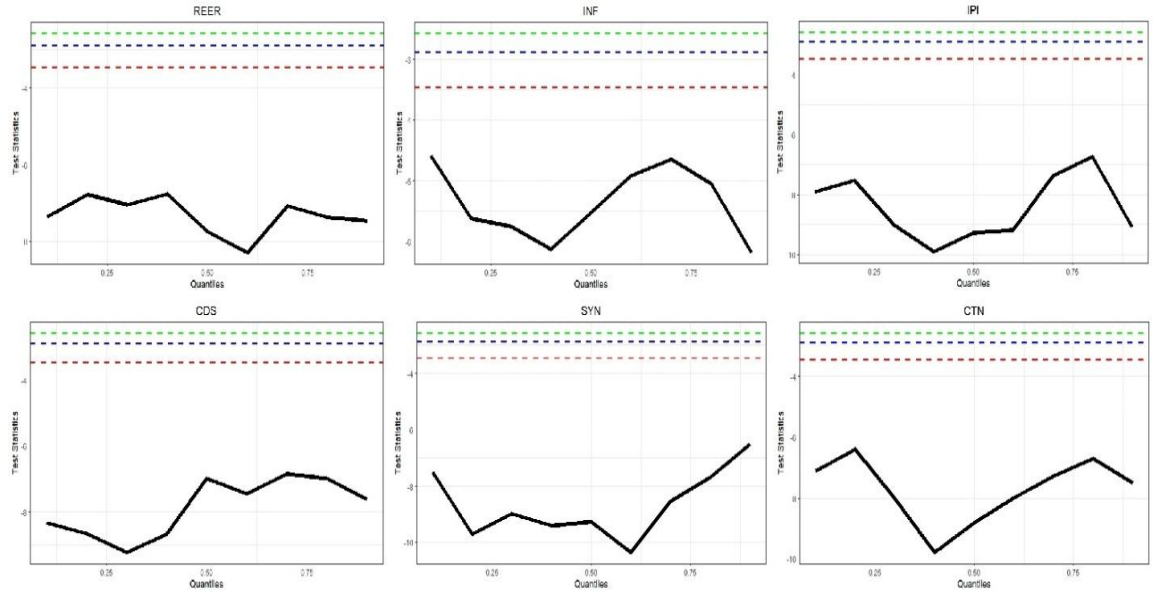

Figure 6. Quantile ADF Unit Root Test Results (first difference)

Note: In the figure, the red, blue, and green lines indicate the 99 %, 95 %, and 90 % confidence levels, respectively, providing a visual reference for statistical significance.

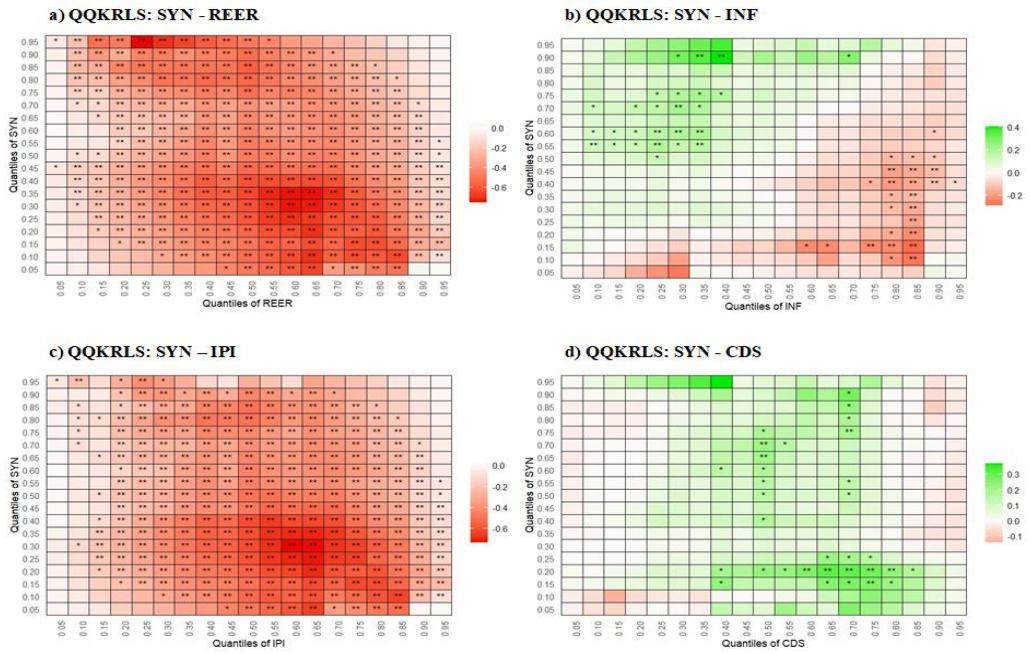

Figure 7. Results of the QQKRLS Test Between Macroeconomic Variables and SYN

Note: The color bars denote the average pointwise marginal effect coefficients. The red and green colors denote negative and positive coefficients. **p < 5 % and *p < 10 %

QQKRLS

In order to examine how the relationships between the variables change across different conditional distributions of both the dependent and independent variables, the QQKRLS method was applied.

Figure 7 presents the QQKRLS test results examining the impacts of macroeconomic variables on Turkiye's SYN. A negative and very strong relationship is observed between the REER and SYN. Accordingly, a decrease in the REER is expected to lead to an increase in SYN. When the REER declines, Turkish yarn producers can offer their products to foreign buyers at more competitive prices while their costs remain relatively stable. This situation enhances price competitiveness and may increase export demand. In addition, a negative but relatively less significant relationship is observed between the lower quantiles of the REER (0.05–0.10) and the upper quantiles of SYN (0.90–0.95). At this point, high sectoral performance is observed alongside a decline in the REER. However, this decline may no longer generate a marginal export advantage, as the sector may have reached a saturation point in terms of competitive advantage.

Panel (b) presents the QQKRLS test results for the relationship between INF and SYN. A positive and statistically significant relationship is observed between the quantiles of INF in the range of 0.25–0.40 and the quantiles of SYN between 0.55–0.90. Another notable finding is that when the quantiles of INF fall within the range of 0.60–0.90, a negative and statistically significant relationship emerges with the SYN quantiles between 0.10–0.45. These results indicate that the impact of the inflation rate on SYN is markedly asymmetric across quantiles. During periods when inflation is relatively low but rising, the uncertainty emerging in the domestic market may have encouraged synthetic yarn producers to shift toward export markets. However, in periods of very high inflation, increased input costs, disruptions in the supply chain, and heightened financial uncertainty may adversely affect this sector-characterized by a high dependence on imported inputs-potentially leading firms to withdraw from export markets.

Panel (c) presents the QQKRLS findings regarding the relationship between IPI and SYN. The results indicate that IPI and SYN exhibit a negative and statistically significant relationship across most quantiles. This relationship is particularly concentrated at the quantiles where SYN ranges between 0.25–0.35 and IPI ranges between 0.55–0.70. In other words, as industrial production increases, SYNs decline. This outcome can be explained by the fact that increases in industrial production may cause synthetic yarn, as an input material, to remain within the domestic market, thereby leading to a decrease in exports. With a contraction in the domestic market, synthetic yarn may again be redirected toward export markets. In addition, the weakened but still negative relationship observed at the upper-right tail quantiles indicates that despite further increases in industrial production, the marginal impact on exports diminishes.

Panel (d) presents the QQKRLS test results examining the relationship between CDS and SYN. A positive and statistically significant relationship is observed between CDS quantiles in the range of 0.55–0.75 and SYN quantiles in the range of 0.15–0.20. This matching indicates that as Turkiye's credit risk premium increases, SYN also increase. This finding can be explained by the fact that an increase in CDS supports exports through the exchange rate channel until it reaches a crisis level.

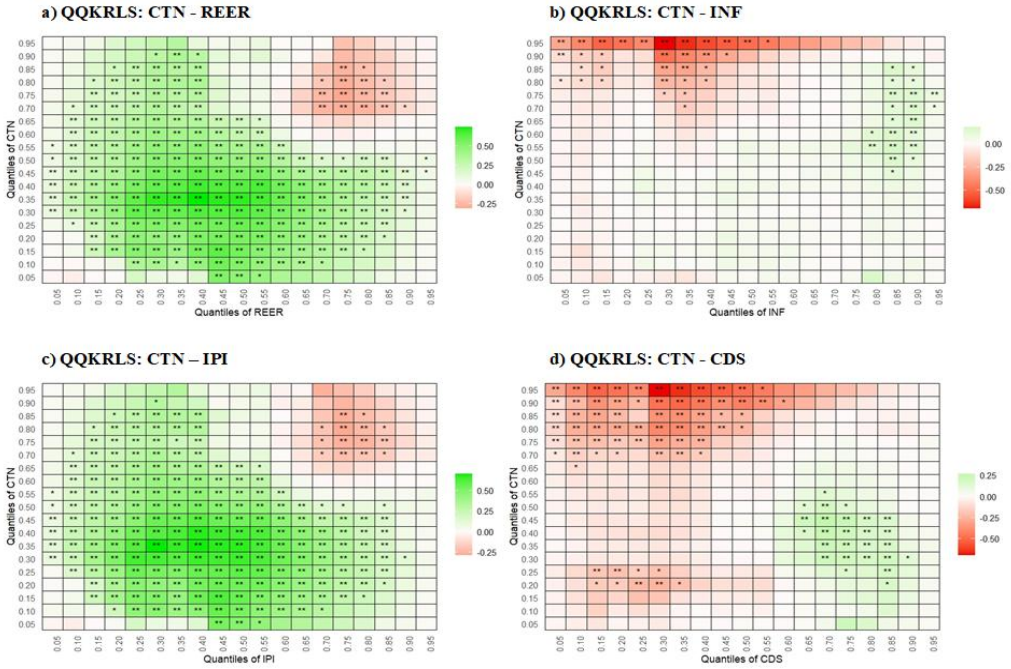

Figure 8. Results of the QQKRLS Test between Macroeconomic Variables and CTN

Note: The color bars denote the average pointwise marginal effect coefficients. The red and green colors denote negative and positive coefficients. **p < 5% and *p < 10%

Figure 8 presents the QQKRLS test results examining the impacts of macroeconomic variables on Turkiye's CTN. First, panel (a) shows that there is generally a positive and significant relationship between REER and CTN. This relationship is particularly concentrated between the medium quantiles of REER (0.25–0.50) and the medium quantiles of CTN (0.25–0.60). However, during periods when REER reaches very high levels, the relationship with CTN is observed to turn negative. At this point, it can be stated that cotton yarn production, due to its higher share of domestic inputs compared to synthetic yarn, benefits more from exchange rate–based competitiveness; nevertheless, beyond a certain threshold, increases in the exchange rate begin to suppress exports through cost and uncertainty channels.

Panel (b) presents the QQKRLS test results for the relationship between INF and CTN. A strong and negative relationship is observed particularly when INF lies between the 0.20–0.45 quantiles and CTN is in the upper quantiles of 0.85–0.95. However, when INF is within the 0.85–0.90 quantile range, a relatively positive and statistically significant relationship emerges. The overall pattern of the graph can be explained by the uncertainty in input costs during periods when inflation begins to rise, which negatively affects CTNs. In contrast, under high-inflation conditions, costs tend to stabilize at certain levels, allowing CTNs to adjust to the new cost structure and recover accordingly.

Panel (c) presents the results of the QQKRLS test measuring the relationship between IPI and CTN. A strong, statistically significant, and positive relationship is observed between IPI and CTN. This relationship is particularly concentrated in the range where IPI quantiles lie between 0.20 and 0.55 and CTN quantiles fall between 0.10 and 0.50. This observed pattern may be explained by the fact that increases in production capacity, supply chain quality, and efficiency positively affect exports. However, an important finding is that the relationship turns negative in regions where industrial production increases further. The primary reason for this shift can be explained by the redirection of cotton yarn stocks toward domestic market producers.

Panel (d) presents the results of the QQKRLS test examining the relationship between CDS and CTN. A negative and statistically significant relationship is observed when CDS quantiles range between 0.05 and 0.55 and CTN quantiles fall within the 0.70–0.95 interval. This finding indicates that CTNs tend to increase during periods of low credit risk. Conversely, when CDS quantiles exceed 0.60 and CTN lies within the mid-quantile range of 0.30–0.55, the relationship turns positive. In this context, cotton yarn, whose raw material input is largely domestic, benefits from a cost advantage. Moreover, heightened country risk and uncertainty in the domestic market may prompt cotton yarn producers to redirect their output toward export markets.

Both sectors responded to the independent variables in distinctly different ways. SYN exhibit a pattern in which performance is driven by periods of crisis, achieving record export levels amid collapses in domestic demand and depreciation of the Turkish Lira. This sector has demonstrated an ability to survive by shifting its market orientation during times of economic turmoil. In contrast, CTNs tend to sustain their performance primarily under conditions of stability. Rather than responding positively to environments characterized by uncertainty in macroeconomic variables, CTNs are able to perform in contexts where economic conditions are clear and predictable, even if such conditions involve relatively high levels of macroeconomic indicators.

QQGC

In order to validate the QQKRLS test used in the paper, the QQGC test was applied to the variables to examine the causal relationships among them. Figure 9 below presents the graphs illustrating the causal relationships between SYN and macroeconomic variables.

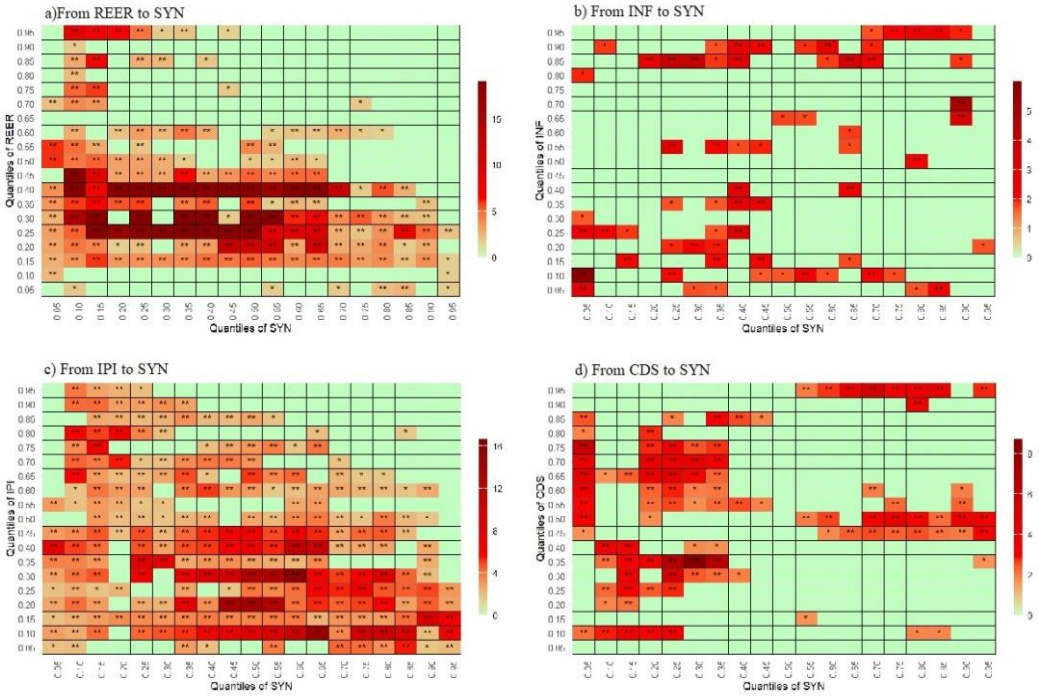

Figure 9. QQGC Test Results between Macroeconomic Variables and SYN

Note: The plot shows the estimated test statistics for each pairwise quantile variable. **p < 5% and *p < 10%. The color ranges from dark-green to red, which signifies the test statistics.

Figure 9 presents the QQGC test results indicating causality running from the explanatory variables toward the dependent variable SYN. In panel (a), which illustrates causality from REER to SYN, substantial variations across quantiles are observed. There exists a statistically strong and significant causality from the low and middle quantiles of REER (0.10–0.55) toward the 0.20–0.45 quantiles of SYN. This finding suggests that the interaction between exports and the exchange rate intensifies under normal and increasingly stressed market conditions. Additionally, a statistically significant causality is detected from the upper quantiles of REER toward the lower quantiles of SYN. This result may indicate that during periods when the Turkish Lira is relatively overvalued in real terms, SYN experience a loss of competitiveness and become compressed in the lower quantiles, demonstrating that SYN performance is highly sensitive to the exchange rate regime. In contrast, no significant causality is identified in regimes where both REER and SYN are located in higher quantiles. This finding suggests that during periods characterized by a strong real exchange rate and high export levels, SYNs are determined less by exchange rate movements and more by global demand conditions, economies of scale, and firm-specific structural factors. While the QQKRLS results reveal the direction and magnitude of the impact of changes in the REER on SYN, the QQGC findings demonstrate that this relationship operates causally, particularly under competitive exchange rate regimes. The strong causality detected in the lower and middle quantiles is consistent with the competitiveness channel underlying the negative relationship identified in the QQKRLS results.

The QQGC findings between INF and SYN shown in panel (b) indicate that the causal relationship running from INF to SYN varies significantly across quantiles. It is observed that the upper quantiles of INF exert a statistically significant impact on the lower quantiles of SYN. This finding can be explained by the rapid increase in input costs, which makes price-setting more difficult and consequently weakens competitiveness. Another important result illustrated in the figure is the significant causality running from the upper quantiles of INF (0.85–0.95) to the upper quantiles of SYN (0.75–0.90). This implies that inflation rates continue to play a significant role in export performance even during periods of high SYNs. While the QQKRLS analysis reveals that the impact of INF on SYN exhibits an asymmetric structure across quantiles, the QQGC results demonstrate that this structure is also valid in a causal sense. Export-oriented behavior under moderate inflation regimes and the weakening of exports due to cost pressures under high inflation regimes are supported by the quantile-sensitive causality patterns identified through the QQGC analysis.

Panel (c) illustrates the causality running from IPI to SYN. It is observed that the causal relationship from IPI to SYN is statistically significant across a wide range of quantiles. In particular, changes in industrial production within the low and medium quantiles of IPI (0.10–0.45) exert a strong impact on the low and medium quantiles of

SYN (0.25–0.70). This finding can be explained by the increase in intermediate goods supply resulting from higher industrial production capacity, which in turn leads to an expansion in SYNs. However, when examining the upper quantiles of both variables, the causality weakens and eventually disappears. This outcome may be interpreted as an indication that industrial production capacity has reached an upper saturation level, beyond which further increases no longer influence export performance. The strong causality observed under low and medium production regimes supports the QQKRLS-based interpretation that increases in industrial production may suppress exports by directing intermediate goods supply toward the domestic market.

In panel (d), the causality running from CDS to SYN is observed to exhibit a pronounced asymmetric structure. First, statistically significant causality is detected from the 0.25–0.85 quantiles of CDS to the 0.05–0.40 quantiles of SYN. This finding may be interpreted as changes in Turkiye's credit risk premium being able to significantly influence export performance during periods when SYNs are weak. When the credit risk premium is low, exporters face fewer financing constraints, which may increase their risk-taking capacity and, consequently, their export propensity. However, as the credit risk premium rises, the fragmented yet persistent causality can be evaluated as negative changes in financing conditions also affecting export performance. In contrast, at the higher quantiles of SYN, the impact of CDS largely disappears, and no statistically significant causality is identified in this regime. This result may be explained by the increased institutional resilience of firms during periods of high SYS volumes, their ability to diversify financing sources, and the development of more flexible strategies against risks. The impact of CDS re-emerges between the 0.45–0.65 quantiles. This may be interpreted as rising risk premiums beginning to affect synthetic yarn exporters despite diversified financing sources. Moreover, statistically significant causality is again detected from the very high CDS quantiles of 0.90–0.95 to the 0.65–0.85 quantiles of SYN. This suggests that even during periods accompanied by high export volumes, an extraordinary increase in country risk may influence the decisions of synthetic yarn exporters through contract renewals, long-term orders, and external financing costs. Overall, the QQGC results indicate that the causal impact of CDS on SYN strengthens particularly in low export regimes and during periods of extreme risk. These findings support the positive and quantile-sensitive relationship between CDS and SYN identified in the QQKRLS analysis.

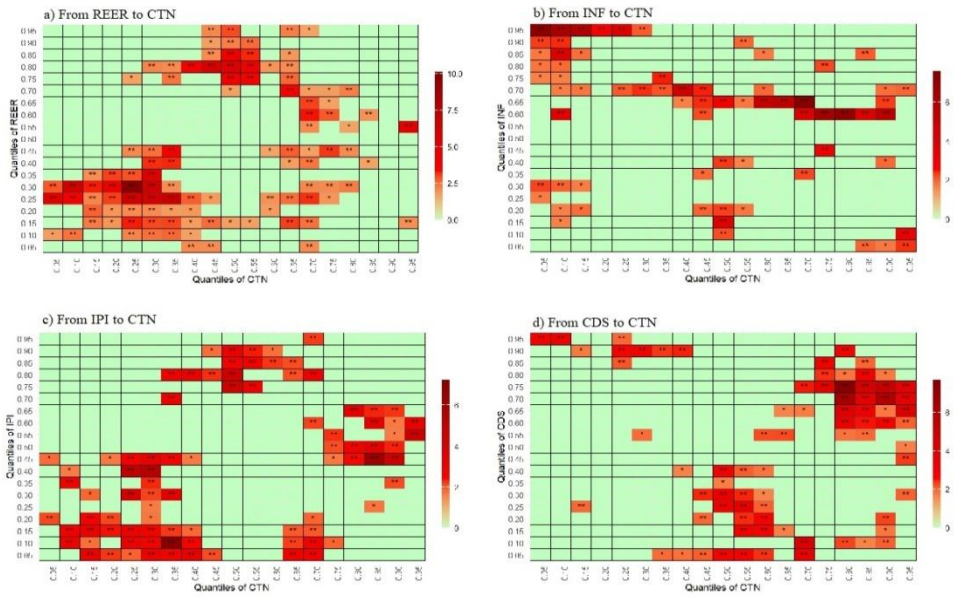

Figure 10. QQGC Test Results between Macroeconomic Variables and CTN.

Note: The plot shows the estimated test statistics for each pairwise quantile variable. **p < 5% and *p < 10%. The color ranges from dark-green to red, which signifies the test statistics

Figure 10 presents the graphs illustrating causality from macroeconomic variables to CTN. In panel (a), a statistically significant causality is observed from REER quantiles in the 0.25–0.45 range toward CTN quantiles in the 0.05–0.35 range. This finding can be interpreted as an increase in the exchange rate sensitivity of CTNs under competitive exchange rate regimes. A narrow and localized causality is also detected from the 0.80 quantile of REER toward the 0.35–0.45 quantiles of CTN. This point corresponds to periods in which the Turkish lira appreciates and price competitiveness weakens. During such periods, excessive real exchange rate appreciation may constrain price competitiveness for new orders, thereby preventing upward movements in CTNs and confining export performance to a middle band. The strong causality identified under moderate exchange rate regimes confirms that cotton yarn production, owing to its high domestic input content, can benefit from exchange rate advantages. In contrast, the limitation of causality to narrow and localized areas under excessively overvalued exchange rate regimes supports the QQKRLS finding that exchange rate appreciation begins to suppress exports beyond a certain threshold.

In panel (b), the causality running from INF to CTN is observed. It is evident that strong and statistically significant causal relationships emerge from the upper quantiles of INF (0.90–0.95) toward the lower and middle quantiles of CTN (0.05–0.30). This finding can be interpreted as indicating that increasing cost pressures in high inflation environments adversely affect the export performance of cotton yarn producers. Moreover, the area of concentrated causality extending from the 0.65–0.70 quantiles of INF toward the 0.25–0.90 quantiles of CTN reflects the period in which inflation continues to rise and the uncertainty it generates persistently influences exporters. Firms may become more sensitive to inflationary shocks within this medium–high inflation band. While the QQKRLS analysis reveals that the relationship between INF and CTN changes direction across quantiles and exhibits a pronounced asymmetric structure, the QQGC findings demonstrate that this structure also holds in a causal sense. In particular, the strong causality detected in high inflation regimes confirms that CTN performance is weakened through cost pressures and uncertainty channels.

In panel (c), the causality running from IPI to CTN becomes particularly pronounced in the medium and high production quantiles. Statistically significant causality is observed from the medium and upper quantiles of IPI toward the medium and partially high quantiles of CTN. This finding indicates that expansions in industrial production support CTN capacity. However, in the highest quantiles of CTN, the impact of IPI weakens and, in some regimes, disappears entirely. This situation can be explained by the fact that during periods when exports reach their peak, export performance is driven more by increases in external demand and the continuity of orders rather than by further growth in production. The strong causality detected in medium production regimes reinforces the QQKRLS interpretation that production capacity and supply chain efficiency support exports. Conversely, the weakening impact of industrial production during periods when exports reach their highest levels confirms, at the causality level, the directional change observed in the QQKRLS results.

In panel (d), the causality from CDS to CTN exhibits a distinctly regime-specific structure. First, a statistically significant causality is detected from the lower quantiles of CDS (0.05–0.40) toward the medium quantiles of CTN (0.40–0.65). This finding can be interpreted as indicating that even during periods when country risk is relatively low, upward movements in CDS may influence the export decisions of cotton yarn exporters operating under moderate export regimes through financing conditions and risk perceptions. Second, a significant causality is observed from the higher quantiles of CDS (0.60–0.90) toward the upper quantiles of CTN (0.75–0.95). This suggests that even in periods when CTNs reach high levels, a substantial increase in country risk can affect export performance, particularly through long-term orders, external financing costs, and contract renewals. The fact that changes in CDS influence export decisions under low-risk regimes, and that CTNs remain sensitive to CDS shocks even under high-risk regimes due to the advantage of domestically sourced inputs, reinforces the underlying mechanisms of the asymmetric relationship identified in the QQKRLS analysis.

Discussion

This paper aims to analyze the macroeconomic factors determining Turkiye's SYN and CTN performance on a product-specific basis by employing nonlinear econometric approaches. The findings reveal that the responses of these two sectors to macroeconomic shocks are not only nonlinear but also fundamentally differentiated.

In this paper, REER is found to exert a generally negative impact on SYN, while having a positive impact on CTNs at middle quantiles. The result obtained for SYNs is consistent with the dominant view in the literature. Similar to studies demonstrating that declines in REER increase exports through price competitiveness (Chan & Au, 2007; Hatırlı *et al.,* 2012; Puspitasari & Fachrudin, 2020; Basak *et al.,* 2025), our findings confirm this general tendency specifically for synthetic yarn. In contrast, the nonlinear positive relationship identified for CTNs diverges from much of the existing literature. This divergence may be explained by the positioning of Turkish cotton yarn in global markets, particularly within the "quality" and "sustainability" segments (e.g., BCI cotton), where demand exhibits low price elasticity. In other words, a moderately higher exchange rate does not immediately deter European buyers; rather, a stable exchange rate environment may enable Turkish producers to invest in technology and quality, thereby positively influencing export volumes.

Inflation is found to have asymmetric and quantile-dependent impacts on the exports of both yarn types. For synthetic yarn, low-to-moderate inflation regimes stimulate exports, whereas high inflation regimes negatively affect exports by creating cost pressures. For CTNs, the findings indicate a more complex structure. While low-to-moderate inflation negatively affects exports, a surprisingly positive relationship emerges under very high inflation regimes. These asymmetric and product-specific findings provide a strong explanation for the conflicting results reported in the literature, such as the negative findings of Puspitasari and Fachrudin (2020) and the positive findings of Basak et al. (2025).

The negative impact of IPI on SYN and its largely positive impact on CTN further accentuate the fundamental divergence between the two sectors. The positive impact identified for cotton yarn is consistent with the findings of Hatırlı and Onder (2010). In addition, the results for CTNs align with studies such as Chan and Au (2007) and Ozer (2014), which report a positive impact of GDP—closely correlated with industrial production index data on an annual basis-on exports. Conversely, the negative relationship observed for synthetic yarn reveals a dynamic often overlooked in general export models: during periods of domestic economic expansion, synthetic yarn, as a critical intermediate input, is absorbed by rising domestic demand and redirected toward the domestic market rather than export markets.

The divergent response of SYN and CTN to industrial production growth highlights fundamental structural differences in their value chains. While CTN benefits from capacity expansion fueled by predominantly domestic raw material sourcing, SYN faces a 'domestic absorption' constraint. This occurs because synthetic yarn serves as a critical intermediate input for Turkiye's broader

downstream textile and apparel manufacturing sectors. During periods of rising industrial activity, domestic manufacturers prioritize securing these petroleum-based inputs to maintain internal production schedules, thereby reducing the surplus available for export. Unlike the cotton sector, the synthetic sector's ability to scale production simultaneously for both markets is constrained by its high dependency on imported chemical intermediates. This makes rapid capacity expansion highly sensitive to foreign exchange liquidity and global supply chain stability, explaining why SYN performance is often 'anti-fragile'—thriving primarily when domestic demand pressure eases during economic shifts.

Furthermore, the significant negative correlation between SYN and CTN exports (r = -0.35) observed in the correlation matrix stems from these contrasting reactions to macroeconomic cycles rather than a direct substitution of physical production factors. Since the machinery used in synthetic fiber extrusion and natural fiber spinning is largely specialized and non-interchangeable in the short term, the 'see-saw' effect is driven by market orientation. When the domestic economy is robust, SYN is absorbed internally as an intermediate good while CTN scales for export; during domestic stress, SYN pivots to foreign markets as an 'anti-fragile' survivor while CTN is suppressed by rising risks. This structural divergence explains why these two sub-sectors of the same industry frequently move in opposite directions.

This 'see-saw' effect carries profound implications for engineering economics, particularly regarding capital budgeting and capacity utilization metrics. Since fiber extrusion lines represent irreversible capital investments with fixed overhead costs, synthetic yarn firms utilize their 'anti-fragile' external pivoting as an operational hedging mechanism to maintain high-capacity utilization when domestic industrial demand collapses. Conversely, for cotton spinning plants, the stability-dependent nature implies that engineering managers must prioritize raw material supply-chain buffering and liquidity conservation over aggressive market expansion during high-risk regimes to prevent cost-push insolvency.

The identifying characteristic of the 'anti-fragile' behavior in SYN exports is its structural divergence from CTN exports. If the observed growth were merely a result of positive global demand shifts, a synchronized upward trend would be expected across all textile sub-sectors. However, the significant negative correlation observed between the two sectors suggests that the export surge in SYN is primarily a response to internal macroeconomic shifts rather than uniform external demand shocks.

The absence of empirical studies in the literature directly examining the impact of CDS on textile exports underscores that the findings related to this variable constitute the most original contribution of the present study. The analysis demonstrates that the impact of CDS is nonlinear and generates different outcomes across regimes for each product. For SYN, the positive relationship observed between exports and CDS during medium-to-high quantile risk periods indicates that crisis dynamics support this sector through the exchange rate channel. For cotton yarn, however, the negative impact of heightened risk perception on exports—even in stable periods characterized by low-to-moderate CDS levels when exports are at high quantiles—demonstrates how sensitive this sector is to financial uncertainty, even during its strongest performance phases.

The 'anti-fragile' nature of SYN exports during high-risk (high CDS) periods is driven by a trade-off between financing costs and price competitiveness. While high CDS premiums undoubtedly increase external financing costs and restrict credit access, they simultaneously exert downward pressure on the Turkish Lira. In the Turkish context, the competitive advantage gained through currency depreciation often outweighs the burden of increased interest rates for export-oriented firms. Furthermore, the 'anti-fragility' of the sector is not merely a sign of structural strength in isolation, but also a result of a 'flight to external markets'. When domestic purchasing power collapses due to high risk and inflation, synthetic yarn producers—who are otherwise absorbed by domestic demand—shift their entire market orientation toward foreign buyers to survive. This survival-driven flexibility, supported by the institutional resilience of firms and their ability to diversify financing sources during high-volume periods, allows the sector to turn systemic disorder into an export opportunity.

The ability of exporters to achieve record volumes despite the soaring financing costs associated with high CDS levels can be explained through three primary mechanisms. First, the 'Price-Cost Trade-off': In the Turkish context, the drastic currency depreciation that typically accompanies rising CDS premiums provides a competitive price advantage that often outweighs the incremental increase in domestic borrowing costs. Second, 'Natural Hedging and Liquidity': Export-oriented firms, particularly in the synthetic yarn sector, earn in hard currencies (USD/EUR), providing them with a natural hedge against domestic inflation and allowing them to self-finance operations or access international trade finance (pre-export credits) that is less sensitive to domestic CDS-driven interest rate hikes. Finally, during periods of domestic credit rationing and collapsed internal demand, firms shift to a 'survival-oriented export' strategy. In this state, maintaining cash flow through foreign sales becomes more critical than profit margins, leading to record export volumes even under severe financial stress. This flexibility is a hallmark of the anti-fragile behavior identified in the study.

Conclusion

In this article, the impacts of macroeconomic variables on Turkiye's SYN and CTN exports are analyzed using quantile-based methods. The QQKRLS results reveal that the relationships between macroeconomic variables and SYN-CTN are non-linear and vary in both direction and intensity across quantiles, while the QQGC findings demonstrate that this asymmetric structure is also valid in the causal dimension. To systematically synthesize the empirical outcomes of our non-linear framework, the statistical validity of the formulated hypotheses is summarized as follows: **H1** is fully supported, confirming that REER heavily suppresses synthetic exports while showing threshold-dependency for cotton yarn. **H2** is fully supported, validating the quantile-dependent structural shift of inflation from an export propensity tool to a severe cost

constraint. **H3** is fully supported, confirming the presence of the domestic absorption channel for synthetic inputs alongside capacity expansions for cotton yarn. **H4** is fully supported, empirically verifying the 'anti-fragile' external market flight of synthetic yarn during high-risk sovereign periods versus the stability-dependent contraction of cotton yarn. Finally, **H5** is fully supported, as both QQKRLS and QQGC frameworks robustly establish that causal trade linkages are strictly regime-dependent and highly sensitive to specific distributional tails.

Among the macroeconomic variables affecting SYN, the REER emerges as the most influential factor. According to the findings, declines in REER have a strong and negative impact on SYN. This indicates that depreciation in the exchange rate provides Turkish producers with a significant price competitiveness advantage in international markets and directly increases export demand. This relationship is also confirmed by the QQGC causality analysis, which shows a strong and unidirectional causality running from the exchange rate to exports, particularly under competitive exchange rate regimes. These findings underline that exchange rate policy is a key determinant of SYN performance. The impact of INF, another macroeconomic variable included in the analysis, on SYN is distinctly asymmetric. Inflation rising from low to moderate levels positively affects export performance by directing firms toward exports amid increased uncertainty; however, when inflation reaches very high levels, it exerts downward pressure on exports by unpredictably increasing imported input costs. The causality results further confirm that high-inflation regimes weaken SYN performance through cost pressures. Additionally, increases in the industrial production index (IPI) are found to negatively affect SYN. This result stems from the role of synthetic yarn as an important intermediate input. When industrial production expands, domestic demand for this input rises, and production is primarily allocated to meet internal market needs. The QQGC test supports this interpretation by showing that increases in industrial production causally suppress exports in low and medium production regimes. Finally, increases in CDS, particularly at medium and high levels, have a positive impact on SYN. This can be explained through two mechanisms: first, heightened risk perception often puts pressure on the exchange rate, indirectly enhancing competitiveness; second, contraction in the domestic market during high-risk periods pushes firms to export their output, creating a "flight to external markets" impact. The causality analysis supports the asymmetric nature of this relationship, showing that increases in CDS causally affect export performance especially during periods of weak exports and can become decisive for export decisions under extremely high-risk conditions.

CTN, which constitutes another focal point of the study, exhibits a structure that, unlike SYN, is supported by macroeconomic stability and predictability. Uncertainty and excessive volatility tend to adversely affect the sector's performance. A positive relationship between REER and CTN is observed at moderate levels; however, excessive appreciation of the exchange rate reverses this relationship into a negative one. This finding indicates that cotton yarn benefits from a competitive exchange rate due to its high share of domestic raw materials, yet excessive currency appreciation suppresses exports through rising costs and reduced economic stability. The causality analysis confirms that this positive relationship operates causally, particularly under moderate exchange rate regimes. Another independent variable examined in relation to CTN is INF. During periods of rising inflation, input cost uncertainty negatively affects CTNs. However, the re-emergence of a positive relationship in environments of very high inflation suggests that the sector adapts to high-inflation conditions and restructures its export activity based on new cost structures. The QQGC test confirms that, especially under high-inflation regimes, cost pressures and uncertainty causally weaken CTN performance. Increases in CDS at low and medium levels negatively affect CTN, indicating that the sector fundamentally favors a low-risk and predictable financing environment. Only during crisis periods, when CDS rises excessively and the domestic market contracts sharply, does the relationship turn positive, suggesting that firms are compelled to shift toward exports. In addition, increases in the IPI generally have a positive impact on CTNs. This outcome is directly associated with rising production capacity and overall economic efficiency. As productivity-driven expansion in cotton yarn production capacity occurs, firms increasingly orient toward foreign markets. The QQGC causality test applied in the study likewise supports this finding, demonstrating that expansions in industrial production causally enhance CTN capacity.

The fundamentally different responses of the two subsectors to macroeconomic shocks stem, as emphasized at the beginning of the study, from their input structures. This distinction profoundly alters the sectors' perceptions of risk and opportunity. The production of synthetic yarn is largely dependent on imported petroleum-based raw materials. This dependency renders the sector more vulnerable to financial shocks such as REER and CDS on the one hand, while on the other hand enabling it to gain a price advantage over competitors during periods of depreciation of the Turkish Lira. In contrast, the predominance of domestic raw materials in cotton yarn production allows this sector to benefit from exchange rate–based competitiveness in a more stable manner. However, this structure also makes the sector far more sensitive to overall macroeconomic instability, particularly to cost pressures arising from high inflation and financing difficulties induced by elevated CDS levels. Another underlying factor behind this divergence is that SYN is intensively used as an intermediate good in industrial production and tends to shift from export markets toward the domestic market during periods of rising internal demand. This behavior constitutes the primary explanation for the negative and suppressive relationship observed between IPI and SYN in the QQKRLS and QQGC results. CTN, by contrast, is capable of simultaneously supplying both domestic and export markets, particularly under moderate production regimes. Consequently, increases in the industrial production index support CTNs only up to certain levels. Overall, these findings demonstrate how misleading a "one-size-fits-all" approach can be in analyses of a broad sector such as textiles and highlight the strategic importance of conducting product-based analyses.

Policy Recommendations

The empirical findings of this paper reveal that economic policies to be implemented in Turkiye's textile industry-one of the country's locomotive sectors-should be tailored to the structural dynamics of sub-sectors rather than adopting a uniform, general approach. The heterogeneous impacts of macroeconomic variables on SYN and CTN necessitate that policymakers develop flexible mechanisms that account for sector-specific sensitivities instead of one-size-fits-all interventions. For industrial managers navigating macroeconomic volatility, strategic orientation must strictly depend on product-specific asset structures. Synthetic yarn (SYN) producers should implement a 'counter-cyclical market pivot' strategy. During periods of domestic monetary tightening and elevated sovereign risk, managers must aggressively divert production capacities away from the collapsing internal manufacturing chain toward high-growth foreign buyers, utilizing foreign-currency earnings (USD/EUR) as a natural operational hedging mechanism against domestic inflation. Conversely, because cotton yarn (CTN) performance is strictly stability-dependent, cotton mill managers cannot afford aggressive external expansion during macroeconomic shocks. Instead, they must prioritize supply-chain buffer stocks, engage in long-term raw material options to lock in input costs, and optimize internal logistics efficiency to survive cost-push inflationary phases.

Specific Actionable Recommendations for Government and Monetary Authorities: Rather than relying on rigid, industry-wide macroprudential policies, the Ministry of Industry and Technology and the Central Bank of the Republic of Turkiye (TCMB) should deploy state-dependent, asymmetric interventions. For the synthetic sector, which relies heavily on petroleum-based intermediate chemical imports, policymakers should not restrict trade finance during sovereign risk surges. Instead, during high-CDS regimes, Turk Eximbank must dynamically expand hard-currency pre-export credit lines and provide targeted energy subsidies to buffer imported input inflation, allowing the sector to function as a national economic stabilizer. For the domestic-input-heavy cotton yarn sector, government interventions should strictly target price stability and supply predictability. Monetary authorities should provide domestic credit guarantee schemes tied to specific CDS and inflation thresholds to insulate agricultural supply networks and prevent cost-driven sector withdrawal. Within this framework, the strategic steps to be followed-ranging from exchange rate regimes and industrial production strategies to inflation control and financial risk management—are detailed below.

For SYN, which meets its raw material requirements largely through imported inputs, maintaining the REER at relatively low levels can be used as a critical tool to secure price-based competitiveness. In contrast, for CTN, it should be noted that exchange rate increases begin to exert a suppressive impact on exports beyond a certain threshold. Considering these dynamics, the Central Bank may avoid excessive exchange rate volatility and aim for a balanced exchange rate level that preserves the sector's domestic input advantage.

With regard to the impacts of the IPI, increases in production directly support CTN exports. The Ministry of Industry and Technology, together with local chambers of industry, may encourage capacity-expanding investments and technological upgrading in cotton yarn production. For SYN, however, rising IPI levels may lead to synthetic yarn being absorbed by the domestic market as an intermediate input, thereby exerting downward pressure on exports. Therefore, even during periods of strong domestic demand, expanding production capacity to a scale that can simultaneously meet both domestic and foreign demand may constitute a strategic objective.

Moreover, INF emerges as a variable where the two sectors diverge significantly. SYN is highly dependent on imported inputs, and during periods of high inflation, tax adjustments or energy subsidies may be implemented to offset rising imported input costs faced by exporters in this sector. For CTN, high inflation-induced uncertainty makes it more difficult to secure long-term export orders. In this context, resolute monetary policies aimed at ensuring price stability are critical for the cotton yarn sector.

In the face of CDS -which exert a common impact on both sectors- state-supported credit guarantee schemes and low-interest export financing instruments (such as those provided by Turk Eximbank) may be used more effectively to facilitate exporters' access to finance.

Additionally, the results of this study highlight the critical necessity for policymakers to implement product-specific and state-dependent industrial and monetary strategies-rather than a 'one-size-fits-all' approach-to effectively mitigate the impacts of global economic volatility on the Turkish textile industry. Specifically, for government authorities, the divergent responses of SYN and CTN exports suggest that the Ministry of Industry and the Central Bank should prioritize facilitating trade finance and logistics support for the 'anti-fragile' synthetic sector during high-CDS (high-risk) periods to leverage its role as an economic stabilizer. Conversely, for the cotton sector, interventions should focus on stabilizing input costs and providing targeted credit guarantees during moderate-risk periods to protect its stability-dependent growth from sudden volatility.

Furthermore, for firms and industrial managers, the findings suggest a strategic shift in operational orientation. Synthetic yarn producers should adopt a 'counter-cyclical' market pivot strategy, maintaining lean domestic inventories while aggressively targeting foreign buyers during periods of domestic financial stress. To overcome high financing costs, managers should pursue 'natural hedging' by denominating operational costs in export-earned currencies. For cotton yarn producers, the focus should remain on domestic supply chain optimization and long-term raw material hedging to mitigate the negative impact of exchange rate fluctuations observed at higher export quantiles.

In conclusion, achieving sustainable export growth and global competitiveness in the synthetic and cotton yarn sub-sectors depends on the coordinated implementation of monetary and industrial policies. While exchange rate and incentive strategies that preserve cost advantages come to the forefront in the synthetic yarn sector, expanding production capacity and ensuring macroeconomic stability

are of critical importance for cotton yarn. Maintaining low CDS levels and reducing financial vulnerabilities constitute a shared foundation that will enhance the resilience of both sectors in global markets.

Limitations and Future Directions

Despite its robust empirical contributions, this paper has several limitations that provide pathways for future research. First, while the QQKRLS and QQGC methods effectively capture non-linearities and regime-specific dependencies, the results can be sensitive to quantile selection and bandwidth parameters, as noted by Li et al. (2025). Future studies could enhance the robustness of these findings by employing alternative non-linear frameworks, such as Threshold Vector Autoregressive (TVAR) models or Markov-Switching approaches, to identify specific dates of regime shifts in the textile industry.

Second, although this study primarily isolates domestic macroeconomic determinants to clarify the internal policy-export nexus, the exclusion of external demand variables remains a boundary. The Turkish textile sector is highly integrated into global value chains. Future research should incorporate external demand factors, such as the GDP growth of major EU trading partners, and supply-side shocks, particularly energy prices and global shipping costs, which are critical determinants of export competitiveness. Additionally, the potential impact of the European Green Deal and Carbon Border Adjustment Mechanism (CBAM) on yarn exports remains an unexplored area that warrants attention, given Turkiye's proximity to the EU market.

Moreover, the exclusion of external demand factors was also necessitated by the mismatch in data frequencies; as official EU GDP growth figures are strictly provided on a quarterly basis, their integration into a monthly-frequency QQKRLS framework would require interpolation techniques that could potentially compromise the robustness of the quantile-based estimates.

Third, while the analysis is centered on synthetic and cotton yarns, Turkiye's textile prowess extends to technical textiles, ready-to-wear garments, and sustainable fibers (e.g., flax and recycled fibers). Expanding the scope to these high-value-added sub-sectors would provide a more holistic view of the industry's resilience. Finally, future investigations could adopt a comparative perspective by analyzing Turkiye alongside other major textile exporters like Vietnam, Bangladesh, or India to determine whether the observed "anti-fragile" or "stability-dependent" characteristics are country-specific or industry-wide phenomena.

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