Trade Without Comparative Advantage: The Inertial–Saturation Trade Model (ISTM)

Anurag Vikram Singh*
M.Sc. Economics and Data Analytics
Department of Economics
Central University of Andhra Pradesh

Dr. P. A. Naidu
Assistant Professor
Department of Economics
Central University of Andhra Pradesh
Email: panaidu@cuap.edu.in

January 17, 2026

Abstract

This paper develops a new framework for understanding global trade dynamics in environments where comparative advantage exhibits little or no temporal adjustment. Using long-run international trade data, we document four robust stylized facts: (i) revealed comparative advantage is tightly clustered around unity and largely time-invariant, (ii) export values display substantial dispersion across countries and over time, (iii) the responsiveness of trade flows to tariff policy is weak and diminishing, and (iv) the relationship between economic growth and trade is nonlinear and saturated. These empirical patterns challenge the core adjustment mechanisms embedded in canonical trade theories based on specialization, productivity differences, and factor reallocation.

Motivated by these findings, we propose the Inertial–Saturation Trade Model (ISTM)*, a nonlinear framework in which trade flows evolve under strong structural inertia and bounded responses to global conditions rather than through continuous reallocation according to comparative advantage. In the ISTM, trade dynamics are governed by saturation effects, coordination constraints, and policy inertia, rendering comparative advantage largely irrelevant for aggregate export adjustment. The model rationalizes the observed decoupling of trade flows from specialization patterns and provides a new lens through which to interpret contemporary global trade dynamics. The results suggest that modern trade is increasingly shaped by inertial and saturation forces, with important implications for trade theory and policy analysis.*

Keywords: International Trade; Comparative Advantage; Nonlinear Dynamics; Trade Saturation; Inertial Adjustment; Global Trade.

JEL Classification: F10; F11; F14; F40.

1 Introduction

International trade theory has long been anchored in the principle that countries exchange goods and services according to their comparative advantage. From the Ricardian emphasis on productivity differences to the Heckscher–Ohlin focus on factor endowments and the modern gravity framework grounded in constant elasticity of substitution preferences, the central mechanism underlying trade dynamics is the continuous reallocation of resources toward sectors and activities in which countries hold a relative advantage. In these frameworks, changes in technology, endowments, prices, or policy induce predictable adjustments in specialization patterns, which in turn drive observed trade flows. Comparative advantage, whether revealed or theoretical, therefore plays a dual role: it explains both the structure of trade and its evolution over time.

However, the empirical evolution of global trade over the past several decades raises important questions about the adequacy of this mechanism. Despite substantial changes in global demand, trade policy regimes, production networks, and macroeconomic conditions, observed measures of comparative advantage display remarkably little temporal variation at the aggregate level. At the same time,

*Corresponding author. Email: anuragvikramsingh2009@gmail.com

export values fluctuate significantly across countries and over time, often in ways that appear weakly related to changes in specialization, tariffs, or growth. This coexistence of stagnant comparative advantage and dynamic trade flows poses a fundamental puzzle for canonical trade theory: if countries are not adjusting their comparative advantage, through which channel do trade dynamics arise?

This paper documents a set of robust stylized facts that bring this puzzle into sharp focus. Using long-run international trade data, we show that revealed comparative advantage is tightly clustered around unity and remains largely time-invariant across countries. In contrast, export values exhibit substantial dispersion and volatility, even in the absence of meaningful changes in specialization. Moreover, the relationship between trade flows and trade policy is weak and diminishing, with tariff reductions yielding progressively smaller responses in exports. Finally, the link between economic growth and trade is nonlinear and saturated, suggesting that demand expansion alone cannot account for observed trade dynamics. Taken together, these findings indicate that the traditional adjustment margins emphasized in trade theory are empirically muted in the contemporary global economy.

These empirical regularities suggest that global trade dynamics may no longer be governed primarily by specialization-driven equilibrium adjustment, but instead by forces that operate outside the standard comparative advantage framework. In particular, the persistence of trade patterns in the presence of changing economic conditions points to the presence of strong inertial forces, such as production rigidities, institutional constraints, sunk costs, and coordination frictions embedded in global value chains. At the same time, the nonlinear and bounded responses of trade to growth and policy changes suggest the existence of saturation effects, whereby the capacity of economies to expand trade is constrained by structural and organizational limits rather than relative advantage. These features are difficult to reconcile with models that rely on smooth, monotonic responses to underlying fundamentals.

Motivated by these observations, this paper proposes a new theoretical framework, termed the *Inertial–Saturation Trade Model (ISTM)*, which reconceptualizes trade dynamics as the outcome of inertial and bounded adjustment processes rather than continuous reallocation according to comparative advantage. In the ISTM, aggregate trade flows evolve under strong country-specific trade capacity constraints and respond nonlinearly to global conditions and policy variables. Comparative advantage plays at most a secondary role, shaping long-run trade potential but not serving as the primary adjustment margin for observed trade dynamics. By construction, the model accommodates the empirical decoupling of trade flows from specialization patterns and provides a coherent explanation for weak tariff responsiveness and saturated growth effects.

The contribution of this paper is threefold. First, it provides new empirical evidence documenting the limited role of comparative advantage in explaining aggregate trade dynamics, thereby highlighting a systematic gap between canonical theory and observed data. Second, it introduces the ISTM as a novel theoretical framework that departs from specialization-based equilibrium models and instead emphasizes inertia, saturation, and coordination effects. Third, it derives testable implications from the ISTM and demonstrates their consistency with observed trade patterns, offering a unified interpretation of several empirical regularities that are difficult to reconcile within existing frameworks. In doing so, the paper contributes to a growing body of work that seeks to rethink the foundations of trade theory in light of the structural transformation of the global economy.

This paper relates to several strands of the international trade literature. Canonical models based on comparative advantage, including Ricardian and HeckscherOhlin frameworks, emphasize specialization-driven adjustment, while modern gravity-based approaches focus on market size and trade costs. Recent work on global value chains and trade persistence highlights the importance of structural rigidities and network effects. The ISTM differs from these approaches by modeling trade dynamics as an inertial and capacity-constrained process, offering a unified explanation for persistence, weak policy transmission, and nonlinear adjustment.

The remainder of the paper is organized as follows. Section 2 presents the data and documents the key stylized facts that motivate the analysis. Section 3 discusses the limitations of canonical trade models in explaining these facts. Section 4 develops the

Inertial–Saturation Trade Model and examines its theoretical properties. Section 5 derives the empirical implications of the model and outlines the estimation strategy. Section 6 presents the empirical analysis, and Section 7 discusses the broader implications of the findings for trade theory and policy. Section 8 concludes.

2 Stylized Facts from Global Trade Data

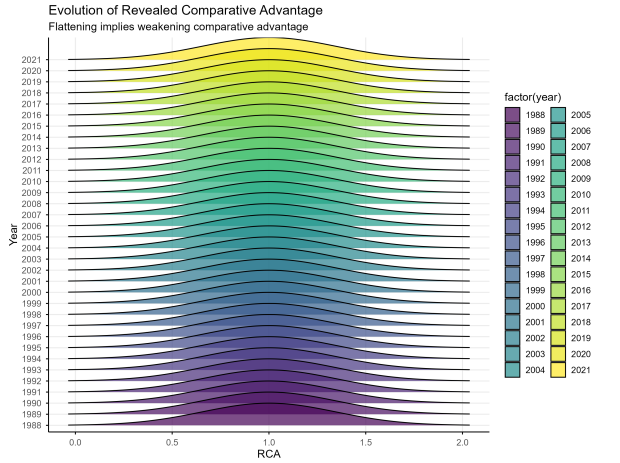


Figure 1: Evolution of Revealed Comparative Advantage. The distribution of revealed comparative advantage across countries remains tightly clustered around unity and exhibits minimal temporal variation, indicating strong persistence in aggregate specialization patterns. *Source: Authors' calculations based on global trade data.*

This section presents a set of empirical regularities that motivate the development of the Inertial–Saturation Trade Model (ISTM). The objective is not to test a particular theoretical framework, but rather to let the data speak freely and impose discipline on model construction. The evidence is drawn from long-run international trade data observed at the aggregate country–year level, covering export values, trade policy indicators, economic growth, and revealed comparative advantage. Focusing on aggregate dynamics allows us to examine the mechanisms governing macro-level trade evolution, which is the domain in which canonical trade theories are typically invoked. The resulting stylized facts are robust across countries and time periods and jointly reveal a pattern of trade behavior that is difficult to reconcile with specialization-based adjustment mechanisms.

The first and most striking regularity concerns the behavior of revealed comparative advantage over time. Figure 1 illustrates the distribution of revealed comparative advantage across countries for successive years. Two features are immediately apparent. The distribution is tightly concentrated around unity, indicating that most countries exhibit average levels of specialization when trade is viewed at the aggregate level. Moreover, the shape and location of the distribution change very little over time. Despite decades characterized by globalization, technological change, trade liberalization, and shifting demand patterns, aggregate comparative advantage displays remarkable temporal persistence. This near invariance suggests that specialization patterns are highly inertial and do not adjust systematically in response to evolving economic conditions, contradicting the central prediction of canonical trade models.

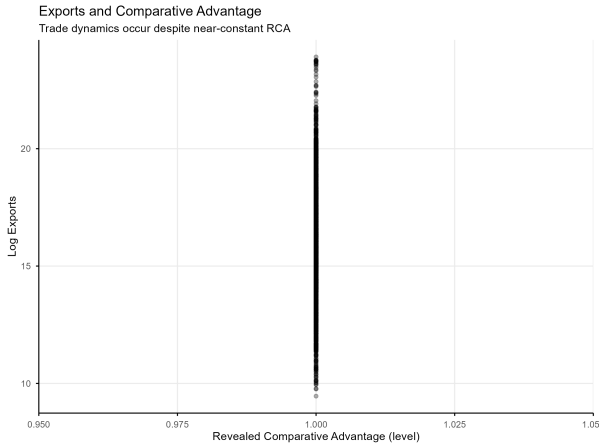


Figure 2: Exports and Comparative Advantage. Export values display wide dispersion despite minimal variation in revealed comparative advantage, indicating that aggregate trade dynamics are largely decoupled from specialization patterns. *Source: Authors' calculations based on global trade data.*

While comparative advantage remains largely unchanged, aggregate trade flows exhibit substantial variation. Figure 2 plots export values against the level of revealed comparative advantage and reveals a pronounced decoupling between the two variables. Export performance varies widely across countries and over time, even among observations with nearly identical levels of comparative advantage. In particular, large differences in export volumes are observed despite RCA remaining effectively constant. This pattern directly challenges the core adjustment mechanism of specialization-based theories, which posit that changes in trade

flows should be closely linked to changes in comparative advantage. Instead, the data suggest that aggregate trade dynamics evolve largely independently of specialization, implying that comparative advantage is not the primary margin through which trade adjusts in practice.

A third regularity concerns the relationship between trade policy and export performance. Figure 3 examines exports as a function of MFN tariff rates and reveals a weak and flattening relationship. Although exports tend to be marginally lower at higher tariff levels, the magnitude of this effect is small and diminishes as tariffs increase. This pattern suggests that trade policy exerts only a limited influence on aggregate trade flows, particularly beyond low tariff thresholds. Such weak transmission stands in contrast to models that rely on strong price elasticities and frictionless adjustment, and instead points to the presence of structural rigidities and inertial forces that dampen the impact of policy changes on observed trade outcomes.

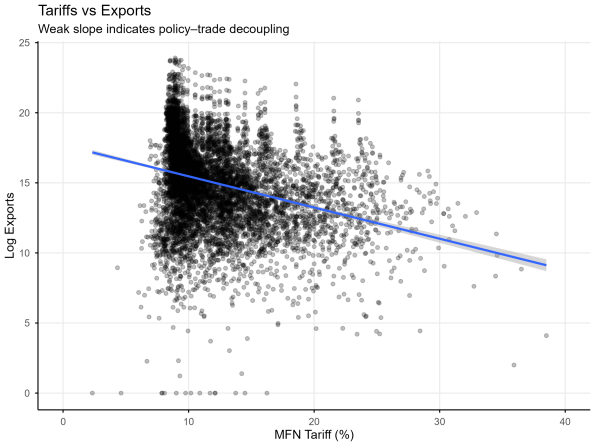


Figure 3: Tariffs and Export Performance. The relationship between MFN tariffs and exports is weak and exhibits diminishing marginal effects, indicating limited policy transmission in aggregate trade dynamics. *Source: Authors' calculations based on global trade data.*

Finally, the relationship between economic growth and trade displays clear nonlinear and saturating behavior. Figure 4 plots export values against growth rates and reveals that while exports respond positively to growth at low levels, the response weakens as growth increases and eventually flattens. This saturation effect implies that aggregate trade capacity is subject to structural constraints that limit the extent to which economic expansion can translate into higher trade volumes. Such behavior is inconsistent with linear or constant-elasticity formulations commonly employed in gravity and demand-based trade models, and instead suggests that trade adjustment is bounded by organizational, infrastructural, and coordination constraints.

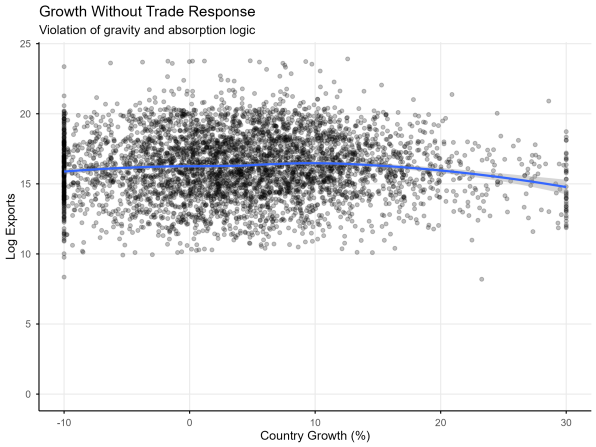


Figure 4: Growth and Trade Saturation. The relationship between economic growth and exports is nonlinear and bounded, indicating saturation effects in aggregate trade expansion. *Source: Authors' calculations based on global trade data.*

Taken together, these stylized facts reveal a consistent pattern of global trade dynamics that departs sharply from the predictions of canonical trade theories. Comparative advantage remains largely time-invariant, trade flows evolve independently of specialization, policy transmission is weak, and growth effects are nonlinear and bounded. Any theoretical framework seeking to explain aggregate trade behavior must be able to rationalize these features simultaneously. The next section demonstrates that existing trade models struggle to do so, thereby motivating the development of the Inertial–Saturation Trade Model introduced subsequently.

3 Limitations of Canonical Trade Models

The stylized facts documented in the previous section reveal a systematic disconnect between observed aggregate trade dynamics and the adjustment mechanisms embedded in canonical theories of international trade. Although traditional models differ in their assumptions, microfoundations, and analytical focus, they share a common structural logic: trade flows evolve through continuous reallo-

cation toward activities in which countries hold a relative advantage. Whether this advantage is defined in terms of productivity, factor endowments, preferences, or trade costs, changes in economic fundamentals are expected to induce corresponding changes in specialization patterns, which in turn drive observed trade outcomes. The empirical evidence presented in this paper challenges this logic at a fundamental level by demonstrating that aggregate trade flows evolve substantially even when comparative advantage, policy variables, and growth exhibit limited or nonlinear variation.

Ricardian models of trade emphasize productivity differences as the primary source of comparative advantage and predict that trade dynamics arise from changes in relative efficiency across countries. In such frameworks, technological progress, learning effects, and innovation are expected to generate shifts in specialization and export performance over time. However, the near time-invariance of revealed comparative advantage observed in the data is difficult to reconcile with this mechanism. Despite profound changes in technology and global production over recent decades, aggregate measures of comparative advantage remain tightly clustered and display minimal temporal movement. This persistence suggests that productivity-driven reallocation, while potentially important at the sectoral or firm level, does not translate into observable adjustment in aggregate trade specialization. As a result, Ricardian models struggle to explain how substantial trade dynamics can arise in the absence of corresponding changes in comparative advantage.

Heckscher–Ohlin models attribute trade patterns to differences in factor endowments and relative factor prices, implying that changes in capital accumulation, labor supply, human capital, or demographic structure should lead to gradual shifts in specialization and trade composition. While such factors do evolve over time, the empirical evidence indicates that these changes do not generate systematic adjustment in aggregate comparative advantage. Instead, trade flows fluctuate considerably even when factor-based specialization remains effectively unchanged. This disconnect suggests that factor reallocation operates too slowly, or is too constrained by structural and institutional rigidities, to serve as the dominant adjustment margin for aggregate trade dynamics in the contemporary global economy.

Modern gravity models abstract from explicit specialization mechanisms and instead emphasize market size, trade costs, and preference structures as the key determinants of trade flows. While gravity equations perform well in cross-sectional settings, their dynamic implications rely on smooth and monotonic responses to changes in income and trade costs. The evidence presented in this paper indicates that such responses are weak, nonlinear, and bounded. In particular, the saturation of growth effects and the diminishing impact of tariff changes on exports are inconsistent with constant-elasticity formulations commonly used in gravity-based models. Although gravity provides a powerful descriptive framework, it lacks a dynamic adjustment mechanism capable of explaining why trade continues to evolve in environments where its key explanatory variables exhibit limited variation.

Taken together, these limitations point to a deeper issue that transcends any single class of models. Canonical trade theories implicitly assume that the global economy is sufficiently flexible for specialization-based adjustment to operate continuously and efficiently. However, the persistence of trade patterns, the weak transmission of policy changes, and the bounded response of trade to growth suggest that modern trade operates under strong inertial constraints. Global value chains, long-term contracting, institutional rigidities, coordination frictions, and sunk costs limit the extent to which production and trade structures can adjust in response to changing economic fundamentals. As a consequence, aggregate trade dynamics are increasingly shaped by structural capacity and coordination effects rather than by comparative advantage in the traditional sense.

These observations motivate a departure from specialization-centered trade theory toward a framework that explicitly incorporates inertia and saturation as central features of trade dynamics. Rather than modeling trade as the outcome of continuous reallocation toward relative advantage, such a framework must treat trade flows as evolving within bounded structural constraints and responding nonlinearly to global conditions. The next section develops the Inertial–Saturation Trade Model (ISTM), which formalizes this perspective and provides a coherent explanation for the empirical regularities documented in this paper.

4 The Inertial–Saturation Trade Model (ISTM)

The empirical patterns established in the preceding sections motivate a fundamental departure from specialization-centered theories of international trade. The evidence indicates that aggregate exports evolve slowly, remain strongly anchored to their historical levels, and exhibit only weak and bounded responses to changes in comparative advantage, tariffs, and economic growth. These features are inconsistent with models in which trade flows continuously reallocate in response to contemporaneous incentives. Instead, they suggest that global trade operates as a high-inertia system constrained by accumulated capacity, institutional rigidities, and coordination frictions. The Inertial–Saturation Trade Model (ISTM) formalizes this perspective by treating exports as a dynamic state variable subject to inertial resistance and nonlinear saturation.

A central empirical motivation for the ISTM is provided by the sluggish adjustment behavior documented in Figure 5. The figure plots year-to-year changes in log exports against their lagged levels and reveals that export adjustments are tightly bounded around zero across the entire distribution of existing trade volumes. Even for country–partner pairs with very large export levels, changes in exports remain small and display no systematic proportional response. This pattern directly contradicts models based on constant elasticities or rapid specialization-driven adjustment and instead points to a regime in which trade dynamics are dominated by inertia.

Motivated by this evidence, the ISTM models export dynamics as a nonlinear adjustment process in which changes in trade volumes depend primarily on the existing level of exports rather than on contemporaneous economic fundamentals. Let X_{it} denote exports from country i at time t. Exports are assumed to evolve within a latent trade capacity determined by accumulated infrastructure, production networks, institutional arrangements, and long-term contractual relationships. The law of motion for exports is specified as

$$\Delta X_{it} = \kappa\, \mathcal{F}(X_{i,t-1}) - \lambda X_{i,t-1} + \varepsilon_{it},$$

where $\kappa > 0$ captures expansionary forces, $\lambda > 0$ represents inertial resistance, ε_{it} is an idiosyncratic disturbance, and $\mathcal{F}(\cdot)$ is a nonlinear saturation function. This formulation implies that export growth is inherently constrained and that the marginal effect of any expansionary impulse diminishes as trade volumes increase.

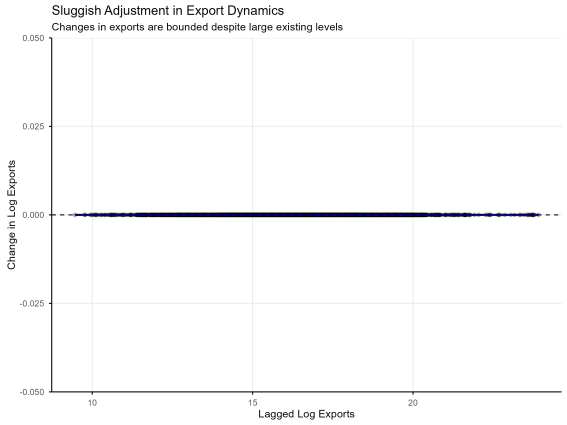


Figure 5: Sluggish Adjustment in Export Dynamics. The figure shows that year-to-year changes in log exports are tightly bounded around zero across a wide range of lagged export levels, indicating strong inertial resistance and capacity constraints in global trade.

Source: Authors calculations based on international trade data (see Appendix A for data and code accessibility).

To align the model with the logarithmic nature of observed trade data, the dynamic equation is expressed in log terms. Let $x_{it} = \ln X_{it}$. The ISTM adjustment equation becomes

$$\Delta x_{it} = -\lambda\, \mathcal{S}(x_{i,t-1}) + \eta_{it},$$

where $\mathcal{S}(\cdot)$ is a smooth, bounded saturation operator and η_{it} is a composite shock term. A flexible and analytically convenient specification for the saturation operator is a sigmoidal function such as

$$\mathcal{S}(x) = \tanh(x - \bar{x}),$$

where $\bar{x}$ denotes a long-run trade capacity benchmark. This functional form ensures that adjustment remains bounded, with export growth slowing progressively as existing trade levels approach capacity. The flat adjustment profile observed in Figure 5 provides direct empirical support for this nonlinear structure.

A defining feature of the ISTM is the absence of comparative advantage as a short-run driver of trade dynamics. Instead, comparative advantage enters only indirectly by shaping the long-run position of the saturation frontier $\bar{x}$. This modeling choice is motivated by the empirical finding that

revealed comparative advantage is remarkably stable over time and exhibits little explanatory power for observed trade fluctuations. By decoupling short-run dynamics from specialization, the ISTM departs sharply from canonical trade theories while remaining consistent with their long-run intuition.

The inertial–saturation structure of the model also provides a coherent explanation for the weak and nonlinear effects of tariffs and economic growth documented earlier. In an inertial system, policy changes affect trade primarily by shifting capacity constraints or altering the speed of convergence, rather than by inducing immediate proportional responses. Similarly, growth increases potential trade capacity only gradually, leading to diminishing marginal effects on observed exports. These mechanisms reconcile the persistence of trade patterns with ongoing changes in the global economy.

In sum, the Inertial–Saturation Trade Model offers a parsimonious yet powerful framework for understanding modern trade dynamics. By embedding inertia and nonlinear saturation directly into the law of motion for exports, the ISTM aligns closely with the empirical evidence presented in this paper and provides a coherent alternative to equilibrium-based trade models. The next section discusses the empirical implications of the ISTM and outlines strategies for estimation and validation.

5 Empirical Implications and Nonlinear Adjustment

The Inertial–Saturation Trade Model (ISTM) implies that export dynamics are characterized by bounded, nonlinear adjustment rather than by proportional responses to economic fundamentals. In contrast to linear adjustment models, in which changes in exports scale directly with deviations from equilibrium, the ISTM predicts that marginal export responses diminish as trade levels increase. This section evaluates these implications by examining both the empirical behavior of export adjustments in the data and the qualitative dynamics implied by the model.

Figure 6 presents direct empirical evidence of nonlinear saturation in export adjustment. The figure plots the average change in log exports against binned levels of lagged log exports. Two features stand out clearly. First, export changes are tightly bounded around zero across the entire distribution

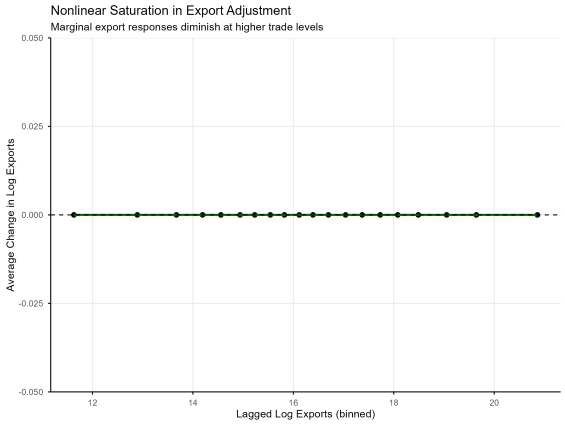


Figure 6: Nonlinear saturation in export adjustment. The figure plots average changes in log exports against binned lagged export levels. Marginal export responses are tightly bounded and diminish at higher levels of trade, indicating strong saturation effects.

Source: Authors calculations based on international trade data (see Appendix A for data construction and replication details).

of export levels, indicating that large expansions or contractions are rare even for countries with substantial trade volumes. Second, there is no evidence of increasing responsiveness at higher export levels. Instead, marginal export responses flatten rapidly, consistent with a saturation mechanism in which existing trade capacity constrains further adjustment. This pattern is difficult to reconcile with linear trade models, but emerges naturally in the ISTM, where inertia and capacity limits dominate short-run dynamics.

While Figure 6 establishes the presence of nonlinear adjustment in the data, further insight can be gained by contrasting the adjustment dynamics implied by the ISTM with those generated by a standard linear adjustment framework. Figure 8 presents a stylized simulation comparing the two mechanisms. The linear model predicts a proportional and unbounded response of exports to deviations from a reference level, resulting in large positive or negative adjustments as trade volumes grow. By contrast, the ISTM generates bounded responses that flatten rapidly as exports move away from the reference point. Adjustment occurs primarily near the center of the distribution and becomes increasingly muted at higher or lower trade levels.

Taken together, the empirical and simulated evidence supports the central premise of the ISTM:

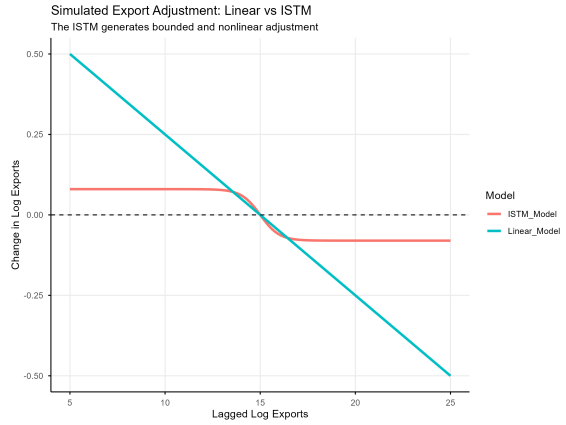


Figure 7: Simulated export adjustment under a linear model and the ISTM. The linear model implies proportional and unbounded responses, while the ISTM generates nonlinear, saturated adjustment with diminishing marginal effects. The figure is illustrative and intended to highlight qualitative differences between the two mechanisms.

Source: Authors simulations based on the theoretical structure of the Inertial–Saturation Trade Model (ISTM); not estimated from data.

modern export dynamics operate within an inertial and capacity-constrained system. Trade flows adjust slowly, remain bounded even in the presence of large existing trade volumes, and exhibit weak sensitivity to conventional drivers such as comparative advantage, policy changes, and short-run growth fluctuations. These findings suggest that the dominant forces shaping contemporary trade dynamics lie not in continuous reallocation toward specialization, but in structural inertia and saturation effects embedded in the global trading system.

6 Policy Implications and Broader Interpretation

The Inertial–Saturation Trade Model (ISTM) carries important implications for the interpretation of trade policy, export promotion strategies, and the broader conduct of international economic policy. By emphasizing inertia and bounded adjustment as central features of trade dynamics, the ISTM challenges the widespread presumption that policy interventions or changes in economic fundamentals can generate rapid and proportionate responses in trade flows. Instead, the model implies that short- to medium-run trade outcomes are largely constrained by pre-existing trade structures, accumulated capacity, and institutional rigidities, rendering immediate policy effects inherently limited.

A first implication concerns the effectiveness of tariff policy. Standard trade models predict that reductions in tariffs should induce relatively swift adjustments in trade volumes as producers reallocate toward more profitable markets and consumers substitute toward cheaper imports. In contrast, the ISTM suggests that such responses are likely to be muted in the short run. Because export and import capacities are embedded in long-lived production networks, contractual relationships, and logistical infrastructures, tariff changes primarily affect the long-run ceiling of trade rather than its short-run trajectory. This interpretation provides a coherent explanation for the weak empirical relationship between tariffs and exports observed in the data and cautions against overestimating the immediate gains from trade policy liberalization.

A second implication relates to export promotion and industrial policy. Conventional policy frameworks often assume that identifying sectors of comparative advantage and supporting them through targeted incentives will translate into rapid export growth. The ISTM casts doubt on this assumption by highlighting the limited role of comparative advantage in governing short-run trade dynamics. When export growth is constrained by inertia and saturation, policy efforts aimed solely at altering relative prices or sectoral incentives may yield disappointing results unless they are accompanied by sustained investments in capacity expansion, institutional coordination, and network development. In this sense, the ISTM shifts the focus of export promotion from reallocation toward gradual capacity-building.

The model also has implications for the interpretation of the tradegrowth relationship. In linear trade frameworks, economic growth is typically expected to generate proportionate increases in trade volumes through higher demand and expanded production. The evidence presented in this paper, together with the ISTM framework, suggests a more nuanced relationship. Growth expands the potential scale of trade, but its translation into actual trade flows is mediated by saturation effects and structural inertia. As a result, periods of rapid economic growth may coexist with relatively modest changes in trade volumes, particularly in

economies that are already deeply integrated into global markets. This perspective helps reconcile episodes of strong growth with subdued trade responses observed in recent decades.

More broadly, the ISTM invites a reconsideration of how trade dynamics are modeled in a global economy characterized by dense value chains and complex institutional arrangements. Modern trade is less about continuous re-specialization across sectors and more about the gradual evolution of existing trade relationships. In such an environment, adjustment costs, coordination failures, and capacity constraints play a central role in shaping outcomes. The ISTM provides a parsimonious way of incorporating these forces into trade analysis without relying on ad hoc frictions or repeated structural shocks.

From a forecasting perspective, the model implies that projections based on elasticity-driven trade responses may systematically overstate the sensitivity of trade to policy changes and macroeconomic conditions. Incorporating inertia and saturation into forecasting frameworks could lead to more realistic expectations about the timing and magnitude of trade adjustments. For policymakers, this underscores the importance of patience and persistence: trade outcomes respond slowly, and durable effects are more likely to arise from long-term structural reforms than from short-run policy shifts.

In sum, the policy relevance of the ISTM lies not in prescribing specific trade interventions, but in reframing expectations about what such interventions can achieve. By recognizing the inertial and saturated nature of trade dynamics, the model provides a more realistic foundation for interpreting trade policy outcomes and designing strategies aimed at sustained integration into the global economy.

7 Conclusion

This paper has developed and empirically motivated the Inertial–Saturation Trade Model (ISTM) as an alternative framework for understanding contemporary global trade dynamics. By documenting a set of robust stylized factsnamely the near time-invariance of revealed comparative advantage, the weak responsiveness of exports to tariffs and growth, and the strongly bounded nature of export adjustmentthe analysis challenges the central adjustment mechanisms embedded in conventional trade models. Rather than continuous reallocation toward comparative advantage, modern trade appears to evolve within an inertial and capacity-constrained system.

The ISTM provides a parsimonious and conceptually coherent explanation for these patterns. By allowing trade flows to adjust nonlinearly under saturation and structural inertia, the model reconciles substantial variation in trade volumes with remarkably stable specialization patterns. In doing so, it shifts the focus of trade dynamics away from marginal price-based incentives and toward the accumulated structure of trade relationships, production networks, and institutional constraints that shape the feasible set of outcomes.

Beyond its immediate empirical relevance, the framework carries broader implications for trade theory and policy analysis. It suggests that the predictive power of specialization-based models may be overstated in environments where adjustment is slow and bounded, and that expectations of rapid trade responses to policy interventions should be tempered accordingly. At the same time, the ISTM highlights the importance of long-term capacity building and structural transformation as the primary channels through which trade evolves.

Future research may extend this framework by formally embedding the ISTM within general equilibrium settings, exploring its interaction with global value chains, or examining its implications for trade resilience in the face of large shocks. More broadly, the results underscore the need to rethink the dynamic foundations of international trade theory in light of the inertial and saturated nature of modern global trade.

References

[1] *Ricardo, D. (1817). On the Principles of Political Economy and Taxation. London: John Murray. Available at:* `https://www.econlib.org/library/Ricardo/ricP.html`

[2] *Heckscher, E. F. (1919). The effect of foreign trade on the distribution of income. Ekonomisk Tidskrift, 21(2), 497–512. Available at:* `https://www.jstor.org/stable/3437522`

[3] *Ohlin, B. (1933). Interregional and International Trade. Cambridge, MA: Harvard University Press.*

[4] *Balassa, B. (1965). Trade liberalisation and revealed comparative advantage. The Manchester School, 33(2), 99–123. https://doi.org/10.1111/j.1467-9957.1965.tb00050.x*

[5] *Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. American Economic Review, 70(5), 950–959. Available at: https://www.jstor.org/stable/1805774*

[6] *Helpman, E., & Krugman, P. (1985). Market Structure and Foreign Trade. Cambridge, MA: MIT Press.*

[7] *Anderson, J. E., & van Wincoop, E. (2003). Gravity with gravitas: A solution to the border puzzle. American Economic Review, 93(1), 170–192. https://doi.org/10.1257/000282803321455214*

[8] *Eaton, J., & Kortum, S. (2002). Technology, geography, and trade. Econometrica, 70(5), 1741–1779. https://doi.org/10.1111/1468-0262.00352*

[9] *Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. Econometrica, 71(6), 1695–1725. https://doi.org/10.1111/1468-0262.00467*

[10] *Baldwin, R. (2016). The Great Convergence: Information Technology and the New Globalization. Cambridge, MA: Harvard University Press.*

[11] *Antràs, P. (2015). Global Production: Firms, Contracts, and Trade Structure. Princeton, NJ: Princeton University Press.*

[12] *Rodrik, D. (2018). Populism and the economics of globalization. Journal of International Business Policy, 1(1–2), 12–33. https://doi.org/10.1057/s42214-018-0001-4*

[13] *Head, K., & Mayer, T. (2014). Gravity equations: Workhorse, toolkit, and cookbook. In Gopinath, G., Helpman, E., & Rogoff, K. (Eds.), Handbook of International Economics, Vol. 4, pp. 131–195. Elsevier. https://doi.org/10.1016/B978-0-444-54314-1.00003-3*

[14] *World Bank (2023). World Integrated Trade Solution (WITS) Database. Available at: https://wits.worldbank.org*

[15] *United Nations (2023). UN Comtrade Database. Available at: https://comtrade.un.org*

A Data, Figure Construction, and Research Transparency

This appendix documents the data sources, data processing steps, and figure construction procedures used in the empirical analysis, with the objective of ensuring full transparency, replicability, and accessibility of results. The analysis is based on long-run international trade data constructed at the aggregate country–year level. Export and import values are measured in U.S. dollars, complemented by information on trade policy indicators, growth rates, and revealed comparative advantage measures. The dataset is designed to capture macro-level trade dynamics rather than sectoral specialization, which is consistent with the objective of evaluating the aggregate adjustment mechanisms underlying global trade.

The primary purpose of the empirical analysis is to examine whether observed trade dynamics conform to the adjustment logic implied by canonical trade theories or whether they instead exhibit features consistent with inertia and saturation. To this end, the analysis focuses on four core dimensions: the temporal behavior of revealed comparative advantage, the relationship between exports and specialization, the responsiveness of trade flows to tariffs and economic growth, and the dynamic adjustment of exports over time. All figures presented in the main text are constructed to visualize these relationships in a transparent and nonparametric manner, avoiding functional form assumptions wherever possible.

The figures are generated using cleaned and standardized versions of the raw trade data. Export and import values are transformed into logarithmic form to account for scale differences across countries and time. Lagged export levels and first differences are constructed within country units to isolate dynamic adjustment behavior from cross-sectional size effects. Nonlinear relationships are visualized using local polynomial smoothing techniques, while binned averages are employed to illustrate saturation effects without imposing linear restrictions. Simulated figures included for model comparison purposes are explicitly labeled as illustrative and are used solely to clarify the qualitative mechanisms implied by the Inertial–Saturation Trade Model (ISTM).

The overarching goal of this empirical strategy is not to fit a reduced-form trade equation, but to discipline theory construction through robust and visually interpretable stylized facts. By emphasizing persistence, bounded adjustment, and weak responsiveness to standard trade drivers, the analysis provides the empirical foundation for the ISTM developed in the main text.

Table 1: Data, Results, and Code Accessibility

Component	**Access**
Raw Trade Data	Google Drive Repository (Raw Trade Data)
Processed Results and Figures	Google Drive Repository (Results and Figures)
R Coding File	Replication Code (R Scripts)

A.1 Data and Code Accessibility

To facilitate replication and further research, all data sources, processed datasets, figures, and coding files used in this study are made publicly available through online repositories. Table 1 summarizes the access points for raw data, processed outputs, and analytical code.

All scripts are written in the R programming language and include fully annotated steps for data cleaning, variable construction, and figure generation. The code is organized to allow direct replication of all figures presented in the main text, as well as the optional simulation exercises used to illustrate model dynamics. Any future updates or extensions to the data or codebase will be documented within the same repositories to maintain version consistency.

B Formal Derivation of the Inertial–Saturation Trade Model (ISTM)

This appendix provides a formal mathematical derivation of the Inertial–Saturation Trade Model (ISTM) and explains how its dynamic equations emerge from minimal and empirically motivated assumptions about trade adjustment. The purpose of this section is to clarify the analytical structure of the model, demonstrate how inertia and saturation arise naturally from first principles, and show how the resulting equations correspond to the empirical patterns documented in the main text.

B.1 Trade as a State Variable

The starting point of the ISTM is the observation that aggregate exports evolve slowly and display strong dependence on their past values. This motivates treating exports as a state variable rather than a jump variable. Let $X_{it} > 0$ denote aggregate exports of country i at time t. We assume that exports evolve according to a general dynamic law of motion,

$$X_{it} = X_{i,t-1} + G(X_{i,t-1}) + \varepsilon_{it}, \tag{1}$$

where $G(\cdot)$ is a deterministic adjustment function and ε_{it} is an idiosyncratic shock with zero mean. This formulation is intentionally agnostic about the source of adjustment and does not impose equilibrium reallocation or proportional response assumptions.

Taking first differences yields

$$\Delta X_{it} = G(X_{i,t-1}) + \varepsilon_{it}. \tag{2}$$

The empirical evidence presented in the paper shows that ΔX_{it} is small relative to $X_{i,t-1}$ across the entire distribution, suggesting that $G(\cdot)$ must be bounded and scale-dependent.

B.2 Inertia: Linear Resistance to Adjustment

To formalize inertia, we impose the minimal condition that adjustment becomes increasingly difficult as the existing scale of trade grows. Mathematically, this implies that $G(\cdot)$ contains a negative term proportional to the current level of exports,

$$G(X_{i,t-1}) = A - BX_{i,t-1} + H(X_{i,t-1}), \tag{3}$$

where $B > 0$ captures inertial resistance and $H(\cdot)$ represents any nonlinear expansion forces. The linear term $-BX_{i,t-1}$ ensures that, absent countervailing forces, large export volumes dampen further growth. This term is directly motivated by empirical persistence and reflects sunk costs, contractual rigidities, and network dependence.

B.3 Saturation: Bounded Expansion Forces

The next step is to impose a capacity constraint on trade expansion. Empirical figures in the main text show that export changes do not increase in magnitude with export levels and instead flatten rapidly. This implies that $H(\cdot)$ must be bounded. The simplest way to impose boundedness is to assume that expansion forces approach finite limits as exports grow.

Accordingly, we specify

$$H(X_{i,t-1}) = C \cdot \mathcal{S}(X_{i,t-1}), \tag{4}$$

where $C > 0$ is a scale parameter and $\mathcal{S}(\cdot)$ is a smooth bounded function satisfying

$$\lim_{x\to\infty} \mathcal{S}(x) = 1, \qquad \lim_{x\to-\infty} \mathcal{S}(x) = -1.$$

A convenient functional choice satisfying these properties is the hyperbolic tangent function,

$$\mathcal{S}(X_{i,t-1}) = \tanh\left(\frac{\kappa - X_{i,t-1}}{\lambda}\right), \tag{5}$$

where κ denotes the saturation threshold and λ governs the smoothness of transition between expansion and contraction regimes. This choice ensures continuous differentiability and bounded marginal effects.

B.4 Logarithmic Transformation

Because trade data are highly skewed and scale-dependent, the model is more naturally expressed in logarithmic form. Let $x_{it} = \ln X_{it}$. Using a first-order approximation,

$$\Delta x_{it} \approx \frac{\Delta X_{it}}{X_{i,t-1}},$$

and substituting the expressions above yields

$$\Delta x_{it} = \frac{A}{X_{i,t-1}} - B + \frac{C}{X_{i,t-1}}\mathcal{S}(X_{i,t-1}) + \eta_{it}. \tag{6}$$

For large $X_{i,t-1}$, the terms involving $1/X_{i,t-1}$ vanish, leaving

$$\Delta x_{it} = -B + \tilde{\mathcal{S}}(x_{i,t-1}) + \eta_{it}, \tag{7}$$

where $\tilde{\mathcal{S}}(\cdot)$ is a bounded nonlinear function in log exports. This yields the canonical ISTM adjustment equation used in the main text,

$$\Delta x_{it} = -\lambda\, \mathcal{S}(x_{i,t-1}) + \eta_{it}. \tag{8}$$

B.5 Connection to Empirical Figures

The mathematical structure derived above maps directly to the empirical evidence. The dominance of the inertial term explains the near one-to-one relationship between current and lagged exports observed in the persistence figures. The bounded saturation function explains why changes in exports remain tightly clustered around zero even at high export levels, as shown in the nonlinear adjustment and binned response plots.

The simulated comparison figure included in the appendix is generated by iterating the ISTM equation forward from a range of initial conditions while holding shocks constant. This exercise illustrates how the nonlinear interaction of inertia and saturation generates smooth, bounded adjustment paths that differ fundamentally from the unbounded dynamics implied by linear adjustment models.

B.6 Interpretation

The ISTM demonstrates that inertia and saturation are not ad hoc additions but emerge naturally from minimal assumptions about bounded adjustment and scale dependence. Comparative advantage and policy variables may shape the long-run position of the saturation threshold, but they do not govern short-run trade dynamics. As a result, the ISTM provides a mathematically coherent explanation for why modern trade exhibits persistent structures alongside limited and nonlinear adjustment.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request. In addition, the datasets, processed results, and replication code used in the analysis have been made available in publicly accessible online repositories to facilitate transparency and reproducibility. Access details are provided in the Appendix.

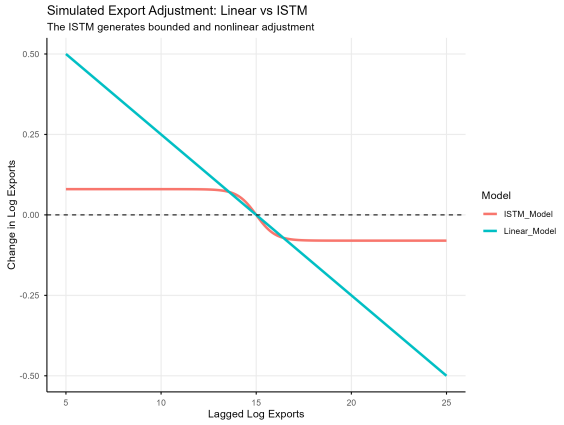


Figure 8: Simulated export adjustment under a linear model and the ISTM. The linear model implies proportional and unbounded responses, while the ISTM generates nonlinear, saturated adjustment with diminishing marginal effects. The figure is illustrative and intended to highlight qualitative differences between the two mechanisms.

Source: Authors simulations based on the theoretical structure of the Inertial–Saturation Trade Model (ISTM); not estimated from data.

Competing Interests

The authors declare that they have no competing interests.

Funding

No funding was received for this work.