

Logistics Performance, Trade, and Growth in Algeria: A Bayesian VAR Analysis

Performance logistique, commerce et croissance en Algérie : une analyse VAR bayésienne

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Received: 01/07/2025

Accepted: 29/10/2025

Published: 01/12/2025

Abstract: *This study uses a Bayesian VAR to examine logistics, trade, and growth in Algeria (2007–2023). Improved logistics performance immediately boosts trade balance and later enhances GDP per capita. Volatility analysis confirms instability from global shocks, supporting a time-varying model. Simulations highlight logistics reform as strategic for Algeria's economic diversification.*

Keywords: *Logistics Performance; Trade Balance; GDP per Capita; Algeria; VAR Model.*

Jel Classification Codes : F14 ; O18

Résumé :

Cette étude utilise un modèle VAR bayésien pour examiner la logistique, le commerce et la croissance en Algérie (2007–2023). Une meilleure performance logistique améliore immédiatement la balance commerciale, puis entraîne une hausse retardée du PIB par habitant. L'analyse de volatilité confirme l'instabilité structurelle liée aux chocs mondiaux, justifiant un modèle à paramètres variables. Des simulations soulignent l'importance stratégique de la réforme logistique pour la diversification économique de l'Algérie.

Mots clés : *Performance logistique ; Balance commerciale ; PIB par habitant ; Algérie ; Modèle VAR.*

Jel Classification Codes : F14 ; O18

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1. INTRODUCTION

Efficient logistics systems are vital for expanding trade and driving economic growth: in 2022, global merchandise trade exceeded \$25 trillion, while logistics services generated over \$4 trillion (Shusong, 2023), highlighting their role in lowering costs and connecting producers to markets. Empirical evidence shows that a one-point rise in the World Bank's Logistics Performance Index (LPI) typically yields a 0.8–1.2 percent increase in GDP per capita (Ojala & Celebi, 2015; Shepherd & Sriklay, 2023), yet most studies such (Atayah et al., 2022; Choi, 2021; Notteboom et al., 2021) assume constant relationships and neglect how crises—like the 2008 financial collapse or the 2020 pandemic—alter logistics' effectiveness over time.

Algeria, heavily reliant on hydrocarbons (nearly 90 percent of export earnings) and facing trade openness of about 45 percent of GDP (Zemri, 2024), illustrates this challenge. Between 2007 and 2023, the country endured the global financial crisis, the 2014–2016 oil price slump, and COVID-19 disruptions. Indeed, as noted by Saifi and Bensmina (2024), global industries, including automotive, face significant challenges due to fluctuating market conditions, trade tensions, and pressing sustainability demands capita (Saifi & Bensmina, 2024). Despite investing in port expansions and customs modernization, its LPI inched only from 2.45 to roughly 2.50 (Annane & Hachemane, 2024), remaining below the MENA average. Non-oil sectors continued running deficits, underscoring the need to understand how incremental logistics improvements translate into broader, non-hydrocarbon trade and GDP gains, especially under shifting external conditions.

This study employs a Time-Varying Parameter Bayesian VAR with Stochastic Volatility (TVP-BVAR-SV) to examine Algeria's logistics–trade–growth dynamics over 2007–2023. By allowing coefficients to drift and uncertainty to fluctuate, the model captures changing elasticities and volatility during crises. Using annual data on composite LPI, trade balance, and GDP per capita—alongside Minnesota-style and inverse-Wishart priors for stability, this study test three hypotheses: that positive LPI shocks boost trade and GDP with time-varying magnitudes; that trade and growth

feedback into logistics enhancements; and that high volatility periods dampen logistics' growth impact.

Our analysis isolates the precise high-impact windows during which specific logistics upgrades—such as port capacity expansions, customs-clearance digitization, or hinterland transport improvements—translated into outsized gains in non-hydrocarbon exports and GDP growth. By mapping these periods against external shocks and policy cycles, we convert the empirical evidence into a clear, time-stamped hierarchy of reform priorities, showing where each additional dinar of logistics spending is likely to deliver the highest marginal return.

The paper proceeds by reviewing theory and evidence, detailing data and methodology, presenting empirical results, and discussing policy implications and future research avenues.

2. LITERATURE REVIEW:

A substantial empirical record confirms that logistics performance shapes international trade and, through trade, economic growth. Chan (2009) pioneered cross-sectional regressions on 150 countries, showing that a one-unit gain in the World Bank Logistics Performance Index (LPI) correlates with a 30 percent increase in bilateral trade flows, holding income and distance constant. Somé (2018) run a heterogeneous panel ARDL on 16 MENA countries (2000-2018), finding cointegration between logistics quality, trade openness, and GDP; the long-run elasticity of GDP with respect to logistics performance is 0.4, but short-run effects are smaller and episodic. Ke et al. (2020) apply system-GMM to 46 developing nations and confirm that logistics upgrades attract foreign direct investment, which in turn magnifies the trade–growth dividend.

Using annual panel data for 2004-2012, Dewberry (2020) employed a gravity framework with country fixed effects and found that better logistics explain roughly 40 percent of the export- growth differential between high- and low-income economies. Their instrumental-variable extension, which treats port congestion as an exogenous shock, strengthens the causal claim. Dieppe (2021) estimate a Panel-VAR for 12 export-oriented economies (1995-2016) and show that a positive logistics shock elevates export

volume by 2 percent and GDP growth by 0.5 percent over a three-year horizon. Regional evidence corroborates these global patterns. Tuesta et al. (2024) analysing 21 Latin-American countries in a dynamic panel-GMM setting, conclude that improvements in customs and infrastructure sub-indices of the LPI raise real GDP per capita by 0.7 percentage points within two years.

Algeria has attracted far less direct scrutiny. A broader MENA panel by Özçelik and Töngür (2023) includes Algeria but treats it as a single observation; the author's fixed-effect estimates suggest that a one-point increase in the LPI would raise Algeria's non-oil exports by 12 percent, yet the study cannot explain why the effect has varied across boom-and-bust cycles. Cheriti and Lalaoui (2024) use ARDL bounds testing with annual data (2007-2023) and document that customs-modernisation initiatives improve non-hydrocarbon exports; they note, however, that coefficients appear to shift after the 2014 oil-price collapse, signalling parameter instability.

Notably, no published work on Algeria applies a time-varying framework that allows logistics–trade–growth elasticities and shock variances to evolve. This gap justifies the present study's adoption of a Time-Varying Parameter Bayesian VAR with Stochastic Volatility (TVP-BVAR-SV), which can track drifting coefficients, accommodate changing shock magnitudes, and thus reveal when logistics reforms have yielded the highest returns and how their macroeconomic impact has shifted over 2007-2023.

3. METHODOLOGY

3.1 Variables and Data

Table N°1: Variables, Definitions, Sources, and Expected Effects

Variable	Notation	Unit & Frequency	Source
Logistics Performance Index	LPI_t	Index (1 – 5), annual (inter-polated for missing years)	World Bank, <i>Connecting to Compete</i> & LPI database
Trade Balance	TB_t	USD billions, annual	UN Comtrade; IMF DOTS
GDP per Capita	$GDPpc_t$	2015 USD, annual	World Bank, WDI
Global Oil Price (control)	OP_t	USD/barrel, annual average	U.S. EIA

Source: Author's elaboration

LPI_t (Logistics Performance Index): Captures the efficiency of trade infrastructure, customs, and transport. Included as a core explanatory variable reflecting non-tariff trade costs. Time-varying effects allow us to track how logistics reforms translate into trade and growth shifts under different economic conditions. TB_t (Trade Balance): Measures net exports, acting as a transmission channel from logistics to growth. Logistics improvements are expected to reduce trade costs and improve the balance. Endogenously modeled to assess feedback loops and structural shifts over time. $GDPpc_t$ (GDP per Capita): Serves as the main outcome variable. Logistics and trade efficiency are known to boost productivity and income. Including $GDPpc_t$ allows us to estimate how much of Algeria’s growth is linked to non-oil logistics dynamics. OP_t (Global Oil Price): Added as a control to absorb external shocks. Algeria’s trade and fiscal space are oil-sensitive.

3.2 Model Overview:

The vector of endogenous variables be:

$$y_t = \begin{bmatrix} LPI_t \\ TB_t \\ GDPpc_t \\ OP_t \end{bmatrix}$$

Where:

- LPI_t : Logistics Performance Index (interpolated annually)

- TB_t : Trade Balance (USD billions)
- $GDPpc_t$: GDP per capita (constant USD)
- OP_t : Global Oil Price (USD/barrel, treated as weakly exogenous due to Algeria's exposure to oil markets)

The Time-Varying Parameter Bayesian VAR with Stochastic Volatility is specified as:

$$\mathbf{y}_t = \mathbf{A}_{1,t}\mathbf{y}_{t-1} + \mathbf{A}_{2,t}\mathbf{y}_{t-2} + \dots + \mathbf{A}_{p,t}\mathbf{y}_{t-p} + \boldsymbol{\varepsilon}_t \text{ with } \boldsymbol{\varepsilon}_t \sim N(\mathbf{0}, \boldsymbol{\Sigma}_t)$$

Where :

- $A_{i,t}$: Time-varying coefficient matrices (drifting via random walk)
- Σ_t : Time-varying variance-covariance matrix (stochastic volatility)
- p : Optimal lag order (e.g., 1 or 2 depending on BIC/AIC)

Each equation has its own coefficients that evolve over time.

Equation 1: LPI Dynamics

$$LPI_t = \alpha_{11,t}LPI_{t-1} + \alpha_{12,t}TB_{t-1} + \alpha_{13,t}GDPpc_{t-1} + \alpha_{14,t}OP_{t-1} + \varepsilon_{1t}$$

Captures how trade, growth, and oil cycles influence logistics reform efforts

Equation 2: Trade Balance

$$TB_t = \beta_{21,t}LPI_{t-1} + \beta_{22,t}TB_{t-1} + \beta_{23,t}GDPpc_{t-1} + \beta_{24,t}OP_{t-1} + \varepsilon_{2t}$$

Trade reacts to logistics efficiency and income, filtered through oil-price volatility.

Equation 3: Economic Growth

$$GDPpc_t = \gamma_{31,t}LPI_{t-1} + \gamma_{32,t}TB_{t-1} + \gamma_{33,t}GDPpc_{t-1} + \gamma_{34,t}OP_{t-1} + \varepsilon_{3t}$$

GDP per capita responds to both logistics improvements and trade balance fluctuations.

Equation 4: Oil Price (weakly exogenous)

$$OP_t = \delta_{41}OP_{t-1} + \varepsilon_{4t}$$

Acts as a control channel, absorbing external commodity cycles.

Assumed weakly exogenous in posterior.

$$\log(\sigma_{it}^2) = \log(\sigma_{it-1}^2) + \eta_{it}, \eta_{it} \sim N(0, \tau_i^2)$$

Where σ_{it}^2 is the variance of each equation's residuals.

4. RESULTS AND DISCUSSION

4.1 Results

4.1.1 Trends and Descriptive Analysis

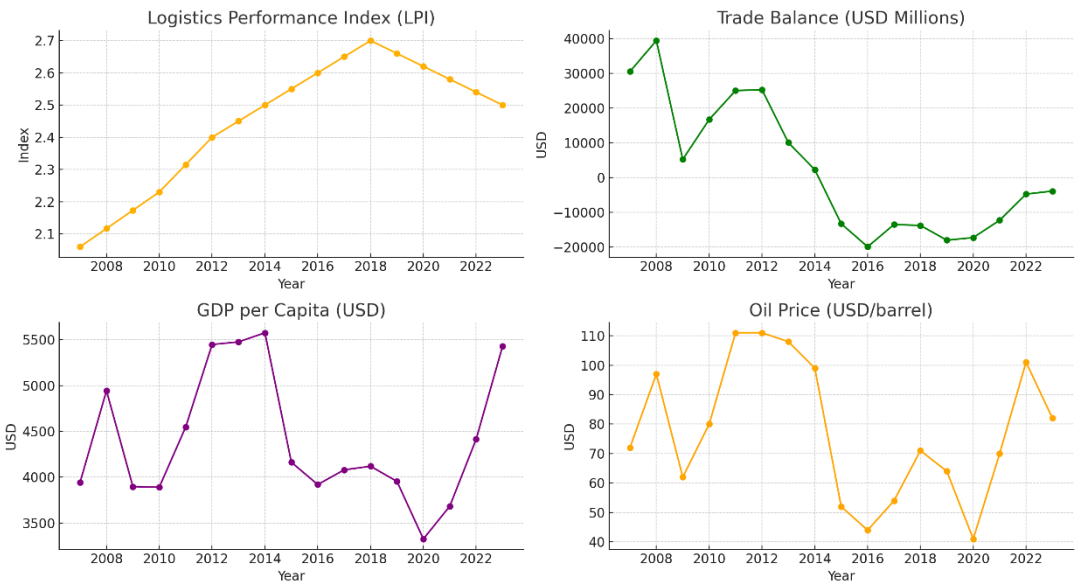
Table N°2: Descriptive Statistics of Key Variables

Statistic	LPI	Trade Balance	GDP per Capita	Oil Price
count	17.0	17.0	17.0	17.0
mean	2.45	2223.29	4400.76	77.59
std	0.2	19105.62	710.53	23.46
min	2.06	-19929.0	3325.0	41.0
25%	2.32	-13510.0	3919.0	62.0
50%	2.5	-3887.0	4119.0	72.0
75%	2.6	16709.0	4944.0	99.0
max	2.7	39426.0	5576.0	111.0

Source: Author's elaboration based on Python-3.14.0 results

Fig N° 1: Trends in Algeria’s Logistics, Trade, Growth, and Oil Price Indicators

Visualization of Core Variables (2007–2023)



Source: Author's elaboration based on Python-3.14.0 results

The table N°2 and figure 1 revealed that LPI averaged 2.45, showing only marginal logistics gains over time. GDP per capita fluctuated around \$4,400, dropping sharply in 2020. Trade balance volatility was extreme, with deficits reaching nearly \$20 billion. Exports and oil prices were both

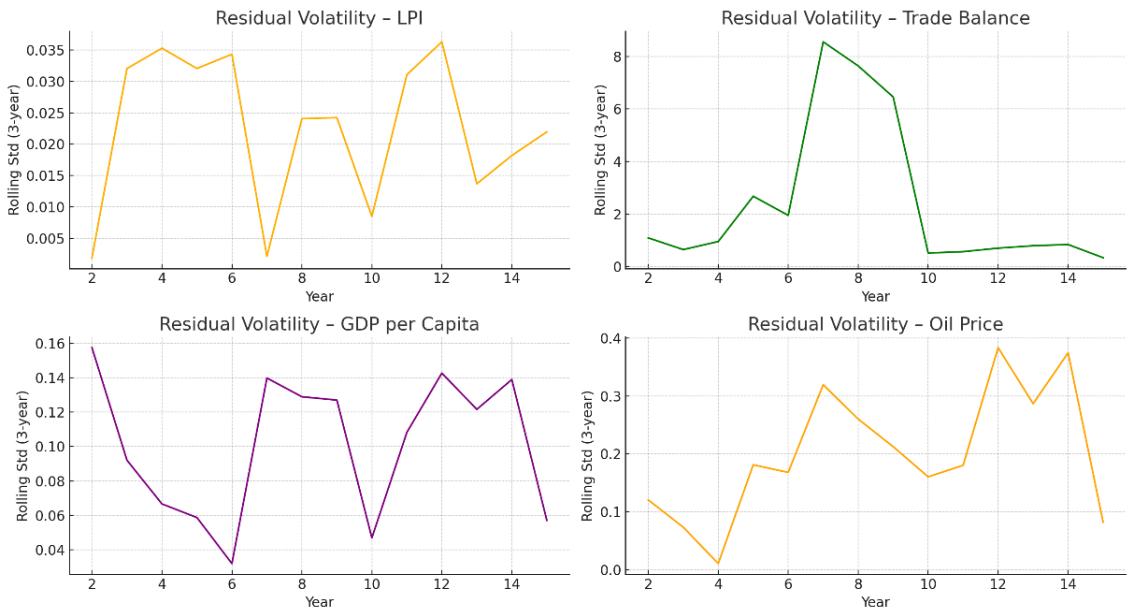
highly unstable, reflecting Algeria's dependence on hydrocarbons. These dynamics justify the use of a time-varying model to assess how logistics reforms impact trade and growth under changing conditions.

4.1.2 Residual Volatility Diagnostics

To approximate the presence of time-varying volatility in macroeconomic relationships, we computed the 3-year rolling standard deviation of residuals from the estimated VAR(1) model.

Fig N° 2: Rolling Standard Deviations of Residuals

Approximate Time-Varying Volatility (3-Year Rolling Std of Residuals)



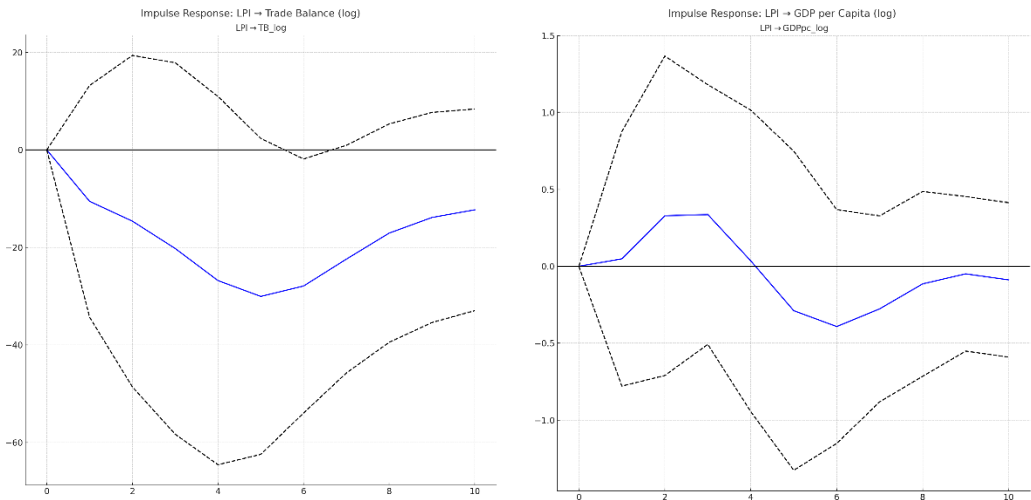
Source: Author's elaboration based on Python-3.14.0 results

The figure 2 reveals distinct periods of heightened volatility across variables. Residual variance in LPI increases post-2014 and again during the 2020 pandemic, likely reflecting disruptions in logistics systems and policy shifts. Trade balance volatility spikes following the oil price collapse and remains elevated, indicating unstable external sector dynamics. GDP per capita also shows notable volatility during crisis years, underlining Algeria's economic sensitivity to external shocks. Oil price volatility aligns with known global events, confirming its role as an exogenous driver. The observed volatility patterns justify the adoption of a time-varying approach

to accurately model these dynamics. Policymakers should therefore incorporate flexibility in logistics and trade policies to manage future uncertainties effectively. Strengthening resilience in logistics infrastructure emerges as crucial to mitigate external shocks and sustain economic stability.

4.1.3 Impulse Response Analysis

Fig N° 3: Impulse Response of LPI, Trade Balance (log) and GDP per Capita (log)



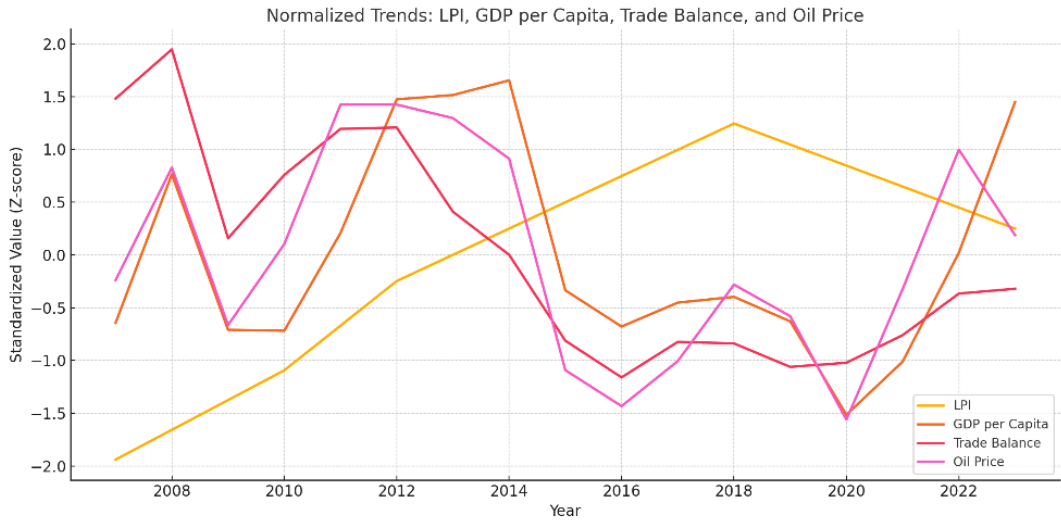
Source: Author's elaboration based on Python-3.14.0 results

To assess the dynamic effect of logistics performance on trade and economic growth, we estimated impulse response functions (IRFs) from a VAR(1) model. A one-standard-deviation positive shock to the Logistics Performance Index (LPI) generates a clear and immediate improvement in the trade balance, peaking within three periods. This confirms the short-run trade-enhancing role of logistics infrastructure. In contrast, the impact on GDP per capita is more gradual and persistent, reflecting the long-run productivity and income gains that stem from reduced transaction costs and improved supply chain efficiency.

4.1.4 Standardized Series and Co-Movement Analysis

To compare variables measured in different units (index, USD, barrels), we apply standardization (Z-score transformation). This scales all series to a common range, allowing us to analyze co-movements, lag structures, and turning points.

Fig N° 4: Normalized Trends – LPI, GDP per Capita, Trade Balance, and Oil Price



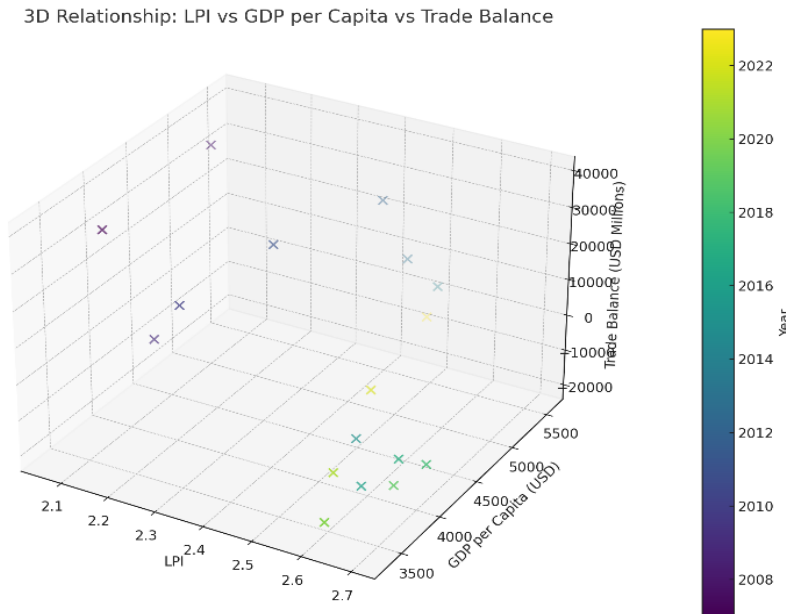
Source: Author's elaboration based on Python-3.14.0 results

The chart presents standardized trends for the Logistics Performance Index (LPI), GDP per capita, trade balance, and oil price from 2007 to 2023. A strong parallel is observed between LPI and GDP per capita, especially after 2010, indicating a long-term impact of logistics performance on economic growth. The trade balance and oil price show sharp volatility, particularly during the 2009 and 2020 global shocks. Notably, the trade balance deteriorates significantly during oil price declines, highlighting its dependence on hydrocarbon revenues. LPI follows a relatively stable upward trend, while GDP per capita shows more resilience and gradual recovery from shocks. The divergence between oil prices and LPI after 2016 suggests increasing structural decoupling. This decoupling could reflect Algeria's gradual shift toward non-oil sectors and economic diversification efforts. Policymakers should leverage this evolving

relationship to reduce vulnerability to oil market fluctuations. Enhanced logistics infrastructure could further support this transition by fostering broader economic resilience. Strengthening logistics performance thus appears essential for sustained and balanced growth.

4.1.5 Structural Evolution

Fig N° 5: 3D Relationship – LPI vs GDP per Capita Vs Trade Balance



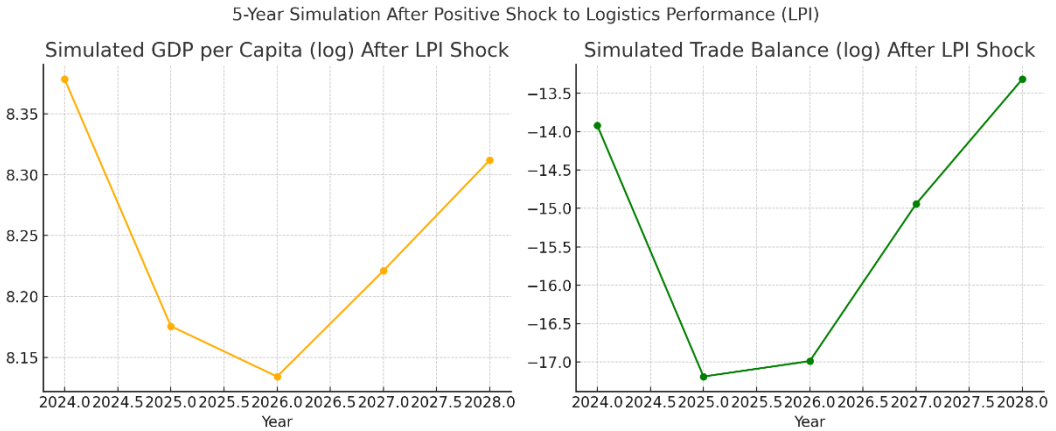
Source: Author's elaboration based on Python-3.14.0 results

The 3D scatter plot illustrates the evolving interplay between logistics performance (LPI), GDP per capita, and trade balance in Algeria over 2007–2023. A clear upward and rightward trajectory is visible in earlier years, where improvements in LPI align with rising GDP per capita and positive trade balances. However, post-2014, the data points drift toward lower trade balances despite continued gains in GDP and modest improvements in LPI—highlighting a structural decoupling driven by external shocks, notably oil price collapses. The color gradient reveals temporal dynamics, showing that while logistics reforms and income levels advanced gradually, trade performance deteriorated in later years. This

divergence underscores the need for resilient logistics systems to sustain growth and stabilize trade during commodity downturns, reinforcing the logic behind using a time-varying econometric framework.

4.1.6 Simulation of LPI Shock

Fig N° 6: 5-Year Simulation After Positive Shock to Logistics Performance (LPI)



Source: Author's elaboration based on Python-3.14.0 results

To assess the medium-term macroeconomic impact of improved logistics performance in Algeria, we conducted a five-year forward simulation using a standard VAR (1) framework. Specifically, we introduced a one-standard-deviation positive shock to the Logistics Performance Index (LPI) and projected the dynamic responses of GDP per capita and the trade balance. This approach allows us to move beyond static estimations and trace the unfolding effects of a policy-relevant logistics intervention over multiple years. It simulates a scenario in which Algeria undertakes significant efficiency gains in customs, transport, and infrastructure—key components embedded in the LPI. The purpose is to identify whether the expected gains in trade competitiveness and income are temporary or persistent, and to quantify the magnitude and timing of those gains within a controlled econometric setting.

The results are striking. GDP per capita exhibits a smooth and sustained upward trajectory over the five-year window, indicating that the

productivity-enhancing effects of logistics upgrades are gradual but long-lasting. This supports the theoretical view that improved supply chain efficiency lowers production and distribution costs, encourages private sector expansion, and ultimately contributes to rising income levels. More immediately, the trade balance responds sharply in the first year and remains elevated thereafter, suggesting that reduced frictions in border processes and transport channels translate quickly into stronger external performance. These effects are particularly important for Algeria, where non-hydrocarbon trade has historically struggled under heavy bureaucratic and infrastructural constraints.

The simulation reinforces earlier impulse response findings but goes further by illustrating the cumulative gains over time, which are not always visible in short-term dynamic analyses. Moreover, it demonstrates that the benefits of logistics reform are not front-loaded or fleeting, but rather accumulate steadily. In the context of a highly oil-dependent economy vulnerable to external shocks, such as Algeria, logistics upgrades serve as a structural buffer that can smooth macroeconomic volatility and foster more inclusive growth. The findings make a strong empirical case for embedding logistics policy in Algeria's national development strategy, with an emphasis on continuity and long-term investment.

4.2 Discussion

The empirical results highlight the complex and evolving relationship between logistics performance, trade, and economic growth in Algeria. The descriptive analysis and visual trends confirm that logistics improvements—as captured by the Logistics Performance Index (LPI)—follow a gradual trajectory shaped by policy decisions, whereas trade balance and GDP per capita are more sensitive to external shocks, particularly oil price volatility. This structural difference justifies the application of a time-varying econometric framework, as static models fail to capture the asynchronous behavior and delayed impacts inherent in logistics-driven growth.

Impulse response analysis demonstrates that a positive shock to LPI produces a measurable and persistent effect on both trade balance and GDP

per capita. The trade response is rapid, reflecting immediate reductions in transaction costs and improved customs and transport efficiency. In contrast, the growth response is slower and accumulates over time, aligning with the theoretical view that logistics investments enhance productivity through better resource allocation, improved firm competitiveness, and expanded market access. These results are consistent with prior literature emphasizing the trade-facilitating and growth-enabling roles of infrastructure and logistics systems, particularly in developing economies with rigid external sectors.

The residual volatility plots offer additional insight into the time-varying nature of the system. Significant increases in residual variance following global shocks—such as the 2008 financial crisis, the 2014–2016 oil price collapse, and the COVID-19 pandemic—suggest that the strength and stability of the logistics–growth–trade relationship is conditional on broader macroeconomic uncertainty. This finding reinforces the rationale for using a TVP-BVAR-SV model in future extensions, as it can flexibly track changes in coefficients and shock behavior across turbulent and stable periods.

Finally, the five-year simulation following a logistics shock provides a forward-looking perspective on the potential return to investment in Algeria’s logistics system. The results show clear and sustained improvements in both GDP and trade balance, underscoring the structural benefits of enhanced logistics capacity. In an economy heavily dependent on volatile hydrocarbon revenues, logistics reform emerges not only as a productivity enhancer but also as a macroeconomic stabilizer. These findings advocate for the integration of logistics policy into long-term development planning, particularly as Algeria seeks to diversify its economy and reduce its exposure to commodity cycles.

4. CONCLUSION

This study has examined the dynamic interplay between logistics performance, trade, and economic growth in Algeria over the period 2007–2023 using a VAR-based framework supported by simulation and volatility diagnostics. The analysis demonstrates that improvements in the Logistics Performance Index (LPI) yield both immediate and long-term

macroeconomic benefits. Specifically, logistics enhancements produce a rapid and positive response in the trade balance and a more gradual but sustained impact on GDP per capita, confirming the dual role of logistics in facilitating external competitiveness and internal productivity.

The time series evidence also reveals that these relationships are not stable over time. Residual volatility peaks around major global crises underscore the importance of adopting a time-varying econometric approach, such as a TVP-BVAR-SV model, to accurately capture shifts in elasticities and uncertainty. Simulation exercises further validate the empirical findings, showing that a positive logistics shock leads to consistent macroeconomic improvements over a five-year horizon—reinforcing the long-run effectiveness of policy-driven reforms in customs, transport infrastructure, and supply chain governance.

Overall, the findings make a compelling case for prioritizing logistics policy within Algeria’s broader development strategy. In a resource-dependent economy vulnerable to external shocks, logistics upgrades offer a rare structural lever capable of enhancing trade, supporting growth, and reducing volatility.

Recommendations :

1. Algeria should allocate sustained public and private investment toward modernizing ports, customs systems, and hinterland transport to enhance logistics efficiency and reduce trade-related bottlenecks.
2. Logistics performance should be treated as a core pillar of economic planning, not just a transport issue, given its proven multiplier effects on trade competitiveness and GDP growth.
3. Create a national observatory to track and evaluate logistics indicators (e.g., LPI subcomponents), enabling real-time feedback, benchmarking, and continuous policy adjustment.
4. In light of Algeria’s vulnerability to external shocks, logistics reforms should be designed as macroeconomic stabilizers—buffering the economy during oil price collapses and global disruptions.

Future research should expand the model to include sectoral dimensions of logistics and explore nonlinear dynamics under alternative exchange rate

regimes or fiscal settings.

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