Modelling Dynamic Dual-Sourcing Supply Chain Resilience under Tariff Burden Sharing

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Abstract

Tariff shocks have become an increasingly common source of disruption in global supply chains. Unlike physical disruptions, tariffs primarily act as cost shocks that propagate through pricing decisions and sourcing adjustments across supply chain tiers. This study develops a system dynamics simulation framework to analyse how tariff transmission and sourcing adaptation jointly influence supply chain resilience. The model represents a two-echelon manufacturer–retailer supply chain operating under a dual-sourcing strategy involving a foreign and a domestic manufacturer. Tariff burden-sharing is governed by two parameters: the incidence share, representing the portion of the tariff absorbed by the foreign manufacturer, and the pass-through share, representing the portion transferred to consumers through retail price adjustments. A dynamic allocation mechanism allows the retailer to shift procurement toward the domestic supplier as a resilience strategy. System performance is evaluated using five resilience metrics: recovery time, lead time ratio, fill rate, profit, and lost contribution. Simulation results show that the relationship between tariff pass-through and system recovery is conditional on the presence of sourcing flexibility. Without dual sourcing, higher pass-through destabilizes the system by reducing demand, whereas with dual sourcing it improves recovery through supply reallocation. The results further show that resilience strategies redistribute disruption rather than eliminate it, with the domestic supplier absorbing a larger share of operational stress. The findings also highlight non-linear and configuration-dependent effects arising from the interaction of tariff severity, burden-sharing, and sourcing adaptation. The proposed framework provides a quantitative tool for analysing tariff transmission and designing resilient supply chains under trade policy uncertainty.

1 Introduction

Global supply chains have become increasingly unstable due to geopolitical tensions, trade disputes, and policy interventions. One of the most prominent policy instruments affecting international trade is the tariff, defined as a tax imposed by a government on goods imported from other countries. Tariffs are implemented for multiple purposes, including protecting domestic industries from foreign competition, generating government revenue, and addressing distortions in international pricing. Tariffs affect all actors within the supply chain, including manufacturers, retailers, and consumers. An increase in import prices typically leads to reduced demand and adjustments in sourcing decisions.

In order to mitigate the impact of such shocks, firms often adopt resilience strategies such as dual sourcing, maintaining buffer inventory, or product substitution. Dual sourcing, in particular, allows firms to maintain relationships with alternative suppliers, often domestic manufacturers, to ensure continuity of supply during disruptions. Recent developments illustrate the growing importance of tariffs in shaping global supply chains. For instance, Canadian consumers reported replacing foreign goods with domestic alternatives in response to tariff threats, reflecting substitution behaviour driven by trade policy (Reid, 2025). Similarly, India imposed a three-year tariff on certain steel products to curb low-cost imports from countries such as China, Vietnam, and Nepal, while simultaneously considering tariff reductions on automobiles during trade negotiations with the European Union (Reuters Staff, 2025; Shah and Blenkinsop, 2026). The United States has also imposed tariffs of up to 126% on solar imports from India, Indonesia, and Laos, citing concerns over unfair subsidies that undermine domestic producers (Moneycontrol World Desk, 2026). In April 2025, the U.S. administration introduced sweeping tariffs, including a baseline 10% levy on all imports alongside higher country-specific rates, triggering retaliatory tariff escalation by China (Harithas et al., 2025).

Tariff shocks differ from traditional supply chain disruptions because they primarily manifest as cost shocks that propagate through pricing decisions across supply chain tiers. Unlike physical disruptions such as supply shortages or transportation delays, tariffs immediately alter input costs while inducing gradual structural adjustments in sourcing and supplier relationships. The burden of tariffs is not distributed uniformly; instead, it is endogenously allocated among manufacturers, intermediaries, and consumers depending on the pricing strategies, pass-through behavior, and market power. When tariffs are imposed unexpectedly, firms initially respond through price renegotiation within existing supplier relationships, leading to partial cost pass-through and shifts in surplus allocation. However, larger or persistent tariffs may render existing supplier relationships unprofitable, forcing firms to search for alternative suppliers and reorganize their sourcing networks. Since new supplier selection, relationship formation, and operational adjustments involve significant costs and delays, tariff shocks can generate persistent disruptions that extend beyond immediate price effects.

Supply chain resilience refers to the ability of a system to maintain operational functionality during disruptions and recover quickly (Behzadi et al., 2020; Zhao et al., 2011). Disruptions can emerge through four fundamental operational dimensions; demand, supply, transport, and cost; which represent the primary channels through which disturbances propagate within supply chains. In this study, we focus on cost disruptions introduced by tariff shocks over a defined duration. In this context, supply chain resilience depends not only on sourcing locations but also on how the tariff burden is redistributed across supply chain tiers and how effectively firms can reconfigure sourcing and operational strategies.

This study investigates how the distribution of tariff burden among retailers, manufacturers, and consumers influences supply chain resilience. A System Dynamics (SD) modelling approach is employed to quantitatively assess resilience in a two-echelon manufacturer–retailer supply chain. The model incorporates a dual-sourcing resilience strategy in which a domestic manufacturer, initially more expensive, can become relatively cost-competitive for the retailer after the introduction of tariffs. The analysis focuses on the roles of incidence share, pass-through share, and allocation share in shaping supply chain performance and resilience under tariff shocks. Resilience is evaluated using five performance metrics that span the dimensions of time, cost, and quantity: recovery time, lead time ratio (LTR), fill rate (FR), profit, and lost contribution (LC). By capturing the dynamic interactions between tariff transmission and sourcing decisions, the System Dynamics framework enables the analysis of non-linear and time-dependent impacts of tariff shocks on supply chain performance, recovery behaviour, and long-run adaptability.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature on tariff disruptions, supply chain resilience, and system dynamics modelling. Section 3 describes the proposed methodology, including the system dynamics framework, tariff transmission mechanism, and dual-sourcing resilience strategy. It further presents the associated mathematical formulation and simulation settings. Section 4 presents and analyses the findings under both no-resilience and dual-sourcing scenarios across varying tariff levels, incidence shares, and pass-through rates. Section 5 discusses the results and outlines the corresponding managerial insights. Finally, Section 6 concludes the study by summarizing key contributions, acknowledging limitations, and outlining avenues for future research.

2 Literature Review

2.1 Tariff Transmission and Trade Network Effects

Economic research on tariffs has primarily focused on how tariff shocks affect trade flows, prices, and welfare across global production networks. Nagurney et al., 2019 developed a competitive global supply chain network model with tariff-rate quotas and showed that tariffs reduced imports, increased consumer prices, and redistributed profits toward protected domestic firms. They assumed rational equilibrium, no dynamics or adaptation under uncertainty. Similarly, Gnocato et al., 2025 demonstrated that tariffs on intermediate inputs generate larger macroeconomic losses than tariffs on final goods because input cost shocks propagate through production networks. While they provided insights into tariff transmission through production networks, they did not model tariff burden sharing across supply-chain actors.

Recent work has also emphasized the microeconomic mechanisms through which tariffs reshape supply chains. Grossman and Helpman, 2024 showed that small tariffs typically led to renegotiation within existing supplier relationships, whereas larger tariffs induced costly supplier search and supply-chain reorganization. They adopted a comparative-static perspective and did not capture dynamic processes central to understanding repeated trade shocks in the supply-chain. At a more aggregate level, nonlinear dynamic models have also examined tariff–export feedback relationships. For example, Idrisi et al., 2025 developed a three-dimensional nonlinear dynamical system integrating export volumes, tariff rates, and national export competitiveness, and demonstrated that tariff shocks can drive the system toward a low-export equilibrium while sustained protectionism risks locking trade flows into a structurally depressed state. However, their model operates at the level of national trade aggregates and abstracts from tariff transmission across supply chain actors.

These studies highlight that tariff shocks propagate across supply networks through price adjustments, bargaining dynamics, and supplier reconfiguration. However, most of this literature adopts comparative-static or aggregate-level modelling frameworks and therefore does not capture the dynamic operational adjustments that occur within supply chains over time.

2.2 Supply Chain Adaptation to Tariff Shocks

A growing stream of operations and supply chain literature examines how firms adapt their sourcing, pricing, and network structures in response to tariff changes. Chae et al., 2019 proposed a conceptual framework showing that the severity, timing uncertainty, and geographic scope of tariff increases influence firms' decisions to form or dissolve supplier relationships, thereby altering supply base complexity. Similarly, Dong and Kouvelis, 2020 analyzed how tariff escalations affect production location decisions and demonstrated that tariffs discourage centralized production and encourage regionalized supply networks. While these studies provide important insights into how tariffs reshape supply bases and production network configurations, their analyses remain largely conceptual.

Empirical and analytical studies have also highlighted several operational responses to tariff shocks. Guo et al., 2025 showed that tariffs increased retail and direct-selling prices while reducing demand and profits in cross-border e-commerce supply chains. However, their analysis primarily relied on static game-theoretic models and focused on equilibrium outcomes. Bonyuet, 2025 documented managerial strategies used to mitigate tariff impacts, including inventory pre-building, supplier diversification, China+1 sourcing, and supplier renegotiation.

While these studies provided valuable insights into firm-level responses to tariff uncertainty, they generally rely on static models or descriptive analyses and therefore did not capture the dynamic propagation of tariff shocks through operational processes such as inventory adjustment, procurement decisions, and demand feedback.

2.3 Dynamic Modelling of Tariffs and Supply Chain Resilience

Simulation approaches are increasingly used to analyze disruption propagation and resilience in supply chains. Ivanov, 2025 characterized tariff crises as macroeconomic shocks that generated ripple and bullwhip effects across supply networks. Their work highlighted the importance of feedback loops between operational decisions and economic outcomes; however, it remained largely conceptual and methodological, limiting its ability to capture detailed operational dynamics.

Several studies have also applied system dynamics methodology to examine tariff-related operational decisions. K. Choi et al., 2012 incorporated tariffs, shipping timing, and production cost differentials into a system dynamics model of global production and distribution and showed that tariff structures influenced optimal postponement strategies. However, they did not examine dynamic tariff transmission, resilience outcomes, or recovery processes under persistent or volatile tariff regimes. Xin-feng et al., 2022 developed a system dynamics model of international dual-source procurement and demonstrated that tariffs shifted sourcing toward domestic suppliers, with the magnitude of this shift influenced by supplier reliability and behavioral factors. However, their analysis was limited to procurement allocation.

Kadam, 2025 proposed a modular framework combining flexible sourcing, localized manufacturing, elastic contracts, and dynamic inventory buffers. While their work advanced managerial understanding of how digital technologies and modular design can mitigate tariff volatility, it remained conceptual and did not model tariff transmission mechanisms. More recently, Dewi et al., 2025 used system dynamics to analyze the impact of tariff pricing decisions on logistics service demand and profitability, highlighting nonlinear feedback effects between pricing and demand. Their simulation results showed that demand-based dynamic tariff adjustments did not necessarily improve profitability, as tariff–demand feedback loops and capacity utilization effects could offset pricing flexibility. While their study demonstrated the usefulness of system dynamics in capturing nonlinear and feedback-driven impacts of tariff decisions, it was limited to firm-level income optimization and did not examine tariff transmission.

Despite these advances, existing simulation and system dynamics models typically treat tariffs as exogenous cost shocks or assume full cost pass-through to demand. They do not explicitly represent how tariff burdens are distributed across supply-chain actors, nor how such burden allocation influences operational dynamics and resilience outcomes. In particular, tariff burden-sharing has not been modeled as a tunable mechanism that allocates tariff incidence across manufacturers, retailers, and consumers. Furthermore, no existing system dynamics model incorporates a dual-sourcing resilience strategy in which firms dynamically reallocate sourcing toward domestic manufacturers in response to tariff shocks. Addressing these limitations requires dynamic models that explicitly represent tariff transmission mechanisms and their interaction with sourcing adaptation and inventory dynamics over time.

3 Methodology

The objective of this study is to analyse how tariff-induced cost shocks propagate through the supply chain and how sourcing allocation between foreign and local manufacturers influences operational and economic performance. A System Dynamics (SD) model of an inventory–production system for a two-echelon supply chain is developed to simulate supply chain behaviour at an aggregate level (Figure 1). The model depicts a single product two-echelon supply chain structure consisting of a retailer and two upstream manufacturers: a foreign manufacturer (M_1) and a domestic manufacturer (M_2). Under normal operating conditions, the retailer follows a dual-sourcing strategy, allocating majority of its orders to the cheaper foreign manufacturer and the balance to the domestic manufacturer. The foreign manufacturer offers a lower unit selling price but is exposed to tariffs and international trade risks, whereas the domestic manufacturer has a higher production cost but is insulated from cross-border disruptions. The retailer sells the products to end customers.

3.1 Model Formulation

In the System Dynamics representation, stocks represent accumulated quantities over time and are defined as the integral of flows. The work-in-progress (WIP), inventory in warehouse, quantity in transit, inventory, forecasted demand, cumulative lost sales, and cumulative sales (Equations 1–9) are represented as rectangular boxes that capture the accumulation of material and information used in decision support for improving resilience. Flows are functions of auxiliary variables (Equations 19–37) that represent system dynamics and operational decision rules (Equations 10–18). The model assumes unmet demand is treated as lost sales. Demand is forecast using first-order exponential smoothing, which introduces an information delay in the decision-support process for quantity in transit and inventory adjustments required to maintain desired levels.

A fixed delay is incorporated in the delivery rate. The delivery rate, defined as a function of lead time and dispatch rate, conserves the flow of goods and ensures delivery exactly after the specified lead time. The order rate is determined by forecasted demand together with adjustments for quantity in transit and inventory levels. The model is implemented and simulated in Vensim. Simulation outputs are exported and analysed in Python to compute resilience metrics and evaluate system performance under different tariff scenarios.

Stocks:

$$INV\ Manufacturer : INV\ M_t = INV\ M_{n-1} + PCR_t - DR_t \tag{1}$$

$$Inventory : INV_t = INV_{n-1} + DLR_t - SR_t \tag{2}$$

$$Work\ in\ progress : WIP_t = WIP_{n-1} + PR_t - PCR_t \tag{3}$$

$$Quantity\ in\ Transit : QIT_t = QIT_{n-1} + DR_t - DLR_t \tag{4}$$

$$Forecasted\ Demand : FD_t = FD_{n-1} + Change\ in\ Forecast_t \tag{5}$$

$$Forecasted\ Demand : FD\ M_t = FD\ M_{n-1} + Change\ in\ Forecast\ M_t \tag{6}$$

$$Cumulative\ Sales : CS_t = CS_{n-1} + SR_t \tag{7}$$

$$Cumulative\ Lost\ orders : CLO_t = LLO_{n-1} + LO_t \tag{8}$$

$$Cumulative\ Lost\ Sales : CLS_t = CLS_{n-1} + LS_t \tag{9}$$

Flows:

$$Prodn\ Rate : PR_t = Max(0, OR\ M_t) \tag{10}$$

$$Prodn\ Completion\ Rate : PCR_t = PR_{n-LT\ M} \tag{11}$$

$$Dispatch\ Rate : DR_t = Min(Max\ Dispatch\ possible_t,\ RD_t) \tag{12}$$

$$Delivery\ rate : DLR_t = DR_{n-LT} \tag{13}$$

$$Sales\ Rate : SR_t = MIN(Max\ sales\ possible_t,\ CD_t) \tag{14}$$

$$Change\ in\ Forecast_t = (CD_t - FD_t) \cdot \rho \tag{15}$$

$$Change\ in\ Forecast\ M = (RD_t - FD\ M_t) \cdot \rho \tag{16}$$

$$Lost\ Sales : LS_t = CD_t - SR_t \tag{17}$$

$$Lost\ Orders : LO_t = RD_t - DR_t \tag{18}$$

Auxiliary Variables:

$$Perceived\ LT_t = QIT_t /\ DLR_t \tag{19}$$

$$Perceived\ LT\ M_t = WIP_t / PCR_t \tag{20}$$

$$Adjustment\ QIT : Adj\ QIT_t = (Desired\ QIT_t - QIT_t) \cdot \alpha \tag{21}$$

$$Adjustment\ WIP : Adj\ WIP_t = (Desired\ WIP_t - WIP_t) \cdot \alpha \tag{22}$$

$$Adjustmnet\ INV : Adj\ INV_t = (Desired\ INV_t - INV_t) \cdot \beta \tag{23}$$

$$Adjustmnet\ INV\ M : Adj\ INV\ M_t = (Desired\ INV\ M_t - INV\ M_t) \cdot \beta \tag{24}$$

$$Desired\ INV_t = FD_t \cdot \omega \tag{25}$$

$$Desired\ INV\ M_t = FD\ M_t \cdot \omega \tag{26}$$

$$Desired\ QIT_t = FD_t \cdot LT_t \tag{27}$$

$$Desired\ WIP_t = FD\ M_t \cdot LT\ M_t \tag{28}$$

$$Order\ rate : OR_t = Adj\ INV_m + Adj\ QIT_t + FD_t \tag{29}$$

$$Order\ rate\ M : OR\ M_t = Adj\ INV\ M_t + Adj\ QIT\ M_t + FD\ M_t \tag{30}$$

$$Retailer\ Demand : RD_t = Max(0, OR_t) \tag{31}$$

$$Customer\ Demand = Base\ Demand * \left(\frac{unit\ SP}{base\ unit\ SP}\right)^{Elasticity} \tag{32}$$

$$Tariff = unit\_SP_{M1} \cdot \tau \cdot (1 - \phi) \tag{33}$$

$$unit\_CP_{M1} = base\_unit\_CP_M + \theta \cdot Tariff \tag{34}$$

$$unit\_CP_R = (unit\_SP_{M1}(1 - \phi)) + Tariff(1 - \theta) + (\phi \cdot unit\_SP_{M2}) \tag{35}$$

$$unit\_SP_R = base\_unit\_SP_R + \delta(1 - \theta) \cdot Tariff \tag{36}$$

$$M_i\ Order\ rate = Allocation\ Share_{M_i} \cdot Retailer\ Demand \tag{37}$$

3.2 Tariff Shock

A tariff disruption is modelled as a tariff imposed on the foreign manufacturer's unit selling price permanently. This tariff increases the effective landed cost of goods sourced from M_1, prompting a redistribution of costs along the supply chain and influencing the retailer's sourcing decisions.

The tariff burden is shared between the foreign manufacturer and the retailer according to two parameters:

1. **Incidence share (θ)** represents the fraction of the tariff absorbed by the foreign manufacturer M_1.
2. **Pass-through share (δ)** represents the fraction of the retailer's tariff burden that is transferred to end consumers through an increase in the retail price.

The retailer's average unit procurement cost is modelled as a weighted combination of the purchasing prices from the two manufacturers (Equation 35). For goods sourced from M_1, the procurement cost includes the effective tariff paid by the retailer, whereas goods sourced from M_2 are tariff-exempt. To capture resilience, the retailer is allowed to adjust its sourcing ratio during the disruption by increasing the share of local procurement from M_2. This sourcing reallocation, characterised by the allocation share $\phi(\tau)$, serves as the resilience strategy. By increasing reliance on the domestic manufacturer during the tariff disruption, the retailer can partially mitigate the cost impact associated with goods sourced from the foreign manufacturer.

By integrating tariff-induced cost changes, burden-sharing responses, and sourcing adjustments, the model quantifies how tariff disruptions affect procurement costs, retail pricing, and overall supply chain performance. This formulation enables the evaluation of resilience strategies under varying levels of tariff severity, manufacturer burden absorption, and retailer pass-through share, thereby providing a structured framework for assessing trade-offs between cost efficiency and supply chain resilience. This study develops

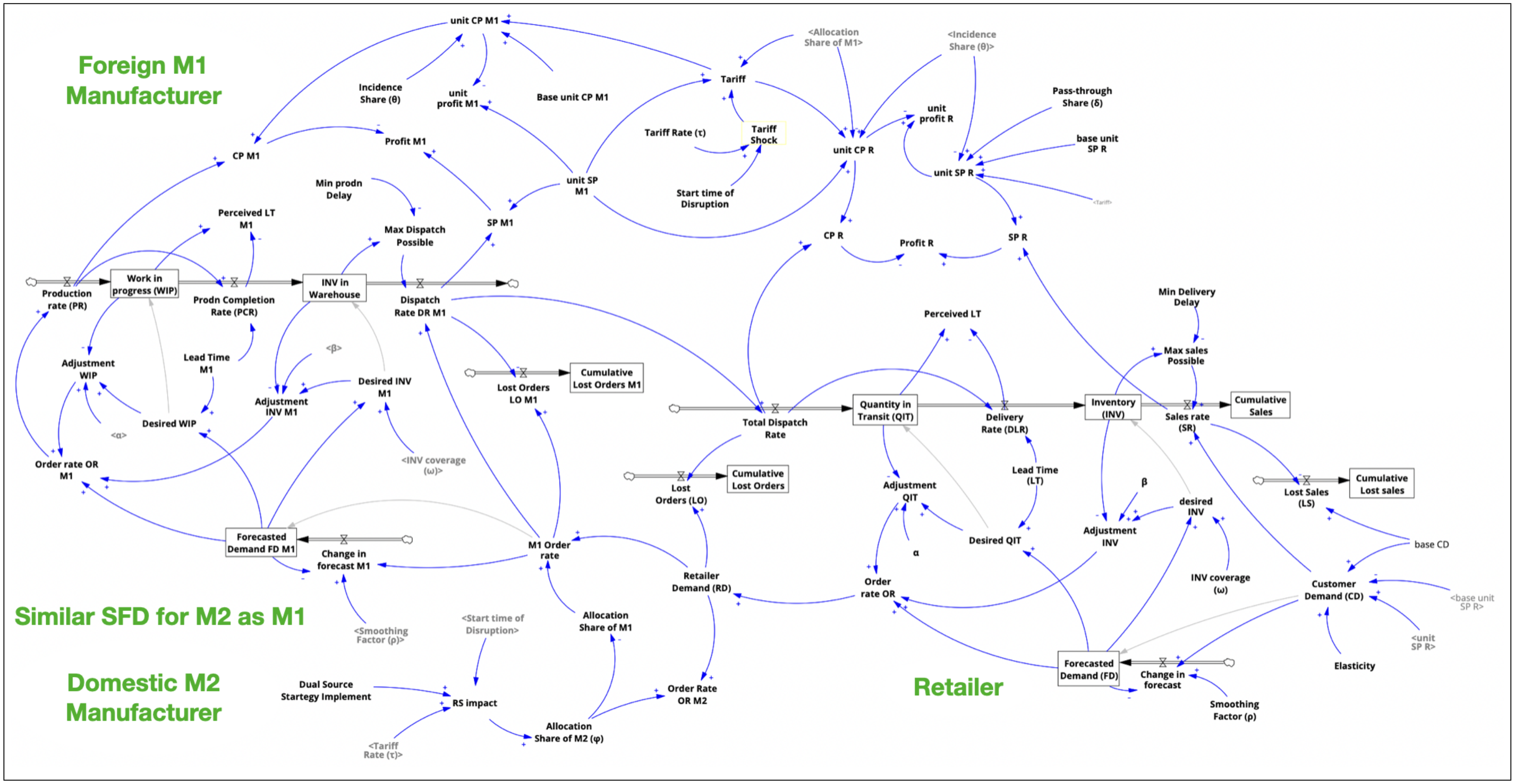


Figure 1: System dynamics stock–flow diagram of the dual-sourcing supply chain under a tariff disruption.

a system-dynamics based quantitative framework that simultaneously models tariff transmission, cost allocation, and resilience strategy of dual-sourcing supply chain. By capturing how these parameters jointly shape resilience outcomes, the model provides insights into supply chain design under tariff uncertainty and contributes a methodological basis for evaluating cost–resilience trade-offs. In this study, the supply chain model assumes lost sales instead of backlog, meaning that any unmet customer demand is considered lost rather than accumulated for future fulfillment.

3.3 Simulation Setting

Customer demand is modeled as a nonlinear decreasing function of the unit selling price to capture price elasticity effects. The assumed price–demand relationship used in the simulation is illustrated in Figure 2. Additionally, the model assumes that goods are non-perishable, implying that inventory does not deteriorate over time and can be carried forward without any loss in quality. The model does not consider multiple products. The assumption of immediate availability of backup suppliers is treated as a boundary case, serving as a best-case benchmark for resilience evaluation. Table 1 presents all model constants used in the simulation together with their numerical values and literature-based justification.

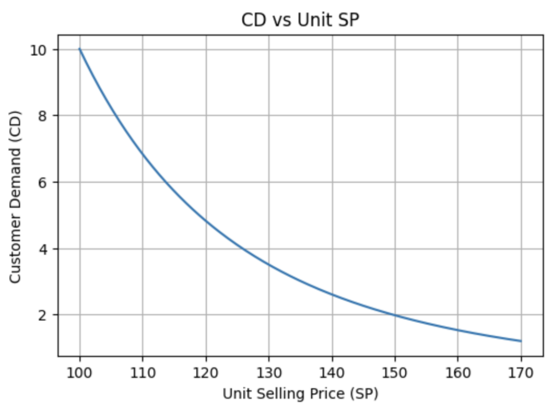


Figure 2: Price-demand elasticity

3.4 Resilience Metrics

Most resilience metrics in the literature have evolved from traditional supply chain Key Performance Indicators (KPIs). In this study, resilience is assessed through a multidimensional set of indicators that capture time, quantity, and economic dimensions of supply chain performance under disruption. Several of these metrics have been widely used in prior resilience studies. For example, the Lead Time Ratio (LTR) has been employed to assess delivery performance under disruptions Sazvar et al., 2021, while the Time to Recovery (TTR) metric has been used to measure the duration required for a system to return to its normal operating state Silva et al., 2023. Quantity-based indicators such as Fill Rate (FR) are commonly used to evaluate service level performance Mirzaaliyan et al., 2024. In addition, revenue-based measures such as profit and lost contribution capture the financial consequences of disruptions Arias-Vargas et al., 2025.

There are five resilience metrics which are considered, recovery time, lead time ratio (LTR), fill rate (FR), profit, and lost contribution (LC). Together, these indicators capture both the operational and economic aspects of resilience. These metrics are evaluated at the level of individual echelons rather than across the entire supply chain. Disruptions propagate differently across echelons, and each stage of the supply chain exhibits distinct dynamic responses, recovery behaviours, and performance losses. Evaluating resilience at the single-echelon level therefore enables a better understanding of how individual entities absorb and recover from disruptions before system-wide effects are aggregated. The parameters t_0 represent the start of a disruption. The formal definitions of these resilience metrics are presented below.

Table 1: Model Constants, Numerical Values, and Justifications

Model Constant	**Value**	**Justification / Literature**
Lead Time (LT) LT M1 LT M2	2 week 3 week 5 week	The lead time is consistent with the 1 to 5 week replenishment times often reported in manufacturing and distribution contexts (Sterman, 2000).
INV Coverage (ω)	1 week	Typical desired-inventory policies of 1 to 2 weeks used in SD supply chain models (Sterman, 2000).
QIT Adjustment parameter (α) INV Adjustment parameter (β)	1/3 1/3	Represent how quickly the system responds to deviations in inventory and orders. They capture the speed at which managers correct gaps between desired and actual states, shaping both recovery time and system stability (Sterman, 2000).
Elasticity	-4	Customer demand is modeled using a constant price-elastic demand function, a commonly used representation in economic and supply chain models Sterman, 2000; Varian, 2017. In this formulation, the price elasticity of demand is assumed to be -4, implying that a 1% increase in price leads to a 4% decrease in quantity demanded.
Tariff Rate (τ)	0–1	Tariff rate applied to imported goods. Although tariffs may exceed 100% in practice, the model considers tariff levels of 0, 0.2, 0.4, 0.6, 0.8, and 1 to evaluate the impact of tariff burden on the supply chain.
Permanent Disruptions	$t_d \to \infty$	During the 2008–2009 financial crisis, hundreds of automotive suppliers (including Lear, Visteon, and Delphi) entered bankruptcy and permanently ceased operations at multiple facilities T. Choi and Linton, 2011. Trade sanctions and export restrictions imposed following the 2022 Russia–Ukraine conflict led firms across consumer goods, fashion, assembly, and manufacturing to discontinue sourcing from Russia. Over 2,100 US-based firms and 1,200 European firms had at least one direct tier-1 supplier in Russia, many of whom were compelled to permanently reconfigure their supply networks (Srai et al., 2023).
Smoothing Factor (ρ)	0.2	The range of 0.1-0.3 is commonly recommended in forecasting literature (Makridakis et al., 1998, Bijulal et al., 2011).
Base Unit CP M_i	20	Base unit production cost of manufacturer M_i
Unit SP M_1	70	Unit selling price of foreign manufacturer M_1 to the retailer
Unit SP M_2	85	Unit selling price of domestic manufacturer M_2 to the retailer
Base Unit SP R	100	Base retail selling price to end customers

1. **Profit (P):** It is defined as average financial gain accrued by each echelon over the recovery period. For the retailer, profit is computed as the difference between revenue generated from sales and the cost of goods dispatched from the manufacturer. For the manufacturer, profit is computed as the difference between revenue received from dispatching goods to the retailer and the cost of production (Equation 38). A higher profit value indicates greater resilience, as it reflects the echelon's ability to sustain revenue generation and contain cost escalation during and after a disruption.

$$P = \frac{1}{t_r - t_0} \sum_{i=t_0}^{i=t_r} SR_t * unit\ SP\ R_t - DR_t * unit\ CP\ R_t \tag{38}$$

$$P\_M = \frac{1}{t_r - t_0} \sum_{i=t_0}^{i=t_r} DR_t * unit\ SP\ M_t - PR_t * unit\ CP\ M_t \tag{39}$$

2. **Lost Contribution (LC):** It is defined as average of product of lost sales and the unit margin of the product (Equation 40). It quantifies the financial impact of lost sales due to supply chain disruptions. Since the implementation of resilience strategies often incurs additional costs, the effective unit mar-

gin may decrease; implying that resilience enhancement comes at a financial trade-off. A lower lost contribution indicates greater resilience, as it demonstrates the system's ability to minimize revenue losses and maintain supply chain performance during and after disruptions.

$$LC = \frac{1}{t_r - t_0} \sum_{i=t_0}^{i=t_r} LS_n * unit\, profit_t \tag{40}$$

3. **Lead time ratio (LTR)**: It is defined as the average of the ratio of lead time perceived after disruption occurs to lead time before disruption (Equation 41).

$$LTR = \frac{1}{t_r - t_0} \sum_{n=t_0}^{n=t_r} \frac{Perceived\, LT_t}{LT_t} \tag{41}$$

4. **Recovery Time (T_r):** It is defined as the time duration required for all the other metrics to stabilize, considering a tolerance of ±2% error, once the disruption incurs. t_d denotes the duration of disruption, and t_r denote the time at which the system stabilizes.

$$T_r = t_r - t_0 \tag{42}$$

5. **Fill Rate (FR):** It is defined as the ratio of sales rate to customer demand. It quantifies the proportion of customer demand that is successfully fulfilled. Since the sales rate cannot exceed customer demand due to its constraints, FR is always $<= 1$. A higher FR represents stronger operational continuity and customer satisfaction despite disruptions, while a lower FR indicates stockouts or unfulfilled orders.

$$FR = \frac{1}{t_r - t_0} \sum_{i=t_0}^{i=t_r} \frac{Sales\, rate_i}{Customer\, Demand_i}, \tag{43}$$

4 Results

This section presents simulation results across two conditions: the *Baseline: No Dual-Sourcing Resilience*, in which the retailer maintains its initial sourcing allocation throughout the disruption, and the *Dual-Sourcing Resilience* strategy, in which the retailer reallocates procurement toward the domestic manufacturer in response to the tariff shock dynamically. Within each condition, results are organised by the key parameter varied: pass-through share (δ), incidence share (θ), and tariff level (τ).

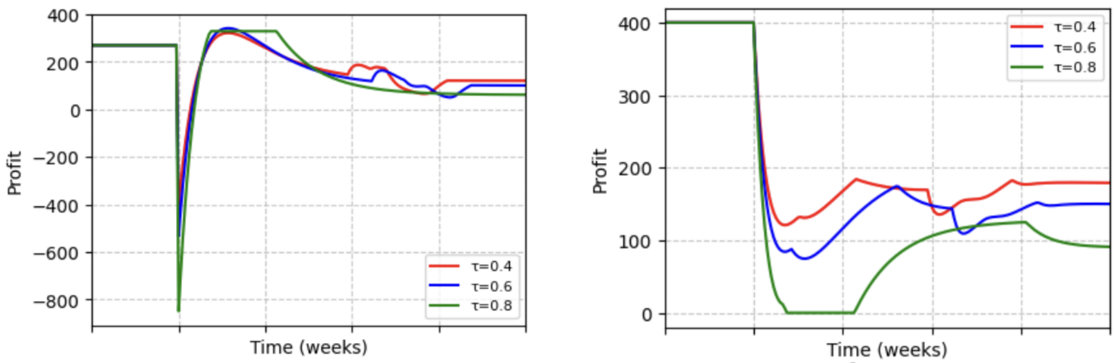
4.1 Baseline: No Dual-Sourcing Resilience

This section presents the baseline scenario in which no resilience strategy is activated and the retailer maintains a fixed sourcing allocation throughout the tariff disruption. Specifically, the retailer continues to procure 80% of its requirements from the foreign manufacturer (M_1) and 20% from the domestic manufacturer (M_2), irrespective of changes in tariff levels. As a result, the supply chain does not adapt through sourcing reallocation, and all adjustments occur through pricing, demand response, and inventory dynamics.

The analysis in this section isolates the impact of tariff parameters—namely tariff rate (τ), incidence share (θ), and pass-through share (δ)—on supply chain performance in the absence of adaptive sourcing. Results are discussed across the subsequent subsections by varying one parameter at a time, while holding others constant.

4.1.1 Extreme Cases

Full Pass Through to Customers (Pass-through share $\delta = 1$, Incidence Share $\theta = 0$): When the retailer transmits its entire tariff burden to end consumers, the retail selling price increases, leading to a reduction in customer demand. Although customers absorb the tariff through higher prices, demand erosion dominates any potential revenue gains. Consequently, profits decline sharply, while lost contribution increases across all supply chain actors. Recovery time increases monotonically for the retailer, as reduced demand slows system stabilisation. As shown in Fig. 3, profits decline sharply with increasing tariff levels, reflecting demand erosion under full pass through.



(a) Retailer Profit

(b) M_1 Profit

Figure 3: Profit trajectories under full pass through ($\delta = 1, \theta = 0$), no resilience.

A non monotonic pattern emerges for M_1 and M_2, recovery time and lost contribution initially increase with tariff severity, and decrease at high tariff levels. The initial increase is driven by demand reduction and adjustment delays. The subsequent decline reflects a system contraction effect, wherein, at sufficiently high tariffs, demand collapses to a level at which manufacturers face reduced exposure to unfulfilled orders, thereby shortening recovery time and reducing lost contribution. Recovery therefore improves not due to enhanced resilience, but due to a contraction in system activity.

Full Retailer Absorption (Pass-through share $\delta = 0$): When the retailer absorbs the entire tariff burden without adjusting retail prices, customer demand remains unchanged. If the incidence share is also zero, only the retailer's profit declines, while all other metrics, recovery time, lost contribution, and manufacturer profits, remain unaffected. In this configuration, tariffs behave as a pure cost shock to the retailer, with no propagation through the supply chain.

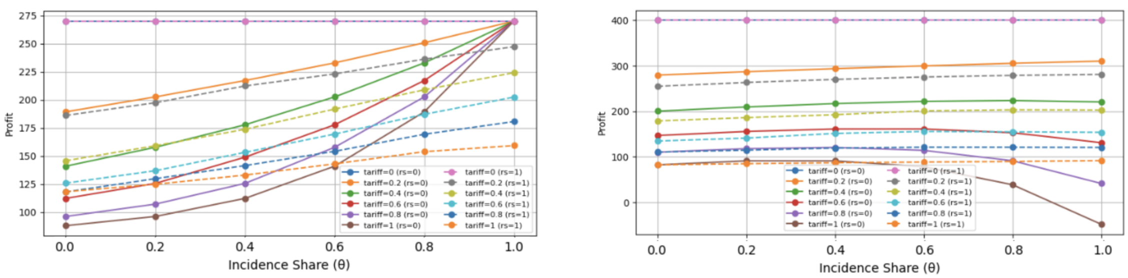
As the incidence share increases under $\delta = 0$, the tariff burden is shared retailer and M_1, retailer profit increases, while M_1 profit declines. These results demonstrate that price rigidity, the retailer's decision not to pass tariff costs to customers, acts as an implicit resilience mechanism that stabilises system level operational performance, at the expense of retailer and M1 profitability. This finding helps explain why firms invest in tariff absorption or cost buffering strategies, particularly in environments with high demand sensitivity.

4.1.2 Effect of Increasing Incidence Share ($\theta : 0 \to 1$) for a Given Pass-through Share δ

As the manufacturer incidence share (θ) increases, a larger fraction of the tariff burden is shifted from the retailer to M_1. Consequently, the recovery time for the retailer and both manufacturers decreases, while the profits of the retailer and M_2 increase. In contrast, the profit of M_1 declines, as it absorbs a greater share of the tariff burden.

However, a different pattern emerges under high pass-through conditions (see Figure 4). At low tariff levels, the profit of M_1 increases with a rising incidence share, as sustained demand offsets the additional tariff burden. In contrast, at moderate to high tariff levels, M_1's profit initially increases but subsequently declines beyond a threshold, indicating that cost absorption eventually dominates the demand-side benefits.

Overall, increasing the tariff incidence on the foreign manufacturer improves system recovery performance and reduces lost contribution, despite adversely affecting M_1's profitability. This finding highlights that supply chain recovery depends more on coordination and cost redistribution than on an equitable allocation of profits across actors.



(a) Retailer Profit (b) M_1 Profit

Figure 4: Profit vs incidence share (θ) for given Pass through share ($\delta = 0.8$)

4.1.3 Effect of Increasing Pass-Through Share (δ: $0 \to 1$)for given θ

Across both low and high incidence configurations, increasing pass-through share consistently raises retailer profit by transferring cost burden to consumers. This is counterintuitive, as with increase in pass through share, demand reduces. The net effect on profit therefore depends on whether the margin recovery per unit outweighs the volume loss. Though with increase in pass through share demand erodes, the retailer transfers that cost burden to consumers.

Moreover, this improvement in retailer profitability comes at a system-level cost: T_r increases for R, M_1, and M_2, and LC of the retailer increases monotonically. Manufacturer profits (M_1, M_2) decline as demand erosion reduces throughput. For high tariff and low incidence combinations, LC of M_1 and M_2 first increases then decreases, consistent with the system contraction effect observed above.

The central insight from the no-resilience condition is therefore a structural trade-off: higher pass-through protects retailer margins but destabilises the system through demand loss. Full retailer absorption, while damaging to retailer profitability, preserves system stability and operational continuity.

4.2 Dual-Sourcing Resilience Activated

Under the dual-sourcing resilience mechanism, the retailer adjusts its sourcing allocation by increasing the share of procurement from the domestic manufacturer (M_2) as tariff levels rise. This adaptive reallocation reflects the growing cost disadvantage of the foreign supplier (M_1), leading to a systematic shift toward local sourcing. As a result, higher tariff levels induce greater allocation to M_2, enhancing supply continuity while altering cost and performance trade-offs within the supply chain. However, the allocation adjustment is subject to a lower bound reflecting contractual or operational constraints, ensuring that the foreign manufacturer (M_1) retains a minimum allocation of 20% even at the highest tariff levels.

4.2.1 Extreme Cases

Full Pass Through to Customers (Pass-through share $\delta = 1$, Incidence Share $\theta = 0$) With Resilience: With dual-sourcing resilience activated, recovery time of R, M_1, and M_2 decreases relative to the no-resilience baseline under full pass-through. Dual sourcing enables faster system re-balancing by shifting procurement load toward M_2, absorbing volume that would otherwise be unmet. An exception arises at low incidence combined with high tariff levels, where M_2 recovery time increases: when M_2 carries a large volume under extreme tariffs without the foreign manufacturer sharing much of the tariff burden, M_2 becomes operationally stressed.

Retailer profit increases at low-to-moderate incidence levels ($\theta \in [0, 0.4]$) but decreases at moderate-to-high incidence ($\theta \in [0.6, 1]$). M_1 profit decreases under low-to-moderate tariffs but *increases* under high tariffs; a reversal absent in the no-resilience case. This occurs because at high tariff levels, the volume reallocated away from M_1 reduces its exposure to tariff costs, improving its margin on reduced but less costly sales. M_2 profit increases consistently as resilience brings additional order volume. Under resilience, M_2 transitions from a marginal buffer to a primary beneficiary of the tariff shock.

LC of R and M_1 decreases relative to the no-resilience baseline, while LC of M_2 increases. This reveals a fundamental property of dual-sourcing resilience: it *redistributes* disruption rather than eliminating it. System-level LC is converted into localised LC concentrated at M_2, which absorbs the operational burden of serving demand that would otherwise be lost entirely.

Full Retailer Absorption (Pass-through share $\delta = 0$) With Resilience: A critical and counter-intuitive result emerges in this configuration: recovery time of R, M_1, and M_2 *increases* when resilience is activated, despite the fact that without resilience and with $\delta = 0$, recovery time was zero. This finding demonstrates that dual-sourcing resilience introduces operational complexity; even in the absence of price transmission, reallocating sourcing between suppliers creates adjustment delays in inventory levels, order pipelines, and lead-time dynamics that extend the recovery horizon. Price rigidity thus removes demand-side disruption but does not neutralise the operational disruption introduced by sourcing reallocation.

Retailer profit increases at low-to-moderate incidence but decreases at high incidence. M_1 profit generally decreases but increases under high incidence combined with moderate-to-high tariffs. Notably, M_2 profit increases consistently and takes the same value regardless of incidence share, indicating that M_2's resilience payoff is structural; driven by the volume reallocation itself; rather than by the distribution of the tariff burden.

LC of M_1 is zero in this configuration, as price stability prevents demand-side disruption at M_1. LC of R and M_2 increases, confirming that dual sourcing completely insulates M_1 from lost sales when retail prices are held fixed.

Full Foreign Manufacturer Absorption ($\theta = 1$): When the foreign manufacturer absorbs the entire tariff burden, only the profit of M_1 declines with increasing tariff levels. The effect is independent of the pass through share. Customer demand remains unaffected. In this setting, the use of dual sourcing as a resilience strategy offers limited benefits. While it may increase the profit of M_2, it worsens performance metrics for other actors.

In particular, without resilience, both the retailer and the foreign manufacturer experience better overall performance, as the system avoids additional coordination complexity and cost redistribution. These results indicate that when tariffs are fully absorbed upstream, the supply chain remains stable, and resilience strategies such as dual sourcing may introduce inefficiencies rather than improving system performance.

4.2.2 Increasing Pass-Through Share δ: $0 \to 1$) With Resilience for given θ

The most striking reversal between the two conditions occurs here. Without resilience, increasing pass-through share *increased* recovery time across all actors. With resilience, increasing pass-through share *decreases* recovery time of R, M_1, and M_2. As shown in Figure 5, recovery time varies systematically with the tariff incidence parameter θ under fixed τ and δ. This reversal arises because, under dual sourcing, higher consumer prices reduce the volume that the system must process, while the allocation of that reduced volume to M_2 provides a stabilising rebalancing effect. The combination of demand compression and supply reallocation jointly improves system recovery.

Retailer profit and M_2 profit increase with pass-through share under resilience. M_1 profit increases only when tariffs, incidence, and pass-through are simultaneously high and dual sourcing is active; a configuration-specific interaction that is absent without resilience.

4.2.3 Increasing Incidence Share (θ: $0 \to 1$) With Resilience (θ: $0 \to 1$ for given δ

Recovery time of R, M_1, and M_2 generally decreases as incidence shifts toward M_1, confirming that removing the retailer's cost burden facilitates faster operational recovery. An exception occurs at high incidence combined with moderate-to-high tariffs, where M_2 recovery time increases as excessive demand load overwhelms the domestic manufacturer's capacity to recover. LC of M_1 and R both decrease with rising incidence share, while LC of M_2 increases, reinforcing the redistribution finding across all resilience configurations. Figure 6 and 7 depict the impact of rising tariffs on profit distribution across the retailer and manufacturers, demonstrating how higher pass-through and varying absorption levels alter the relative gains and losses of M_1 and M_2, particularly under dual-sourcing resilience. M_1 profit decreases monotonically

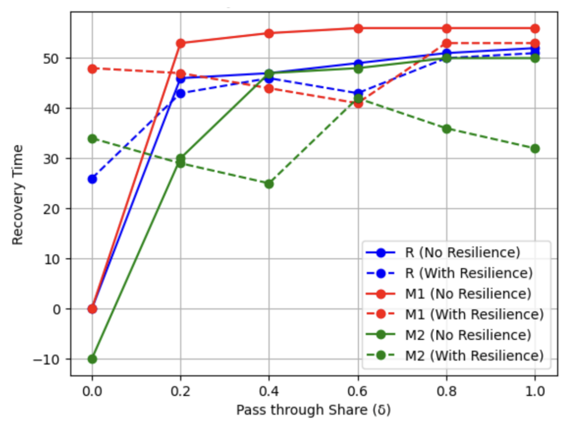


Figure 5: Recovery Time vs Pass through Share δ ($\tau = 0.4$, $\theta = 0.4$)

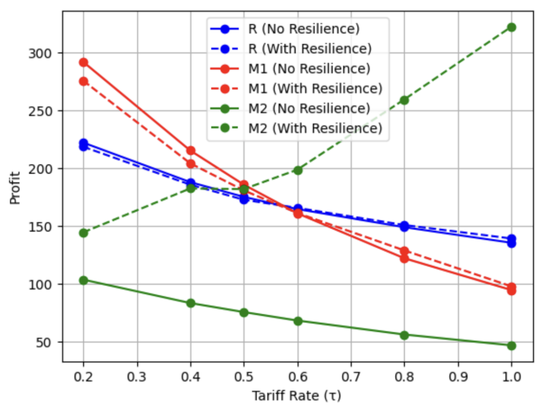


Figure 6: Profit response to increasing tariffs (τ) at $\delta = 0.4$, $\theta = 0.8$

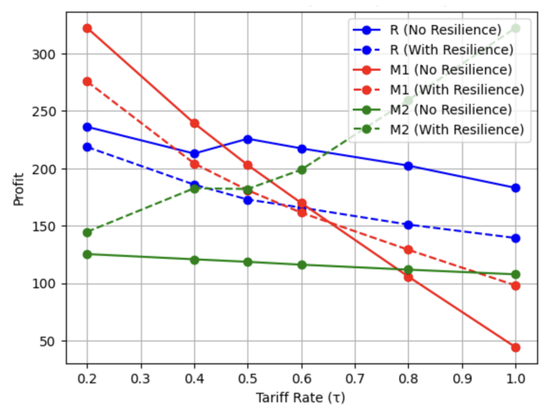


Figure 7: Profit response to increasing tariffs (τ) at $\delta = 0.8$, $\theta = 0.4$

with incidence under most configurations but increases at high tariff, high incidence, and high pass-through levels when dual sourcing is present.

5 Discussion

The study demonstrates that the relationship between pass-through behaviour and system recovery is not monotonic, but is conditioned by the presence of a dual-sourcing resilience strategy. In the absence of dual sourcing, higher pass-through destabilises the system by eroding demand. In contrast, under dual sourcing, the same increase in pass-through improves recovery by enabling supply rebalancing. This finding challenges the conventional view that pass-through is uniformly destabilising and highlights the interdependence of pricing strategy and sourcing structure as joint resilience levers.

The results further reveal that dual-sourcing resilience operates primarily through tariff burden redistribution rather than disruption elimination. The domestic manufacturer consistently absorbs operational stress, reflected in increased lost contribution and, under certain configurations, extended recovery time, as the cost of protecting system-level performance. This has important implications for supplier relationship management, as domestic backup suppliers in dual-sourcing strategies bear a disproportionate burden due to sudden increases in order volumes and may face capacity constraints.

The analysis identifies price rigidity as an implicit resilience mechanism that stabilises demand-side dynamics at the expense of retailer margins and, paradoxically, introduces additional operational complexity when combined with sourcing reallocation. This trade-off between demand stability and operational performance suggests that tariff absorption strategies and sourcing adaptation strategies are not independent; rather, their interaction determines the overall resilience outcome. Firms must therefore jointly optimise pricing and sourcing decisions when responding to tariff shocks.

The study also uncovers a system contraction effect at high tariff levels, where recovery metrics appear to improve due to demand collapse rather than genuine system recovery. These apparent improvements in resilience are therefore driven by reduced system activity rather than enhanced system performance.

5.1 Managerial Implications

The results provide actionable guidance for supply chain managers navigating tariff uncertainty. Firms should treat the incidence share, negotiated with foreign suppliers through contract renegotiation, as an active resilience lever rather than an exogenous outcome, as shifting a greater share of the tariff burden upstream consistently improves retailer and system-level recovery metrics. When demand is elastic, partial price absorption is preferable to full pass-through as a system-stabilising response, provided that sufficient margin headroom is maintained. Dual-sourcing capacity should be developed proactively, as resilience benefits are significantly higher when sourcing reallocation can be activated early in the disruption period.

6 Conclusions

This study develops a system dynamics model of a two-echelon dual-sourcing supply chain to examine how tariff burden-sharing and sourcing reallocation jointly influence supply chain performance and resilience under tariff disruptions. The model introduces two key parameters—the incidence share (θ) and the pass-through share (δ)—along with the allocation share $\phi(\tau)$, enabling a unified analysis of tariff transmission and sourcing adaptation across supply chain tiers.

The study makes several interrelated contributions to the supply chain resilience and tariff modelling literature. First, it develops a system dynamics framework that explicitly captures tariff burden-sharing across supply chain actors. The model formalises how tariff costs are distributed among the foreign manufacturer, the retailer, and consumers, enabling systematic analysis of their effects on procurement costs, pricing decisions, and inventory dynamics under multi-tier tariff structures. Second, the study integrates tariff transmission with a dynamic dual-sourcing resilience strategy. The retailer's allocation decision $\phi(\tau)$ captures the reallocation of procurement from the foreign to the domestic manufacturer in response to tariff-induced cost pressures. By embedding this mechanism within a feedback-driven inventory–production system, the model captures how sourcing adaptation influences recovery dynamics and operational performance.

Third, the study evaluates resilience using multiple performance metrics spanning time, cost, and quantity dimensions, including lost contribution (LC). This multidimensional assessment reveals important trade-offs between cost efficiency and operational performance and provides a structured basis for evaluating sourcing strategies under disruption. Finally, the analysis identifies a four-way interaction between tariff severity, incidence share, pass-through share, and dual-sourcing resilience strategy. Notably, even under high tariffs, the foreign manufacturer's profit can increase under specific configurations, highlighting the non-linear and context-dependent nature of tariff transmission. Such interaction effects are not observable in static analytical models, underscoring the value of system dynamics as a modelling approach for analysing supply chain resilience under trade policy shocks.

Collectively, these contributions bridge insights from international trade economics and supply chain resilience by integrating tariff transmission, burden allocation, and dynamic sourcing adaptation within a unified simulation framework. The model offers both methodological contributions and practical insights for designing resilient supply chains under trade policy uncertainty.

This study makes several simplifying assumptions that offer avenues for future research. Demand is modelled solely as a function of price using a constant elasticity formulation; incorporating demand uncertainty or substitution effects would provide additional realism. The dual-sourcing reallocation process is assumed to be deterministic, whereas in practice it involves delays, contractual frictions, capacity constraints, and uncertainty regarding supplier reliability. Future research could extend the model to include stochastic disruptions, multi-product settings, and network structures beyond a two-echelon supply chain. Additionally, the assumption of immediate availability of the domestic manufacturer may be relaxed, and empirical calibration using firm-level data from tariff-affected industries would enhance the external validity of the findings.

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