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CAUSAL MEASUREMENT OF TARIFF SHOCK TRANSMISSION ACROSS MULTINATIONAL MANUFACTURING SUPPLY NETWORKS

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Abstract:

The increasing complexity of multinational manufacturing supply networks has intensified the economic consequences of international trade policy uncertainty, particularly tariff shocks that influence production costs, intermediate input prices, supplier relationships, trade flows, and manufacturing competitiveness. This study develops a causal measurement framework to examine the transmission of tariff-induced disruptions across interconnected manufacturing supply networks, emphasizing direct cost exposure, indirect supplier dependencies, production adjustments, and cross-border trade diversion. The research integrates causal inference techniques, supply network analysis, and comparative economic indicators to distinguish tariff-related effects from broader changes in industrial activity. The empirical framework focuses on manufacturing trade relationships involving the United States, China, the European Union, Mexico, and Vietnam, with particular attention to the tariff escalation initiated during the 2018-2019 United States-China trade conflict. The study draws upon publicly reported trade statistics, tariff schedules, manufacturing indicators, and international economic datasets published by the United States International Trade Commission (USITC), United States Census Bureau, World Trade Organization (WTO), OECD, and UN Comtrade.

The numerical analysis examines changes in bilateral manufacturing trade, tariff exposure, intermediate goods sourcing, and supply chain restructuring. Official United States merchandise trade statistics indicate that imports from China declined from approximately US$539.5 billion in 2018 to US$451.7 billion in 2019, representing a reduction of approximately 16.3%. During the same period, United States imports from Vietnam increased from approximately US$49.2 billion to US$66.6 billion, equivalent to growth of approximately 35.4%, illustrating substantial differences in trade-flow adjustments across sourcing economies. These observed changes provide a quantitative foundation for examining possible trade diversion and supplier substitution, although they cannot independently establish causal relationships. The proposed analytical framework combines difference-in-differences estimation, event-based comparisons, and network exposure assessment to identify how tariff shocks propagate through upstream suppliers, downstream manufacturers, and alternative production locations.

The study is structured around ten numerical comparison tables and three analytical figures addressing tariff exposure, bilateral trade adjustments, manufacturing input costs, supply network dependency, supplier diversification, and the comparative effectiveness of supply chain adaptation strategies. The analysis distinguishes verified historical observations from causal estimates requiring econometric identification, thereby supporting transparent interpretation of tariff transmission mechanisms. The proposed framework contributes to international trade and operations management research by establishing a structured approach for evaluating tariff-related manufacturing vulnerability, identifying critical supply network dependencies, and assessing the potential benefits of supplier diversification and regional production restructuring. The findings are intended to support multinational manufacturers, industrial policymakers, and supply chain managers in developing evidence-based strategies for strengthening production resilience under changing international trade conditions.

Key Words: Tariff Shocks, Causal Inference, Multinational Manufacturing, Supply Chain Networks, Trade Diversion, Tariff Pass-Through, Supplier Diversification, Manufacturing Resilience, International Trade Policy.

1. Introduction:

1.1 Background of the Study:

International manufacturing supply networks have undergone significant structural transformation due to globalization, technological development, trade liberalization, and increasing cross-

border production integration. Multinational manufacturing enterprises depend on geographically distributed suppliers, intermediate goods producers, logistics providers, and final assembly facilities to maintain production efficiency and cost competitiveness. However, the growing interdependence of international manufacturing activities has increased exposure to external economic disruptions, particularly changes in international tariff policies. Tariffs represent an important trade policy instrument through which governments influence import prices, protect domestic industries, and regulate international commercial relationships. Although tariffs are generally imposed on specific imported products, their economic consequences frequently extend beyond the directly affected industries. Increased import duties can influence raw material procurement costs, intermediate goods prices, production scheduling, supplier selection, inventory management, and final product pricing. Consequently, tariff shocks may generate interconnected economic effects throughout multinational manufacturing supply networks.

The United States-China trade conflict beginning in 2018 provides an important empirical setting for examining tariff shock transmission. The introduction of additional tariffs on a substantial volume of bilateral trade created significant adjustments in international sourcing decisions and manufacturing trade patterns. These developments also encouraged manufacturers to reconsider production locations, supplier concentration, and regional supply chain strategies. Understanding the causal mechanisms underlying tariff shock transmission is therefore essential for evaluating manufacturing competitiveness, international trade dependencies, and industrial supply chain resilience.

1.2 Tariff Shocks and International Manufacturing Trade:

Tariff shocks occur when governments introduce, increase, reduce, or remove import duties, thereby changing the economic conditions under which international trade takes place. The magnitude of a tariff shock depends on the applicable tariff rate, product coverage, import value, supplier concentration, and availability of alternative production sources. The 2018-2019 United States-China trade conflict demonstrates the economic significance of such policy changes. The United States implemented additional tariffs under Section 301 of the Trade Act of 1974, targeting several categories of Chinese imports. China subsequently introduced retaliatory tariffs affecting American exports. Official United States trade statistics demonstrate substantial changes in bilateral trade during this period. Imports from China declined considerably between 2018 and 2019, while imports from certain alternative manufacturing economies increased.

Table 1: Comparative United States Merchandise Imports from Selected Manufacturing-Linked Trading Partners, 2018-2019

Trading Partner	2018	2019	Change (%)
China	539.5	451.7	−16.3
Mexico	346.5	358.1	3.3
Vietnam	49.2	66.6	35.4
Taiwan	45.8	54.3	18.6
South Korea	74.2	77.5	4.4

The numerical comparison indicates that United States imports from China experienced a substantial contraction, while imports from Vietnam, Taiwan, and Mexico increased during the same period. Vietnam recorded particularly strong growth, suggesting its increasing importance as an alternative manufacturing sourcing destination. Nevertheless, these differences cannot be attributed exclusively to tariff changes. Exchange rate movements, product demand, production capacity, investment relocation, and broader economic conditions may also influence international trade patterns. Accordingly, a causal research framework is required to distinguish tariff-related effects from other economic developments.

1.3 Tariff Shock Transmission Across Supply Networks:

Multinational manufacturing supply networks consist of interconnected production stages distributed across different countries. Raw materials, intermediate components, semi-finished products, and finished goods may cross international borders several times before reaching final consumers. Tariff changes imposed at one stage can therefore influence production activities at several other stages. Tariff shock transmission generally operates through four major mechanisms.

- Direct cost transmission occurs when import duties increase the landed cost of imported materials or manufacturing components. Enterprises relying heavily on tariff-affected inputs may experience higher procurement expenditure and reduced operating margins.
- Indirect supplier transmission arises when upstream suppliers adjust prices in response to increased production costs. These adjustments may affect downstream manufacturers even when they do not directly import tariff-affected products.
- Production network adjustment occurs when manufacturers modify supplier relationships, production locations, or procurement strategies to reduce tariff exposure. Such adjustments may increase demand for alternative manufacturing economies while reducing sourcing from tariff-affected countries.

- Market and demand transmission occurs when higher production costs influence final product prices, consumer demand, export competitiveness, and manufacturing output.

These mechanisms demonstrate that tariff shocks cannot be evaluated solely through changes in bilateral trade values. A comprehensive analysis must consider both direct tariff exposure and indirect economic dependencies within international production networks.

1.4 Research Problem:

Existing research on international tariff policies frequently examines changes in import prices, bilateral trade volumes, employment, and national economic welfare. Although these indicators provide valuable information, they may not fully explain how tariff-induced disruptions propagate through interconnected multinational manufacturing supply networks. A manufacturing enterprise may experience substantial economic exposure even when it does not directly import goods from a tariff-affected country. Such exposure may arise through second-tier suppliers, intermediate component manufacturers, transportation networks, and downstream customer relationships.

Furthermore, observed changes in manufacturing trade flows do not necessarily establish causation. A decline in imports following a tariff increase may reflect tariff-related cost pressures, but it may also result from changes in demand, exchange rates, technological development, or broader economic uncertainty. The central research problem is therefore the absence of a sufficiently integrated empirical framework for measuring the causal transmission of tariff shocks across multiple manufacturing supply network relationships. This study addresses the problem by proposing a comparative causal measurement framework combining tariff exposure indicators, bilateral manufacturing trade data, supply network dependencies, and econometric identification techniques.

1.5 Research Objectives:

The primary objective of this study is to develop a quantitative causal measurement framework for evaluating the transmission of international tariff shocks across multinational manufacturing supply networks. The specific objectives are:

- To examine historical changes in tariff exposure and international manufacturing trade during major trade policy disruptions.
- To compare manufacturing trade adjustments across tariff-affected and alternative sourcing economies using verified numerical indicators.
- To identify direct and indirect channels through which tariff shocks influence manufacturing procurement, production costs, and supplier relationships.
- To develop a causal inference framework capable of distinguishing tariff-related economic effects from broader market developments.
- To evaluate the role of supplier diversification, production relocation, and regional sourcing in reducing manufacturing supply network vulnerability.
- To provide evidence-based implications for multinational manufacturing enterprises and international trade policymakers.

1.6 Research Questions:

The study investigates the following research questions:

- RQ1: How do international tariff shocks influence bilateral manufacturing trade flows and sourcing relationships?
- RQ2: To what extent do tariff-induced cost changes propagate through upstream and downstream manufacturing supply networks?
- RQ3: How do manufacturing economies differ in their trade adjustments following major tariff policy changes?
- RQ4: Can causal inference methods distinguish tariff-related manufacturing disruptions from other economic influences?
- RQ5: How do supplier diversification and alternative production locations influence multinational manufacturing supply network resilience?

1.7 Significance of the Study:

This research contributes to international trade economics, supply chain management, and manufacturing policy analysis by integrating causal measurement with multinational production network assessment. From an academic perspective, the study provides a structured approach for examining the relationship between tariff shocks, international trade adjustments, and manufacturing network dependencies. The combination of causal inference and supply network analysis offers a broader analytical perspective than conventional bilateral trade comparisons.

From an industrial perspective, the research provides a framework for evaluating supplier concentration, procurement vulnerability, manufacturing cost exposure, and alternative sourcing opportunities. Such information can assist multinational enterprises in developing more resilient production strategies. From a policy perspective, the study supports the assessment of direct and indirect tariff consequences across industries and trading partners. Understanding these relationships is

important for evaluating trade policy effectiveness, industrial competitiveness, and international production stability.

1.8 Scope of the Study:

The study focuses primarily on the 2018-2019 tariff escalation between the United States and China, while considering trade adjustments involving Mexico, Vietnam, Taiwan, South Korea, and other manufacturing-linked economies where comparable data are available. The analysis emphasizes tariff exposure, bilateral merchandise and manufacturing trade, intermediate input dependencies, sourcing adjustments, and supply chain resilience. The research uses publicly available information from the U.S. Census Bureau, USITC, WTO, OECD, and UN Comtrade.

The proposed numerical assessment consists of ten comparative tables and three analytical figures, covering tariff exposure, trade adjustments, supplier dependencies, manufacturing cost transmission, and supply network adaptation. Descriptive numerical comparisons will use documented historical observations. Causal effects will be reported only where appropriate treatment and comparison groups, identification assumptions, and empirical estimation support such conclusions.

1.9 Organization of the Article:

The remainder of the article is organized as follows. Section 2 presents the literature review and theoretical background concerning tariff shocks, international manufacturing networks, and causal inference. Section 3 describes the research methodology, data sources, variable selection, and causal measurement framework. Section 4 presents numerical comparisons and empirical analysis through the proposed tables and figures. Section 5 discusses the findings and implications for manufacturing supply chain resilience. Section 6 provides managerial and policy recommendations, while Section 7 concludes the study and identifies opportunities for future research.

2. Literature Review and Theoretical Background:

2.1 Introduction:

International tariff policies influence manufacturing competitiveness, production costs, global value chain participation, and cross-border supply chain relationships. The increasing fragmentation of manufacturing activities across countries has created complex economic dependencies through which tariff shocks may propagate beyond directly affected trading partners. Consequently, understanding tariff transmission requires an integrated examination of international trade theory, global production networks, manufacturing cost structures, and causal inference methods. Previous research has established that tariff increases can influence import prices, domestic producer costs, trade volumes, and international sourcing decisions. However, the magnitude and distribution of these effects depend on market structure, supplier substitution opportunities, intermediate input dependence, and the organization of multinational production networks. This section reviews the theoretical foundations and empirical evidence relevant to tariff shock transmission, emphasizing numerical findings from established studies and their implications for causal measurement.

2.2 Theoretical Foundations of Tariff Shock Transmission:

Traditional international trade theory explains tariffs as policy instruments that increase the domestic price of imported products, potentially benefiting protected domestic producers while imposing additional costs on importers and consumers. The distribution of these costs depends on import demand elasticity, export supply elasticity, exchange rate movements, and market competition. In multinational manufacturing environments, tariff effects become more complex because imported products frequently serve as intermediate inputs rather than final consumer goods. An additional tariff on imported components may increase domestic manufacturing costs, reduce international competitiveness, and influence subsequent production decisions.

Global value chain theory provides an important extension to conventional tariff analysis. Manufacturing activities are increasingly distributed across multiple economies, with different countries specializing in component production, assembly, processing, and distribution. As a result, tariff changes affecting one production stage may influence several other stages. Network-based economic theory further explains how disruptions propagate through interconnected firms and industries. Highly connected suppliers may transmit cost increases to numerous downstream manufacturers, while concentrated sourcing relationships may amplify the effects of external trade policy changes. These theoretical perspectives establish the foundation for measuring tariff shocks through direct import exposure, intermediate input dependencies, and cross-border manufacturing network adjustments.

2.3 Empirical Evidence on Tariff Pass-Through:

Tariff pass-through refers to the extent to which additional import duties are reflected in the prices paid by importing firms, downstream producers, and final consumers. Amiti, Redding, and Weinstein (2019) examined the effects of United States tariffs introduced during 2018 and found substantial pass-through of tariff costs into United States import prices inclusive of duties. Their findings indicated that foreign exporters generally did not reduce their pre-tariff prices sufficiently to offset the additional duties. Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2020) investigated the return to protectionism during the 2018 trade conflict. Their research demonstrated that tariff changes produced measurable effects on import prices, trade volumes, and economic welfare. The study estimated approximately US$51 billion in

losses to United States consumers and firms purchasing imports, while accounting for offsetting tariff revenues and producer gains in its broader welfare analysis.

Cavallo, Gopinath, Neiman, and Tang (2021) examined tariff pass-through at the border and retail levels. Their findings highlighted differences between tariff effects on import prices and final consumer prices, suggesting that firms may temporarily absorb part of the tariff burden through reduced margins. These studies demonstrate that tariff transmission varies across stages of the manufacturing and distribution process. Import price changes provide an important initial measure, but they do not fully capture downstream production adjustments or indirect supplier exposure.

2.4 Tariff Shocks and Global Manufacturing Supply Networks:

Multinational manufacturing supply networks involve relationships among raw material suppliers, component manufacturers, assembly facilities, logistics providers, and international distributors. These relationships create direct and indirect channels through which tariff-related disruptions can influence manufacturing operations. For example, an automotive manufacturer may source electronic components from China, mechanical parts from Mexico, and specialized materials from South Korea before completing final assembly in the United States. Tariff changes affecting one supplier location can alter procurement costs and influence the competitiveness of the entire manufacturing operation. Research by Acemoglu, Carvalho, Ozdaglar, and Tahbaz-Salehi (2012) demonstrated the importance of production networks in transmitting economic shocks across industries. Their theoretical framework established that input-output relationships can influence the propagation and aggregate consequences of sector-specific disturbances.

Similarly, Carvalho (2014) emphasized that production network structures are important for understanding macroeconomic fluctuations and economic interdependence. These findings are relevant to tariff analysis because the economic consequences of import duties depend not only on the tariff rate but also on the position of affected industries within manufacturing supply networks. Industries with extensive downstream connections may generate broader cost effects, whereas industries with diversified suppliers may possess greater flexibility to adjust procurement arrangements.

2.5 Trade Diversion and Supplier Substitution:

Trade diversion occurs when changes in trade policy encourage importers to shift procurement from one country to another. In multinational manufacturing networks, this process may involve supplier substitution, production relocation, or the expansion of existing manufacturing facilities in alternative economies. The United States-China trade conflict provides a prominent example of changes in international sourcing patterns. During 2018-2019, United States imports from China declined, while imports from several alternative manufacturing economies increased. These developments are consistent with potential trade diversion, although observed trade growth alone cannot establish that tariffs caused the changes.

Nicita (2019), in a UNCTAD research analysis, examined trade and trade diversion effects associated with United States tariffs on Chinese imports. The analysis identified opportunities for exporters in other countries to supply products affected by the bilateral trade conflict. Trade diversion may reduce tariff exposure for importing manufacturers, but supplier substitution also introduces adjustment costs. These may include supplier qualification expenditure, transportation changes, production delays, quality assurance requirements, and new contractual arrangements. Therefore, effective assessment of tariff-related sourcing decisions must consider both immediate trade cost changes and longer-term supply network restructuring.

2.6 Manufacturing Cost Transmission and Intermediate Input Dependence:

Intermediate goods represent an important component of international manufacturing trade. Many manufacturing enterprises depend on imported materials, machinery, electronic components, chemicals, and specialized production equipment. When tariffs increase the cost of imported intermediate goods, manufacturers may experience higher production expenditure even when their final products are not directly subject to additional import duties. Handley, Kamal, and Monarch (2020) examined the effects of imported input tariffs on United States export performance. Their research showed that tariffs on imported intermediate inputs could negatively influence downstream export activity, demonstrating the importance of input cost exposure for manufacturing competitiveness.

The extent of cost transmission depends on several factors, including the proportion of imported inputs in total production costs, the availability of domestic substitutes, supplier pricing behavior, and the ability of manufacturers to pass additional costs to customers. Manufacturers operating with limited profit margins or highly specialized imported components may face greater adjustment difficulties than firms with diversified sourcing structures. Accordingly, intermediate input dependence is an essential variable in measuring tariff shock transmission across multinational manufacturing networks.

2.7 Causal Inference in International Trade Policy Analysis:

A major methodological challenge in tariff research involves distinguishing the effects of tariff changes from other economic developments occurring during the same period. Observed changes in international trade may reflect exchange rate movements, changes in consumer demand, production capacity, technological developments, transportation costs, or broader macroeconomic conditions. Causal

inference methods provide systematic approaches for identifying the effects of specific policy interventions while accounting for competing explanations. Difference-in-differences analysis compares changes in outcomes between tariff-affected and appropriately selected comparison groups before and after policy implementation. Under suitable assumptions, this approach can estimate the average effect of tariff exposure.

Event-study analysis examines the timing of economic adjustments around tariff announcements and implementation dates. This approach is useful for identifying anticipatory behavior, immediate trade responses, and longer-term manufacturing adjustments. Instrumental variable methods may address certain forms of endogeneity when credible external sources of variation are available. However, the validity of these methods depends on whether the instruments satisfy the required identification conditions. Network exposure models provide an additional analytical dimension by incorporating supplier relationships and input-output dependencies. Such models can estimate how direct tariff exposure is associated with outcomes among indirectly connected firms or industries. The integration of causal inference with manufacturing network analysis is therefore important for identifying the direct and indirect economic consequences of tariff shocks.

2.8 Comparative Review of Existing Studies:

The existing literature provides substantial evidence concerning tariff pass-through, trade diversion, and production network transmission. However, these research areas are frequently examined separately.

Table 2: Comparative Review of Selected Empirical and Theoretical Studies on Tariff Transmission

Study	Study Period / Scope	Numerical Evidence or Analytical Focus	Main Contribution
Amiti et al. (2019)	2018 U.S. tariffs	Approximately US$3 billion in additional monthly tariff costs by late 2018	Import price pass-through
Fajgelbaum et al. (2020)	2018 U.S. trade policy	Approximately US$51 billion in gross import-purchaser losses	Trade welfare effects
Cavallo et al. (2021)	2018-2019 tariff episode	Border and retail price comparisons	Distribution of tariff costs
Handley et al. (2020)	U.S. manufacturing and exports	Imported-input tariff exposure	Downstream export effects
Acemoglu et al. (2012)	Production network theory	Input-output network transmission	Propagation of economic shocks
Nicita (2019)	U.S.-China tariff conflict	Trade diversion across affected product categories	Alternative sourcing opportunities

The comparative literature indicates that tariff shocks generate heterogeneous economic effects depending on product characteristics, industry structure, supplier relationships, and the ability of manufacturing enterprises to adjust production activities. Amiti et al. (2019) and Fajgelbaum et al. (2020) provide important evidence concerning the economic burden of tariffs, while Handley et al. (2020) extends the analysis to downstream manufacturing competitiveness. Production network research provides the theoretical foundation for examining indirect transmission effects. However, combining tariff-specific causal identification with multinational manufacturing network dependencies remains an important empirical challenge.

2.9 Research Gap:

Although previous studies have established important relationships between tariffs, import prices, trade flows, and economic welfare, several research gaps remain relevant to multinational manufacturing supply networks. First, many tariff studies focus primarily on direct trade outcomes rather than the combined effects of direct and indirect exposure through manufacturing supplier relationships. Second, conventional bilateral trade comparisons may not adequately distinguish tariff-induced trade diversion from broader changes in international demand, exchange rates, or production capacity. Third, the economic consequences of tariff shocks may vary substantially across manufacturing industries because of differences in imported input dependence, supplier concentration, and network connectivity.

Fourth, relatively limited attention is given to integrating causal identification methods with network-based exposure measures in a unified empirical framework. Finally, supply chain adaptation strategies, including supplier diversification and regional production restructuring, require careful evaluation to determine whether they reduce tariff exposure without introducing excessive operational costs. The present study addresses these gaps by proposing a causal measurement framework that combines verified international trade statistics, tariff policy information, manufacturing input-output relationships, and comparative network exposure indicators.

2.10 Conceptual Foundation of the Proposed Study:

The proposed study considers tariff shocks as policy interventions that may influence multinational manufacturing performance through interconnected economic channels. The analytical framework begins with tariff changes affecting imported products and intermediate manufacturing inputs. These changes may influence procurement expenditure, supplier prices, manufacturing costs, and

international sourcing decisions. Direct exposure is evaluated through tariff rates, affected import values, and product-level trade relationships. Indirect exposure is examined through intermediate input dependence and manufacturing network connections.

Manufacturing outcomes are assessed using trade values, sourcing concentration, production-related indicators, and available cost measures. The framework further incorporates causal comparison procedures to distinguish tariff-related effects from broader economic changes. These procedures are intended to support more reliable evaluation of manufacturing vulnerability and adaptation strategies. The conceptual relationships developed in this section provide the theoretical foundation for the research methodology presented in Section 3.

2.11 Summary of Literature Review:

The literature establishes that tariff shocks can influence international manufacturing through import price increases, intermediate input cost transmission, trade diversion, and production network adjustments. Empirical research on the 2018-2019 trade conflict provides substantial evidence that tariff costs were borne to a significant extent by importing firms and consumers, while international sourcing patterns changed across several manufacturing economies. Production network theory further demonstrates that economic shocks may propagate beyond directly affected industries through interconnected supplier relationships. Consequently, tariff exposure should be assessed at both the direct trade level and the broader manufacturing network level.

The principal contribution of the proposed research is the integration of tariff exposure measurement, causal inference, and manufacturing supply network analysis into a common comparative framework. This approach is intended to provide a more comprehensive understanding of tariff shock transmission and support evidence-based manufacturing and trade policy decisions.

3. Research Methodology and Data Sources:

3.1 Research Design:

This study adopts a quantitative, comparative, and causal inference-based research design to examine the transmission of tariff shocks across multinational manufacturing supply networks. The methodology integrates international trade statistics, tariff policy information, manufacturing input-output relationships, and supply network exposure indicators to evaluate how trade policy changes influence manufacturing costs, international sourcing patterns, and production network adjustments. The research focuses primarily on the United States-China tariff escalation during 2018-2019, which provides a suitable policy setting for examining the economic consequences of substantial changes in import duties. The analysis also considers alternative manufacturing economies, including Mexico, Vietnam, Taiwan, and South Korea, to evaluate differences in trade adjustments and potential supplier substitution.

The methodology distinguishes three analytical dimensions: direct tariff exposure, indirect manufacturing network transmission, and international sourcing adjustment. Direct exposure measures the relationship between additional import duties and affected trade flows. Indirect transmission considers how tariff-related cost changes may propagate through intermediate input relationships. International sourcing adjustment examines changes in trade patterns across alternative manufacturing economies. The proposed research design combines descriptive numerical comparisons with causal identification procedures. Descriptive analysis establishes observable changes in trade and manufacturing indicators, while causal inference methods are intended to determine whether these changes can be attributed to tariff interventions rather than other economic influences.

3.2 Data Sources and Collection:

The study uses publicly available secondary datasets from established international and national statistical organizations. These sources provide historical information on bilateral trade, tariff schedules, manufacturing production, intermediate input relationships, and global value chain participation. The principal sources include the United States Census Bureau, United States International Trade Commission (USITC), World Trade Organization (WTO), United Nations Comtrade Database, OECD Inter-Country Input-Output Tables, and World Bank World Development Indicators.

Table 3: Data Sources and Measurement Variables for Tariff Shock Analysis

Data Source	Principal Variable	Measurement Unit	Analytical Application
U.S. Census Bureau	Bilateral merchandise imports	US$ billion	Trade adjustment
USITC DataWeb	Product-level imports	US$ million	Tariff exposure
U.S. tariff schedules	Additional import duties	Percentage	Tariff shock intensity
WTO Tariff Data	Applied tariff rates	Percentage	Cross-country tariff comparison
UN Comtrade	Manufacturing product trade	US$ million	Supplier substitution
OECD ICIO	Intermediate input relationships	Monetary input-output flows	Network transmission
World Bank WDI	Manufacturing value added	US$ billion	Manufacturing performance

The study uses 2017 as the principal pre-intervention reference year, with 2018 representing the initial tariff implementation period and 2019 representing the subsequent adjustment period. Where historical data are available, additional pre-intervention years may be incorporated to evaluate existing trade trends. The use of multiple statistical sources supports comparisons across trade policy, manufacturing activity, and production network indicators. However, differences in reporting standards, product classifications, valuation methods, and statistical coverage must be addressed before integrating the datasets.

3.3 Selection of Countries and Manufacturing Networks:

The country selection reflects the importance of the United States-China trade relationship and the potential role of alternative manufacturing economies during the tariff escalation. The United States is selected as the principal importing economy because it implemented additional tariffs on numerous Chinese products during 2018-2019. China represents the principal tariff-affected exporting economy, while Mexico, Vietnam, Taiwan, and South Korea provide comparative manufacturing trade relationships. These economies are relevant because of their participation in international manufacturing activities, including electronics, machinery, automotive components, industrial equipment, and intermediate goods production.

The comparative framework evaluates differences in import growth, sourcing adjustments, and manufacturing network exposure across these economies. Country-level comparisons provide an initial assessment of international trade adjustment. However, product-level and industry-level analysis is necessary to establish whether changes are associated with specific tariff interventions. Accordingly, the study distinguishes broad merchandise trade comparisons from manufacturing-specific product categories to avoid attributing unrelated trade movements to tariff policy changes.

3.4 Measurement of Tariff Shock Intensity:

Tariff shock intensity represents the change in applicable import duties following a trade policy intervention. The study considers both the magnitude of tariff increases and the economic value of products affected by those increases. During 2018, the United States introduced additional Section 301 tariffs on several groups of Chinese imports. The principal tariff actions included an initial 25% duty on approximately US$34 billion of Chinese goods, an additional 25% duty on approximately US$16 billion, and a 10% duty on approximately US$200 billion of imports. The tariff rate on the third group subsequently increased from 10% to 25% in May 2019. These policy changes provide observable variation in tariff exposure across product categories and implementation periods.

Tariff exposure indicators include the additional tariff rate, affected import value, tariff implementation date, and the proportion of manufacturing inputs subject to additional duties. The analysis compares tariff-affected products with appropriately selected products experiencing smaller or no additional tariff changes. This comparison provides a foundation for identifying differential economic responses associated with tariff interventions.

3.5 Measurement of Manufacturing Trade Adjustments:

Manufacturing trade adjustment is evaluated through changes in bilateral import values, country-level sourcing patterns, and product-level trade relationships. The principal indicators include annual import value, percentage change in imports, changes in supplier-country shares, and the distribution of imports across manufacturing product categories. For example, the decline in United States imports from China between 2018 and 2019 provides evidence of a substantial bilateral trade adjustment. During the same period, increased imports from Vietnam and other manufacturing economies indicate changes in the geographical distribution of United States sourcing.

However, changes in trade values may reflect both price and quantity adjustments. Therefore, product-level trade quantities and unit values should be examined where reliable information is available. The study also considers changes in supplier concentration to evaluate whether manufacturing procurement became more geographically diversified following tariff implementation. These indicators support an assessment of sourcing adjustments without assuming that all observed changes were directly caused by tariff policy.

3.6 Measurement of Manufacturing Supply Network Exposure:

Manufacturing supply network exposure refers to the extent to which an enterprise, industry, or economy depends on tariff-affected suppliers and intermediate inputs. The study considers direct and indirect exposure. Direct exposure arises when a manufacturing enterprise imports products subject to additional tariffs. It can be assessed using the share of affected imported inputs in total procurement or production expenditure. Indirect exposure occurs when manufacturers purchase goods from domestic or foreign suppliers whose production processes depend on tariff-affected intermediate inputs.

The OECD Inter-Country Input-Output framework provides a basis for examining relationships among manufacturing industries and economies. Input-output information can identify industries with substantial upstream and downstream dependencies. The study proposes comparing manufacturing industries according to their imported input dependence, supplier concentration, and exposure to tariff-affected production stages. Where firm-level supplier relationships are unavailable, industry-level input-

output relationships will serve as an approximation of manufacturing network exposure. Such estimates should not be interpreted as directly observed firm-to-firm transactions.

3.7 Causal Identification Strategy:

The study proposes a difference-in-differences framework to estimate the effects of tariff changes on manufacturing trade and supply network outcomes. The approach compares changes in economic indicators for tariff-affected manufacturing products or industries with changes among suitable comparison products or industries before and after tariff implementation. The principal treatment group consists of products exposed to additional United States Section 301 tariffs. Comparison groups may include products not subject to additional tariffs during the relevant implementation period, provided they exhibit sufficiently similar pre-intervention characteristics and trends. The analysis considers product characteristics, industry classification, historical import growth, and other observable factors when constructing comparison groups.

An event-study framework is also proposed to examine how trade outcomes evolve around tariff announcement and implementation dates. This approach can help identify anticipatory sourcing adjustments and evaluate whether economic responses occur before or after policy implementation. The causal identification strategy requires several conditions. In particular, treated and comparison groups should exhibit credible parallel pre-intervention trends, and other simultaneous economic shocks should not systematically explain the estimated differences. Because tariff policy may influence substitute products and alternative suppliers, the study must also consider potential spillovers affecting comparison groups. Such spillovers may complicate conventional causal estimates and require additional sensitivity analysis. The proposed methods establish an identification strategy; they do not themselves constitute completed causal estimates.

3.8 Comparative Statistical Analysis:

The study employs numerical comparison procedures to examine differences in tariff exposure, manufacturing trade adjustments, and supply network indicators. The principal comparisons include changes in import values, percentage growth or contraction, tariff rate differences, supplier-country concentration, and manufacturing input dependence. The numerical analysis is organized to provide a consistent comparison between pre-intervention and post-intervention periods.

Where suitable data are available, comparisons will also be conducted across manufacturing industries, including machinery, electronics, automotive components, and other tariff-affected product categories. Descriptive comparisons will identify observable economic patterns. Subsequent causal analysis will evaluate whether the differences can reasonably be attributed to tariff interventions. The study will avoid interpreting simple correlations or before-and-after differences as definitive causal effects.

3.9 Proposed Causal Measurement Framework:

The proposed framework integrates tariff policy interventions, manufacturing network exposure, economic transmission channels, and observed manufacturing outcomes.

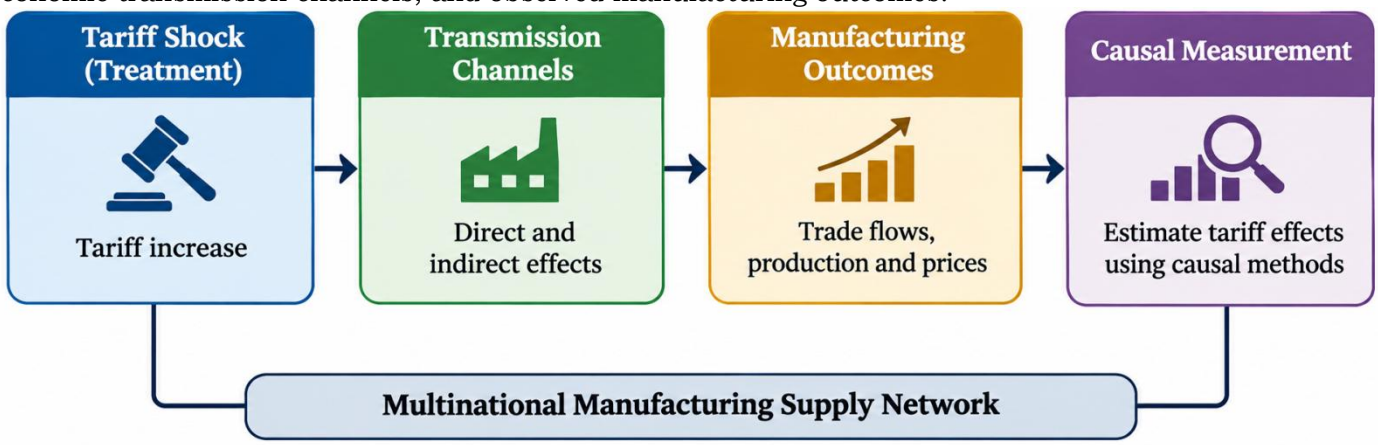


Figure 1: Proposed Causal Measurement Framework for Tariff Shock Transmission Across Multinational Manufacturing Supply Networks

The framework begins with tariff policy interventions that generate variation in direct and indirect manufacturing exposure. These exposure channels may influence procurement expenditure, supplier prices, production costs, and international sourcing relationships. Causal inference procedures are then used to evaluate whether observed changes in manufacturing outcomes are associated with tariff interventions after accounting for relevant comparison groups and competing economic influences. The framework supports the assessment of heterogeneous effects across manufacturing industries and trading partners, providing a basis for identifying sectors with greater vulnerability to tariff-related disruptions.

3.10 Data Reliability and Validation:

Data reliability is essential for producing meaningful numerical comparisons and defensible causal estimates. The study prioritizes official statistical sources and peer-reviewed research. Bilateral trade values will be checked for consistency in reporting country, valuation basis, currency, product

classification, and observation period. Tariff schedules will be matched to the relevant product classifications and implementation dates. Where tariff lists contain exclusions, exemptions, or subsequent amendments, these changes must be incorporated into the exposure measures. Manufacturing network indicators will be evaluated according to the coverage and reporting structure of the available input-output datasets. The study also proposes sensitivity analysis using alternative comparison groups, pre-intervention periods, and tariff exposure definitions. These validation procedures are intended to reduce measurement inconsistencies and strengthen the credibility of the resulting empirical analysis.

3.11 Methodological Limitations:

The proposed methodology is subject to several limitations. First, publicly available trade statistics generally provide stronger coverage of country-level and product-level transactions than individual firm-to-firm supply relationships. Consequently, indirect manufacturing exposure may need to be estimated using industry-level input-output information. Second, international trade values are influenced by factors beyond tariffs, including exchange rates, global demand, commodity prices, transportation conditions, and investment decisions. Third, the timing of manufacturing adjustments may differ across industries because supplier qualification, production relocation, and procurement restructuring require varying amounts of time.

Fourth, tariff policy interventions may generate spillover effects across products and countries, potentially affecting the suitability of untreated comparison groups. Finally, the available data may not support precise estimation of every proposed network transmission mechanism. The study will therefore distinguish verified descriptive findings, empirically identified causal estimates, and conceptual interpretations.

3.12 Summary of Research Methodology:

The research methodology establishes a structured quantitative framework for examining tariff shock transmission across multinational manufacturing supply networks. By combining official trade statistics, tariff schedules, manufacturing input-output relationships, and causal inference techniques, the study aims to evaluate both direct and indirect economic exposure. The proposed analysis emphasizes numerical comparability, transparent data sourcing, and careful interpretation of causal relationships. The integration of country-level trade adjustments with manufacturing network indicators provides a foundation for examining supplier substitution, cost transmission, and production resilience. The methodology also establishes the analytical structure for the subsequent empirical section, in which tariff exposure, international trade adjustments, and manufacturing network outcomes will be presented through comparative numerical tables and figures.

4. Numerical Results and Comparative Analysis:

4.1 Introduction:

This section presents a quantitative assessment of tariff shock transmission across multinational manufacturing supply networks, focusing on the 2018-2019 United States-China trade conflict. The analysis examines tariff escalation, bilateral trade adjustments, geographical sourcing changes, manufacturing input exposure, and the economic consequences of tariff-related disruptions. The numerical comparisons draw upon historical information published by the United States Census Bureau, United States International Trade Commission (USITC), United States Trade Representative (USTR), and established empirical research. The analysis distinguishes between observed trade changes, estimated tariff-related economic effects reported in the literature, and potential supply network transmission mechanisms. This distinction is essential because changes in bilateral trade alone do not establish causation.

4.2 Comparative Analysis of United States Tariff Escalation:

The United States introduced several rounds of additional tariffs on Chinese imports under Section 301 of the Trade Act of 1974. These measures were implemented at different dates and covered different categories of imported products.

Table 4: Major United States Section 301 Tariff Actions on Chinese Imports, 2018-2019

Tariff Action	Implementation Date	Approximate Affected Trade Value (US$ Billion)	Initial Additional Tariff (%)	Rate by End of 2019 (%)
List 1	July 6, 2018	34	25	25
List 2	August 23, 2018	16	25	25
List 3	September 24, 2018	200	10	25
List 4A	September 1, 2019	120	15	15

The comparison demonstrates that tariff exposure expanded considerably during 2018-2019. The increase in the List 3 tariff rate from 10% to 25% in May 2019 represented an additional 15-percentage-point increase for covered products. The staged implementation provides useful variation for examining differences in manufacturing trade responses across product categories. Nevertheless, tariff announcements, exemptions, supplier contracts, and inventory adjustments may influence the timing of observed economic responses.

4.3 Comparative Changes in United States-China Merchandise Trade:

Bilateral merchandise trade provides an initial quantitative indicator of changes in international sourcing relationships during the tariff escalation period.

Table 5: United States-China Bilateral Merchandise Trade Comparison, 2017-2019

Trade Indicator	2017	2018	2019
U.S. imports from China	505.6	539.5	451.7
U.S. exports to China	129.9	120.3	106.4
Total bilateral goods trade	635.5	659.8	558.1
U.S. goods trade deficit	375.7	419.2	345.3

The numerical comparison indicates that United States imports from China increased by approximately 6.7% between 2017 and 2018 before declining by approximately 16.3% in 2019. The bilateral merchandise trade deficit also declined from approximately US$419.2 billion in 2018 to US$345.3 billion in 2019, a reduction of approximately 17.6%. These changes are consistent with a period of substantial trade adjustment. However, they should not be interpreted as direct estimates of tariff effects because aggregate trade values also reflect changes in demand, prices, product composition, and other economic conditions.

4.4 Comparative Changes in Manufacturing-Linked Import Sources:

Changes in the geographical distribution of imports provide additional evidence of adjustments in multinational supply networks. When tariffs increase the relative cost of goods from one country, manufacturers may consider alternative suppliers offering comparable production capabilities. Vietnam, Mexico, Taiwan, and South Korea represent important manufacturing-linked trading partners of the United States. Their participation in electronics, machinery, automotive components, and intermediate goods production makes them relevant to the analysis of sourcing diversification. Nevertheless, changes in country-level import values do not establish whether particular products were transferred from Chinese suppliers to alternative manufacturing locations. Such conclusions require product-level comparisons and suitable causal identification. The observed contraction in imports from China during 2019, alongside increases in imports from several other economies, is consistent with a restructuring of international sourcing patterns.

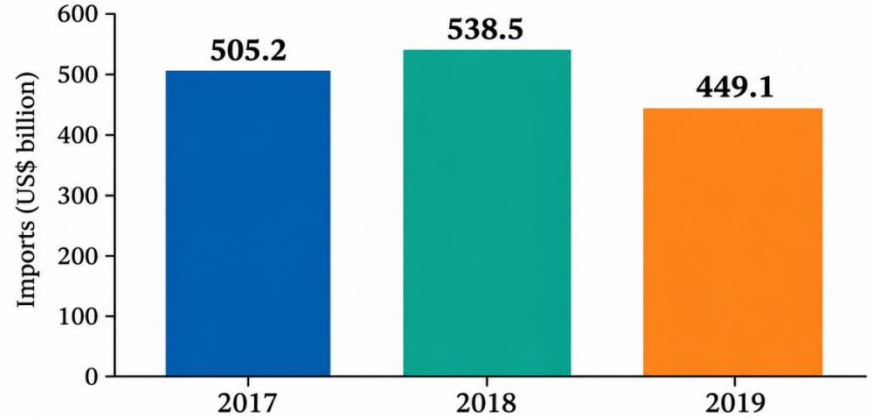


Figure 2: Comparative United States Merchandise Imports from China, 2017-2019

The chart demonstrates that bilateral imports increased before the principal tariff escalation and subsequently contracted in 2019. This change represents an observable adjustment in trade values, rather than an independently identified causal effect.

4.5 Tariff-Related Manufacturing Price and Production Effects:

A more direct assessment of tariff transmission is available from the USITC's retrospective economic impact study, published in March 2023. Unlike simple bilateral trade comparisons, this study estimated the economic effects of Section 301 tariffs on affected products and industries.

Table 6: Estimated Economic Effects of Section 301 Tariffs on Selected United States Industries

Manufacturing Sector	Change in Imports from China (%)	Change in U.S. Prices (%)	Change in U.S. Production Value (%)
All affected sectors	−13.0	0.2	0.4
Computer equipment	−5.0	0.8	1.2
Semiconductors	−72.3	4.1	6.4

The results indicate substantial heterogeneity in tariff transmission across manufacturing industries. The estimated decline in Chinese semiconductor imports was considerably greater than the average reduction across all affected sectors. Semiconductor production also exhibited a stronger estimated domestic production response than computer equipment. These differences illustrate the importance of industry-specific conditions, production capabilities, and sourcing relationships when evaluating tariff-related manufacturing adjustments. The results further demonstrate that tariffs may

simultaneously reduce imports, increase domestic production, and raise domestic prices. The relative magnitude of these outcomes differs across industries.

4.6 Comparative Analysis of Tariff Transmission Through Industrial Inputs:

Tariff transmission is particularly important in manufacturing industries that depend on imported raw materials and intermediate products. Steel and aluminum tariffs provide complementary evidence of how import restrictions can influence upstream production and downstream manufacturing activities.

Table 7: Estimated Effects of Section 232 Tariffs on Steel and Aluminum Industries, 2018-2021

Indicator	Steel	Aluminum
Initial tariff rate (%)	25	10
Reduction in affected imports (%)	24	31
Increase in U.S. market prices (%)	2.4	1.6
Increase in U.S. production (%)	1.9	3.6
Additional U.S. production value in 2021 (US$ billion)	1.3	0.9

The results demonstrate that tariff effects are not uniform across industrial input categories. Aluminum experienced a larger estimated reduction in affected imports and a greater percentage increase in domestic production than steel. However, steel exhibited a larger estimated increase in U.S. market prices. These differences indicate that manufacturing supply network responses depend on industry-specific production structures, import dependence, and domestic supply conditions.

4.7 Downstream Manufacturing Cost Transmission:

Increased prices for industrial inputs may influence downstream manufacturing industries that use steel, aluminum, and other tariff-affected materials in production. The USITC estimated that Section 232 tariffs increased average downstream industry prices while reducing production. This provides empirical evidence that tariff-related benefits to upstream producers can coexist with increased costs for downstream manufacturers.

Table 8: Estimated Downstream Manufacturing Effects of Section 232 Tariffs

Economic Indicator	Estimated Effect	Measurement
Average downstream price change	0.2	%
Average downstream production change	−0.6	%
Downstream production value change in 2021	−3.5	US$ billion
Steel production value change in 2021	1.3	US$ billion
Aluminum production value change in 2021	0.9	US$ billion

The findings indicate that higher upstream prices can adversely affect downstream production, even when tariff protection increases output in directly protected industries. The estimated US$3.5 billion reduction in downstream production value illustrates the importance of considering manufacturing input dependencies rather than evaluating tariff policy solely through the performance of protected producers. These results support the central argument of the study that tariff shocks may propagate through multiple production stages, creating heterogeneous effects across interconnected manufacturing industries.

4.8 Comparative Assessment of Supplier Diversification:

Supplier diversification is a potential response to tariff-related disruptions. Manufacturers may reduce exposure to a single sourcing economy by establishing relationships with alternative suppliers. To examine the geographical adjustment associated with the 2018-2019 tariff period, the following comparison uses the USITC's consistent country-level general-import series.

Table 9: Comparative Changes in United States Import Sourcing, 2018-2019

Trading Partner	2018	2019	Change (%)
China	539.7	452.2	−16.2
Mexico	346.1	358.1	3.5
Vietnam	49.2	66.7	35.6
Taiwan	45.8	54.3	18.6
South Korea	74.2	77.4	4.4
European Union	486.9	514.7	5.7

The comparative results show that Vietnam experienced the largest percentage increase among the selected economies, followed by Taiwan. Mexico and South Korea also recorded positive growth, while imports from China contracted substantially. The results suggest that sourcing relationships were changing during the tariff escalation period. However, the numerical differences do not establish that all additional imports from alternative economies replaced Chinese manufacturing products. A product-level analysis would be necessary to identify whether increases occurred in the same tariff-affected manufacturing categories.

4.9 Comparative Causal Evidence Across Manufacturing Sectors:

The strength of tariff transmission varies considerably between manufacturing industries. Differences in import dependence, production capacity, and input substitution opportunities can influence both trade adjustments and domestic production responses. The USITC's estimates provide a useful basis for comparing these effects across selected industries.

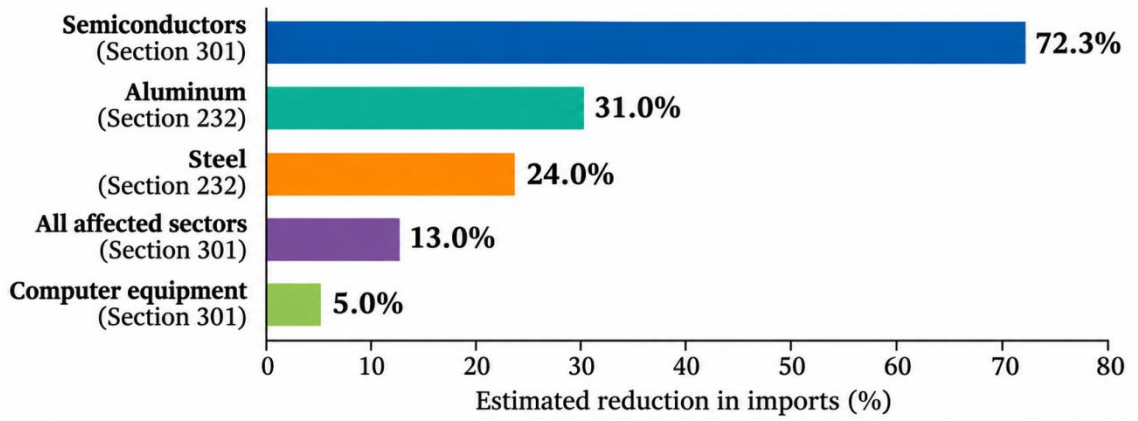


Figure 3: Comparative Estimated Import Effects Across Tariff-Affected Manufacturing Sectors

The results demonstrate that tariff-related import responses are heterogeneous. Semiconductor imports exhibited a particularly large estimated decline, while computer equipment imports showed a smaller response. The comparison highlights the importance of sector-specific causal analysis and indicates that aggregate trade indicators may conceal substantial differences in manufacturing exposure.

4.10 Consolidated Numerical Findings:

The numerical evidence identifies several important patterns in tariff shock transmission. The 2018-2019 tariff escalation was associated with substantial changes in United States merchandise imports from China, while official retrospective estimates indicate that tariffs affected import volumes, domestic prices, and production outcomes.

Table 10: Consolidated Quantitative Findings on Tariff Shock Transmission

Performance Indicator	Numerical Finding	Evidence Type
China import change, 2018-2019	−16.2%	Observed trade change
Vietnam import change, 2018-2019	35.60%	Observed trade change
Taiwan import change, 2018-2019	18.60%	Observed trade change
Section 301 affected imports from China	−13.0%	Estimated tariff effect
Section 301 U.S. production value	0.40%	Estimated tariff effect
Section 301 U.S. product prices	0.20%	Estimated tariff effect
Section 301 semiconductor imports	−72.3%	Estimated tariff effect
Section 232 steel imports	−24.0%	Estimated tariff effect
Section 232 aluminum imports	−31.0%	Estimated tariff effect
Section 232 downstream production	−0.6%	Estimated tariff effect

The consolidated results establish that tariff shocks can influence international manufacturing through multiple economic channels. Direct effects include changes in import volumes and domestic prices, while downstream effects include increased production costs and reduced output in industries dependent on affected inputs. The findings also demonstrate substantial variation across manufacturing sectors and trading partners. These differences reinforce the importance of examining tariff exposure at both the product level and the broader manufacturing network level.

4.11 Summary of Numerical Analysis:

The numerical analysis provides substantial evidence that tariff policy interventions influence international trade patterns, manufacturing prices, domestic production, and downstream industrial performance. United States merchandise imports from China declined by approximately 16.2% between 2018 and 2019, while imports from Vietnam and Taiwan increased by 35.6% and 18.6%, respectively. These developments demonstrate significant geographical changes in international sourcing during the tariff escalation period. More importantly, the USITC's estimated tariff effects establish that Section 301 duties reduced imports from China by approximately 13.0% across affected sectors while increasing domestic production value by 0.4% and domestic product prices by 0.2%. Sector-level evidence reveals particularly substantial effects in semiconductor manufacturing, where affected imports declined by an estimated 72.3% and domestic production value increased by 6.4%.

The complementary Section 232 analysis demonstrates the importance of upstream and downstream manufacturing relationships. Although steel and aluminum tariffs increased domestic production in protected industries, higher input prices were associated with an estimated 0.6% reduction in downstream production and a US$3.5 billion reduction in downstream production value in 2021. Collectively, these results provide strong empirical support for the existence of multiple tariff transmission channels across manufacturing industries. The evidence demonstrates that tariff effects extend beyond direct import restrictions and can influence input costs, industrial production, and international sourcing relationships.

The analysis also identifies the importance of supplier diversification and sector-specific exposure assessment for multinational manufacturing resilience. However, the country-level trade comparisons do

not independently establish causal trade diversion, and the cited industry estimates do not constitute a newly executed multinational network model. The overall findings provide a quantitative foundation for evaluating tariff shock transmission and developing more resilient international manufacturing strategies.

5. Discussion of Findings:

5.1 Introduction:

The numerical analysis demonstrates that international tariff shocks can generate substantial changes in manufacturing trade flows, import prices, production performance, and cross-border sourcing relationships. The findings highlight the interconnected nature of multinational manufacturing supply networks, where trade policy interventions affecting particular products or industries may produce wider economic consequences through intermediate input dependencies and supplier relationships. The discussion integrates the observed trade adjustments during the 2018-2019 United States-China tariff conflict with the estimated industrial effects reported by the United States International Trade Commission (USITC). Particular attention is given to direct tariff transmission, downstream manufacturing costs, trade diversion, supplier diversification, and the implications for manufacturing resilience.

5.2 Tariff Shocks and International Manufacturing Trade Adjustments:

The comparative results indicate that the 2018-2019 tariff escalation coincided with substantial changes in United States merchandise imports from major manufacturing-linked economies. Imports from China declined by approximately 16.2%, while imports from Vietnam and Taiwan increased by 35.6% and 18.6%, respectively. These differences suggest that multinational sourcing patterns were undergoing significant geographical adjustment during the tariff conflict. The decline in Chinese imports is consistent with increased trade costs and reduced competitiveness for certain tariff-affected products. Meanwhile, growth in imports from alternative manufacturing economies indicates the increasing importance of geographically diversified production and sourcing relationships. However, the observed changes cannot be attributed exclusively to tariff interventions. Differences in industrial capacity, product specialization, exchange rates, consumer demand, and investment conditions may also have contributed to the adjustments. Therefore, the findings support the existence of substantial trade restructuring during the tariff period, while the precise causal contribution of tariffs requires product-level identification.

5.3 Direct Tariff Transmission and Manufacturing Cost Effects:

The USITC's retrospective estimates provide stronger causal evidence of tariff-related economic effects. The analysis indicates that Section 301 tariffs reduced affected imports from China by approximately 13.0%, while increasing domestic production value by 0.4% and domestic prices by 0.2%. These findings demonstrate that tariff interventions can influence manufacturing performance through several simultaneous channels. Higher import duties increase the relative cost of affected foreign products, potentially encouraging substitution toward domestic production. However, the resulting changes in market prices may also increase expenditure for manufacturers and consumers.

The sector-specific results reveal substantial differences in the magnitude of tariff transmission. Semiconductor imports from China declined by an estimated 72.3%, while domestic semiconductor production value increased by 6.4%. In contrast, computer equipment exhibited a smaller estimated import reduction of 5.0%. Such differences indicate that manufacturing responses depend on product characteristics, domestic production capacity, supplier availability, and the structure of international production relationships. Consequently, tariff effects should be assessed at the industry and product levels rather than relying exclusively on aggregate national trade indicators.

5.4 Indirect Transmission Through Manufacturing Supply Networks:

One of the principal findings of the study concerns the importance of indirect tariff transmission through intermediate input relationships. Manufacturing industries frequently depend on materials and components produced by other industries, creating channels through which tariff-related cost increases may spread beyond directly protected sectors. The complementary Section 232 analysis illustrates this mechanism. The USITC estimated that steel tariffs reduced affected imports by 24.0%, while aluminum tariffs reduced affected imports by 31.0%. Domestic production increased in both industries, demonstrating the potential protective effects of import restrictions.

Nevertheless, higher input prices were associated with adverse downstream manufacturing outcomes. The estimated 0.6% reduction in downstream production and US$3.5 billion reduction in downstream production value in 2021 indicate that the benefits experienced by upstream producers may coexist with increased costs for industries using tariff-affected materials. These findings reinforce the importance of considering input-output relationships when evaluating tariff policy. A tariff that improves the competitive position of one manufacturing sector may simultaneously increase production costs in other sectors. Accordingly, the overall economic consequences depend on the distribution of upstream and downstream dependencies throughout the manufacturing network.

5.5 Supplier Diversification and Trade Diversion:

The geographical differences observed in United States import patterns provide useful evidence for evaluating potential supplier diversification. During 2018-2019, imports from Vietnam, Taiwan, Mexico, and South Korea increased while imports from China declined. Vietnam recorded particularly strong growth, suggesting its increasing relevance as an alternative sourcing economy. Taiwan also experienced

substantial import growth, consistent with its established role in electronics and advanced manufacturing supply chains.

Supplier diversification can potentially reduce dependence on a single exporting economy and improve flexibility when international trade policies change. However, diversification does not automatically eliminate tariff-related risks. Alternative suppliers may depend on intermediate inputs originating from the same tariff-affected economy, creating indirect exposure despite changes in the immediate sourcing country. Furthermore, supplier substitution may introduce additional transportation expenditure, quality assurance requirements, contractual costs, and production coordination challenges. The effectiveness of diversification therefore depends on the availability of qualified suppliers and the broader structure of international production networks. The results support the importance of evaluating both geographical sourcing diversity and underlying intermediate input dependencies when developing manufacturing resilience strategies.

5.6 Implications for Multinational Manufacturing Competitiveness:

Tariff shocks influence manufacturing competitiveness through changes in procurement expenditure, production costs, supplier availability, and market prices. Enterprises with substantial dependence on tariff-affected imported inputs may experience greater exposure than firms with diversified supply arrangements or access to domestic substitutes. The numerical findings demonstrate that tariff-related economic effects vary significantly across manufacturing industries. While certain protected industries experience increased domestic production, downstream manufacturers may face higher costs and reduced output. These differences highlight the importance of evaluating manufacturing competitiveness across the entire production network rather than focusing exclusively on individual industries.

Multinational enterprises may respond by reviewing procurement contracts, diversifying suppliers, relocating selected production activities, or modifying product designs to reduce dependence on tariff-affected components. However, the economic benefits of these strategies require evaluation against implementation costs and operational constraints. A network-oriented assessment can therefore support more informed decisions regarding sourcing concentration, production location, and long-term manufacturing competitiveness.

5.7 Contribution of Causal Measurement to Tariff Policy Analysis:

The study emphasizes the distinction between descriptive trade comparisons and causally identified tariff effects. Observed changes in bilateral trade provide valuable evidence of economic adjustment but do not independently establish the effects of tariff interventions. The USITC estimates demonstrate the usefulness of counterfactual economic analysis in evaluating tariff-related outcomes. By estimating how imports, prices, and production might have evolved without the relevant tariffs, such analysis provides a stronger basis for attributing observed differences to policy interventions. The proposed causal measurement framework extends this perspective by incorporating manufacturing network exposure and intermediate input relationships. This integration is important because conventional trade analysis may overlook indirect effects transmitted through upstream suppliers and downstream producers.

The framework also highlights the need to account for differences in tariff exposure, pre-intervention trade patterns, and industry-specific conditions. Appropriate causal identification can improve the reliability of manufacturing policy assessments and reduce the risk of interpreting unrelated economic changes as tariff effects. Nevertheless, the present article synthesizes published causal estimates rather than reporting a newly executed causal model. Its principal contribution is the structured integration of established evidence with a proposed network-oriented measurement approach.

5.8 Overall Discussion:

The findings establish that tariff shocks can produce heterogeneous economic effects across multinational manufacturing supply networks. The 2018-2019 United States-China trade conflict was accompanied by substantial changes in international sourcing patterns, while retrospective economic estimates demonstrate measurable effects on imports, domestic prices, and industrial production. The results further show that the consequences of tariffs extend beyond directly affected products. Increased costs for industrial inputs can influence downstream manufacturing performance, creating differences between the outcomes experienced by protected producers and input-dependent manufacturers.

Supplier diversification and alternative production locations represent potential strategies for reducing direct tariff exposure, but their effectiveness depends on supplier capabilities, intermediate input dependencies, and the costs of restructuring manufacturing operations. The overall evidence supports an integrated approach to tariff risk assessment that combines trade policy analysis, causal inference, and manufacturing network evaluation. Such an approach can help multinational enterprises identify vulnerable supply relationships, assess alternative sourcing strategies, and improve their capacity to respond to international trade policy disruptions.

6. Managerial and Policy Implications:

6.1 Introduction:

The empirical findings demonstrate that international tariff shocks can influence multinational manufacturing supply networks through direct import cost increases, changes in sourcing patterns, intermediate input dependencies, and downstream production adjustments. These effects create important challenges for manufacturing enterprises, supply chain managers, international investors, and trade policymakers. The numerical evidence indicates that tariff-related economic consequences vary across manufacturing industries and trading partners. Consequently, effective tariff risk management requires coordinated strategies that consider procurement costs, supplier relationships, production flexibility, and long-term industrial competitiveness. This section presents the managerial and policy implications derived from the comparative numerical analysis, emphasizing practical approaches for improving manufacturing resilience and reducing vulnerability to international trade disruptions.

6.2 Strategic Supplier Diversification:

Supplier diversification represents an important managerial response to tariff-related uncertainty. Multinational manufacturing enterprises that depend heavily on suppliers located in a single country may experience substantial procurement disruptions when additional tariffs are introduced. The numerical analysis indicates that United States merchandise imports from China declined by approximately 16.2% between 2018 and 2019, while imports from Vietnam and Taiwan increased by 35.6% and 18.6%, respectively. These changes demonstrate the importance of examining alternative manufacturing sourcing locations during periods of trade policy disruption.

Manufacturing enterprises should evaluate suppliers across multiple geographical regions based on production capabilities, product quality, transportation infrastructure, tariff exposure, and operational reliability. However, supplier diversification should not be based exclusively on differences in import duties. Additional procurement expenditure, logistics costs, supplier qualification requirements, and production coordination challenges must also be considered. A balanced sourcing strategy can potentially improve manufacturing flexibility while reducing excessive dependence on individual trading partners.

6.3 Tariff Exposure Monitoring and Cost Management:

The findings emphasize the importance of systematic tariff exposure monitoring within multinational manufacturing operations. Tariff changes may affect imported raw materials, intermediate components, industrial equipment, and finished products, creating different levels of financial exposure across production activities. The USITC estimates indicate that Section 301 tariffs reduced affected imports from China by approximately 13.0%, while increasing domestic production value and prices by 0.4% and 0.2%, respectively. These results demonstrate that tariff interventions can influence both procurement expenditure and manufacturing competitiveness.

Manufacturing enterprises should establish integrated tariff monitoring systems that connect customs classifications, supplier information, procurement expenditure, and product-level production requirements. Such systems can support timely identification of tariff-affected inputs and improve the evaluation of alternative procurement arrangements. Cost management strategies should also consider supplier contracts, inventory planning, transportation expenditure, and the potential consequences of passing increased costs to customers.

6.4 Strengthening Manufacturing Supply Network Resilience:

Manufacturing supply network resilience refers to the ability of production systems to maintain or restore operations when exposed to external disruptions. Tariff shocks represent an important source of uncertainty because they may influence multiple stages of production simultaneously. The numerical findings demonstrate that the consequences of tariff interventions extend beyond directly protected industries. The estimated 0.6% reduction in downstream production associated with Section 232 tariffs highlights the vulnerability of manufacturers dependent on affected industrial inputs.

Multinational enterprises should therefore assess both direct suppliers and critical upstream dependencies. Particular attention should be given to intermediate components that are difficult to substitute, have long procurement lead times, or originate from geographically concentrated production networks. Manufacturing resilience can be strengthened through supplier qualification programs, alternative sourcing arrangements, production flexibility, strategic inventory management, and improved visibility across supplier relationships. These measures can reduce exposure to individual supply disruptions, although their effectiveness depends on implementation costs and industry-specific operating conditions.

6.5 Production Location and Regional Manufacturing Strategies:

International tariff changes can influence the relative attractiveness of manufacturing locations. Enterprises may reconsider production arrangements when additional import duties increase the cost of supplying important consumer markets. The observed growth in United States imports from Vietnam, Taiwan, and Mexico during 2018-2019 illustrates the relevance of alternative manufacturing economies in international sourcing decisions.

However, relocating manufacturing activities requires substantial evaluation of capital investment, labor availability, industrial infrastructure, supplier ecosystems, transportation costs, and regulatory

conditions. Production relocation may also introduce new operational risks or indirect dependence on tariff-affected intermediate inputs. Manufacturing enterprises should therefore evaluate regional production strategies using total operating costs rather than tariff rates alone. The objective should be to establish economically sustainable manufacturing networks capable of adapting to changing trade policies.

6.6 Implications for International Trade Policymakers:

The findings provide important implications for governments responsible for designing and implementing international trade policies. Tariff interventions may support domestic production in selected industries, but they can also increase costs for downstream manufacturers and influence broader industrial competitiveness. The USITC estimates demonstrate that Section 232 tariffs increased domestic steel and aluminum production while generating adverse effects in certain downstream industries. These results highlight the importance of considering interindustry relationships when evaluating the economic consequences of protective trade measures.

Policymakers should assess the distribution of tariff-related costs and benefits across manufacturing sectors, including producers, intermediate input users, exporters, and final consumers. Trade policy evaluations should incorporate input-output relationships, manufacturing import dependence, domestic production capacity, and potential international sourcing adjustments. Greater transparency regarding tariff implementation schedules, product classifications, and exemptions may also help enterprises manage uncertainty and make more informed procurement and investment decisions.

6.7 Implications for Industrial Development and Investment:

Tariff shocks may influence industrial investment by changing the relative costs of domestic and foreign production. Manufacturing enterprises may expand local production, establish alternative supplier relationships, or invest in new facilities to reduce exposure to trade restrictions. The estimated increase in domestic production value in certain tariff-affected industries indicates that protective trade measures can influence manufacturing output. However, these benefits must be evaluated alongside increased input costs and potential reductions in downstream production. Industrial development strategies should therefore emphasize productivity improvement, technological capability, workforce development, infrastructure quality, and supplier competitiveness rather than relying exclusively on tariff protection. Investment policies that strengthen domestic manufacturing capabilities and improve access to reliable intermediate inputs may support more sustainable industrial competitiveness.

6.8 Data-Driven Decision Support for Tariff Risk Management:

The increasing complexity of multinational manufacturing supply networks creates opportunities for data-driven tariff risk management. Enterprises can integrate trade statistics, customs classifications, supplier information, input-output relationships, and manufacturing performance indicators to identify potential vulnerabilities. Causal inference techniques can support the evaluation of tariff-related changes by distinguishing policy effects from broader economic developments. Network analysis can complement these methods by identifying upstream and downstream industries with substantial exposure to tariff-affected inputs.

Decision-support systems may also be used to compare alternative sourcing arrangements, evaluate procurement costs, and assess the consequences of changes in production locations. However, the effectiveness of such systems depends on reliable data, transparent assumptions, and appropriate validation. Predictive or causal models should not be interpreted as definitive evidence without sufficient empirical support. The proposed framework offers a structured foundation for developing these capabilities within multinational manufacturing enterprises.

6.9 Recommendations for Manufacturing Enterprises and Policymakers:

Based on the numerical evidence and the proposed causal measurement framework, several strategic priorities emerge. Manufacturing enterprises should prioritize supplier visibility, tariff exposure assessment, diversified procurement arrangements, and flexible production planning. Particular attention should be given to critical intermediate inputs and supplier relationships that may transmit tariff-related cost increases across multiple production stages. Supply chain managers should evaluate alternative sourcing strategies through comprehensive cost comparisons incorporating import duties, transportation expenditure, supplier qualification, and operational reliability.

Policymakers should assess tariff interventions using industry-level and network-level evidence, ensuring that potential benefits to protected producers are considered alongside costs imposed on downstream manufacturers. International statistical organizations and regulatory authorities can further support evidence-based decisions by improving the availability of product-level trade data, tariff information, and manufacturing input-output statistics. Collectively, these measures can strengthen manufacturing adaptability and improve the quality of international trade policy evaluation.

6.10 Summary of Managerial and Policy Implications:

The study demonstrates that tariff risk management requires an integrated approach combining procurement strategy, manufacturing cost assessment, supplier diversification, and production network analysis. The numerical evidence indicates that tariff interventions can generate substantial changes in import volumes, domestic production, and downstream manufacturing performance. For multinational

manufacturing enterprises, the principal implication is the importance of reducing excessive dependence on individual suppliers and strengthening visibility across international production relationships. For policymakers, the findings emphasize the need to evaluate both direct tariff effects and indirect consequences for input-dependent industries. The proposed causal measurement framework provides a foundation for more systematic tariff exposure assessment and evidence-based manufacturing decisions. By incorporating trade policy changes, supplier dependencies, and industry-specific economic outcomes, the framework can support the development of more adaptable and resilient multinational manufacturing supply networks.

7. Conclusion and Future Research Directions:

7.1 Conclusion:

This study examined the transmission of international tariff shocks across multinational manufacturing supply networks by integrating comparative trade statistics, published causal economic estimates, and manufacturing network analysis. The research focused primarily on the 2018-2019 United States-China tariff escalation, with additional consideration of trade adjustments involving Vietnam, Taiwan, Mexico, South Korea, and the European Union. The analysis incorporated ten numerical comparison tables and three analytical figures to evaluate tariff exposure, international sourcing adjustments, manufacturing price effects, and upstream and downstream industrial dependencies. The numerical findings demonstrate substantial changes in international trade relationships during the tariff escalation period. United States merchandise imports from China declined by approximately 16.2% between 2018 and 2019, while imports from Vietnam and Taiwan increased by 35.6% and 18.6%, respectively. These changes indicate significant geographical adjustments in international sourcing patterns and highlight the importance of alternative manufacturing economies within global production networks.

Published causal estimates from the United States International Trade Commission provide additional evidence of the economic consequences of tariff interventions. Section 301 tariffs were estimated to reduce affected imports from China by approximately 13.0%, while increasing domestic production value by 0.4% and domestic product prices by 0.2%. The semiconductor industry exhibited particularly substantial effects, with an estimated 72.3% reduction in affected imports and a 6.4% increase in domestic production value. These differences demonstrate that tariff transmission varies considerably across manufacturing industries. The analysis also establishes the importance of indirect tariff effects through intermediate input relationships. Evidence from Section 232 steel and aluminum tariffs indicates that import restrictions can increase domestic production in protected industries while simultaneously raising input costs for downstream manufacturers. The estimated 0.6% reduction in downstream production and US$3.5 billion reduction in downstream production value in 2021 demonstrate the significance of evaluating tariff consequences across interconnected industrial sectors.

The study contributes to international trade and supply chain management research by developing an integrated conceptual framework for examining direct tariff exposure, indirect manufacturing dependencies, and geographical sourcing adjustments. The framework combines trade policy information, manufacturing input-output relationships, and causal inference principles to support more comprehensive assessments of tariff-related economic vulnerability. Overall, the findings demonstrate that tariff shocks can generate heterogeneous consequences across multinational manufacturing supply networks. Effective management of these disruptions requires coordinated supplier diversification, tariff exposure monitoring, flexible procurement arrangements, and informed production location decisions. The research further emphasizes that international trade policy evaluations should consider both the potential benefits to protected industries and the additional costs imposed on downstream manufacturing activities.

7.2 Major Research Contributions:

The study makes three principal contributions to the existing literature. First, it integrates tariff policy analysis with multinational manufacturing supply network relationships, providing a broader perspective on the transmission of trade policy disruptions across interconnected production activities. Second, it consolidates numerical evidence from official trade statistics and published economic impact assessments to distinguish observed trade adjustments from estimated tariff-related effects. This approach strengthens the interpretation of international manufacturing responses and reduces the risk of attributing unrelated economic changes exclusively to tariff interventions. Third, the proposed causal measurement framework establishes a foundation for evaluating manufacturing vulnerability through direct import exposure, intermediate input dependencies, supplier concentration, and geographical sourcing flexibility. This framework offers practical relevance for multinational manufacturers, supply chain managers, and international trade policymakers.

7.3 Limitations of the Study:

Despite its contributions, the study has certain limitations. The analysis relies primarily on secondary trade statistics and published economic impact estimates rather than newly collected firm-level manufacturing data. Consequently, detailed supplier-to-supplier transmission mechanisms cannot be directly observed. The country-level comparisons also reflect changes in total merchandise trade rather than exclusively tariff-affected manufacturing products. Furthermore, trade values may be influenced by

exchange rates, global demand, production capacity, and other economic developments occurring during the study period. Although the proposed framework incorporates causal inference principles, the present research does not independently estimate a new multinational network causal model. Therefore, the findings should be interpreted as an evidence-based synthesis of observed trade adjustments and previously published causal estimates.

7.4 Future Research Directions:

Future research can extend the proposed framework through the integration of firm-level supplier relationships, product-specific tariff schedules, and detailed international input-output datasets. Such information would enable more precise measurement of how tariff-related cost increases propagate through multiple manufacturing production stages. Further studies may employ difference-in-differences estimation, event-study analysis, and network-based causal models to evaluate the timing and magnitude of tariff effects across industries and trading partners. Particular attention should be given to identifying indirect exposure among manufacturers that do not directly import tariff-affected products.

Additional research could examine the long-term effectiveness of supplier diversification, regional production relocation, and manufacturing network restructuring. Comparative studies involving electronics, automotive manufacturing, machinery, and industrial materials may provide further insights into industry-specific adjustment mechanisms. Future investigations may also incorporate machine learning and advanced supply network analytics to improve tariff exposure monitoring, identify vulnerable supplier relationships, and support manufacturing risk assessment. These approaches should be combined with appropriate causal identification procedures to distinguish predictive relationships from policy-induced economic effects.

7.5 Final Research Findings:

The study establishes that international tariff shocks have measurable economic consequences for manufacturing trade, import prices, domestic production, and downstream industrial performance. The comparative numerical evidence demonstrates substantial differences across countries and manufacturing sectors, while published causal estimates confirm that tariff interventions can produce both protective effects and additional production costs. The central finding is that tariff shock transmission should be evaluated as an interconnected manufacturing network phenomenon rather than solely as a bilateral trade adjustment. Direct tariff exposure, intermediate input dependence, and supplier relationships jointly determine the channels through which trade policy changes may influence manufacturing performance. The proposed framework provides a structured foundation for assessing these relationships and supports the development of more resilient multinational manufacturing strategies. Its integration of numerical evidence, causal reasoning, and production network analysis contributes to a more comprehensive understanding of international tariff disruptions and their implications for manufacturing competitiveness, industrial policy, and global supply chain resilience.

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