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Multinational Production and Global Shock Propagation during the Great Recession

Abstract

I investigate multinational production (MP) patterns during the Great Recession and their impact on trade and shock transmissions across countries. Addressing the "Multinationals' Resilience Puzzle" – which questions why multinational enterprise (MNE) sales were more resilient than domestic counterparts in an average country yet MP's share in global GDP decreased – I find that larger countries faced greater MP declines and high MP intensity countries saw larger GDP drops. These patterns can be explained by adverse MNE productivity shocks in major economies that propagated to their MNEs elsewhere and reduced GDP in MP intensive countries. To quantify the spillover effects, I develop a model of MP, sectoral linkages, and global value chains. The model shows that, considering MNEs' involvement in trade, supply-side productivity shocks contributed almost as much to world total trade decline as demand shocks. MNE shocks had a more significant impact on cross-country trade variations compared to demand shocks. MP linkages amplified productivity shocks from key headquarters countries on global MP, trade, and welfare, highlighting the importance of productivity shocks and their propagation through MNEs in understanding the "Multinationals' Resilience Puzzle".

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1 Introduction

While economists have acknowledged the significant involvement of multinational enterprises (MNEs) in international trade, understanding of their impact on shock transmissions and trade patterns across countries during the Great Recession remains limited.[1] What roles did MP and trade play in the global propagation of shocks? Did multinational production (MP) exacerbate or mitigate the decline in trade? These insights guide policymakers in deciding whether MP and foreign direct investment (FDI) should be strengthened during times of crisis and escalating trade tensions.

I start with addressing the "Multinationals' Resilience Puzzle" during the Great Recession. As shown in Figure 1, from 2008 to 2009, global foreign affiliate sales by multinational enterprises ("global MP") declined by 11% relative to world GDP (when global trade declined by 12% relative to world GDP – the "Great Trade Collapse").[2] Interestingly, Alviarez et al. (2017) find that MNEs did not significantly differ from domestic firms in performance whereas other previous studies (Alfaro and Chen 2012 and Kamal and Kroff 2021) show that MNEs experienced smaller sales declines during the Great Recession.

I resolve this puzzle by documenting that the decline of global MP mainly stemmed from the negative performance of MNEs originating from major economies and operating within MP-intensive countries. Decomposing the global MP and trade declines relative to GDP within and between countries, I find that MP declined less than GDP for an average country, consistent with previous works.[3] However, countries with larger GDPs experienced a greater MP decline, while countries with high MP intensity saw a larger GDP decline. Hence, the global MP decline was likely driven by a few key headquarters countries, contrasting with the widespread trade collapse in nearly all countries.

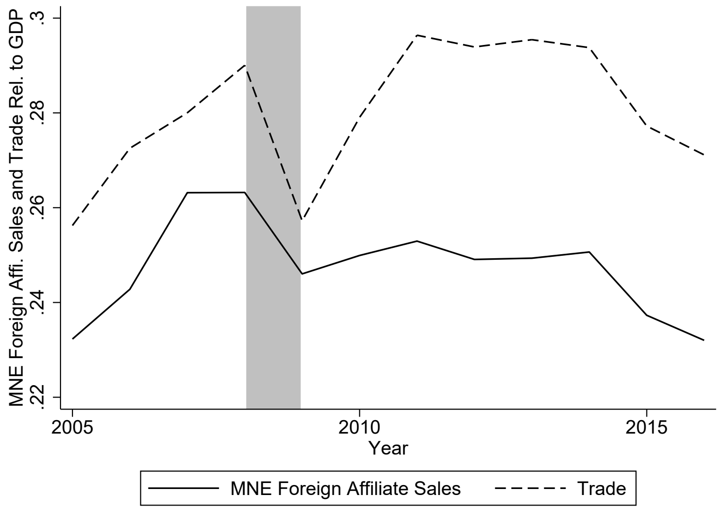
Adverse MNE productivity shocks in key headquarters countries, which subsequently spread to and negatively affected their MNEs' performance in other nations, thereby re-

[1]Specifically, Bernard et al. (2009) shows that MNEs account for 1.1% of all US firms but 90% of US exports and imports. According to the OECD Analytical Activities of Multinationals Database (Cadestin et al., 2019), MNE foreign affiliates account for 10% of global GDP but 40% of global trade with foreign affiliates on at least one side of the transaction (in 2008). Also see Antràs and Yeaple (2014), Ramondo et al. (2015), among others.

[2]This paper refers to the Great Recession as the period between 2008 and 2009. The ratio of world aggregate trade to world GDP fell from 0.29 to 0.26. The ratio of world total foreign affiliate sales to world GDP fell from 0.26 to 0.24. As a benchmark, world real GDP dropped by 1.7% (World Bank). Measures of global MNE foreign affiliate sales, trade, and GDP are acquired from the OECD Analytical Activities of Multinational Enterprises Database (Cadestin et al., 2019). See Levchenko et al. (2010), among others, for a review of the literature on the Great Trade Collapse.

[3]I also find that MP declined less than GDP for an average country-sector pair.

Figure 1: **Global MP and Trade Collapse in the Great Recession**



Description: The figure shows that both world total foreign affiliate sales and world total trade collapsed relative to world GDP in the Great Recession (2008-2009, shadowed years). The data source is OECD Analytical Activities of Multinationals (OECD AAMNE) Database.

ducing GDP in MP-intensive countries, could explain these patterns. To quantify the spillovers on international trade and welfare, I develop a model of multinational production and global value chains, taking into account shocks affecting sectoral final demand, MNEs' final demand, domestic and foreign affiliate productivity, as well as trade and MP costs. The model's key feature is that MNEs face headquarters-trade partner specific frictions for international trade. These frictions govern MNEs' vertical/horizontal-ness and explain why MNE status and headquarters countries influencing MNEs' sourcing and selling locations. Additionally, to produce tradable output, firms utilize labor and MNE-specific composite goods from all sectors.[4] These composite goods exhibit a nested sourcing structure, with an outer nest allowing substitution across host economies and an inner nest enabling substitution across MNEs within host economies. The MNE sourcing and selling frictions, along with the nesting structure, allow the model to precisely match the data. The matched market shares facilitate the computation of model counterfactuals.

I estimate parameters and shocks in the model using a new dataset that covers sectoral, international trade, and domestic sales by domestic firms and foreign affiliates - the OECD Analytical Activities of Multinational Enterprises Database (OECD AAMNE). I develop a new method to estimate sectoral trade elasticity and MNE elasticity (substitution elasticity across MNEs within the host economy), taking advantage of tariff exposures that shift the production costs by domestic firms and MNEs differently.[5] The estimated sectoral trade and MNE elasticities are higher for durable manufacturing sector than for

[4]These composite goods includes both physical goods and services.
[5]The estimation strategy is built on Head and Mayer (2019).

non-durable manufacturing and non-manufacturing sectors. Additionally, the MNE elasticities are smaller than the trade elasticities. I use data and model inversion to precisely back out the shocks related to MNE productivity, their ability to source from and sell to countries that are not their headquarters, and final demand for MNEs, which I term **MNE-specific shocks**. Additionally, I obtain the shocks that have been examined by previous trade collapse literature using trade-only models.

The cross-sectional fact that I documented – foreign affiliates trade more with their headquarters and countries in closer proximity to their headquarters – became more pronounced during the Great Recession. MNE-specific shocks were affected by distances: larger distance between countries resulted in increased sourcing and selling frictions between MNE headquarters and trade partners, as well as reduced MNE productivity and final demand for MNEs between MNE headquarters and host countries during the Great Recession. However, these shocks were less adverse when the headquarters had stronger pre-Recession trade and investment ties with the host countries.[6]

To examine the propagation of domestic productivity shocks through MP linkages, I estimate the share of headquarters' productivity in foreign affiliates' productivity. Documenting that a foreign affiliate's productivity consists of both headquarters' and host country's components, it can vary differently than domestic firms in both countries, causing domestic productivity shocks to propagate through MP networks. I find that the headquarters accounts for 6% (non-durable manufacturing) to 37% (durable manufacturing) of foreign affiliate's productivity.

My first set of simulation results highlights the importance of shocks affecting MNEs. Accounting for MP, supply-side productivity shocks contributed almost as much (36%) as demand-side forces (38%) to global trade decline. Without MP, the majority of the impact from MNE-specific shocks would be seen as final demand shocks, making them appear responsible for the majority of the trade collapse. Among the MNE-specific shocks examined, MNE relative productivity shocks had the most significant impact on both world total trade and MP collapse. After the Great Recession, due to the recovery in headquarters countries, MNE-specific shocks also contributed to the global trade recovery.

MNE-specific shocks played an even larger role in cross-country trade variation.[7] Due to greater heterogeneity in MP collapse compared to trade collapse across countries,

[6]This finding is consistent with Alfaro and Chen (2012), who find that the foreign affiliates with stronger intermediate goods trade and financial ties with the headquarters were more resilient during the Great Recession.

[7]I measure country-level trade collapse with the changes in the average of its imports and exports relative to its GDP. I measure a country's MP collapse with the changes in the average of its inward MP (sales made by foreign affiliates hosted by this country) and its outward MP (sales made by the country's affiliates hosted by other countries) relative to its GDP.

and the MP collapse's concentration in a few key headquarters countries, MNE-specific shocks accounted for 25% of trade collapse variation, nearly as much as domestic productivity shocks (29%), and 12% of welfare variation. In contrast, final demand shocks were responsible for just 2% of cross-country trade variations. Among MNE-specific shocks, reduced sourcing from non-headquarters countries contributed the most to trade collapse variation, and relative productivity shocks had the greatest impact on MP collapse variation. The high trade intensity of MNEs, driven by sourcing and selling frictions, was the primary reason for MNE shocks affecting the trade collapse.

In the second set of simulations, I explore cross-border shock propagation. I find that domestic productivity shocks in a country can significantly impact the global economy if propagated through MP headquarters linkages by affecting MNE productivity. Through these links, the impact of domestic productivity shocks on global trade collapse increased by 40%, and global MP collapse by 20%. Additionally, the impact of domestic productivity shocks on cross-country variations of trade collapse, MP collapse, and welfare changes increased by 12%, 84%, and 45% when propagated through MP headquarters linkages.

MP allows shocks in major countries to spread more extensively than through international trade alone. MNE-specific shocks impacting top global MP headquarters significantly influenced MP collapse and welfare in other countries. For example, MNE-specific shocks in the top ten headquarters countries explained 30% of MP collapse variation and 8% of welfare changes elsewhere. In contrast, domestic productivity shocks in the top ten countries in terms of trade, MP, or GDP did not explain variations in other countries' trade collapse or welfare when propagated only through trade. However, when domestic productivity shocks in the top ten headquarters countries could spread through MP linkages, they explained 17% of trade collapse variation across other countries.

In the end, examining the "Multinationals' Resilience Puzzle" using the model, the puzzle can be explained by productivity shocks and their transmission from key MP headquarters to host countries. Productivity shocks from the top ten headquarters cause more significant declines in MP relative to GDP in larger countries, increased GDP reductions in MP-intensive countries, and resilience of MP relative to GDP in an average country. However, final demand shocks or domestic productivity shocks, if they only propagate through trade linkages, are unable to account for these patterns.

These findings show that MNE-specific shocks in these key headquarters countries propagated globally, leading to the joint declines of their MNE performances and MP-intensive countries' output. Consequently, shocks to MNEs had a greater impact on cross-country variations in trade collapse, MP collapse, and welfare. In contrast, final demand shocks against durable manufacturing goods occurred in nearly all countries and contributed to the decline of world total trade but had limited effect on the cross-country variations. The post-Recession recovery in MP headquarters also contributed to global trade recovery after the Great Recession. Therefore, global policymakers, particularly in countries hosting numerous MP activities, should strengthen MP linkages with economically stable headquarters.

This paper contributes to the literature on MNE performances during the Great Recession by building on the empirical findings of Alfaro and Chen (2012), Alviarez et al. (2017), Kamal and Kroff (2021), and Basco et al. (2023). These studies explore potential factors driving the MP collapse and highlight a previously unexplored international dimension of recessions. Moreover, Biermann and Huber (2019) and Bena et al. (2022) investigate the transmission of shocks from headquarters and key subsidiaries to a broader set of foreign affiliates. This paper also connects to the extensive literature on trade collapse, with works like Alessandria et al. (2010a,b), Bems et al. (2010), Levchenko et al. (2010), and Eaton et al. (2016), who attribute the global trade collapse primarily to the decline in demand for the durable manufacturing sector, a sector with higher trade intensity. While previous literature analyzed trade and MP collapses separately, this paper proposes a quantitative framework to assess the mutual impact of trade and MP shocks, revealing that MNE-specific shocks account for a significant portion of the trade collapse. Furthermore, this paper is the first to reveal that compared to the final demand shocks, MP shocks contributed more to the cross-country variations in the trade and MP collapse.

The paper builds on the literature that studies the propagation of shocks across regions and sectors. Several previous studies have found that trade linkages (Kehoe and Ruhl 2008, Di Giovanni et al. 2018, Huo et al. 2019, Dhyne et al. 2021, among others), input-output connections (Caliendo and Parro 2015, Caliendo et al. 2017, Baqaee and Farhi 2019a, Baqaee and Farhi 2019b, Foerster et al. 2019, among others), and relationships between MNE headquarters and host countries (Cravino and Levchenko 2017, Alviarez et al. 2020, Bilir and Morales 2020) can result in economic shocks affecting other parts of the economy. I introduce a tractable framework accounting for all three channels. I find that MP propagation from headquarters to foreign affiliates significantly amplified the impact of domestic productivity shocks in top headquarters countries on trade, MP, and welfare in other countries.

This paper also builds on the theoretical literature of multinational production. It extends Ramondo and Rodríguez-Clare (2013), Tintelnot (2017), Arkolakis et al. (2018) to incorporate sector linkages and the MNEs' sourcing and selling frictions with non-headquarters countries. It introduces the MNE sourcing frictions and sectoral input-output linkages into Head and Mayer (2019) and Wang (2019), and it introduces both the sourcing and selling frictions into Alviarez (2019). An analysis ignoring either friction will not capture differences in MNEs' sourcing and selling patterns from various headquarters. Moreover, disregarding these frictions underestimates the impact of MNE-specific shocks on trade collapse.

The rest of the paper is organized as follows: Section 2 presents new facts about multinational production during the Great Recession and in the cross section. Section 3 describes the model. Section 4 takes the model to the data to calibrate the shocks and estimate the elasticities. Section 5 presents the simulation results. Section 6 concludes.

2 Data and Empirical Facts

2.1 OECD Analytical Activities of Multinationals Database

As far as I am aware, this is the first academic study to utilize the OECD AAMNE database. The database offers information on bilateral gross output and international trade for domestic/foreign firms across 59 countries and a constructed rest of the world.[8] It comprises two data tables. The first presents a complete matrix of MNE gross output by headquarters country, host country, and industry (34 in total).[9] The second extends OECD intercountry input-output database coverage to all countries and sectors, dividing each cell into four based on whether the buyer or seller of each trade flow is a domestic firm or foreign affiliate. OECD AAMNE covers 2005 to 2016.

In order to ensure comparability with Eaton et al. (2016), I use the same sector classification, collapsing the 34 industries in the OECD AAMNE Database into three broad categories: durable manufacturing, nondurable manufacturing, and non-manufacturing. Table A.2 lists the industries in OECD AAMNE and their mappings to the broad sectors.

The data is supplemented with country-sector-level GDP data from the UN National Account Database and labor force data from Penn World Table version 9.1 (Lederman et al., 2017).[10] Additionally, I obtain country-bilateral variables such as distance, common

[8]OECD AAMNE advances the existing OECD Activities of Multinationals Database. The old database was used in several past works, including Alviarez et al. (2017), Alviarez (2019), etc. While the old database covers many aspects of MNE activities, for example, gross output, value added, total imports and exports, for OECD countries, it does not include important emerging market economies, such as Brazil, China, and India. Additionally, the database provides only the aggregate trade statistics of foreign affiliates (e.g., the total export of foreign affiliates in China); it does not provide a breakdown among their trading partners. Table A.1 shows the countries in OECD AAMNE.

[9]OECD ICIO, a database that documents international trade between country-sector pairs. See Ahmad et al. 2006.

[10]The variable used is "Number of persons engaged (in millions)".

language, and contiguity from CEPII data (Head et al. 2010, Head and Mayer 2014), along with the latest global trade agreements information from Head and Mayer (2019).

Following Eaton et al. (2016), I measure country-level trade collapse using changes in a country's average imports and exports relative to its GDP (between 2008 and 2009). Similarly, I define country-level MP collapse using changes in a country's average inward and outward foreign affiliate sales relative to its GDP (between 2008 and 2009). Inward foreign affiliate sales represent sales of foreign affiliates headquartered elsewhere and operating within a country. Outward foreign affiliate sales represent sales of foreign affiliates headquartered in the country and operating abroad.

2.2 Resolving the "Multinationals' Resilience Puzzle"

Figure 1 shows that, similar to trade, worldwide sales by multinational foreign affiliates also declined as a share of world GDP. Figure A.1 shows that these patterns are consistent across all sectors, indicating that sectoral compositions may not be the sole driving force. However, prior research (e.g., Alfaro and Chen 2012, Alviarez et al. 2017, Kamal and Kroff 2021) indicates that MNEs were more resilient and declined less in sales during the Great Recession compared to domestic firms.[11] To comprehensively understand MNE performances during the Great Recession, it is crucial to address these discrepancies, which I refer to as the "Multinationals' Resilience Puzzle".

The "Multinationals' Resilience Puzzle" can be resolved using a between-within-country decomposition. This solution offers insights into the sources of MP and trade collapses and their propagation mechanisms across countries. Equation (1) decomposes the decline in world total MNE foreign affiliate sales relative to world GDP into three terms: (A) representing whether MP declines more in countries with larger GDPs; (B) representing whether GDP declines more in countries with higher MP intensity; and (C) the within-country effect, which is the decline in MP relative to GDP for an average country. In technical terms, in Equation (1), i represents a country, N the total number of countries, $MP_{i,t}$ the average of country i's inward and outward MP in year t, and $GDP_{i,t}$ the country i's GDP in year t. Term A is the covariance between the country-level MP collapse and the time-average of countries' shares of world GDP (adjusted for the number of countries). Term B is the covariance between the changes in countries' shares of world GDP and the time-average of countries' MP intensity (adjusted for the number of countries).

[11] Although Alviarez et al. (2017) report that an average MNE performed worse than a domestic firm if various firm-level characteristics were not controlled, the connection between global aggregate declines in MP relative to GDP and the average resilience of MNEs remains unexplored.

The within-country effect is the average MP collapse across countries.[12]

$$\frac{\sum_{i=1}^{N} MP_{i,2009}}{\sum_{i=1}^{N} GDP_{i,2009}} - \frac{\sum_{i=1}^{N} MP_{i,2008}}{\sum_{i=1}^{N} GDP_{i,2008}} =$$

$$\underbrace{\underbrace{N\,\text{cov}_i\Big(\frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}}, \frac{\frac{GDP_{i,2009}}{\sum_{i=1}^{N} GDP_{i,2009}} + \frac{GDP_{i,2008}}{\sum_{i=1}^{N} GDP_{i,2008}}}{2}\Big)}_{\text{A}} + \underbrace{N\,\text{cov}_i\Big(\frac{GDP_{i,2009}}{\sum_{i=1}^{N} GDP_{i,2009}} - \frac{GDP_{i,2008}}{\sum_{i=1}^{N} GDP_{i,2008}}, \frac{\frac{MP_{i,2009}}{GDP_{i,2009}} + \frac{MP_{i,2008}}{GDP_{i,2008}}}{2}\Big)}_{\text{B}}}_{\text{Between-country Effects}}$$

$$+ \underbrace{\frac{1}{N}\sum_{i=1}^{N}\Big(\frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}}\Big)}_{\text{C: Within-country Effect}}. \quad (1)$$

Fact 1: MP declined more in countries with larger GDPs and GDP declined more in MP intensive countries.

The MP collapse was concentrated in countries with larger GDPs. The within-country term in Table 1 shows that, during the Great Recession, MP is more resilient than GDP for an average country, hence resolving the puzzle. Furthermore, MP declined more in larger countries, with the covariance between country-level MP collapse and country size accounting for 104% of the global MP decline. GDP declined more in MP-intensive countries, and term B contributed 49% to the global MP collapse. These two covariance terms accounted for the entire global MP collapse.

Adverse domestic productivity shocks in major headquarters countries, which spread to other nations through MNEs, could explain these patterns. The Great Recession arose from a crisis in the financial system and real estate sector in the United States, which rapidly spread to the financial sectors of other advanced economies. Since MNE operations rely on financing from their headquarters, these shocks negatively impacted the performance of MNEs originating from these advanced economies, which also happen to be key global headquarters countries.[13] Since MNEs conduct significant economic activities in MP-intensive countries, the decline in their performance also led to GDP decreases in these nations. These points will be further examined in Section 4.4. Shocks in these key headquarters countries may have also significantly impacted global trade and welfare, as MNEs have high trade intensity and concentrate in durable manufacturing sectors (these facts will be presented in Section 2.3).

These insights may also help reconcile different findings in prior research. While most

[12]To decompose the global trade collapse, replace $MP_{i,t}$ with the average of country i's imports and exports in year t.

[13]See Biermann and Huber (2019) and Bena et al. (2022), which provide empirical support for these arguments.

Table 1: **MP Declined More in Larger Countries and GDP Declined More in MP Intensive Countries**

	MP/Trade Declined More in Larger Countries	GDP Declined More in MP/Trade Intensive Countries	Within-country	Total
All				
MP	–0.018 (104.0%)	–0.008 (49.0%)	0.009 (–53.0%)	–0.017 (100%)
Trade	0.008 (–23.4%)	–0.002 (6.7%)	–0.038 (116.6%)	–0.033 (100%)
I. Durable Manufacturing				
MP	–0.056 (237.7%)	–0.032 (136.7%)	0.065 (–274.4%)	–0.024 (100%)
Trade	0.037 (–44.6%)	–0.007 (8.9%)	–0.112 (135.8%)	–0.083 (100%)
II. Non-durable Manufacturing				
MP	–0.013 (35.2%)	–0.033 (88.4%)	0.009 (–23.6%)	–0.038 (100%)
Trade	0.009 (–20.7%)	–0.012 (27.8%)	–0.041 (92.9%)	–0.044 (100%)
III. Non-manufacturing				
MP	–0.012 (107.4%)	–0.007 (58.6%)	0.007 (–66.0%)	–0.011 (100%)
Trade	0.005 (–24.3%)	–0.002 (9.7%)	–0.023 (114.6%)	–0.020 (100%)

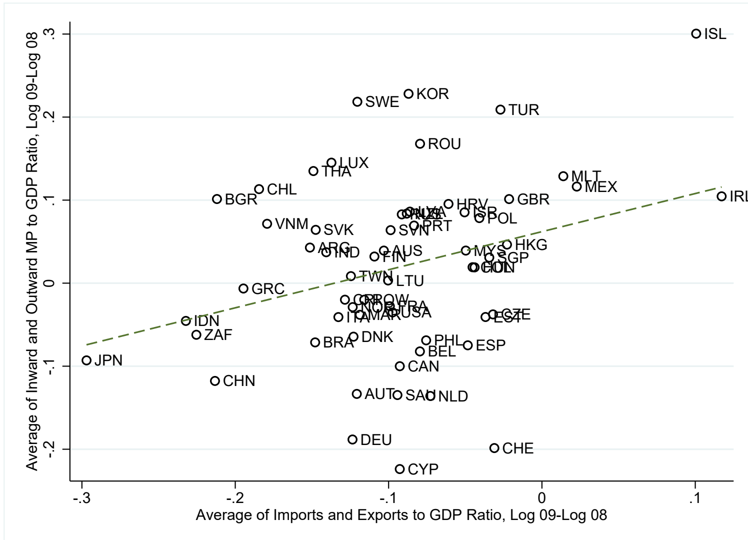
Description: This table presents the decomposition of the change in the ratio of world total trade to world GDP and the ratio of world total MP to world GDP from 2008 to 2009. The first component measures how much MP/trade decreased in larger countries. The second component measures how much GDP declined in countries with high MP/trade intensities. The third component measures the contribution of cross-country simple averages of changes in multinational production and trade as a proportion of GDP. Equation (1) shows the decomposition formula. The numbers outside the brackets refer to the magnitude of each term, while the numbers inside the brackets refer to its percentage contribution.

studies agree that MNEs were at least as resilient as domestic firms, Alfaro and Chen (2012) and Kamal and Kroff (2021) report higher resilience compared to Alviarez (2019). This discrepancy may stem from the latter's focus on OECD countries, which are more advanced and experienced a greater decline in MNEs.

Compared to the MP collapse, the global trade collapse appeared in almost all countries and displayed less cross-country heterogeneity. This is supported by the within-country term accounting for the entirety of the trade collapse (also see Figure 2). Larger countries didn't experience a more significant trade decline, nor did those with higher trade intensity see a larger GDP decline. For an average country, trade declined significantly more relative to GDP. These patterns suggest that shocks contributing to the global trade collapse arose in almost all countries.

Table 1 Panels I-III demonstrate that the "Multinationals' Resilience Puzzle" and the difference between MP and trade collapses apply to all sectors. Table A.3 further breaks down MP and trade declines in each country into three terms: (C.1) larger sector MP/trade decline, (C.2) sectoral GDP decline in MP/trade-intensive sectors, and (C.3) cross-sector average MP/trade decline relative to GDP. All "between-country" and "between-sector" effects contributed to the global MP collapse, implying strong propagation across countries and sectors. For an average country and sector, MP is notably more resilient than GDP. In contrast, the global trade collapse mainly resulted from factors within countries and sectors. Tables A.4 and A.5 decompose the post-Recession recovery and 2013-2016

Figure 2: **MP and Trade Collapses were Positively Correlated at the Country Level**



Description: This figure shows the changes in the average of inward and outward affiliate sales, as well as the average of imports and exports in relation to the GDP for each country from 2008 to 2009. The data source is OECD Analytical Activities of Multinationals (OECD AAMNE) Database.

trade and MP declines.

2.3 Additional Facts about Multinational Production during the Great Recession and in the Cross Section

Fact 2: There was a positive correlation between the collapses of MP and trade across countries.

Figure 2 displays a positive correlation between MP and trade collapses. This suggests that MP shocks may have played a role in trade variations, and vice versa.[14] The MP collapse was more heterogeneous across countries compared to trade, with all but three countries experiencing trade collapse while MP decreased relative to GDP in less than half of them. However, some countries, such as Germany, saw MP decline over 20% in relation to GDP. Examining the shocks affecting these countries could be crucial for the global economy. Figure A.2 shows that these relationships hold for each sector.

Fact 3: MNEs are more intensive in the durable manufacturing sector and international trade.

Figure 3a indicates that MP activities are most intensive in durable manufacturing sector. Foreign affiliates account for 14% of gross output in non-manufacturing sector,

[14] Regressing the MP collapse on the trade collapse at the country level gives a coefficient of .504 and a standard error of 0.182.

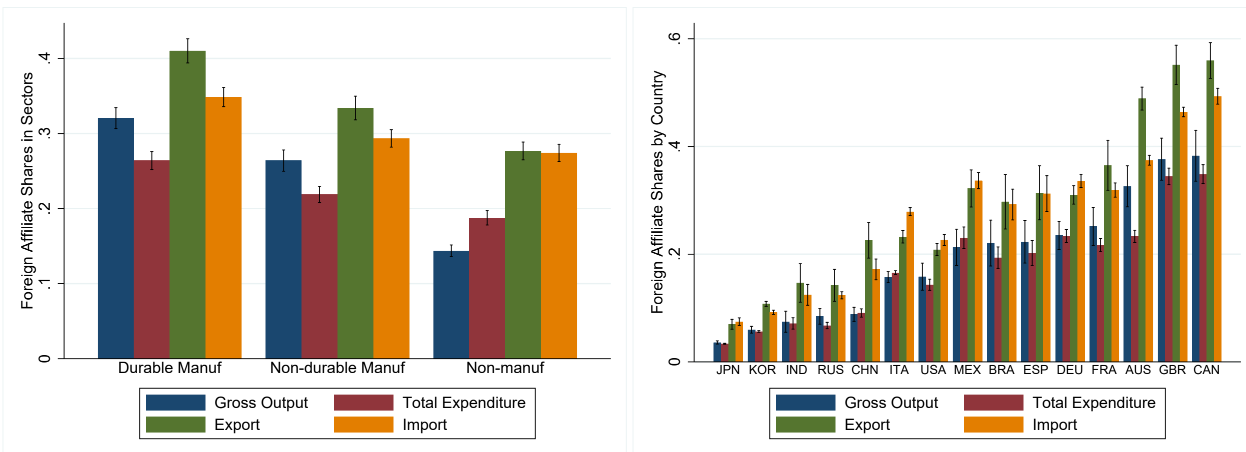
27% in non-durable manufacturing sector, and 33% in durable manufacturing sector.[15]

Figure 3b shows that foreign affiliates account for higher shares in exports and imports than in gross output and intermediate input expenditure.[16] For an average country and sector, foreign affiliates account for 8.2% higher shares in imports than expenditure on intermediate input and 9.8% higher shares in exports than gross output.[17]

Figure 3: **Foreign Affiliate Shares by Sector and Country**

(a) Foreign Affiliate Shares by Sector

(b) Foreign Affiliate Shares by Country



Description: The left panel plots foreign affiliate shares in world total gross output, total intermediate input expenditure, total import and total export, in non-manufacturing, nondurable manufacturing and durable manufacturing sectors. For each sector, the height of the bar denotes the average value and the spike and caps denote the 95% CI for all countries and years. The right panel plots foreign affiliate shares in country-level gross output, intermediate input expenditure, imports and exports. These statistics are presented for the top ten countries in terms of GDP (in 2007) for the purpose of clarity. For each country, the height of the bar denotes the average value and the spike and caps denote the 95% CI for all sectors and years. The data source is OECD Analytical Activities of Multinationals (OECD AAMNE) Database.

Fact 4: MNEs' foreign affiliates import relatively more from their headquarters countries, and from countries that are proximate to their headquarters.

I investigate the relationship between MNE status and trade on the firm level. First, I

[15]In addition to visualization with Figure 3a, I also consider the following regressions:

$$S_{csyv} = \beta_1 \mathbf{1}(s = \text{Durable manuf}) + \beta_2 \mathbf{1}(s = \text{Non-durable manuf}) + \delta_c + \zeta_y + \epsilon_{csy,v=GO},$$

where S_{csyv} denotes foreign affiliate shares in $v \in \{\text{Gross Output, Total Intermediate Expenditure, Exports, Imports}\}$ of country c, sector s in year y. I get $\beta_1 = .176(.003)$, $\beta_2 = .120(.003)$ for gross output, $\beta_1 = .076(.002)$, $\beta_2 = .031(.002)$ for total intermediate input expenditure, $\beta_1 = .133(.005)$, $\beta_2 = .057(.005)$ for exports, and $\beta_1 = .074(.003)$, $\beta_2 = .019(.003)$ for imports.

[16]These statistics are presented for the top ten countries in terms of GDP (in 2007) for the purpose of visualization.

[17]I consider the following regression:

$$S_{csyv} = \beta_1 \mathbf{1}(v = \text{Total expenditure}) + \beta_2 \mathbf{1}(s = \text{Export}) + \beta_3 \mathbf{1}(s = \text{Import}) + \delta_c + \gamma_s + \zeta_y + \epsilon_{csyv}$$

where S_{csyv} denotes foreign affiliate shares in $v \in \{\text{Gross Output, Total Intermediate Expenditure, Exports, Imports}\}$ of country c, sector s in year y. I get $\beta_1 = -.019(.005)$, $\beta_2 = .097(.005)$, $\beta_3 = .062(.005)$ with standard errors in parenthesis.

show that MNEs participate more in both importing and exporting even when accounting for firm-level controls. Furthermore, a firm's headquarters location influences its sourcing and sales. I take advantage of Chinese firm-level databases, including the Annual Survey of Chinese Manufacturing Database for business statistics, China Customs Records Database for import/export transactions, and the Foreign-Invested Enterprise Survey Database for ownership nationalities of foreign affiliates in China.[18]

Adopting the empirical strategy from Wang (2019) and elaborating further in Section A.3, two facts are established for foreign affiliates' importing decisions.[19] Considering firm-level characteristics, foreign affiliates are 36% more likely to import and import 14% more relative to total sales than local firms (Table A.6). When accounting for the firm and importing origin fixed effects, foreign affiliates are 13% more likely to source from their headquarters. A 1% increase in distance between headquarters and sourcing origin leads to a 0.3% drop in sourcing probability and a 0.2% decline in importing values (Table A.7).

These findings suggest MNEs encounter transaction frictions in global sourcing and exporting specific to their headquarters and trading partners, as will be modeled in Section 3.[20] In Section 4.1, I show that these frictions were amplified as a function of distances during the Great Recession, offering a mechanism through which MNEs contributed to the trade collapse. MNE selling frictions may stem from distribution network costs, marketing expenses, or limited consumer preference knowledge. MNE sourcing frictions could result from technology incompatibility, regulatory differences, or insufficient information on global sourcing options.

3 Model

A quantitative analysis is crucial for understanding shock propagation through MP and trade across countries and identifying the shocks responsible for the "Multinationals' Resilience Puzzle". To this end, I construct a model of multinational production and global value chains, with the model's features inspired by empirical facts.

The model's environment is the following: the global economy consists of N countries

[18]Detailed information about these data sets are presented in Section A.3.

[19]Wang (2019) finds that, conditional on firm characteristics, foreign affiliates are more likely to export and to export more than local firms. Foreign affiliates also export more back to their headquarters and to destinations closer to their headquarters. I thank Zi Wang for guiding me through the detailed procedure to clean and merge the three databases.

[20]Wang (2019) shows that other things constant, foreign affiliates engage more in exporting, and export more to the headquarters and to the countries that are close to their headquarters. I replicate these findings in Section A.4.

and S sectors. Each country m, sector s has a technology that is used to produce in any country n in the world. Agents in the economy are workers and firms/MNEs. Firms are considered foreign affiliates if the host economy n differs from the headquarters m, and domestic otherwise. MNEs are defined by their headquarters m, host country n, and sector s. They use labor and MNE-specific composite goods as inputs. All markets are competitive.[21]

3.1 The Firm's Problem

In country n, sector s, country m's MNE produces tradable output y^s_{nm} by combining labor and MNE-specific composite intermediate inputs from all sectors:[22]

$$y^s_{nm} = A^s_{nm} \left(\frac{L^s_{nm}}{\gamma^s_n} \right)^{\gamma^s_n} \prod_{s'=1}^{S} \left(\frac{M^{ss'}_{nm}}{\gamma^{ss'}_n} \right)^{\gamma^{ss'}_n} . \tag{2}$$

The firm's productivity, A^s_{nm}, varies with respect to both headquarters and host country.[23] Domestic firms' productivity, A^s_{nn}, is referred to as **domestic productivity**, while the **MNE relative productivity** is $\frac{A^s_{nm}}{A^s_{nn}}$ (I will parameterize it in Section 4.4). Labor hired by MNEs is denoted as L^s_{nm}, and non-tradable, MNE-specific composite goods of sector s' for producing s output are $M^{ss'}_{nm}$. The MNE-specific composite input price is P^s_{nm}, and the production function has constant returns to scale with $\gamma^s_n + \sum_{s'=1}^{S} \gamma^{ss'}_n = 1$.[24] MNEs operating in the same host country differ in TFP and MNE-specific composite input prices.

3.2 International Trade by MNEs

The composite intermediate input is assumed to be a nested-CES aggregate over global tradable output:

$$Q^s_{nm} = \left[\sum_{j=1}^{N} \left(\sum_{i=1}^{N} \left(q^s_{nmji} \right)^{\frac{\zeta^s - 1}{\zeta^s}} \right)^{\frac{\zeta^s}{\zeta^s - 1} \frac{\sigma^s - 1}{\sigma^s}} \right]^{\frac{\sigma^s}{\sigma^s - 1}} . \tag{3}$$

[21]These assumptions follow from Ramondo and Rodríguez-Clare (2013), Caliendo and Parro (2015), Eaton et al. (2016), Caliendo et al. (2017), Cravino and Levchenko (2017), and Alviarez et al. (2017).

[22]I assume technology and trade flow from right to left in the subscripts.

[23]The same idea is considered by Cravino and Levchenko (2017), Tintelnot (2017), and others.

[24]I assume that all MNEs in platform country n have the same input-output shares γ^s_n and $\gamma^{ss'}_n$ – the same assumption is used by Alviarez (2019).

The composite intermediate input is produced using a "love-of-variety" production function, combining tradable output from upstream host countries and MNEs in each host country. The trade-offs between host countries are modeled in the outer-nest with an elasticity of substitution σ^s. The inner nest combines all MNEs in the host country, characterized by an elasticity of substitution ζ^s. σ^s and ζ^s are referred to as trade and MNE elasticity, respectively. Tradable output varies based on production location and technology source. q^s_{nmji} indicates the volume of output sold from an MNE headquartered in country i, operating in j, to an MNE headquartered in country m, operating in n.

The price paid by an MNE from country m, operating in n, for a unit of output from an MNE in country i, operating in j, is:

$$\tilde{H}^s_{ni}\tilde{h}^s_{mj}k^s_{nj}t^s_{nj}\frac{\Theta^s_{ji}}{A^s_{ji}}. \tag{4}$$

$\Theta^s_{ji} = (w_j)^{\gamma^s_j}\prod_{s'=1}^{S}\left(P^{s'}_{ji}\right)^{\gamma^{ss'}_j}$ represents the input bundle cost or sourcing capability, with $\frac{\Theta^s_{ji}}{A^s_{ji}}$ as the factory gate price for one unit of output. This follows from profit maximization and the perfect competition assumption. Trade between countries j and n faces iceberg, **non-tariff trade barriers**, k^s_{nj}, and ad-valorem **tariffs** at rate τ^s_{nj}, where $t^s_{nj} = 1 + \tau^s_{nj}$. Tariff revenue is transferred to country n's households for consumption.[25] MNEs face iceberg, headquarters-trade partner specific bilateral frictions when sourcing from and selling to non-headquarter countries. $\tilde{h}^s_{mj}$ represents the MNE sourcing friction for an MNE headquartered in country m to source from country j, while $\tilde{H}^s_{ni}$ denotes the MNE selling friction for an MNE headquartered in country i to sell to country n.[26]

The nested-CES aggregator and the price of tradable output imply two sets of market shares that govern the international trade patterns by MNEs: the **MNE output shares** and **MNE sourcing shares**. The MNE output shares refer to those of the selling MNE (headquartered in i and operating in j) in the trade flows from host country j to destination n. They are the inner-nest shares and equal the following:

$$S^s_{n\cdot ji} = \frac{H^s_{ni}\left(\frac{\Theta^s_{ji}}{A^s_{ji}}\right)^{1-\zeta^s}}{\sum_{k=1}^{N} H^s_{nk}\left(\frac{\Theta^s_{jk}}{A^s_{jk}}\right)^{1-\zeta^s}}. \tag{5}$$

I relabel $H^s_{ni} = (\tilde{H}^s_{ni})^{1-\zeta^s}$, denoting **MNE selling efficiency** for MNEs headquartered in i

[25] I assume the tariff barriers are multiplicative separable from the non-tariff trade barriers. The same assumption is used by Caliendo and Parro (2015), among others.

[26] Non-tariff trade barriers within a country, as well as MNEs' selling and sourcing frictions with the headquarters, are normalized to one: $k^s_{nn} = \tilde{H}^s_{ii} = \tilde{h}^s_{mm} = 1$.

selling to country n. This efficiency will be exactly backed out using data and model inversion in Section 4. Country j's producer price index for shipments to n, $P^{s,p}_{nj}$, is defined using the denominator of Equation (5): $(P^{s,p}_{nj})^{1-\zeta^s} = \sum_{k=1}^{N} H^s_{nk} \left(\frac{\Theta^s_{jk}}{A^s_{jk}}\right)^{1-\zeta^s}$. A lower producer price index for country j shipping to n indicates higher productivity, lower input prices, or greater selling efficiency for MNEs hosted by country j.

The MNE sourcing shares refer to those of the buying MNE (headquartered in m and operating in n) from the origin country (country j). They are the outer-nest shares and equal the following:

$$\pi^s_{nmj\cdot} = \frac{h^s_{mj}(k^s_{nj}t^s_{nj}P^{s,p}_{nj})^{1-\sigma^s}}{\sum_{l=1}^{N} h^s_{ml}(k^s_{nl}t^s_{nl}P^{s,p}_{nl})^{1-\sigma^s}}. \tag{6}$$

I relabel $h^s_{mj} = (\tilde{h}^s_{mj})^{1-\sigma^s}$, where it denotes the efficiency of MNEs headquartered in m to source from j, also known as the **MNE sourcing efficiency**. This efficiency will also be backed out with data and model inversion in Section 4.[27] The composite intermediate input price index of the MNE from m operating in n can be defined with the following: $(P^s_{nm})^{1-\sigma^s} = \sum_{l=1}^{N} h^s_{ml}(k^s_{nl}t^s_{nl}P^{s,p}_{nl})^{1-\sigma^s}$. The MNE headquartered in m producing in n will face lower composite input prices if country n benefits from lower trade barriers and lower producer price indices, or if country m's MNE is more efficient at global sourcing.

In the alternative to the nested-CES setup, in Section B.1, I build on Eaton and Kortum (2002), Ramondo and Rodríguez-Clare (2013), and others, to develop a micro foundation for this MNE's sourcing problem. In this problem, the downstream MNE draws correlated productivity shocks for upstream host countries and upstream MNEs and source from the lowest-cost supplier. As a result of the other model setup, the same market shares are obtained as in Equations (5) and (6).

MNE sourcing and selling efficiencies determine their vertical/horizontal nature. Consider three cases: (1) If $h^s_{mj} = 0, \ \forall j \neq m$, foreign affiliates source exclusively from their headquarters m. Such forward-vertical MNEs have headquarters as the sole input supplier, e.g., Toyota dealers in the US importing cars only from Japan; (2) If $H^s_{ni} = 0, \ \forall n \neq i$, foreign affiliates sell only to their headquarters. These backward-vertical MNEs have headquarters as the exclusive buyer, e.g., Toyota's tire suppliers in Thailand providing tires solely to Japan; and (3) If $h^s_{mj} = H^s_{ni} = 1, \ \forall m, n, j, i$, foreign affiliates have the same sourcing shares as domestic firms in the host country, and their sales shares equal to those of domestic firms. These horizontal MNEs differ from domestic firms in productivity but

[27] Both the selling and sourcing efficiencies are relative to selling and buying with the MNE headquarters, with the normalization $H^s_{ii} = 1 \ \forall i$ and $h^s_{mm} = 1 \ \forall m$.

not trade patterns – where they source from and sell to.[28] Hence, heterogeneous MNE sourcing and selling efficiencies could explain why foreign affiliates engage more in both importing and exporting than domestic firms, and trade more with their headquarters and partners in closer proximity to their headquarters (patterns documented in Figure 3a and 3b and Section 2.3).

In reality, most MNEs exhibit a mix of forward-vertical, backward-vertical, and horizontal characteristics.[29] Thus, the true values of MNE sourcing and selling efficiencies are unlikely to fall strictly into any of these three cases. I will exactly back out the sourcing and selling efficiencies using data.

Additionally, expenditure share of an MNE from country m that operates in n, on the tradable output from an MNE headquartered in country i that operates in j, is found to be separable in the corresponding sourcing share and output share:

$$\pi^s_{nmji} = \pi^s_{nmj\cdot} S^s_{n\cdot ji}.$$

3.3 The Consumer's Problem

Representative households in country n have a CES utility function over sectoral final goods:

$$U_n = \left(\sum_{s=1}^{S} (\alpha^s_n)^{\frac{1}{\lambda}} (C^s_n)^{\frac{\lambda-1}{\lambda}} \right)^{\frac{\lambda}{\lambda-1}}.$$

C^s_n denotes sector s final goods and λ denotes the elasticity of substitution across sectors. To understand how sector compositions affect the collapses of trade and MP, I let α^s_n denote sectoral preferences and shocks to α^s_n refer to the **sectoral final demand shocks**.[30]

[28] Compare a foreign affiliate headquartered in m and producing in n with a domestic firm in country n. With $h^s_{mj} = 1,\ \forall m, j$, the two producers have the same sourcing shares from any given origin country: $\pi^s_{nmj\cdot} = \pi^s_{nnj\cdot},\ \forall m, n, j$. Next, compare a foreign affiliate headquartered in i and producing in j with country j's domestic firms. With $H^s_{ni} = 1,\ \forall n, i$, MNEs have the same output shares in trade flows for any given destination: $S^s_{n\cdot ji} = S^s_{j\cdot ji}, \forall n$. Denote total sales from country j to any country n in sector s with T^s_{nj}. The gross output by the foreign affiliate headquartered in i and hosted by j equals $\sum_{n=1}^{N} T^s_{nj} S^s_{n\cdot ji}$. The share of destination n in this MNE's total output equals: $\frac{T^s_{nj} S^s_{n\cdot ji}}{\sum_{n=1}^{N} T^s_{nj} S^s_{n\cdot ji}} = \frac{T^s_{nj}}{\sum_{n=1}^{N} T^s_{nj}}$, which is invariant to the MNE's headquarters and is the same regardless of whether it is a foreign affiliate.

[29] See Yeaple (2003), Antràs and Yeaple (2014), Baldwin and Okubo (2014), Ramondo et al. (2016), among others.

[30] I impose the normalization that $\alpha^s_n = 1$ for the non-manufacturing sector.

This implies that the sectoral final expenditure share equals the following:

$$s_n^s = \frac{\alpha_n^s (P_n^s)^{1-\lambda}}{\sum_{s'=1}^S \alpha_n^{s'} (P_n^{s'})^{1-\lambda}}, \tag{7}$$

where P_n^s denotes the price index of sectoral final goods. Sectoral final goods combine MNE-specific composite goods supplied by both domestic and foreign firms:

$$C_n^s = \left(\sum_{m=1}^N (\alpha_{nm}^s)^{\frac{1}{\delta^s}} (C_{nm}^s)^{\frac{\delta^s - 1}{\delta^s}} \right)^{\frac{\delta^s}{\delta^s - 1}}.$$

C_{nm}^s denotes MNE-specific composite goods for sale to final users. δ^s denotes sectoral elasticities of substitution across different MNEs in final expenditure. α_{nm}^s denotes the preference for MNEs by final consumers and shocks to α_{nm}^s refer to the **MNE final demand shocks**.[31] This implies that MNE nm's share in country n sector s consumption bundle equals the following:[32]

$$s_{nm}^s = \frac{\alpha_{nm}^s (P_{nm}^s)^{1-\delta^s}}{\sum_{m'=1}^N \alpha_{nm'}^s (P_{nm'}^s)^{1-\delta^s}}. \tag{8}$$

Households have three sources of income: labor income, for which households inelastically supply L_n units of labor at wage rate w_n; the tariff revenue R_n; and a transfer from other countries that compensates for the trade deficit observed in the data, D_n. I use I_n to denote the household income. The household's budget constraint is therefore the following:

$$\sum_{s=1}^S \sum_{m=1}^N P_{nm}^s C_{nm}^s = I_n = w_n L_n + R_n + D_n.$$

Market Clearing To close the model, the market has to clear for labor and composite intermediate input. The labor market clearing condition in j is the following:

$$w_j L_j = \sum_{s=1}^S \gamma_j^s \sum_{n=1}^N \sum_{m=1}^N \frac{X_{nm}^s \pi_{nmj\cdot}^s}{t_{nj}^s} \tag{9}$$

[31] I impose the normalization that $\alpha_{nn}^s = 1$ for domestic firms' composite goods.

[32] Hence, sectoral final goods prices and MNE-composite goods prices have the following relationship: $P_n^s = \left(\sum_{m=1}^N \alpha_{nm}^s (P_{nm}^s)^{1-\delta^s} \right)^{\frac{1}{1-\delta^s}}$.

On the right-hand side, $\sum_{m=1}^{N} \frac{X_{nm}^{s} \pi_{nmj\cdot}^{s}}{t_{nj}^{s}}$ denotes the pre-tariff trade flow from country j to country n in sector s. Aggregated over all destinations n, this leads to country j's gross output in sector s. Wage bill in country j equals the sum of all sectoral gross output multiplied by the sector's value-added share.

Similarly, the market clearing condition for MNE-specific composite goods equals the following:

$$X_{ji}^{s} = I_j s_j^s s_{ji}^s + \sum_{s'=1}^{S} \gamma_j^{s's} \sum_{m=1}^{N} \sum_{n=1}^{N} \frac{X_{nm}^{s'}}{t_{nj}^{s'}} \pi_{nmji}^{s'}. \tag{10}$$

The equilibrium is defined by a set of global prices, including wages $\{w_n\}$, producer price indices $\{P_{nj}^{s,p}\}$, and composite intermediate input prices $\{P_{nm}^{s}\}$, such that the MNE sourcing and output shares follow Equation (5) and (6), the final expenditure shares follow Equations (7) and (8), and labor and composite intermediate input markets clear, following Equations (9) and (10).

3.4 Equilibrium in changes

To simulate counterfactuals, I utilize the "exact hat algebra" technique, rewriting variables as changes relative to the baseline equilibrium using $\hat{x} = \frac{x'}{x}$. MNE sourcing and output shares, baseline tariffs, sectoral final goods expenditure shares, MNE-specific composite goods expenditure shares, and household income sufficiently characterize endogenous variables' response to shocks. The model in "exact hat" is presented in Section B.2.[33]

4 Model Inversion and Elasticity Estimation

This section outlines the process of obtaining the model's shocks by taking the model to data and estimating the elasticities. Key shocks involve those affecting MNE sourcing and selling frictions, productivity, non-tariff trade costs, and final demand. The elasticities include trade and MNE elasticities, substitution elasticities across MNEs and sectors in final expenditure, as well as the headquarters' contribution to foreign affiliates' productivity.

[33]This method reduces the data requirement for counterfactual analysis: I no longer need to know the levels of economic fundamentals such as the TFP, which are generally difficult to estimate.

4.1 Back out MNE Sourcing and Selling Efficiencies

First, I compute the expenditures on MNE-specific composite goods, X^s_{nm}, using Equation (10). This equation relies on MNE gross output, country-level income, input-output coefficients, and final expenditure shares on sectors and MNEs. Then, as the trade flow from country j to n equals total expenditure by all MNEs (and domestic firms) in n on tradable output from j, I derive the following relationship:

$$T^s_{nj} = \frac{\sum_{m=1}^{N} X^s_{nm}\pi^s_{nmj\cdot}}{t^s_{nj}} = \frac{\sum_{m=1}^{N} X^s_{nm}\pi^s_{nnj\cdot}\frac{\pi^s_{nmj\cdot}}{\pi^s_{nnj\cdot}}}{t^s_{nj}}. \tag{11}$$

In the second equation, I divide and multiply with domestic firms' expenditure share, $\pi^s_{nnj\cdot}$ from the data. To express the ratio, $\frac{\pi^s_{nmj\cdot}}{\pi^s_{nnj\cdot}}$, in terms of the known variables, I manipulate the MNE sourcing shares expression as follows using Equation (6):

$$\frac{\pi^s_{nmj\cdot}}{\pi^s_{nnj\cdot}} = \frac{\frac{h^s_{mj}}{h^s_{nj}}}{\sum_{l=1}^{N}\pi^s_{nnl\cdot}\frac{h^s_{ml}}{h^s_{nl}}}. \tag{12}$$

Combining Equations (11) and (12), we get the following system of equations for solving h^s_{mj}:

$$h^s_{nj} = \frac{\pi^s_{nnj\cdot}}{T^s_{nj}t^s_{nj}}\sum_{m=1}^{N} X^s_{nm}\frac{h^s_{mj}}{\sum_{l=1}^{N}\pi^s_{nnl\cdot}\frac{h^s_{ml}}{h^s_{nl}}}. \tag{13}$$

With the backed-out MNE sourcing efficiencies and Equation (12), we can calculate the sourcing shares of any given MNE, $\pi^s_{nmj\cdot}$.

MNE selling efficiency is computed with the difference between domestic firms' shares of the host country's gross output and their shares of the host country's exports. Starting with domestic firms' output shares in Equation (5), I get:

$$\frac{1}{S^s_{n\cdot jj}} = \sum_{k=1}^{N}\frac{\left(\frac{\Theta^s_{jk}}{A^s_{jk}}\right)^{1-\zeta^s}}{\left(\frac{\Theta^s_{jj}}{A^s_{jj}}\right)^{1-\zeta^s}}\frac{H^s_{nk}}{H^s_{nj}}. \tag{14}$$

To connect the cost ratios, $\frac{\left(\frac{\Theta^s_{jk}}{A^s_{jk}}\right)^{1-\zeta^s}}{\left(\frac{\Theta^s_{jj}}{A^s_{jj}}\right)^{1-\zeta^s}}$, to the known variables, I take advantage of the MNE gross output data by noting that:

$$GO^s_{ji} = \sum_{n=1}^{N} T^s_{nj} S^s_{n\cdot ji} = \sum_{n=1}^{N} T^s_{nj} S^s_{n\cdot jj} \frac{S^s_{n\cdot ji}}{S^s_{n\cdot jj}} = \frac{\left(\frac{\Theta^s_{ji}}{A^s_{ji}}\right)^{1-\zeta^s}}{\left(\frac{\Theta^s_{jj}}{A^s_{jj}}\right)^{1-\zeta^s}} \sum_{n=1}^{N} T^s_{nj} S^s_{n\cdot jj} H^s_{ni}.$$

The gross output of an MNE is the sum of its sales to all markets. Sales to a market equal the host country's total trade flow to that destination, multiplied by the MNE's share of the trade flow. I then divide and multiply the trade flow with domestic firms' output shares, $S^s_{n\cdot jj}$, from the data. In the third equality, I incorporate the expression for MNE output shares using Equation (5), resulting in:

$$\frac{\left(\frac{\Theta^s_{ji}}{A^s_{ji}}\right)^{1-\zeta^s}}{\left(\frac{\Theta^s_{jj}}{A^s_{jj}}\right)^{1-\zeta^s}} = \frac{GO^s_{ji}}{\sum_{p=1}^{N} T^s_{pj} S^s_{p\cdot jj} H^s_{pi}}. \tag{15}$$

Plugging Equation (15) into Equation (14), we get the following system of equations for solving H^s_{ni}:

$$H^s_{nj} = S^s_{n\cdot jj} \sum_{k=1}^{N} \frac{GO^s_{jk}}{\sum_{p=1}^{N} T^s_{pj} S^s_{p\cdot jj} \frac{H^s_{pk}}{H^s_{pj}}} H^s_{nk}. \tag{16}$$

With H^s_{ni} backed out, one may calculate the output shares of an arbitrary MNE, $S^s_{n\cdot ji}$.[34]

For each sector s, Equations (13) and (16) have N^2 equations with N^2 unknowns – the MNE sourcing/selling efficiencies. In these equations, h^s_{mj} and H^s_{ni} are identified up to a scale. If we multiply the sourcing or selling efficiencies of any headquarters country m or i with all countries by the same constant, the equations still hold. Consequently, I normalize the sourcing and selling efficiency with the headquarter economy, h^s_{mm} and H^s_{ii}, to 1, fixing the remaining unknown parameters. Calibrating the MNE sourcing and selling efficiencies does not require knowledge of the elasticity of substitution σ^s and ζ^s. I solve Equations (13) and (16) for all sectors and years.[35]

Table A.10 shows that MNE sourcing and selling efficiencies are higher if the trade is with the MNE headquarters. These efficiencies are also negatively correlated with the distance between the headquarters and the trade partner country, and are higher if the headquarters shares a common legal origin, border, language and trade agreement with

[34]Note that $S^s_{n\cdot ji} = S^s_{n\cdot jj} \frac{H^s_{ni}(\frac{\Theta^s_{ji}}{A^s_{ji}})^{1-\zeta^s}}{H^s_{nj}(\frac{\Theta^s_{jj}}{A^s_{jj}})^{1-\zeta^s}}$, where the ratio of factory gate prices is from Equation (15).

[35]For each problem, I try different starting values and find they all converge to the same solution.

the trader partner. These results align with empirical findings in Section 2.3.

Table 2: **Gravity of MNE Sourcing and Selling Shocks during the Great Recession**

VARIABLES	Log Chg. Sourcing Efficiency				Log Chg. Selling Efficiency			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log (dist)	-0.0306***	-0.0289***	-0.0209***	-0.0202***	-0.0213***	-0.0206***	-0.0102*	-0.0100*
	(0.00479)	(0.00483)	(0.00553)	(0.00554)	(0.00520)	(0.00525)	(0.00599)	(0.00600)
1 (legal)	0.0133***	0.0119**	0.0114**	0.0103**	0.0102*	0.00958*	0.00822	0.00790
	(0.00516)	(0.00519)	(0.00519)	(0.00521)	(0.00545)	(0.00549)	(0.00547)	(0.00550)
1 (contiguity)	0.0921***	0.0929***	0.0856***	0.0868***	0.0172	0.0173	0.00881	0.00902
	(0.0125)	(0.0125)	(0.0126)	(0.0126)	(0.0137)	(0.0137)	(0.0139)	(0.0139)
1 (common lang.)	0.00978	0.00829	0.00706	0.00598	0.0423***	0.0417***	0.0394***	0.0391***
	(0.00966)	(0.00967)	(0.00968)	(0.00969)	(0.0108)	(0.0108)	(0.0108)	(0.0108)
1 (trade agree.)	0.00160	-0.000321	-0.000615	-0.00209	0.0199**	0.0192**	0.0176*	0.0172*
	(0.00882)	(0.00885)	(0.00884)	(0.00886)	(0.00966)	(0.00969)	(0.00968)	(0.00970)
log (Pre. Investment)		0.00108***		0.000927**		0.000424		0.000235
		(0.000411)		(0.000414)		(0.000432)		(0.000435)
log (Pre. Trade)			0.00960***	0.00887***			0.0107***	0.0105***
			(0.00276)	(0.00277)			(0.00288)	(0.00290)
Observations	10,620	10,620	10,620	10,620	10,620	10,620	10,620	10,620
FE	ls,is	ls,is	ls,is	ls,is	ms,ls	ms,ls	ms,ls	ms,ls
Mean Dep. Var	-0.182	-0.182	-0.182	-0.182	-0.252	-0.252	-0.252	-0.252
Mean Log Dist.	8.456	8.456	8.456	8.456	8.456	8.456	8.456	8.456
R^2	0.784	0.784	0.784	0.784	0.826	0.826	0.827	0.827

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table presents the correlations between MNE sourcing and selling shocks during the Great Recession and gravity variables. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Decreasing sourcing and selling efficiencies with distance between headquarters and trade partners became even more pronounced during the Great Recession. From 2008 to 2009, MNE sourcing and selling shocks – year-on-year changes in the MNE sourcing and selling efficiencies $\hat{h}^s_{mj}$ and $\hat{H}^s_{ni}$ – were negatively correlated with the distance between MNE headquarters and sourcing origin/selling destination (Columns 1 and 5 of Table 2). This indicates that trade with countries farther from MNE headquarters was more adversely affected, causing MNEs to rely more on their headquarters for sourcing and exporting. Hence, in addition to foreign investment (see, for example, Alfaro et al. 2004 and Forbes and Warnock 2012), MNEs also retrenched sales to their headquarters, which might have reduced international trade during the Great Recession.

Strong pre-Recession linkages can alleviate the negative impact of the Great Recession on international trade by MNEs. In Table 2, I include pre-Recession (2007) bilateral portfolio investment and trade between headquarters and trade partners in Columns 2-4 for sourcing shocks and Columns 6-8 for selling shocks.[36]

[36] I measure country-bilateral investment using the Coordinated Direct Investment Survey of the International Monetary Fund. To construct the variables in the regression, I take the average of inward and outward investments, as well as the average of imports and exports.

4.2 Estimate Trade and MNE Elasticities

Leveraging information on MNE sourcing and selling efficiencies, and using market share data and tariff variations, I estimate trade and MNE elasticities. First, consider a country's domestic firms' sourcing shares:

$$\pi^s_{nnj\cdot} = \frac{h^s_{nj}(P^{s,p}_{nj}k^s_{nj}t^s_{nj})^{1-\sigma^s}}{(P^s_{nn})^{1-\sigma^s}}. \tag{17}$$

The right-hand side includes MNE sourcing efficiency h^s_{nj}, tariff t^s_{nj}, producer price index $P^{s,p}_{nj}$, and non-tariff barriers k^s_{nj}. The producer price is unknown, but by manipulating Equation (5), it can be expressed as a function of the factory gate price of domestic firms in the origin, $\frac{\Theta^s_{jj}}{A^s_{jj}}$, MNE selling efficiency H_{nj}, and the output share of domestic firms $S^s_{n\cdot jj}$ in bilateral trade:

$$P^{s,p}_{nj} = \underbrace{\frac{\Theta^s_{jj}}{A^s_{jj}}}_{B^s_j}\left(\underbrace{\frac{S^s_{n\cdot jj}}{H^s_{nj}}}_{C^s_{nj}\text{, adjusted output shares, data+model inversion}}\right)^{\frac{1}{\zeta^s-1}}. \tag{18}$$

To collect notations I denote $B^s_j = \frac{\Theta^s_{jj}}{A^s_{jj}}$ and $C^s_{nj} = \frac{S^s_{n\cdot jj}}{H^s_{nj}}$. I call C^s_{nj} the adjusted output share. C^s_{nj} is known because $S^s_{n\cdot jj}$ is from data and H_{nj} is acquired in Section 4.1. Plug Equation (18) into Equation (17) to eliminate the producer price:

$$\underbrace{\frac{\pi^s_{nnj\cdot}}{h^s_{nj}}}_{D^s_{nj}\text{, adjusted sourcing shares, data+calibration}} = \frac{(C^s_{nj})^{-\frac{\sigma^s-1}{\zeta^s-1}}(B^s_j k^s_{nj}t^s_{nj})^{1-\sigma^s}}{(P^s_{nn})^{1-\sigma^s}}. \tag{19}$$

The left-hand side represents the sourcing share divided by the sourcing efficiency. To consolidate notations, I rename the left-hand side D^s_{nj} and refer to it as adjusted sourcing shares. D^s_{nj} is known, with $\pi^s_{nnj\cdot}$ from data and h^s_{nj} from model inversion. Parameter estimation is based on Equation (19), where the identification strategy for σ^s and ζ^s is based on Head and Mayer (2019). I assume k^s_{nj} takes the following form:

$$\log(k^s_{nj}) = \beta_1\log(\text{dist}_{nj}) + \beta_2\mathbf{1}(\text{contiguity}_{nj}) + \beta_3\mathbf{1}(\text{common lang}_{nj}) + \beta_4\mathbf{1}(\text{trade agreement}_{nj}) + FE^s_n + FE^s_j + \phi^s_{nj}. \tag{20}$$

The log of non-tariff barriers is assumed to be a linear function of log distances between importing and exporting countries, border-sharing, common official language, and trade agreement dummies. Origin and destination fixed effects account for asymmetric trade costs as per Waugh (2010). ϕ^s_{nj} denotes the error term, .

Taking logs of Equation (19), plugging in Equation (20), and adding a time subscript gives the estimation equation:

$$\log\left(D^s_{nj,t}\right) = \frac{1-\sigma^s}{1-\zeta^s}\log\left(C^s_{nj,t}\right) + (1-\sigma^s)\log\left(t^s_{nj,t}\right) + \gamma^s_1\log(\text{dist})_{nj,t} + \gamma^s_2\mathbf{1}(\text{contiguity})_{nj,t} + \gamma^s_3\mathbf{1}(\text{common lang})_{nj,t} + \gamma^s_4\mathbf{1}(\text{trade agreement})_{nj,t} + FE^s_n + FE^s_j + FE^s_t + \epsilon^s_{nj,t}. \tag{21}$$

Tariff variation identifies trade elasticity, σ^s, while adjusted output share variation, $C^s_{nj,t}$, identifies $\frac{1-\sigma^s}{1-\zeta^s}$, yielding ζ^s.[37] I instrument $\log(C^s_{nj,t})$ with tariffs imposed by origin country j on destination n (in the opposite direction of the trade flow in the main regression) in their own, upstream, and downstream sectors, using input-output shares as per Acemoglu et al. (2016).[38] These instruments are relevant: n's foreign affiliates in j have greater imports and exports with n than j's domestic firms, and hence they are more exposed to the tariff shock. When j raises tariffs on n, the cost of n's affiliates in j increases more than that of j's domestic firms. Consequently, n's affiliates' shares in j decrease, while domestic firms' shares in j's sales to n increase, resulting in an increase in $\log(C^s_{nj,t})$.

Table 3: **Estimated MNE and Trade Elasticities**

VARIABLES	(1) Durable Manufacturing	(2) Non-durable Manufacturing	(3) Non-manufacturing	(4) Durable Manufacturing	(5) Non-durable Manufacturing	(6) Non-manufacturing
	Tariff Instruments with Direct Shares			Tariff Instruments with Total Shares		
$\log\left(C^s_{nj,t}\right)$	1.771*	3.496***	2.717***	9.770***	6.048***	2.708***
	(1.100)	(1.130)	(0.454)	(1.347)	(2.244)	(0.435)
$\log\left(t^s_{nj,t}\right)$	-3.475***	-2.020***	-1.464**	-5.707***	-2.056***	-1.470***
	(0.559)	(0.398)	(0.570)	(1.184)	(0.520)	(0.564)
$\log\left(\text{dist}_{nj,t}\right)$	-1.043***	-0.989***	-1.301***	-1.158***	-0.974***	-1.300***
	(0.0184)	(0.0120)	(0.0129)	(0.0299)	(0.0184)	(0.0128)
$\mathbf{1}\left(\text{legal}_{nj,t}\right)$	0.147***	0.142***	0.0616***	0.299***	0.147***	0.0616***
	(0.0236)	(0.0121)	(0.0143)	(0.0369)	(0.0162)	(0.0143)
$\mathbf{1}\left(\text{common lang.}_{nj,t}\right)$	0.332***	0.266***	0.0808***	0.168***	0.248***	0.0808***
	(0.0308)	(0.0238)	(0.0270)	(0.0573)	(0.0334)	(0.0270)
$\mathbf{1}\left(\text{contiguity}_{nj,t}\right)$	0.154***	0.286***	0.665***	-0.0558	0.295***	0.664***
	(0.0404)	(0.0305)	(0.0421)	(0.0765)	(0.0402)	(0.0417)
$\mathbf{1}\left(\text{trade agree.}_{nj,t}\right)$	0.319***	0.314***	0.319***	0.353***	0.326***	0.319***
	(0.0182)	(0.0197)	(0.0227)	(0.0426)	(0.0271)	(0.0227)
Observations	42,480	42,480	42,480	42,480	42,480	42,480
FE	n, j, t	n, j, t	n, j, t	n, j, t	n, j, t	n, j, t
Mean Dep. Var	-5.296	-5.602	-6.974	-5.296	-5.602	-6.974
Mean Indep. Var	0.328	0.246	0.180	0.328	0.246	0.180
First Stage F	16.55	27.71	150.8	63.83	11.97	163.5
Implied σ^s	4.475	3.020	2.464	6.707	3.056	2.470
Implied ζ^s	2.962	1.578	1.539	1.584	1.340	1.543

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table presents the estimated elasticities of substitution across different sourcing origin countries (trade elasticities) and elasticities of substitution across MNEs within each origin country (MNE elasticities). Elasticities are estimated for the durable manufacturing sector, non-durable manufacturing sector, and non-manufacturing sector. Regressors and instruments are constructed according to Section 4.2. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3 reveals higher trade and MNE elasticities in durable manufacturing than in

[37] Following Head and Mayer (2019), I assume tariff variation is uncorrelated with $\epsilon^s_{nj,t}$, the unobserved term in bilateral non-tariff frictions.

[38] See Section A.6 for more details.

non-durable manufacturing and non-manufacturing sectors. Trade elasticity consistently exceeds MNE elasticity across all sectors, indicating downstream MNEs' technology preferences are more heterogeneous (Head and Mayer 2019). These findings persist regardless of upstream and downstream tariff construction methods (with direct input-output shares in Columns 1-3 and total input-output shares in Columns 4-6). Furthermore, these results are robust when alternative fixed effect controls are used (Table A.12) or when all sectors are grouped (Table A.13).

4.3 Back out MNE Relative Productivity, Trade Cost, and Domestic Productivity Shocks

The productivity of a foreign affiliate relative to domestic firms in the same host country can be computed with the ratio of its input price relative to its output price:

$$\frac{A_{ji}^s}{A_{jj}^s} = \frac{\Theta_{ji}^s}{\Theta_{jj}^s} \Bigg/ \frac{\frac{\Theta_{ji}^s}{A_{jj}^s}}{\frac{\Theta_{jj}^s}{A_{jj}^s}}. \tag{22}$$

In Section B.3, I detail the computation of these relative prices using data on MNE gross output, trade flows, market shares, and the backed-out MNE sourcing and selling efficiencies. I then calculate the year-on-year changes in MNE relative productivity, $\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}$, representing the MNE relative productivity shocks.

Multinational production incurs a productivity loss, which increases with the distance between headquarters and host countries. This is corroborated by Table A.11, which displays the correlations between an MNE's productivity relative to domestic firms in the host country and gravity variables, by sector.

During the Great Recession, MNE relative productivity shocks were also negatively correlated with the distance between headquarters and host countries, as shown in Table 4, mirroring patterns of MNE sourcing and selling shocks documented in Table 2. Columns 2-4 indicate that pre-Recession investment and trade flows positively correlated with MNE relative productivity shocks (in line with Alfaro and Chen 2012). This suggests MNEs with closer proximity to their headquarters in terms of distance, investment, and trade were more resilient during the Great Recession. Since MNEs are more trade-intensive than domestic firms, the relative productivity shocks experienced by MNEs, which exhibited the documented patterns, may have also contributed to a reduction in international trade.

Table 4: **Gravity of MNE Relative Productivity Shocks and MNE Final Demand Shocks during the Great Recession**

VARIABLES	Log Chg. MNE Prod.				Log Chg. Final Demand for MNE			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log (dist)	-0.0355***	-0.0326***	-0.0199**	-0.0185**	-0.0841***	-0.0828***	-0.0406*	-0.0406*
	(0.00794)	(0.00803)	(0.00923)	(0.00925)	(0.0199)	(0.0201)	(0.0231)	(0.0231)
1 (legal)	-0.000502	-0.00288	-0.00308	-0.00491	0.0133	0.0122	0.00560	0.00557
	(0.00862)	(0.00867)	(0.00865)	(0.00869)	(0.0213)	(0.0214)	(0.0214)	(0.0215)
1 (contiguity)	-0.0158	-0.0145	-0.0260	-0.0241	0.0104	0.0110	-0.0186	-0.0186
	(0.0209)	(0.0209)	(0.0211)	(0.0212)	(0.0528)	(0.0528)	(0.0533)	(0.0534)
1 (common lang.)	-0.0247	-0.0270*	-0.0296*	-0.0312*	-0.0239	-0.0250	-0.0377	-0.0378
	(0.0160)	(0.0160)	(0.0160)	(0.0161)	(0.0402)	(0.0402)	(0.0403)	(0.0404)
1 (trade agree.)	-0.0276*	-0.0305**	-0.0312**	-0.0333**	0.00286	0.00151	-0.00690	-0.00694
	(0.0147)	(0.0147)	(0.0147)	(0.0147)	(0.0369)	(0.0370)	(0.0370)	(0.0371)
log (Pre. Investment)		0.00169**		0.00144**		0.000792		2.14e-05
		(0.000686)		(0.000691)		(0.00171)		(0.00172)
log (Pre. Trade)			0.0152***	0.0141***			0.0425***	0.0425***
			(0.00457)	(0.00461)			(0.0114)	(0.0115)
Observations	10,620	10,620	10,620	10,620	10,620	10,620	10,620	10,620
FE	ls,is	ls,is	ls,is	ls,is	ms,ls	ms,ls	ms,ls	ms,ls
Mean Dep. Var	-0.0438	-0.0438	-0.0438	-0.0438	-0.131	-0.131	-0.131	-0.131
Mean Log Dist.	8.456	8.456	8.456	8.456	8.456	8.456	8.456	8.456
R^2	0.250	0.251	0.251	0.252	0.263	0.263	0.264	0.264

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table presents the correlations between MNE relative productivity shocks and MNE final demand shocks during the Great Recession and gravity variables. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

I back out the non-tariff barriers by manipulating the sourcing shares of domestic firms, noting that:

$$\frac{\pi^s_{nnj\cdot}}{\pi^s_{jjj\cdot}} = \frac{h^s_{nj}}{h^s_{jj}}\left(\frac{t^s_{nj}k^s_{nj}P^{s,p}_{nj}}{t^s_{jj}k^s_{jj}P^{s,p}_{jj}}\right)^{1-\sigma^s}\frac{1}{\sum_{p=1}^{N}\pi^s_{jjp\cdot}\frac{h^s_{np}}{h^s_{jp}}\left(\frac{t^s_{np}k^s_{np}P^{s,p}_{np}}{t^s_{jp}k^s_{jp}P^{s,p}_{jp}}\right)^{1-\sigma^s}}.$$

By plugging in the expression for producer price indices, Equation (18), and by guessing and verifying, I am able to obtain:

$$k^s_{nj} = \left(\frac{\pi^s_{nnj\cdot}}{\pi^s_{jjj\cdot}}\frac{h^s_{jj}}{h^s_{nj}}\right)^{\frac{1}{1-\sigma^s}}\frac{\left(\frac{H_{jj}}{S^s_{j\cdot jj}}\right)^{\frac{1}{1-\zeta^s}}t^s_{jj}}{\left(\frac{H_{nj}}{S^s_{n\cdot jj}}\right)^{\frac{1}{1-\zeta^s}}t^s_{nj}},$$

which is a function of known variables only. Shocks to non-tariff trade costs are the year-on-year changes of k^s_{nj}, denoted with $\hat{k}^s_{nj}$.

I back out the domestic productivity shocks by solving a system of equations involving the shocks themselves and prices. First, Section B.4 shows that this shock can be expressed in terms of changes in home sourcing shares of domestic firms, domestic firms' shares in home sales, and prices:

$$\hat{A}_{jj}^{s} = \left(\hat{\pi}_{jjj\cdot}^{s}\right)^{\frac{1}{\sigma^{s}-1}} \frac{\hat{\Theta}_{jj}^{s}}{\hat{P}_{jj}^{s}} \left(\hat{S}_{j\cdot jj}^{s}\right)^{\frac{1}{\zeta^{s}-1}}$$

Additionally, Equations (B.1), (B.2), and (B.3) demonstrate that price changes can be expressed as a function of global shocks and wage changes. Using this system of equations, I can iteratively solve for $\hat{A}_{jj}^{s}$ and $\hat{P}_{jj}^{s}$.[39]

4.4 Estimate Headquarters' Share in MNE Productivity

I estimate the contribution of headquarters to MNE productivity by sector, building on studies such as Cravino and Levchenko (2017), Alviarez et al. (2020), and Bilir and Morales (2020), who find that domestic productivity shocks at headquarters impact MNE productivity and can propagate to host countries. Assume that MNE's productivity follows a Cobb-Douglas function in relation to both the headquarters' and host country's productivity (augmented by a country-bilateral term):

$$A_{ji}^{s} = \left(A_{jj}^{s}\right)^{1-\phi^{s}} \left(A_{ii}^{s}\right)^{\phi^{s}} \gamma_{ji}^{s},$$

where A_{jj}^{s} and A_{ii}^{s} denote the domestic productivity in the host country and the headquarters, γ_{ji}^{s} the bilateral friction, and ϕ^{s} the sector-specific headquarters' share. Hence, the MNE relative productivity defined earlier equals the following:

$$\frac{A_{ji}^{s}}{A_{jj}^{s}} = \left(\frac{A_{ii}^{s}}{A_{jj}^{s}}\right)^{\phi^{s}} \gamma_{ji}^{s}. \tag{23}$$

This equation indicates that MNE relative productivity is influenced by domestic productivity shocks in both headquarters and host countries when these shocks can propagate through MP. When allowing MP propagation, an increase in the domestic productivity in the headquarters raises the productivity of their MNE relative to domestic firms in the host country. Conversely, an increase in domestic productivity in the host country reduces the productivity of MNEs hosted there compared to the country's domestic firms, as the host country's productivity accounts for only a portion of the MNE's productivity.

Knowing MNE relative productivity shocks and domestic productivity shocks, I run

[39] See details in Section B.4.

a regression to identify ϕ^s – the headquarters' share of MNE productivity:

$$\log\left(\frac{\hat{A}^s_{ji,t}}{\hat{A}^s_{jj,t}}\right) = \phi^s \log\left(\frac{\hat{A}^s_{ii,t}}{\hat{A}^s_{jj,t}}\right) + FE^s_j + FE^s_i \ + \epsilon^s_{ji,t}.$$

Table 5 shows that headquarters account for 37%, 6%, and 32% of MNE productivity in durable manufacturing, non-durable manufacturing, and non-manufacturing, respectively. These results are robust, with or without fixed effects (Columns 1-3 and 4-6).

Table 5: **Estimated Headquarters' Share in MNE Productivity**

VARIABLES	(1) Durable Manufacturing	(2) Non-durable Manufacturing	(3) Non-manufacturing	(4) Durable Manufacturing	(5) Non-durable Manufacturing	(6) Non-manufacturing
	HQ fixed effect, host country fixed effect			OLS		
$\log(\frac{\hat{A}^s_{ii}}{\hat{A}^s_{jj}})$	0.372***	0.0641***	0.316***	0.367***	0.0640***	0.312***
	(0.00883)	(0.00168)	(0.00996)	(0.00864)	(0.00168)	(0.00975)
Observations	39,600	39,600	39,600	39,600	39,600	39,600
FE	j,i	j,i	j,i	NA	NA	NA
Mean Dep. Var	0.00661	0.000198	-0.000414	0.00661	0.000198	-0.000414

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table shows, by sector, the correlation between the MNE relative productivity shock and the difference in the domestic productivity shocks to the headquarters' country and the host country. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A.14 indicates that productivity shocks of MNEs ($\hat{A}^s_{ji} = \hat{A}^s_{jj}\frac{\hat{A}^s_{ji}}{\hat{A}^s_{jj}}$) are correlated with domestic productivity shocks of both headquarters and host countries. It further confirms that the headquarters' contribution to MNE productivity is the smallest in the non-durable manufacturing sector (with or without fixed effect controls). Figure A.5 displays the correlations using bin scatter plots for MNE productivity shocks and domestic productivity shocks in headquarters/host countries.

4.5 Estimate Final Demand Elasticities

I estimate the elasticity of substitution across MNE-specific composite goods in sectoral final expenditure using the following regression, representing the log change of Equation (8):

$$\log(\hat{s}^s_{nm,t}) = \tilde{\delta}^s \log(\hat{P}^s_{nm,t}) + FE^s_{n,t} + \epsilon^s_{nm,t}, \tag{24}$$

where $\tilde{\delta}^s = 1 - \delta^s$. I instrument $\log(\hat{P}^s_{nm})$ with the domestic productivity shock in the foreign headquarters multiplied by the MNE's sales share in its host country:

$$Instrument^s_{nm} = \frac{GO^s_{nm}}{\sum_{m=1}^{N} GO^s_{nm}} \hat{A}^s_{mm}.$$

Hence, the identifying assumption is that the domestic productivity shock in the foreign headquarters is uncorrelated with the demand shock for MNEs in the host country.

Table 6 Columns 1-4 indicate that the final demand elasticity for MNEs is 3.167 for durable manufacturing, 2.170 for non-durable manufacturing, and 1.819 for non-manufacturing, with an average of 2.479 across all sectors. Columns 5-9 demonstrate the robustness of these estimates to alternative fixed effect controls.

Table 6: **Estimated Elasticity of Substitution across MNEs in Sectoral Final Goods**

VARIABLES	(1) Durable Manufacturing	(2) Non-durable Manufacturing	(3) Non-Manufacturing	(4) All	(5) Durable Manufacturing	(6) Non-durable Manufacturing	(7) Non-Manufacturing	(8) All
log_p_nm	-2.167***	-1.170**	-0.819**	-1.479***	-3.280***	-1.425***	-0.874*	-1.941***
	(0.388)	(0.513)	(0.414)	(0.273)	(0.520)	(0.473)	(0.500)	(0.300)
Observations	39,600	39,600	39,600	118,800	39,600	39,600	39,600	118,800
FE	nt	nt	nt	nst	nt, mt	nt, mt	nt, mt	nst, mst
Instrument	MNE productivity	MNE productivity	MNE productivity	MNE productivity	MNE productivity	MNE productivity	MNE productivity	MNE productivity
Mean Dep. Var	0.00437	0.00111	0.00302	0.00283	0.00437	0.00111	0.00302	0.00283
Mean Indep. Var	-0.0210	-0.0966	0.00104	-0.0389	-0.0210	-0.0966	0.00104	-0.0389
First Stage F	237	16.76	16.76	91.56	455.6	57.77	57.77	250.3
Implied δ^s	3.167	2.170	1.819	2.479	4.280	2.425	1.874	2.941

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table presents the estimated elasticities of substitution across MNE composite goods in sectoral final goods for durable manufacturing sector, non-durable manufacturing sector, non-manufacturing sector, and sectoral average. Regressors and instruments are constructed according to Section 4.5. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

By setting $\hat{\alpha}^s_{nn} = 1$, I derive the final demand shocks for MNE-specific composite goods:

$$\hat{\alpha}^s_{nm} = \frac{\hat{s}^s_{nm}}{\hat{s}^s_{nn}} \frac{(\hat{P}^s_{nn})^{1-\delta^s}}{(\hat{P}^s_{nm})^{1-\delta^s}}$$

Columns 5-8 of Table 4 reveal that during the Great Recession, a country's preference for foreign MNEs in final demand decreased with distance from their headquarters. However, pre-Recession trade linkages mitigated this decline.

Similarly, I estimate the sectoral final demand elasticity with the regression equation which is the log change of Equation (7):

$$\log(s^s_{n,t}) = \tilde{\lambda} \log(P^s_{n,t}) + \Phi_{n,t} + \epsilon^s_{n,t}. \tag{25}$$

where $\tilde{\lambda} = 1 - \lambda$. I instrument $\log(P^s_{n,t})$ with the domestic productivity shocks in all foreign headquarters multiplied by their respective sales shares in the gross output of the host country:

$$Instrument^s_n = \sum_{m \neq n} \frac{GO^s_{nm}}{\sum_{m=1}^N GO^s_{nm}} \hat{A}^s_{mm}.$$

Hence, the identifying assumption is that the domestic productivity shocks in foreign headquarters are uncorrelated with the sectoral final demand shocks in the host country.

Column 1 of Table 7 shows that sectoral final goods are weak substitutes with elasticity of substitution equal to 1.582. Column 2 shows that the effect is robust to additional sector fixed effect controls. Columns 3 and 4 show that the elasticities would be incorrect if the fixed effects were not controlled or if instruments were not used.

Table 7: **Estimated Elasticity of Substitution across Sectoral Final Goods in Final Use**

VARIABLES	(1)	(2)	(3)	(4)
$\log(P^s_{n,t})$	-0.582*	-0.447**	-4.746	0.0248***
	(0.339)	(0.216)	(13.06)	(0.00920)
Observations	1,980	1,980	1,980	1,980
FE	nt	nt, s	NA	nt
Instrument	MNE productivity	MNE productivity	MNE productivity	
Mean Dep. Var	-0.00301	-0.00301	-0.00301	-0.00301
Mean Indep. Var	-0.0772	-0.0772	-0.0772	-0.0772
First Stage F	4.198	7.683	0.132	NA
λ	1.582	1.447	5.746	0.975

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table presents the estimated elasticities of substitution across sectoral final goods in final use. Regressors and instruments are constructed according to Section 4.5. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

By normalizing $\hat{\alpha}^s_n = 1$ for the non-manufacturing sector, we derive the sectoral final demand shocks for other sectors:

$$\hat{\alpha}^s_n = \frac{\hat{s}^s_n}{\hat{s}^{\text{non-manuf}}_n} \frac{\left(\hat{P}^{\text{non-manuf}}_n\right)^{1-\lambda}}{\left(\hat{P}^s_n\right)^{1-\lambda}}$$

For clarity, in the following section, I discuss the impact of shocks in groups rather than individually, as there are numerous shocks to consider. I organize the model's shocks in Table 8 based on whether they belong to supply or demand shocks – as previous works argued that demand shocks had a greater impact on trade collapse than supply shocks – and if they are MNE-specific or considered in previous trade-only models. MNE-specific shocks include relative productivity, final demand, sourcing, and selling shocks that affect MNEs differently than domestic firms. Traditional supply and demand shocks involve domestic productivity and sectoral final demand shocks. Other less impactful shocks include trade costs, labor endowment, and trade deficit.[40] In this model, supply shocks include domestic productivity shocks and shocks that affect MNE's productivity relative to domestic firms. Demand shocks include MNE final demand shocks and sectoral final demand shocks.[41] The classification of the model's shocks is displayed in Figure A.4.

[40]According to the literature, such as Eaton et al. (2016), these other shocks had minimal impact on the global trade collapse.

[41]Other shocks, like trade cost or MNE sourcing and selling efficiencies, affect both supply and demand, making their classification unclear

Table 8: **Types of Shocks**

	MNE-specific Shocks	Supply and Demand Shocks in Trade-only Model	Other Shocks
Supply Shocks	MNE Relative Productivity Shocks	Domestic Productivity Shocks	
Demand Shocks	MNE Final Demand Shocks	Final Demand Shocks	
Other Shocks	MNE Sourcing Shocks MNE Selling Shocks		Trade Cost Shocks Labor Endowment Shocks Trade Balance Shocks

Description: This table displays the shocks explored in the model and identifies them as either supply or demand shocks.

5 Simulations

In this section, I analyze MP's influence on the global trade decline and international shock propagation. I first evaluate the importance of different types of shocks – in particular, MNE-specific shocks – and then explore their transmission across countries.

5.1 Importance of Shocks

5.1.1 Global Trade and MP Collapse

During the Great Recession, shocks that significantly contributed to the global trade decline also had a substantial impact on MP decline, and vice versa. This underscores the critical role of MNEs in conducting trade. Figure 4 displays the effects of different groups of shocks when only that group of shocks was present.[42] Table 9 presents the impact of individual group of shocks on the world trade and world MP to world GDP ratios in percentage points and as a percent of the actual trade and MP declines relative to GDP. Only the specified group of shocks is activated, while all other shocks remain muted. Sectoral final demand, domestic productivity, and MNE-specific shocks contributed 1.61 (40%), 1.09 (27%), and 0.39 (10%) percentage points to global trade decline, respectively.[43] Concurrently, these shocks contributed 0.40 (20%), 0.64 (33%), and 0.53 (27%) percentage points to global MP collapse.[44]

Considering MNEs' role in trade, supply shocks contributed nearly as much (36%) to the global trade collapse as demand shocks (38%). This is because MNE-specific shocks mainly affected supply rather than demand. Meanwhile, the global MP collapse was influenced substantially more by supply shocks than demand shocks.

[42]Dashed lines indicate the impact of individual shock groups. Segments after 2009 show counterfactual outcomes based on 2009 counterfactual market shares (as a result of different shocks) and influenced by actual, post-2009 shocks.

[43]Global trade collapse is measured by the change in the world trade-to-GDP ratio.

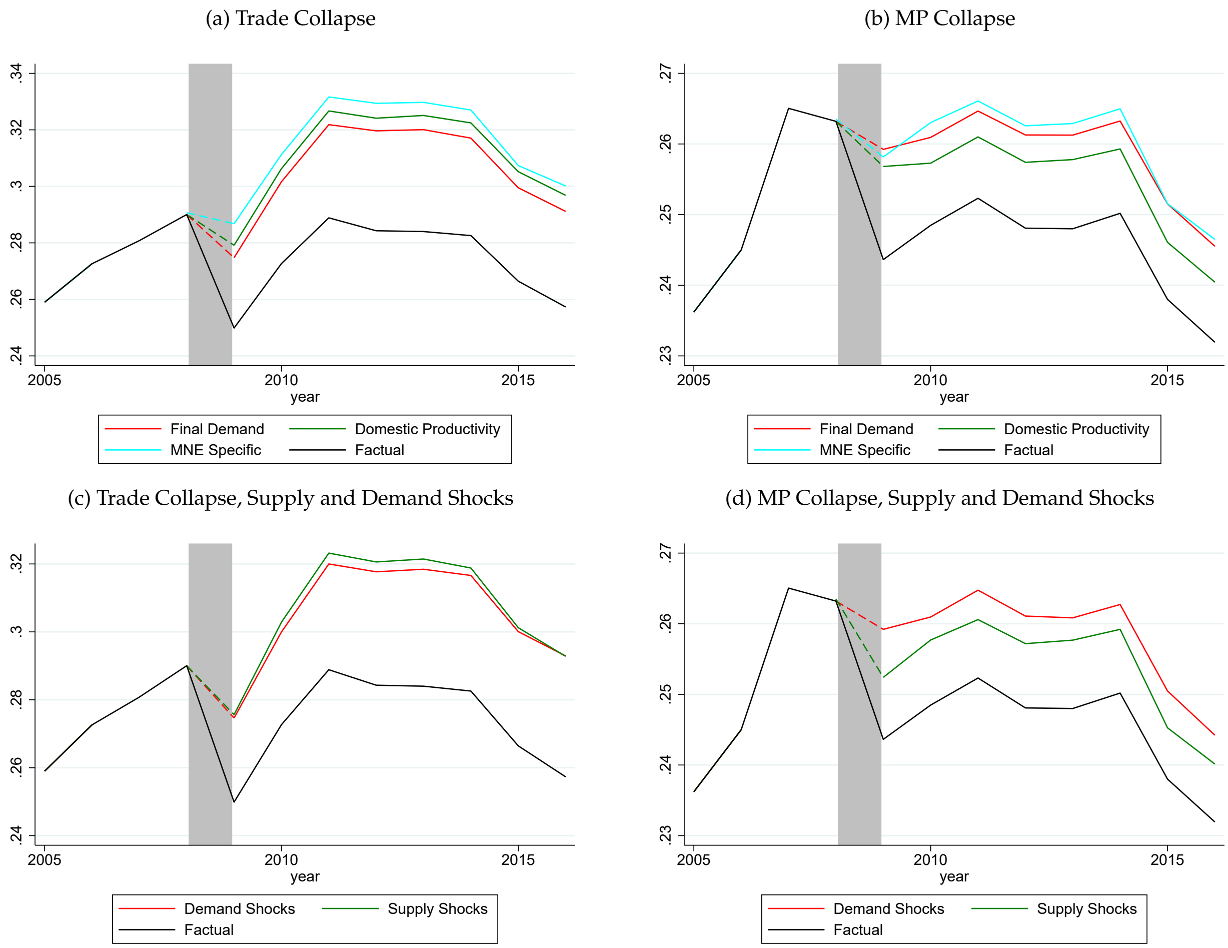
[44]Global MP collapse is measured by the change in world MP-to-GDP ratio (sales by MNE foreign affiliates).

Table 9: **Impact of Shocks on Declines of World Total Trade and MP**

Shocks	Trade Collapse	Trade Collapse (Percent)	MP Collapse	MP Collapse (Percent)
	(1)	(2)	(3)	(4)
MNE-specific Shocks	–0.39%	9.67%	–0.53%	27.32%
Domestic Productivity Shocks	–1.09%	27.11%	–0.64%	32.65%
Final Demand Shocks	–1.61%	40.02%	–0.40%	20.30%
Supply Shocks	–1.44%	35.85%	–0.89%	45.65%
Demand Shocks	–1.54%	38.37%	–0.40%	20.44%
All Shocks	–4.02%	100.00%	–1.96%	100.00%

Description: This table shows the effects of various shock types on global trade and MP collapse during the Great Recession. The global trade collapse is measured by the change in the world trade-to-GDP ratio, while the global MP collapse is measured by the change in the world MP-to-GDP ratio (sales by MNE foreign affiliates).

Figure 4: **Importance of Shocks for Global Trade and MP Collapse**



Description: These figures illustrate the effects of various shock types on global trade and MP collapse during the Great Recession (2008-2009, shaded years). Dashed lines represent individual shock group impacts, while segments after 2009 show counterfactual outcomes based on 2009 counterfactual market shares (as a result of different shocks) and influenced by actual, post-2009 shocks.

Model without MP or without MNE International Transaction Frictions A model without MNEs would attribute around half of the global trade collapse to final demand shocks, which would appear more important than supply shocks. Overlooking MNEs' role in trade assigns the impact of MNE-specific shocks on the global trade collapse mainly to the effect of final demand shocks (see Table A.15 and Figure A.6).[45]

MNEs' high trade intensity contributed to the simultaneous global trade and MP collapse. In a model without MNEs' comparative advantage in international sourcing and selling, MNE-specific shocks had minimal impact on the global trade collapse. In fact, world trade would increase by 0.07% relative to world GDP due to MNE-specific shocks in this scenario (see Table A.17 and Figure A.8).[46]

5.1.2 Cross-country Variation

As Section 2.2 shows MP collapse heterogeneity across countries, it's crucial to comprehend why some countries performed better and the shocks causing these differences. This analysis also offers insights into shock propagation across countries, which cannot be assessed based only on global totals. To examine the effects of shocks on cross-country variations in trade, MP, and welfare changes during the Great Recession, I adopt the method utilized by Klenow and Rodriguez-Clare (1997), Alviarez et al. (2020), and others. Let $\log(\hat{y}_i)$ represent the log change in country i's variable of interest in the data, and $\log(\hat{x}_i)$ signify the model counterpart from counterfactual simulations with a group of shocks. The following accounting identity holds:

$$\log(\hat{y}_i) = \log(\hat{x}_i) + z_i,$$

where z_i represents the contribution from other shocks. The proportion of cross-country variation in the variable of interest, explained by the shocks, can be assessed using:

$$\frac{\text{cov}_i(\log(\hat{y}_i), \log(\hat{x}_i))}{\sigma_i^2(\log(\hat{y}_i))}. \tag{26}$$

This value corresponds to the slope coefficient obtained by regressing the model counterfactual against the data.

As compared to the world total, the MNE-specific shocks accounted for an even greater proportion of trade collapse variations across countries. Figure 5 reveals that MNE-specific shocks significantly contributed to 25% of trade collapse variation (also see Table 10) and 64% of MP collapse variation across countries – consistent with the observed positive correlation between trade and MP collapses across countries. They also explained

[45]Section B.5 presents the model that does not have MNEs.

[46]In this model I set the sourcing and selling efficiencies with non-headquarters countries all to one: $h^s_{mj} \equiv H^s_{ni} \equiv 1$, and all other parameters take their values in the full model. As a result, domestic firms and foreign affiliates have the same sourcing shares and sell the same share of their output to a specific destination country. See Section 3.2 for the discussion.

12% of welfare variation. Table A.18 shows that among all MNE-specific shocks, MNE sourcing shocks – a reduction in MNE sourcing from non-headquarters countries – contributed the most to trade collapse variation. Meanwhile, MNE-relative productivity shocks contributed the most to MP collapse and welfare change variations.

Final demand shocks significantly impacted global trade decline but were not the main cause of differences across countries. As suggested by Figure 5 and Table 10, domestic productivity shocks accounted for 29% of cross-country trade collapse variations, while final demand shocks explained only 2%. Thus, compared to demand shocks, supply shocks contributed more to cross-country variations of trade collapse, MP collapse and welfare changes.

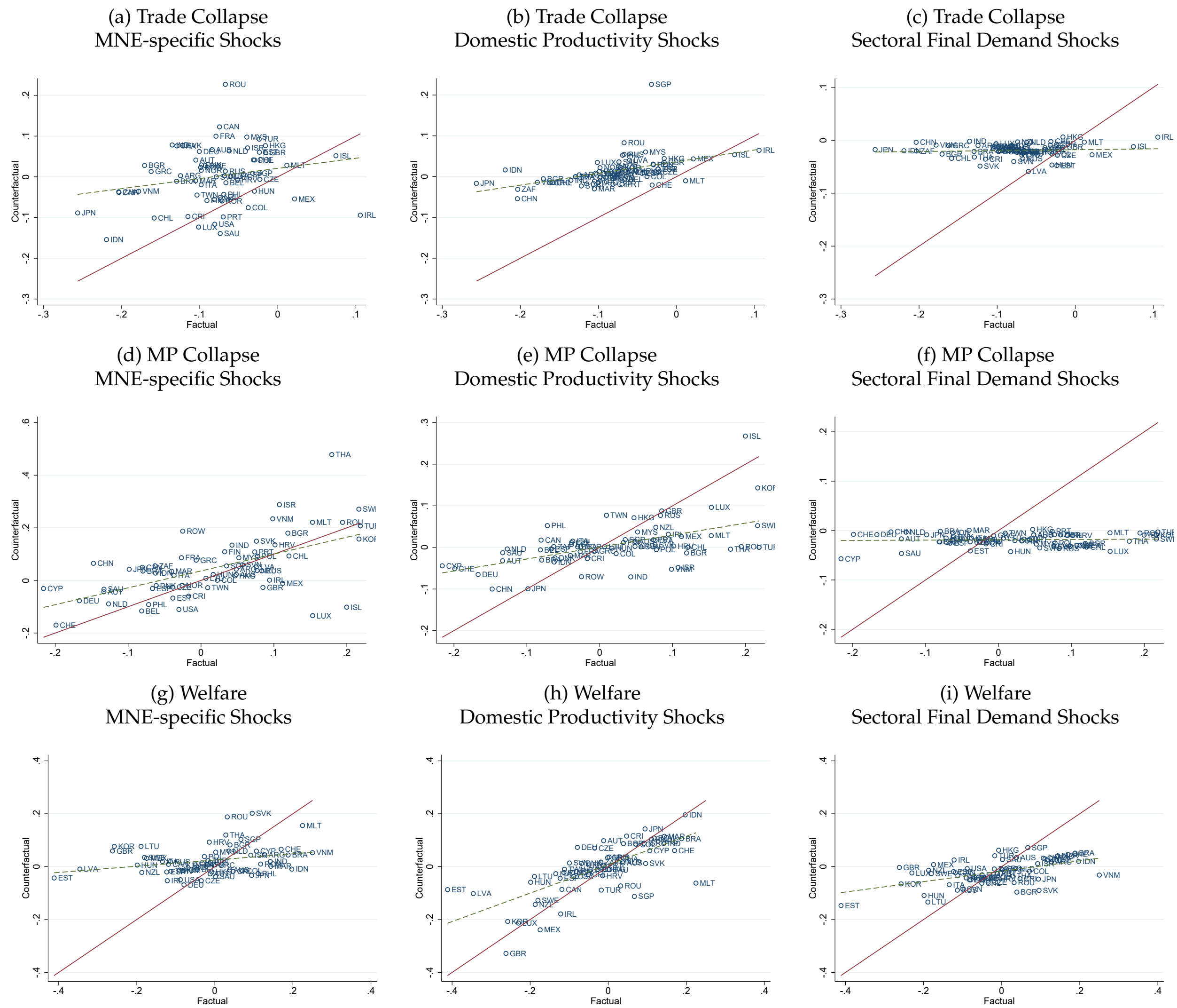
Table 10: **Importance of Shocks for Cross-country Variations of Trade Collapse, MP Collapse, and Welfare Changes**

Shocks	Trade Collapse (1)	MP Collapse (2)	Welfare (3)
MNE-specific Shocks	24.90%	64.10%	11.72%
Domestic Productivity Shocks	28.72%	28.74%	53.75%
Final Demand Shocks	1.70%	0.63%	19.66%
Supply Shocks	24.46%	78.00%	58.31%
Demand Shocks	7.06%	9.91%	27.76%
All Shocks	100.00%	100.00%	100.00%

Description: This table displays the effects of various shocks on cross-country trade, MP, and welfare changes during the Great Recession. Trade collapse is measured with changes in average imports and exports relative to GDP, while MP collapse is measured with changes in average inward and outward MP relative to GDP. The share of cross-country variation explained by shock groups is calculated using Equation (26).

Model without MP or without MNE International Transaction Frictions Table A.19 indicates that without MP, neither domestic productivity nor final demand shocks could absorb MNE-specific shocks' impact on cross-country trade collapse variations. Table A.20 demonstrates that without the sourcing and selling frictions for MNEs, MNE-specific shocks couldn't explain cross-country trade collapse variations (-0.4%). This supports findings from Section 5.1.1 on global trade collapse, reiterating that MNEs' high trade intensity was the main reason their shocks impacted trade collapse.

Figure 5: **Importance of Shocks in Cross-country Variation of Trade Collapse, MP Collapse, and Welfare Changes**



Description: These figures illustrate the effects of various shocks on cross-country trade, MP, and welfare changes during the Great Recession. Trade collapse is measured by changes in average imports and exports relative to GDP, while MP collapse is measured by changes in average inward and outward MP relative to GDP. The share of cross-country variation explained by shock groups is determined using Equation (26). The green dashed line represents the fitted regression, while the red line signifies the 45-degree line.

5.1.3 Impact of Shocks during Other Episodes

Post-Great Recession, global trade recovered, with the global trade to GDP ratio rising from 0.25 in 2009 to 0.29 in 2010. Table A.21 and Figure A.10 show MNE-specific shocks as the primary recovery driver. In contrast, domestic productivity shocks and final demand shocks had limited impact on the trade recovery. MNE-specific shocks alone would restore the MP-to-GDP ratio to pre-Recession levels, but global MP didn't fully recover due to reduced contributions from domestic productivity shocks and final demand shocks. These findings, supported by the decomposition results in Table A.4, indicate that post-

Recession, MP recovered relative to GDP in an average country, aiding trade rebound.[47] However, MP-intensive countries, especially in Europe, experienced sluggish recoveries, preventing global MP from recovering to its pre-Recession level.[48]

From 2013, world trade and MP declined again relative to GDP. Table A.22 and Figure A.11 show all shocks contributed to these declines without a single dominant shock (consistent with decomposition findings in Table A.5).[49] Additionally, MNEs underperformed domestic firms in an average country, further contributing to trade and MP declines.

Discussion I document that MNE-specific shocks had a more significant impact on cross-country differences in the trade collapse compared to sectoral final demand shocks. The literature examining the trade collapse suggests that the financial crisis at the root of the Great Recession led to a reduction in demand for durable investment goods, which are more tradable, in many countries. Consistent with their findings, I observe that these sectoral final demand shocks contributed to the decline in world total trade. However, given that the MP collapse was heterogeneous and concentrated in major headquarters countries, and MNEs are trade-intensive, the MNE-specific shocks, which were the primary driver of the MP collapse, had a more significant impact on the differences across countries. Although within-country final demand shocks contributed to the trade collapse in an average country, as the trade collapse was a nearly universal experience, these shocks did not substantially affect cross-country variations.

Moreover, the literature argues that the trade collapse was temporary because demand for durable goods would rebound as the financial crisis subsided. I provide a new explanation for the transitory trade collapse. Since a significant portion of the trade collapse resulted from MNE-specific shocks in key MP headquarters, and these MNE-specific shocks recovered after the Great Recession, leading to a rebound in trade.

5.2 Propagation of Shocks

I examine the amplification of domestic productivity shocks in headquarters countries on trade and MP collapses through MP linkages. Additionally, I explore the impact of top global MP headquarters' shocks on other countries through MP and trade.

[47]Table A.23 shows the impact of shocks on cross-country variations in trade, MP, and welfare changes from 2009 to 2010.

[48]For Europe's lack of recovery, see discussions in Nelson et al. (2012), Bean et al. (2015), among others.

[49]Table A.24 shows the impact of shocks on cross-country variations in trade, MP, and welfare changes from 2013 to 2016, confirming that no single shock predominantly contributed to these declines during this period. This period was marked by stagnant euro-zone growth, crises in emerging markets, and weak global commodity demand. See, for example, Constantinescu et al. (2016).

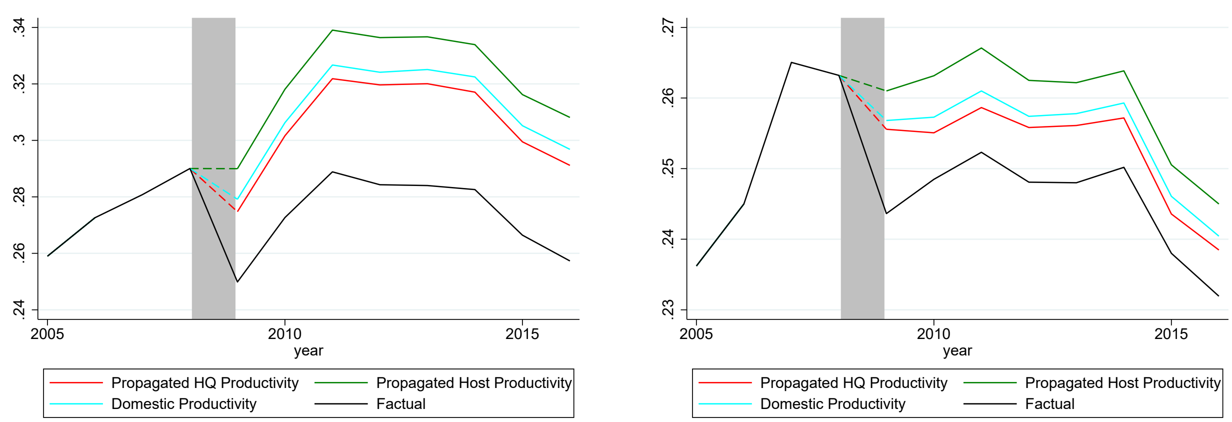
5.2.1 Domestic Productivity Shocks Propagation through MP Linkages

Domestic productivity shocks in headquarters and host countries influence the productivity of MNEs compared to host country domestic firms (see Section 4.4). Due to these propagation effects, these shocks contributed to MNE-specific shocks, which significantly impacted trade, MP, and welfare collapses (Section 5.1).

For quantification, we examine the effects of three shock combinations: (1) propagated headquarters productivity shocks, where domestic productivity in the headquarters country determines MNE's relative productivity to host country domestic firms: $\left\{\hat{A}^s_{ii}, \frac{\hat{A}^s_{ji}}{\hat{A}^s_{jj}} = \left(\hat{A}^s_{ii}\right)^{\phi^s} |\forall i, j\right\}$ per Equation (23); (2) propagated host country productivity shocks, where host country domestic productivity determines MNE's relative productivity: $\left\{\hat{A}^s_{jj}, \frac{\hat{A}^s_{ji}}{\hat{A}^s_{jj}} = \left(\frac{1}{\hat{A}^s_{jj}}\right)^{\phi^s} |\forall i, j\right\}$; and (3) only domestic productivity shocks, with MNE relative productivity unaffected by headquarters or host country shocks: $\left\{\hat{A}^s_{ii}, \frac{\hat{A}^s_{ji}}{\hat{A}^s_{jj}} = 1 |\forall i, j\right\}$.[50] All other shocks in the model are muted.

Figure 6: **Propagation of Domestic Productivity Shocks through MP Headquarters and Host Countries: Global Trade Collapse and MP Collapse**

(a) Trade Collapse (b) MP Collapse



Description: These figures illustrate the impact of domestic productivity shocks, their propagation through MP headquarters, and host country linkages on global trade and MP collapse during the Great Recession (2008-2009, shaded years). Dashed lines represent individual shock groups' impacts, while post-2009 lines indicate counterfactual outcomes influenced by actual shocks, stemming from counterfactual market shares due to individual shock groups.

Figure 6 and Table A.25 indicate that if domestic productivity shocks propagated through MP headquarters linkages, the impact of domestic productivity shocks on the global trade collapse was increased by 40% (from 1.09 percentage points or 27% of actual

[50] $\hat{A}^s_{ji}$ denotes the change in the MNE (headquartered in i and operating in j) productivity from its pre-recession 2008 level to the counterfactual level.

decline in world trade to GDP ratio to 1.53 percentage points or 38% of actual decline in world trade to GDP ratio). With this mechanism, adverse domestic productivity shocks not only reduced the output and competitiveness in the countries that were directly affected by these shocks, but also undermined the productivity of MNEs headquartered in these countries. The propagation effect amplified domestic productivity shocks' impact on trade, as these shocks adversely affected key MP headquarters, whose MNEs were responsible for a substantial portion of global trade. Through the MP headquarters linkages, the impact of domestic productivity shocks on the global MP collapse was also increased by 20% (from 0.64 percentage points or 33% of actual decline in world MP to GDP ratio to 0.76 percentage points or 39% of actual decline in world MP to GDP ratio).

Propagation through MP host country linkages reduced the impact of domestic productivity shocks. The consequence of such propagation is that, if the domestic productivity of a country were to be adversely affected, the foreign affiliates in that country would perform better than their domestic counterparts. This mechanism thus undermined the impact of domestic productivity shocks on the collapse of MP and, consequently, on trade.

In terms of cross-country variations, propagation through MP headquarters increased the impact of domestic productivity shocks on trade collapse, MP collapse, and welfare changes by 21%, 9%, and 45% (Table 11 and Figure A.12). Remarkably, these propagated domestic productivity shocks can account for over 80% of the cross-country variation in welfare changes. On the other hand, propagation through the host country reduced the effects of domestic productivity shocks. Tables A.26 and A.27 show that propagation through MP headquarters also increased the impacts of domestic productivity shocks during the post-Recession recovery period and during the trade and MP declines from 2013 to 2016.

Table 11: **Propagation of Domestic Productivity Shocks through MP Headquarters and Host Countries: Cross-country Variations in Trade Collapse, MP Collapse, and Welfare**

Shocks	Trade Collapse (1)	MP Collapse (2)	Welfare (3)
Propagation through Headquarters	34.84%	32.19%	82.69%
Propagation through Host Countries	14.20%	19.77%	24.73%
Domestic Productivity Shocks	28.72%	28.74%	57.01%

Description: This table displays the impact of domestic productivity shocks, their propagation through MP headquarters, and host country linkages on cross-country variations in trade collapse, MP collapse, and welfare changes during the Great Recession. Trade collapse is gauged by changes in imports and exports relative to GDP, while MP collapse is determined by changes in inward and outward MP relative to GDP. Cross-country variation shares are calculated using Equation (26).

5.2.2 Top Headquarters' MNE-specific Shocks

I explore whether shocks spread more broadly through MP than international trade by examining the impact of MNE-specific shocks in the top ten MP headquarters on the global economy. Additionally, I investigate domestic productivity shocks affecting top exporters and sectoral final demand shocks in top importers for comparison.

MNE-specific shocks in the top ten headquarters countries Ω are defined as: $\left\{\hat{A}_{ji}, \hat{h}_{ij}, \hat{H}_{ni}, \hat{\alpha}^s_{ni} | i \in \Omega, \forall j, n\right\}$. These shocks relate to MNEs headquartered in $i \in \Omega$ and capture changes in their relative productivity and final demand compared to the host country domestic firms, as well as their sourcing and selling efficiencies to non-headquarter countries. Similarly, MNE-specific shocks in the top ten host countries Ω' are defined as: $\left\{\hat{A}_{ji}, \hat{h}_{mj}, \hat{H}_{ji}, \hat{\alpha}^s_{jm} | j \in \Omega', \forall i, m\right\}$. These host economy shocks capture changes in the relative productivity and final demand of MNEs hosted by country j compared to country j's domestic firms and changes in global MNEs' sourcing and selling efficiencies from and to country j.[51] All other shocks in this model are muted.

Table 12 and Figure A.13 reveal that MNE-specific shocks that originated from the top ten global MP headquarters accounted for 20% of MP collapse variation and 8% of welfare change variation across the fifty other countries.[52] MNE-specific shocks in the top ten host countries explained 13% of MP collapse variation and 2% of welfare changes. However, neither domestic productivity shocks in top exporters nor sectoral final demand shocks in top importers significantly impacted trade, MP, or welfare in other countries.

These findings indicate that shocks spread more widely through MP than international trade. Countries with limited outward MP, like China and India, may receive substantial inward MP from major headquarters such as the US, making their economic activities vulnerable to MNE-specific shocks. As imports and exports are generally balanced, countries with minimal trade aren't greatly impacted by shocks affecting top global exporters and importers. To explain a universal trade collapse, shocks that happened in almost all countries were necessary.

[51] As of 2007, the top ten global headquarters were: USA, JPN, GBR, DEU, FRA, NLD, CHE, ITA, ROW, and CAN; the top ten global host countries were (ISO code): USA, DEU, GBR, CHN, FRA, CAN, ITA, AUS, ESP, and NLD; the top ten importers were: USA, DEU, CHN, JPN, GBR, FRA, ITA, CAN, KOR, and RUS; and the top ten exporters were: USA, JPN, CHN, DEU, GBR, FRA, ITA, ESP, CAN, and RUS.

[52] Table 10 shows that all MNE-specific shocks contributed 12%.

Table 12: **Propagation of MNE-specific Shocks in the Top Headquarters and Host Countries: Cross-country Variations in Trade Collapse, MP Collapse, and Welfare for Other Countries**

Shocks	MP Collapse (1)	Trade Collapse (2)	Welfare (3)
MNE-specific Shocks in Top 10 Headquarters	19.33%	4.22%	8.43%
MNE-specific Shocks in Top 10 Host Countries	12.89%	3.87%	2.32%
Domestic Productivity Shocks in Top 10 Exporters	4.02%	–0.46%	0.05%
Final Demand Shocks in Top 10 Importers	0.06%	–1.34%	0.10%

Description: This table shows the impact of MNE-specific shocks in the top 10 headquarters and host countries, domestic productivity shocks in top 10 exporters, and final demand shocks in top 10 importers on cross-country variations in trade collapse, MP collapse, and welfare changes during the Great Recession. Trade collapse is measured by changes in average imports and exports relative to GDP, while MP collapse is assessed by changes in inward and outward MP relative to GDP. Cross-country variation shares are calculated using Equation (26).

5.2.3 Top Headquarters' Domestic Productivity Shocks Propagation via MP Linkages

The findings presented in Section 2.2 suggest that adverse productivity shocks in key headquarters countries, along with their propagation to these countries' MNEs operating abroad, can help explain the "Multinationals' Resilience Puzzle": they led to a decrease in MP in larger countries and a reduction in GDP in MP-intensive countries during the Great Recession. When domestic productivity shocks propagate through MP headquarters linkages, they can also significantly influence other countries' trade and welfare.

In this exercise, similar to Section 5.2.1 and based on Equation (23), I analyze four scenarios: (1) domestic productivity shocks in the top ten headquarters, with these shocks propagating through MNEs: $\left\{\hat{A}^s_{ii}, \frac{\hat{A}^s_{ji}}{\hat{A}^s_{jj}} = \left(\hat{A}^s_{ii}\right)^{\phi^s} | i \in \Omega, \forall j\right\}$, where Ω denotes the top ten headquarters (see Section 5.2.2); (2) domestic productivity shocks in the top ten host countries propagating through MNEs: $\left\{\hat{A}^s_{jj}, \frac{\hat{A}^s_{ji}}{\hat{A}^s_{jj}} = \left(\frac{1}{\hat{A}^s_{jj}}\right)^{\phi^s} | j \in \Omega', \forall i\right\}$, where Ω' denotes the top ten host countries (see Section 5.2.2); (3) domestic productivity shocks in the top ten headquarters with MNE relative productivity unaffected by these headquarters shocks: $\left\{\hat{A}^s_{ii}, \frac{\hat{A}^s_{ji}}{\hat{A}^s_{jj}} = 1 | i \in \Omega, \forall j\right\}$; and (4) domestic productivity shocks in the top ten host countries with MNE relative productivity unaffected by these host country shocks: $\left\{\hat{A}^s_{jj}, \frac{\hat{A}^s_{ji}}{\hat{A}^s_{jj}} = 1 | j \in \Omega', \forall i\right\}$. All other shocks in this model are muted.

Table 13 and Figure A.14 demonstrate that domestic productivity shocks in the top ten global headquarters, when propagated through their linkages, lead to considerable cross-country variation (17% of the factual level) in trade collapse. These propagated shocks also explain 6% and 4% of cross-country variation in the MP collapse and welfare changes, respectively.

Conversely, consistent with Section 5.2.2, Table 13 and Figure A.14 also reveals that

Table 13: **Propagation of Domestic Productivity Shocks in Top Headquarters and Host Countries: Cross-country Variations in Trade Collapse, MP Collapse, and Welfare across Other Countries**

Shocks	Trade Collapse (1)	MP Collapse (2)	Welfare (3)
Propagation of Domestic Productivity Shocks in Top 10 Headquarters	17.19%	6.60%	4.48%
Domestic Productivity Shocks in Top 10 Headquarters	–1.55%	–2.64%	0.13%
Propagation of Domestic Productivity Shocks in Top 10 Host Countries	–0.15%	1.01%	–0.55%
Domestic Productivity Shocks in Top 10 Host Countries	–2.23%	1.03%	0.13%

Description: This table presents the impact of domestic productivity shocks in the top 10 headquarters countries, these shocks propagated through MP headquarters, and these shocks propagated through MP host country linkages, on the cross-country variation in the collapse of trade, MP, and welfare changes during the Great Recession. Country-level trade collapse is measured with the change in the average of its imports and exports relative to its GDP. Country-level MP collapse is measured with the change in the average of its inward MP (sales made by foreign affiliates hosted by this country) and its outward MP (sales made by the country's affiliates hosted by other countries) relative to its GDP. The share of cross-country variation explained by a group of shocks is calculated with Equation (26).

without MP propagation (only trade), domestic productivity shocks in top headquarters and host countries do not significantly affect changes in trade, MP, or welfare in other countries. Furthermore, shocks in top host countries have limited impact on others, even when propagated through MP host linkages (as seen in Section 5.2.1).

5.2.4 Understanding the "Multinationals' Resilience Puzzle" through the Model

Table 14 demonstrates that the propagation of domestic productivity shocks through headquarters linkages could explain the "Multinationals' Resilience Puzzle". A counterfactual involving domestic productivity shocks in the top 10 headquarters (as in Section 5.2.3), which spread to the rest of the world, leads to more pronounced MP declines in larger countries, steeper GDP declines in MP-intensive countries, and increased MP resilience compared to GDP in an average country. These shocks not only reduce outward MP from the key headquarters countries but also affect countries with high MP intensity due to their high exposure to productivity shocks in the major headquarters. These propagated headquarters shocks can also account for the decline in trade relative to GDP observed in an average country.

Table 14: **Decomposition of World Total MP and Trade Declines into Between-country and Within-country Components under Different Shock Scenarios**

Scenarios	(A) MP/Trade Declined More in Larger Countries	(B) GDP Declined More in MP/Trade Intensive Countries	(C) Within-country	Total
	MP Collapse			
Data	*–0.018 (104.0%)*	*–0.008 (49.0%)*	*0.009 (–53.0%)*	*–0.017 (100%)*
Domestic Prod. Shocks in Top 10 HQ Prop. through HQ	–0.011 (139.4%)	–0.008 (94.8%)	0.011 (–134.2%)	–0.008 (100%)
Domestic Prod. Shocks in Top 10 Hosts Prop. through Hosts	–0.001 (12.8%)	–0.005 (92.9%)	0.000 (–5.6%)	–0.006 (100%)
Domestic Productivity Shocks in Top 10 Exporters	0.009 (–208.2%)	0.000 (–0.2%)	–0.013 (308.4%)	–0.004 (100%)
Final Demand Shocks in Top 10 Importers	0.008 (–280.8%)	0.005 (–153.4%)	–0.016 (534.2%)	–0.003 (100%)
	Trade Collapse			
Data	*0.008 (–23.4%)*	*–0.002 (6.7%)*	*–0.038 (116.6%)*	*–0.033 (100%)*
Domestic Prod. Shocks in Top 10 HQ Prop. through HQ	–0.000 (0.0%)	–0.003 (23.4%)	–0.009 (76.5%)	–0.011 (100%)
Domestic Prod. Shocks in Top 10 Hosts Prop. through Hosts	0.004 (–41.8%)	–0.002 (15.3%)	–0.013 (126.5%)	–0.010 (100%)
Domestic Productivity Shocks in Top 10 Exporters	0.004 (–40.9%)	–0.002 (20.9%)	–0.013 (120.0%)	–0.011 (100%)
Final Demand Shocks in Top 10 Importers	0.005 (–33.9%)	–0.003 (23.2%)	–0.016 (110.7%)	–0.014 (100%)

Description: This table presents the decomposition of changes in world total trade to GDP and world total MP to GDP ratios from 2008 to 2009 under various shock scenarios. These include factual data, domestic productivity shock propagation in top 10 headquarters, host countries, exporters, and final demand shocks in top 10 importers through respective linkages. The first component measures how much MP/trade decreased in larger countries. The second component measures how much GDP declined in countries with high MP/trade intensities. The third component measures the contribution of cross-country simple averages of changes in multinational production and trade as a proportion of GDP. Equation (1) shows the decomposition formula. The numbers outside the brackets refer to the magnitude of each term, while the numbers inside the brackets refer to its percentage contribution.

In contrast, domestic productivity shocks in the top ten host countries, propagated through host country linkages, have a limited impact on the "Multinationals' Resilience Puzzle". This is because MP decreases only weakly more in larger countries under these shocks. Additionally, domestic productivity shocks in the top ten exporters and final demand shocks in the top ten importers, as they propagate only through trade, result in a significant decline in MP relative to GDP in an average country. This indicates that traditional sectoral final demand shocks or productivity shocks propagated solely through trade are insufficient in explaining the puzzle. Nevertheless, all these shocks contribute to a decline in trade relative to GDP in an average country.

6 Conclusion

In this paper, I show that shocks to MNEs significantly contributed to the declines of trade during the Great Recession, both globally and across countries. The linkages between MP headquarters and the rest of the world amplified the effects of domestic productivity shocks on the declines of trade, MP, and welfare.

I begin by resolving the "Multinationals' Resilience Puzzle" and find that while MNEs were more resilient than GDP for an average country, MP declined more in larger countries and GDP declined more in MP intensive countries. These heterogeneity led to the decline of world total MP. I also document MNEs' higher intensity in durable manufacturing and international trade, particularly with headquarters and nearby countries.

The answer to the "Multinationals' Resilience Puzzle" indicates that domestic productivity shocks in key headquarters countries and their subsequent transmission to other countries through MNEs likely played a role in the MP collapse, impacting global trade and welfare. To quantity these effects, I develop a model of multinational production and global value chains considering trade, MP, and sectoral input-output linkages, accounting for the barriers MNEs face when sourcing from and selling to non-headquarters countries. This innovation, along with the MNE's sourcing problem nesting structure, allows the model to match the new OECD AAMNE Database and replicate the empirical facts. I introduce new methods for estimating the model's elasticities, including trade, MNE, substitution across sectors and MNEs in final demand, and headquarters' productivity share within an MNE.

Using model simulations, I find that MNE-specific shocks significantly contributed to the trade collapse, as supply-side productivity shocks nearly equaled the impact of demand shocks. Due to the heterogeneity in the MP collapse across countries, MNE-specific shocks played a significant role in driving cross-country variations in the trade collapse. Meanwhile, final demand shocks contributed to the decline in world total trade but affected little the cross-country variations. Ignoring MP would assign the impact of MNE shocks as final demand shocks, overestimating demand-side effects. MNEs' high trade intensity was the main reason their shocks influenced the trade collapse.

I find that MP headquarters linkages considerably intensified the impact of domestic productivity shocks on the global economy when they affected MNEs in other countries. Without MP propagation, these shocks didn't significantly impact the rest of the world, even when hitting top exporters or importers. However, when domestic productivity shocks in key headquarters countries spread through MP links, they substantially affected trade declines and welfare in other nations.

Using the model's framework, I conclude that the propagation of productivity shocks through MP headquarters are crucial in resolving the "Multinationals' Resilience Puzzle". In contrast, sectoral final demand shocks explain the substantial trade decline in an average country but not the cross-country heterogeneity patterns in MP collapse nor the resilience of MP relative to GDP in an average country.

This framework highlights the role of international trade by MNEs in propagating shocks across countries and sectors, affecting national welfare. Ignoring the MP margin may lead to misunderstanding welfare changes and incorrect policies. Policymakers should monitor shocks impacting foreign headquarters with substantial MP activities in their local economies. During the Great Recession, these shocks were more vital for domestic welfare than trade shocks. FDI/MP-friendly policies, essential in promoting trade, are particularly relevant amidst intensifying tariff wars. Beyond the Great Recession, this framework applies to policy contexts with strong adjustments in openness margins, such as trade and technology wars, COVID crisis lockdowns, and deep trade agreements.

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A Data appendix

Table A.1: **Country Names and Country Codes**

AAMNE countries	Country code	AAMNE countries	Country code
Argentina	ARG	Italy	ITA
Australia	AUS	Japan	JPN
Austria	AUT	Korea	KOR
Belgium	BEL	Lithuania	LTU
Bulgaria	BGR	Luxembourg	LUX
Brazil	BRA	Latvia	LVA
Canada	CAN	Morocco	MAR
Switzerland	CHE	Mexico	MEX
Chile	CHL	Malta	MLT
China	CHN	Malaysia	MYS
Colombia	COL	Netherlands	NLD
Costa Rica	CRI	Norway	NOR
Cyprus	CYP	New Zealand	NZL
Czech Republic	CZE	Philippines	PHL
Germany	DEU	Poland	POL
Denmark	DNK	Portugal	PRT
Spain	ESP	Romania	ROU
Estonia	EST	Rest of the World	ROW
Finland	FIN	Russian Federation	RUS
France	FRA	Saudi Arabia	SAU
U.K.	GBR	Singapore	SGP
Greece	GRC	Slovak Republic	SVK
Hong Kong, China	HKG	Slovenia	SVN
Croatia	HRV	Sweden	SWE
Hungary	HUN	Thailand	THA
Indonesia	IDN	Turkey	TUR
India	IND	Taiwan	TWN
Ireland	IRL	U.S.	USA
Iceland	ISL	Vietnam	VNM
Israel	ISR	South Africa	ZAF

Description: This table presents the names and 3-digit ISO codes of the countries covered in the OECD AAMNE Database.

Table A.2: **Industries in the OECD AAMNE Database**

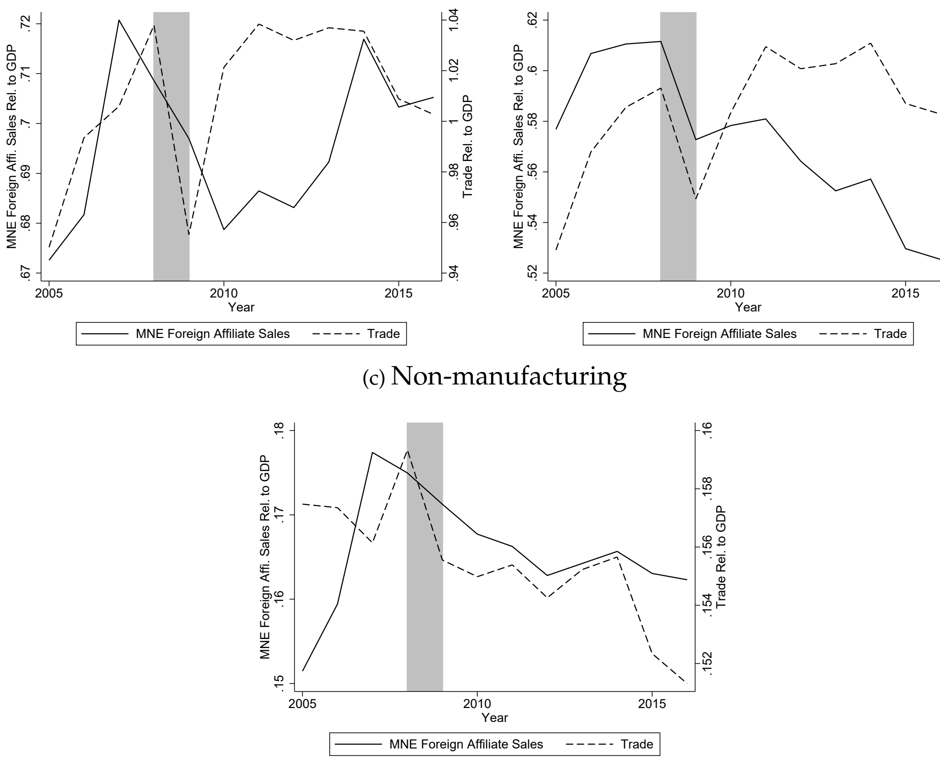
AAMNE industries	Industry name	Durability
A	Agriculture	Non-manufacturing
B	Mining	Non-manufacturing
C10T12	Food	Non-durable
C13T15	Textile	Non-durable
C16	Wood	Durable
C17T18	Paper	Non-durable
C19	Petroleum	Non-manufacturing
C20T21	Chemicals	Non-durable
C22	Plastic	Non-durable
C23	Minerals	Durable
C24	Basic metals	Durable
C25	Metal products	Durable
C26	Electronic & Optical	Durable
C27	Electrical equipment	Durable
C28	Machinery n.e.c	Durable
C29	Auto	Durable
C30	Other Transport & Other mfg	Durable
C31T33	Manufacturing n.e.c and recycling	Non-durable
DTE	Electricity	Non-manufacturing
F	Construction	Non-manufacturing
G	Retail	Non-manufacturing
H	Transport	Non-manufacturing
I	Hotels	Non-manufacturing
J58T60	Publishing & media	Non-manufacturing
J61	Telecommunications	Non-manufacturing
J62T63	Computer service	Non-manufacturing
K	Finance	Non-manufacturing
L	Real Estate	Non-manufacturing
MTN	Other Business	Non-manufacturing
O	Public	Non-manufacturing
P	Education	Non-manufacturing
Q	Health	Non-manufacturing
RTS	Other services	Non-manufacturing
T	Private	Non-manufacturing

Description: This table presents the Industries in the OECD AAMNE Database (based on ISIC Rev.4 classification) and their mappings to the three broad sectors considered in this study.

Figure A.1: **Global MP and Trade Collapse in the Great Recession by Sector**

(a) Durable Manufacturing (b) Non-durable Manufacturing

(c) Non-manufacturing



Description: The figure shows that during the Great Recession (2008-2009, shadowed years), both world total foreign affiliate sales and world total trade experienced a significant decline relative to world total value added across all sectors. The data source is OECD Analytical Activities of Multinationals (OECD AAMNE) Database.

A.1 Other Decomposition Results

I further decompose the within-country effect presented in Equation (1) into three terms: within each country, (C.1) whether MP/trade declined more in larger sectors; (C.2) whether sectoral GDP declined more in MP/trade intensive sectors; and (C.3) the cross-sector average of MP/trade decline relative to GDP. I use the following formula:

$$\frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}} = \frac{\sum_{s=1}^{S} MP^s_{i,2009}}{\sum_{s=1}^{S} GDP_{i,2009}} - \frac{\sum_{s=1}^{S} MP^s_{i,2008}}{\sum_{s=1}^{S} GDP^s_{i,2008}}$$

$$\underbrace{\underbrace{S\,\mathrm{cov}_s\Big(\frac{MP^s_{i,2009}}{GDP^s_{i,2009}} - \frac{MP^s_{i,2008}}{GDP^s_{i,2008}}, \frac{\frac{GDP^s_{i,2009}}{\sum_{s=1}^{S} GDP^s_{i,2009}} + \frac{GDP^s_{i,2008}}{\sum_{s=1}^{N} GDP^s_{i,2008}}}{2}\Big)}_{\text{C.1}} + \underbrace{S\,\mathrm{cov}_s\Big(\frac{GDP^s_{i,2009}}{\sum_{s=1}^{S} GDP^s_{i,2009}} - \frac{GDP^s_{i,2008}}{\sum_{s=1}^{N} GDP^s_{i,2008}}, \frac{\frac{MP^s_{i,2009}}{GDP^s_{i,2009}} + \frac{MP^s_{i,2008}}{GDP^s_{i,2008}}}{2}\Big)}_{\text{C.2}}}_{\text{Between-country Effects}}$$

$$+ \underbrace{\frac{1}{S}\sum_{s=1}^{S}\Big(\frac{MP^s_{i,2009}}{GDP^s_{i,2009}} - \frac{MP^s_{i,2008}}{GDP^s_{i,2008}}\Big)}_{\text{C.3: Within-country Effect}}. \tag{A.1}$$

Here, S denotes the total number of sectors. $MP^s_{i,t}$ denotes the average of inward and outward MP in country i, sector s, and year t. $GDP^s_{i,t}$ denotes country i, sector s' GDP in year t.

The complete decomposition of global MP and trade collapses into between-country, within-country-between sector, and within-country-within-sector forces consists of the following five terms:

1. A: $N\text{cov}_i\left(\frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}}, \frac{\frac{GDP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} + \frac{GDP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}}{2}\right)$;

2. B: $N\text{cov}_i\left(\frac{GDP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} - \frac{GDP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}, \frac{\frac{MP_{i,2009}}{GDP_{i,2009}} + \frac{MP_{i,2008}}{GDP_{i,2008}}}{2}\right)$;

3. $C.1$: $\frac{1}{N}\sum_{n=1}^N S\text{cov}_s\left(\frac{MP^s_{i,2009}}{GDP^s_{i,2009}} - \frac{MP^s_{i,2008}}{GDP^s_{i,2008}}, \frac{\frac{GDP^s_{i,2009}}{\sum_{s=1}^S GDP^s_{i,2009}} + \frac{GDP^s_{i,2008}}{\sum_{s=1}^N GDP^s_{i,2008}}}{2}\right)$;

4. $C.2$: $\frac{1}{N}\sum_{n=1}^N S\text{cov}_s\left(\frac{GDP^s_{i,2009}}{\sum_{s=1}^S GDP^s_{i,2009}} - \frac{GDP^s_{i,2008}}{\sum_{s=1}^N GDP^s_{i,2008}}, \frac{\frac{MP^s_{i,2009}}{GDP^s_{i,2009}} + \frac{MP^s_{i,2008}}{GDP^s_{i,2008}}}{2}\right)$;

5. $C.3$: $\frac{1}{N}\sum_{n=1}^N \frac{1}{S}\sum_{s=1}^S\left(\frac{MP^s_{i,2009}}{GDP^s_{i,2009}} - \frac{MP^s_{i,2008}}{GDP^s_{i,2008}}\right)$.

Table A.3 presents the decomposition results.

Table A.3: **Decomposition of Changes in Global MP and Trade**

	MP/Trade Changed More in Larger Countries	GDP Changed More in MP/Trade Intensive Countries	Within Country MP/Trade Changed More in Larger Sectors	Within Country GDP Changed More in MP/Trade Intensive Sectors	Within Country within Sectors	Total
2008-2009: Global Trade and MP Collapse						
MP	–0.018 (104.0%)	–0.008 (49.0%)	–0.014 (80.4%)	–0.004 (25.1%)	0.027 (–158.5%)	–0.017 (100%)
Trade	0.008 (–23.4%)	–0.002 (6.7%)	0.027 (–81.7%)	–0.006 (19.4%)	–0.059 (178.9%)	–0.033 (100%)
2009-2010: Post-Recession Recovery						
MP	0.007 (182.3%)	–0.006 (-143.8%)	–0.013 (-329.5%)	0.004 (104.1%)	0.011 (286.9%)	0.004 (100%)
Trade	–0.010 (-43.7%)	–0.000 (-0.2%)	–0.023 (-103.2%)	0.007 (31.7%)	0.047 (215.4%)	0.022 (100%)
2013-2016: Trade and MP Declines						
MP	–0.006 (40.3%)	–0.005 (30.3%)	–0.027 (170.8%)	–0.002 (11.0%)	0.024 (–152.4%)	–0.016 (100%)
Trade	–0.015 (57.4%)	–0.005 (17.3%)	–0.024 (91.4%)	0.001 (–3.3%)	0.017 (–62.8%)	–0.027 (100%)

Description: This table presents the decomposition of the change in the ratio of world total trade to world GDP and the ratio of world total MP to world GDP for three periods: Great Recession from 2008 to 2009, post-Recession recovery from 2009 to 2010, and the trade and MP decline from 2013 to 2016. The first component measures how much MP/trade decreased in larger countries. The second component measures how much GDP declined in countries with high MP/trade intensities. The third component measures, for an average country, how much MP/trade declined in larger sectors. The fourth component measures, for an average country, how much sectoral GDP declined in the sectors with high MP/trade intensities. The fifth component measures the contribution of cross-country, cross-sector simple averages of changes in multinational production and trade as a proportion of GDP. The formula for such decomposition is presented in Equation (1). The numbers outside the brackets refer to the magnitude of each term, while the numbers inside the brackets refer to its percentage contribution.

Table A.4: **Decomposition of Changes in Global MP and Trade, 2009-2010**

	MP/Trade Increased More in Larger Countries	GDP Increased More in MP/Trade Intensive Countries	Within Country	Total
All				
MP	0.007 (182.3%)	–0.006 (-143.8%)	0.002 (61.5%)	0.004 (100%)
Trade	–0.010 (-43.7%)	–0.000 (-0.2%)	0.031 (143.9%)	0.022 (100%)
A. Durable Manufacturing				
MP	–0.038 (209.4%)	–0.015 (80.0%)	0.035 (–189.4%)	–0.018 (100%)
Trade	–0.000 (-0.1%)	–0.003 (-4.6%)	0.069 (104.6%)	0.066 (100%)
B. Non-durable Manufacturing				
MP	0.024 (427.8%)	–0.019 (-345.6%)	0.001 (17.8%)	0.006 (100%)
Trade	–0.014 (-42.1%)	–0.007 (-19.1%)	0.055 (161.2%)	0.034 (100%)
C. Non-manufacturing				
MP	0.009 (304.2%)	–0.004 (-137.0%)	–0.002 (-67.2%)	0.003 (100%)
Trade	–0.006 (-62.3%)	–0.000 (-2.2%)	0.017 (164.4%)	0.010 (100%)

Description: This table presents the decomposition of the change in the ratio of world total trade to world GDP and the ratio of world total MP to world GDP from 2008 to 2009. The first component measures how much MP/trade decreased in larger countries. The second component measures how much GDP declined in countries with high MP/trade intensities. The third component measures the contribution of cross-country simple averages of changes in multinational production and trade as a proportion of GDP. The formula for such decomposition is presented in (1). The numbers outside the brackets refer to the magnitude of each term, while the numbers inside the brackets refer to its percentage contribution.

Table A.5: **Decomposition of Changes in Global MP and Trade, 2013-2016**

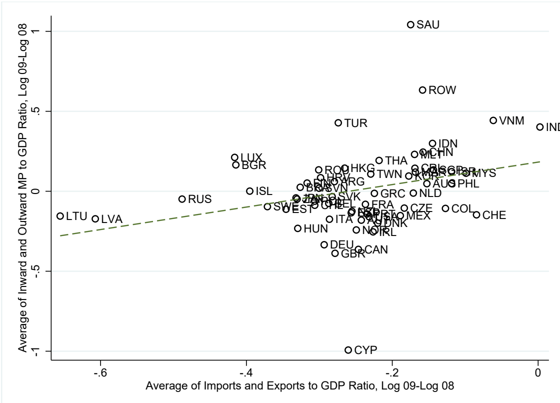
	MP/Trade Declined More in Larger Countries	GDP Declined More in MP/Trade Intensive Countries	Within Country	Total
All				
MP	–0.006 (40.3%)	–0.005 (30.3%)	–0.005 (29.4%)	–0.016 (100%)
Trade	–0.015 (57.4%)	–0.005 (17.3%)	–0.007 (25.3%)	–0.027 (100%)
A. Durable Manufacturing				
MP	–0.039 (-295.1%)	–0.016 (-121.6%)	0.069 (516.7%)	0.013 (100%)
Trade	–0.068 (174.6%)	–0.015 (37.5%)	0.043 (–112.1%)	–0.039 (100%)
B. Non-durable Manufacturing				
MP	–0.019 (66.8%)	–0.025 (87.2%)	0.015 (–54.1%)	–0.029 (100%)
Trade	–0.035 (98.0%)	–0.022 (61.5%)	0.021 (–59.5%)	–0.036 (100%)
C. Non-manufacturing				
MP	–0.004 (21.9%)	–0.004 (21.5%)	–0.011 (56.7%)	–0.019 (100%)
Trade	–0.007 (26.4%)	–0.004 (16.3%)	–0.015 (57.2%)	–0.025 (100%)

Description: This table presents the decomposition of the change in the ratio of world total trade to world GDP and the ratio of world total MP to world GDP from 2008 to 2009. The first component measures how much MP/trade decreased in larger countries. The second component measures how much GDP declined in countries with high MP/trade intensities. The third component measures the contribution of cross-country simple averages of changes in multinational production and trade as a proportion of GDP. The formula for such decomposition is presented in Equation (1). The numbers outside the brackets refer to the magnitude of each term, while the numbers inside the brackets refer to its percentage contribution.

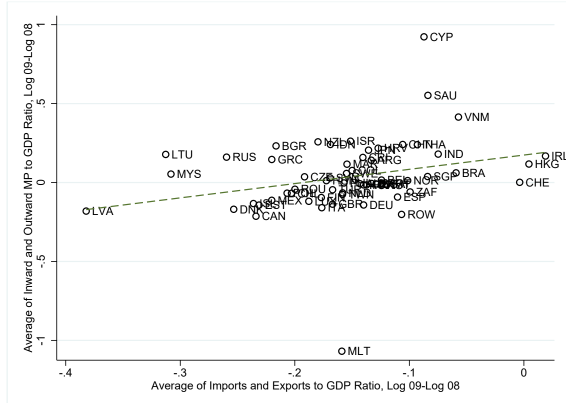
A.2 Other Empirical Findings

Figure A.2: MP and Trade Collapses were Positively Correlated at the Country Level for Each Sector

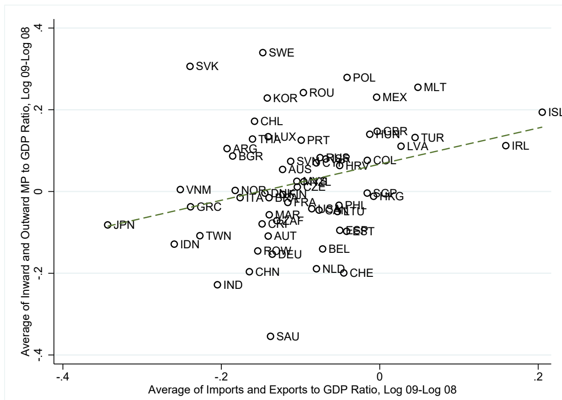
(a) Durable Manufacturing



(b) Non-durable Manufacturing



(c) Non-manufacturing



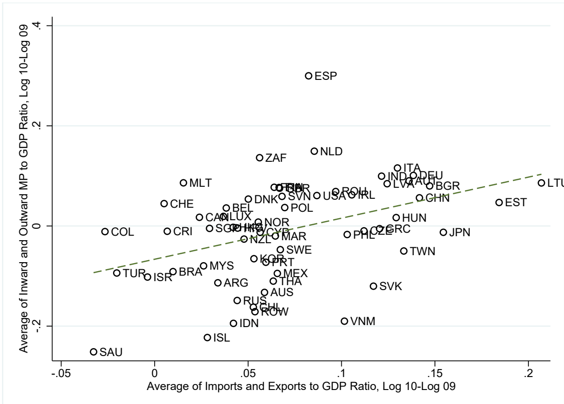
Description: This figure shows, by sector, the changes in the average of inward and outward affiliate sales, as well as the average of imports and exports in relation to the GDP for each country from 2008 to 2009. Regressing the MP collapse on the trade collapse at the country level gives a coefficient of 0.702 and a standard error of 0.294 for durable manufacturing, a coefficient of 0.904 and a standard error of 0.422 for non-durable manufacturing, and a coefficient of .442 and a standard error of 0.188 for non-manufacturing. The data source is OECD Analytical Activities of Multinationals (OECD AAMNE) Database.

A.3 Impact of MNE Status and Headquarters Locations on Foreign Affiliate Importing and Exporting

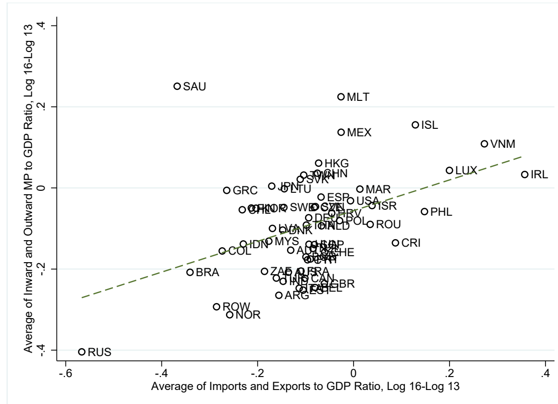
I study how foreign affiliates differ from domestic firms with regard to importing. I take advantage of the Annual Survey of Chinese Manufacturing (ASCM) Database, which covers firm-level business statistics, e.g. sales, capital, etc., for all Chinese manufacturing firms whose annual sales top 5 million RMB (roughly 0.6 million dollars). I link it with the Chinese Customs Records (CCR) Database, which covers all international transactions by Chinese firms, including imports and exports values, 8-digit HS code, firm registration information, among others. A third database is the Foreign-Invested Enterprise Survey in China (FIESC), which documents the ownership nationalities of all foreign affiliates in China. ASCM and FIESC could be exactly matched with a unique numeric firm identifier, whereas CCR and ASCM are matched according to the registration information,

Figure A.3: Positive Correlation Between Changes in MP-to-GDP Ratio and Changes in Trade-to-GDP Ratio at the Country Level for 2009-2010, 2014-2016, and Year-over-Year Changes

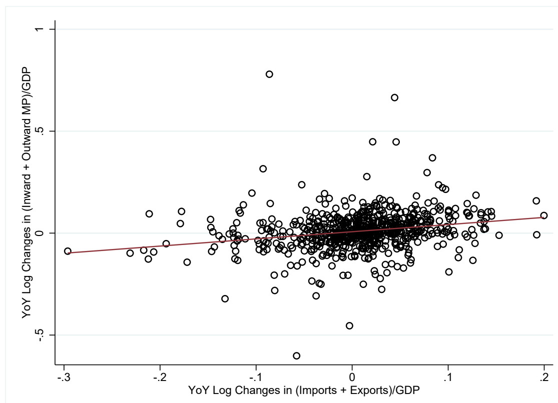
(a) 2009-2010



(b) 2014-2016



(c) Year-over-Year



Description: This figure shows the log changes in the average of inward and outward affiliate sales, along with the average of imports and exports, in relation to each country's GDP for three periods: 2009-2010 (post-Recession recovery), 2013-2016 (trade and MP declines), and year-over-year changes. At the country level, regressing the MP collapse on the trade collapse yields a coefficient of 0.819 and a standard error of 0.198 for changes from 2009 to 2010, a coefficient of 0.378 and a standard error of 0.106 for changes from 2013 to 2016, and a coefficient of 0.351 and a standard error of 0.062 for year-over-year changes. The data source is the OECD Analytical Activities of Multinationals (OECD AAMNE) Database.

e.g. name, address, etc. Similar to Wang (2019), I take a cross-section of the databases in 2001. More information about the database and the matching algorithm could be found in Wang (2019).

The first fact I establish is conditional on firm-level characteristics, foreign affiliates are more likely to import and import more than domestic firms. I regress a dummy variable indicating whether or not a firm imports as well as its share of imported intermediate input in total sales (level and log) on its status as a foreign affiliate. I control for the firm's employment, capital, intermediate input, TFP, as well as the 2-digit industry fixed effect.

Therefore, I consider the following regression specification:

$$S_f = \beta_1 \mathbf{1}(\text{Foreign subsidiary})_f + \beta_2 \log(\text{emp}_f) + \beta_3 \log(\text{cap}_f) + \beta_4 \log(\text{interm}_i) + \beta_5 \log(\text{TFP}_f) + FE_{s(f)} + \epsilon_f,$$

where S_f denotes whether the firm imports: $\mathbf{1}(\text{Imp})_f$, the share of imported intermediate input in firm sales: $\frac{\text{Imp}_f}{\text{Sales}_f}$, or the share in log: $\log(\frac{\text{Imp}_f}{\text{Sales}_f})$.

The results are presented in Table A.6. Being a foreign affiliate is strongly positively associated with both the firm's importing decision and the share of imported intermediate input in total sales. On average, foreign affiliates are 36% more likely to import (Column 1), 14 percentage points higher for imports as a share of total sales (Column 2), and 187 percent higher for those having positive imports (Column 3). Therefore, foreign affiliates engage more in importing than domestic firms with similar firm-level characteristics.

Table A.6: **Conditional on Firm-level Characteristics, Foreign Affiliates Import More**

	(1)	(2)	(3)
	$\mathbf{1}(\text{Imp})_f$	$\frac{\text{Imp}_f}{\text{Sales}_f}$	$\log(\frac{\text{Imp}_f}{\text{Sales}_f})$
$\mathbf{1}(\text{Foreign subsidiary})_f$	0.360***	0.140***	1.870***
	(0.00840)	(0.0174)	(0.103)
$\log(\text{emp}_f)$	0.0102***	0.0139**	-0.100
	(0.00342)	(0.00647)	(0.107)
$\log(\text{cap}_f)$	0.0213***	0.00841***	0.302***
	(0.00232)	(0.00179)	(0.0432)
$\log(\text{interm}_f)$	0.0201***	-0.0144**	-0.269**
	(0.00160)	(0.00669)	(0.114)
$\log(\text{TFP}_f)$	0.0118***	0.000381	-0.244**
	(0.00297)	(0.00391)	(0.104)
Fixed effects	2-digit industry	2-digit industry	2-digit industry
Observations	139613	139613	16518

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Description: The table shows the association between importing and foreign affiliate status. In Columns (1), (2), and (3), the dependent variables are: a dummy variable for whether the firm imports, the firm's share of imported intermediate inputs in total sales, and the firm's log share of imported intermediate inputs in total sales. The independent variables are: a dummy variable to indicate whether the firm is a foreign affiliate, log firm employment, log capital, log total intermediate input, and log total factor productivity (estimated with the Olley and Pakes (1996) method). 2-digit industry fixed effects are also controlled. I exclude the state-owned firms, processing traders and firms in the exporting zones.

Next I show that conditional on importing, foreign affiliates source more from their headquarters and the origin countries closer to their headquarters. Therefore, the sample drops Chinese domestic firms and the firms that do not import. For dependent variables, I consider whether a foreign affiliate headquartered in country m and operating in China imports from an origin country j, as well as the importing values. I regress them on whether the importing origin is the headquarters and the distance between m and j. I add whether m and j share a common language, common border and common legal origin as controls. I use the origin fixed effect to control for the bilateral trade cost from the sourcing origin to China. I use the firm fixed effect to control for the potentially confounding firm characteristics. Therefore, the variation is within firm, between the foreign affiliate's headquarters and the sourcing origin. I use the following regression

Table A.7: **Conditional on Importing, Foreign Affiliates Import More from the Headquarters and the Origin Countries Closer to the Headquarters**

	(1) Full sample $\mathbf{1}(x_{f,\text{CN}mj\cdot} > 0)$	(2) $m \neq j$ $\mathbf{1}(x_{f,\text{CN}mj\cdot} > 0)$	(3) Full sample $\log(x_{f,\text{CN}mj\cdot})$	(4) $m \neq j$ $\log(x_{f,\text{CN}mj\cdot})$
$\mathbf{1}(m = j)$	0.130***		2.456***	
	(0.0244)		(0.214)	
$\log(\text{dist})_{mj}$		-0.00278***		-0.192***
		(0.000579)		(0.0361)
$\mathbf{1}$ (common lang.)$_{mj}$		0.000317		0.0861
		(0.000610)		(0.136)
$\mathbf{1}$ (contiguity)$_{mj}$		0.0127***		0.162
		(0.00317)		(0.152)
$\mathbf{1}$ (legal)$_{mj}$		0.000428		-0.0610
		(0.000915)		(0.0851)
Fixed effects	f, j	f, j	f, j	f, j
Cluster	$m - j$	$m - j$	$m - j$	$m - j$
Observations	3889704	3889704	25428	25428

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Description: The table shows conditional on importing, the association between a foreign affiliate's imports from a sourcing origin, with whether or not the origin is the foreign affiliate's headquarters, and if not, the distance between the importing origin and the headquarters. Column (1) and (3) compare sourcing from headquarters with non-headquarters. Column (2) and (4) study the sample of sourcing from non-headquarters. Dependent variables are dummy variables for Column (1) and (2) and importing values (in log) for Column (3) and (4), denoting a foreign affiliate headquartered in m operating in China, importing from origin j. The independent variables include whether the sourcing origin is the headquarters, and if not, the distance between the sourcing origin and the headquarters (in log). Whether the headquarters share a common language, common border, and legal origin with the sourcing origin are added as controls. The firm and origin fixed effects are also controlled. Standard errors are clustered on the headquarter-origin level. Following Wang (2019), I exclude the state-owned firms, processing traders and firms in the exporting zones. I exclude firms headquartered in Hong Kong, Macao, Taiwan and China (mainland).

specification:

$$
\begin{aligned}
S_{f,CNmj} =& \beta_1 \mathbf{1}(m = j) + \beta_2 \log(\text{dist})_{mj} + \beta_3 \mathbf{1}\,(\text{common lang.})_{mj} + \beta_4 \mathbf{1}\,(\text{contiguity})_{mj} + \beta_5 \mathbf{1}\,(\text{legal})_{mj} \\
&+ \delta_f + \zeta_j + \epsilon_{f,CNmj},
\end{aligned}
$$

where $S_{f,CNmj}$ denote whether the firm f that is headquartered in country m and hosted in China (CN) imports from country j: $\mathbf{1}(x_{f,\text{CN}mj\cdot} > 0)$, or the log value of the firm f that is headquartered in country m imports from country j: $\log(x_{f,\text{CN}mj\cdot})$.

Table A.7 shows that, conditional on importing, foreign affiliates on average are 13 percentage points more likely to source from their headquarters (Column 1) and source 246% more from headquarters than non-headquarters (Column 3). Column 2 and 4 show that, one percent increase in the distance between the headquarter and the sourcing origin is associated with 0.3 percentage points decline in the probability of sourcing and 0.2% decline in importing values.

A.4 Foreign Affiliates Differ from Domestic Firms in terms of Exporting

In this section I replicate the findings in Wang (2019). I show that conditional on firm characteristics, foreign affiliates are more likely to export and export more than local firms. Furthermore, conditional on exporting, foreign affiliates are also more likely to export and export more back to their headquarters and the countries closer to their headquarters.

Conditional on firm-level characteristics, foreign affiliates are more likely to export and export more than domestic firms. I regress a dummy variable indicating whether or not a firm exports as well as its share of exports in total sales (level and log) on its status as a foreign affiliate. I control for the firm's employment, capital, intermediate input, TFP, as well as the 2-digit industry fixed effect. I consider the following regression specification:

$$\begin{aligned} S_f = &\beta_1 \mathbf{1}(\text{Foreign subsidiary})_f + \beta_2 \log(\text{emp}_f) + \beta_3 \log(\text{cap}_f) \\ &+ \beta_4 \log(\text{interm}_i) + \beta_5 \log(\text{TFP}_f) + FE_{s(f)} + \epsilon_f, \end{aligned}$$

where S_f denotes whether the firm exports: $\mathbf{1}(\text{Exp})_f$, the share of exports in firm sales: $\frac{\text{Exp}_f}{\text{Sales}_f}$, or the share in log: $\log(\frac{\text{Exp}_f}{\text{Sales}_f})$.

The results are presented in Table A.8. Being a foreign affiliate is strongly positively associated with both the firm's exporting decision and the share of exports in total sales. On average, foreign affiliates are 34$\%$ more likely to export (Column 1), 25 percentage points higher for imports as a share of total sales (Column 2), and 96 percent higher for those having positive imports (Column 3). Therefore, foreign affiliates engage more in exporting than domestic firms with similar firm-level characteristics.

Conditional on exporting, foreign affiliates export more to their headquarters and the destination countries closer to their headquarters. For dependent variables, I consider whether a foreign affiliate headquartered in country i and operating in China exports to

Table A.8: **Conditional on Firm-level Characteristics, Foreign Affiliates Export More**

	(1)	(2)	(3)
	$\mathbf{1}(\text{Exp})_f$	$\frac{\text{Exp}_f}{\text{Sales}_f}$	$\log(\frac{\text{Exp}_f}{\text{Sales}_f})$
$\mathbf{1}$(Foreign subsidiary)$_f$	0.338***	0.254***	0.962***
	(0.0122)	(0.0313)	(0.0705)
$\log(\text{emp}_f)$	0.0314***	0.0407***	0.259***
	(0.00293)	(0.00903)	(0.0459)
$\log(\text{cap}_f)$	0.00953***	-0.00346	-0.170***
	(0.00270)	(0.00269)	(0.0331)
$\log(\text{interm}_f)$	0.0194***	-0.0213**	-0.323***
	(0.00234)	(0.00813)	(0.0436)
$\log(\text{TFP}_f)$	0.00185	-0.00307	-0.336***
	(0.00234)	(0.00292)	(0.0469)
Fixed effects	2-digit industry	2-digit industry	2-digit industry
Observations	139613	139613	19569

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Description: The table shows the association between exporting and foreign affiliate status. In Columns (1), (2), and (3), the dependent variables are: a dummy variable for whether the firm exports, the firm's share of exports in total sales, and the firm's log share of exports in total sales. The independent variables are: a dummy variable to indicate whether the firm is a foreign affiliate, log firm employment, log capital, log total intermediate input, and log total factor productivity (estimated with the Olley and Pakes (1996) method). 2-digit industry fixed effects are also controlled. I exclude the state-owned firms, processing traders and firms in the exporting zones.

a destination country n, as well as the exporting values. I regress them on whether the exporting destination is the headquarters and the distance between i and n. I add whether i and n share a common language, common border and common legal origin as controls. I use the destination fixed effect to control for the bilateral trade cost from China to the exporting destination. I use the firm fixed effect to control for the potentially confounding firm characteristics. Therefore, the variation is within firm, between the foreign affiliate's headquarters and the selling destinations. I use the following regression specification:

$$S_{f,n\cdot\text{CN}i} = \beta_1\mathbf{1}(i=n) + \beta_2\log(\text{dist})_{ni} + \beta_3\mathbf{1}\,(\text{common lang.})_{ni} + \beta_4\mathbf{1}\,(\text{contiguity})_{ni} + \beta_5\mathbf{1}\,(\text{legal})_{ni} + \delta_f + \zeta_n + \epsilon_{f,n\cdot\text{CN}i},$$

where $S_{f,n\cdot\text{CN}i}$ denote whether the firm f that is headquartered in country i and hosted in China (CN) exports to country n: $\mathbf{1}(x_{f,n\cdot\text{CN}i} > 0)$, or the log value of the firm f that is headquartered in country i exports to country n: $\log(x_{f,n\cdot\text{CN}i})$.

Table A.9: **Conditional on Exporting, Foreign Affiliates Export More to the Headquarters and the Destination Countries Closer to the Headquarters**

	(1)	(2)	(3)	(4)
	Full sample	$n \neq i$	Full sample	$n \neq i$
	$\mathbf{1}(x_{f,n\cdot\text{CN}i} > 0)$	$\mathbf{1}(x_{f,n\cdot\text{CN}i} > 0)$	$\log(x_{f,n\cdot\text{CN}i})$	$\log(x_{f,n\cdot\text{CN}i})$
$\mathbf{1}(n = i)$	0.124***		1.613***	
	(0.0244)		(0.157)	
$\mathbf{1}\,(\text{common lang.})_{ni}$		-0.00128**		-0.0538***
		(0.000509)		(0.00535)
$\mathbf{1}\,(\text{contiguity})_{ni}$		-0.000465		0.125
		(0.000593)		(0.0857)
$\mathbf{1}\,(\text{contiguity})_{ni}$		0.00540**		-0.0331
		(0.00234)		(0.0935)
$\mathbf{1}\,(\text{legal})_{ni}$		0.00130		0.0718
		(0.000850)		(0.0548)
Fixed effects	f,n	f,n	f,n	f,n
Cluster	i-n	i-n	i-n	i-n
Observations	3889704	3889704	25428	25428

Standard errors in parentheses
$^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$

Description: The table shows conditional on exporting, the association between a foreign affiliate's exports from a sourcing origin, with whether or not the origin is the foreign affiliate's headquarters, and if not, the distance between the exporting destination and the headquarters. Column (1) and (3) compare exporting to headquarters with non-headquarters. Column (2) and (4) study the sample of sourcing from non-headquarters. Dependent variables are dummy variables for Column (1) and (2) and exporting values (log) for Column (3) and (4), denoting a foreign affiliate headquartered in i operating in China, exporting to destination n. The independent variables include whether the exporting destination is the headquarters, and if not, the distance between the exporting destination and the headquarters (in log). Whether the headquarters shares a common language, common border, and legal origin with the exporting destination are added as controls. The firm and destination fixed effects are also controlled. Standard errors are clustered on the headquarter-origin level. Following Wang (2019), I exclude the state-owned firms, processing traders and firms in the exporting zones. I exclude firms headquartered in Hong Kong, Macao, Taiwan and China (mainland).

Table A.9 shows that, conditional on exporting, foreign affiliates on average are 12 percentage points more likely to export to their headquarters (Column 1) and export 161% more to headquarters than non-headquarters (Column 3). Column 2 and 4 show that, one percent increase in the distance between the headquarter and the exporting destination is associated with 0.1 percentage points decline in the probability of exporting and 0.1% decline in exporting values.

A.5 Properties of the Estimated Parameters and Shocks

Table A.10: **Gravity of MNE Sourcing and Selling Efficiencies**

VARIABLES	(1) Durable Manufacturing	(2) Non-durable Manufacturing	(3) Non-manufacturing	(4) All	(5) Durable Manufacturing	(6) Non-durable Manufacturing	(7) Non-manufacturing	(8) All
$\mathbf{1}(i=j)$	0.918***	0.737***	0.758***	0.804***	0.348***	0.428***	0.391***	0.389***
	(0.0159)	(0.0169)	(0.0176)	(0.0117)	(0.0220)	(0.0215)	(0.0258)	(0.0151)
$\log$ (dist)	-0.146***	-0.188***	-0.100***	-0.144***	-0.0190***	-0.0374***	-0.00906	-0.0218***
	(0.00362)	(0.00383)	(0.00399)	(0.00265)	(0.00500)	(0.00488)	(0.00586)	(0.00342)
$\mathbf{1}$ (legal)	0.0325***	0.0496***	0.0291***	0.0371***	0.00654	-0.000117	-0.00156	0.00162
	(0.00416)	(0.00440)	(0.00459)	(0.00305)	(0.00575)	(0.00561)	(0.00673)	(0.00393)
$\mathbf{1}$ (contiguity)	0.0657***	0.129***	0.175***	0.123***	0.0365**	0.160***	0.116***	0.104***
	(0.0103)	(0.0109)	(0.0114)	(0.00756)	(0.0143)	(0.0139)	(0.0167)	(0.00974)
$\mathbf{1}$ (common lang.)	0.0546***	0.0491***	0.0694***	0.0577***	-0.0348***	0.0192*	-0.00840	-0.00802
	(0.00780)	(0.00826)	(0.00860)	(0.00572)	(0.0108)	(0.0105)	(0.0126)	(0.00737)
$\mathbf{1}$ (trade agree.)	-0.00744	0.0428***	0.0392***	0.0249***	-0.00162	0.0143*	0.0450***	0.0192***
	(0.00628)	(0.00665)	(0.00693)	(0.00461)	(0.00868)	(0.00847)	(0.0102)	(0.00594)
Observations	43,200	43,200	43,200	129,600	43,200	43,200	43,200	129,600
FE	n j t	n j t	n j t	n j t	n j t	n j t	n j t	n j t
Mean Dep. Var	-1.159	-1.031	-0.894	-1.028	-0.378	-0.477	-0.379	-0.411
Mean Log Dist.	8.456	8.456	8.456	8.456	8.456	8.456	8.456	8.456
R^2	0.582	0.614	0.477	0.386	0.446	0.384	0.298	0.210

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table presents the correlations between the MNE sourcing and selling efficiencies backed out in Section 4.1 and gravity variables: if the MNE is sourcing from and selling to their headquarters, the distance between the headquarters and sourcing origin/selling destination, as well as whether the headquarters share the same legal origin, common border, common language, and trade agreements with the trade partner. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A.11: **Gravity of MNE Relative Productivity**

VARIABLES	(1) Durable Manufacturing	(2) Non-durable Manufacturing	(3) Non-manufacturing	(4) All
$\mathbf{1}(i=j)$	3.860***	17.38***	4.606***	8.617***
	(0.0843)	(0.324)	(0.127)	(0.145)
$\log$ (dist)	-0.917***	-3.739***	-2.134***	-2.263***
	(0.0192)	(0.0737)	(0.0288)	(0.0330)
$\mathbf{1}$ (legal)	0.228***	1.500***	0.556***	0.761***
	(0.0220)	(0.0847)	(0.0331)	(0.0379)
$\mathbf{1}$ (contiguity)	1.473***	7.034***	2.224***	3.577***
	(0.0546)	(0.210)	(0.0821)	(0.0939)
$\mathbf{1}$ (common lang.)	0.647***	1.301***	0.739***	0.896***
	(0.0413)	(0.159)	(0.0621)	(0.0711)
$\mathbf{1}$ (trade agree.)	-0.326***	-1.215***	-0.558***	-0.700***
	(0.0332)	(0.128)	(0.0500)	(0.0572)
Observations	43,200	43,200	43,200	129,600
FE	n j t	n j t	n j t	n j t s
Mean Dep. Var	-9.212	-37.82	-14.83	-20.62
Mean Log Dist.	8.456	8.456	8.456	8.456
R^2	0.577	0.632	0.666	0.855

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table presents the correlations between the productivity of an MNE relative to domestic firms in the same host country backed out in Section 4.3 and gravity variables: whether the MNE is operating in their headquarters, the distance between the headquarters and the host country, as well as whether the headquarters share the same legal origin, common border, common language, and trade agreements with the host country. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A.12: **Estimated MNE and Trade Elasticities**

VARIABLES	(1) Durable Manufacturing	(2) Non-durable Manufacturing	(3) Non-manufacturing	(4) Durable Manufacturing	(5) Non-durable Manufacturing	(6) Non-manufacturing
	Tariff Instruments with Direct Shares			Tariff Instruments with Total Shares		
$\log\left(C^s_{nj,t}\right)$	2.737**	4.278***	2.559***	9.005***	9.293**	2.389***
	(1.184)	(1.474)	(0.472)	(1.081)	(4.412)	(0.447)
$\log\left(t^s_{nj,t}\right)$	-3.697***	-1.849***	-1.898***	-4.069***	-1.099	-2.040***
	(0.560)	(0.502)	(0.646)	(1.106)	(0.974)	(0.627)
$\log\left(\text{dist}_{nj,t}\right)$	-1.055***	-0.986***	-1.299***	-1.153***	-0.961***	-1.298***
	(0.0211)	(0.0130)	(0.0129)	(0.0265)	(0.0280)	(0.0126)
$\mathbf{1}\left(\text{legal}_{nj,t}\right)$	0.166***	0.143***	0.0613***	0.284***	0.154***	0.0610***
	(0.0253)	(0.0126)	(0.0138)	(0.0312)	(0.0217)	(0.0136)
$\mathbf{1}\left(\text{common lang.}_{nj,t}\right)$	0.312***	0.261***	0.0817***	0.184***	0.224***	0.0823***
	(0.0330)	(0.0255)	(0.0260)	(0.0498)	(0.0488)	(0.0256)
$\mathbf{1}\left(\text{contiguity}_{nj,t}\right)$	0.130***	0.288***	0.657***	-0.0368	0.305***	0.649***
	(0.0438)	(0.0316)	(0.0412)	(0.0669)	(0.0518)	(0.0402)
$\mathbf{1}\left(\text{trade agree.}_{nj,t}\right)$	0.330***	0.316***	0.315***	0.355***	0.348***	0.317***
	(0.0200)	(0.0222)	(0.0226)	(0.0389)	(0.0426)	(0.0222)
Observations	42,480	42,480	42,480	42,480	42,480	42,480
FE	nt, j	nt, j	nt, j	nt, j	nt, j	nt, j
Mean Dep. Var	-5.296	-5.602	-6.974	-5.296	-5.602	-6.974
Mean Indep. Var	0.328	0.246	0.180	0.328	0.246	0.180
First Stage F	18.83	21.30	144.9	89.07	6.019	157.1
Implied σ^s	4.697	2.849	2.898	5.069	2.099	3.040
Implied ζ^s	2.350	1.432	1.742	1.452	1.118	1.854

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table presents the estimated elasticities of substitution across different sourcing origin countries (trade elasticities) and elasticities of substitution across MNEs within each origin country (MNE elasticities). Elasticities are estimated for the durable manufacturing sector, non-durable manufacturing sector, and non-manufacturing sector. Regressors and instruments are constructed according to Section 4.2. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A.13: **Estimated Average MNE and Trade Elasticities**

VARIABLES		(1)	(2)	(3)	(4)
		Tariffs Instrumented with Direct Shares		Tariffs Instrumented with Total Shares	
$\log\left(C^s_{nj,t}\right)$		1.490***	1.710***	5.349***	5.688***
		(0.467)	(0.499)	(0.645)	(0.636)
$\log\left(t^s_{nj,t}\right)$		-2.425***	-2.710***	-1.821***	-1.283***
		(0.247)	(0.312)	(0.365)	(0.443)
$\log\left(\text{dist}_{nj,t}\right)$ #	Durable Manuf.	-1.041***	-1.040***	-1.098***	-1.104***
		(0.0119)	(0.0126)	(0.0173)	(0.0176)
	Non-durable Manuf.	-0.999***	-0.998***	-0.979***	-0.979***
		(0.0100)	(0.00997)	(0.0148)	(0.0147)
	Non-manuf.	-1.290***	-1.290***	-1.321***	-1.329***
		(0.0104)	(0.0108)	(0.0153)	(0.0157)
$\mathbf{1}\left(\text{legal}_{nj,t}\right)$ #	Durable Manuf.	0.142***	0.146***	0.215***	0.221***
		(0.0144)	(0.0146)	(0.0208)	(0.0205)
	Non-durable Manuf.	0.137***	0.138***	0.146***	0.146***
		(0.0114)	(0.0113)	(0.0169)	(0.0167)
	Non-manuf.	0.0596***	0.0600***	0.0658***	0.0660***
		(0.0113)	(0.0112)	(0.0168)	(0.0167)
$\mathbf{1}\left(\text{common lang.}_{nj,t}\right)$ #	Durable Manuf.	0.339***	0.334***	0.261***	0.254***
		(0.0233)	(0.0234)	(0.0342)	(0.0339)
	Non-durable Manuf.	0.281***	0.279***	0.253***	0.250***
		(0.0216)	(0.0215)	(0.0320)	(0.0318)
	Non-manuf.	0.0855***	0.0851***	0.0728**	0.0711**
		(0.0214)	(0.0212)	(0.0317)	(0.0315)
$\mathbf{1}\left(\text{contiguity}_{nj,t}\right)$ #	Durable Manuf.	0.162***	0.158***	0.0626	0.0537
		(0.0313)	(0.0315)	(0.0459)	(0.0457)
	Non-durable Manuf.	0.279***	0.279***	0.293***	0.293***
		(0.0289)	(0.0286)	(0.0428)	(0.0426)
	Non-manuf.	0.607***	0.618***	0.785***	0.798***
		(0.0359)	(0.0364)	(0.0520)	(0.0513)
$\mathbf{1}\left(\text{trade agree.}_{nj,t}\right)$ #	Durable Manuf.	0.328***	0.336***	0.364***	0.370***
		(0.0179)	(0.0181)	(0.0264)	(0.0267)
	Non-durable Manuf.	0.297***	0.293***	0.326***	0.331***
		(0.0179)	(0.0184)	(0.0264)	(0.0271)
	Non-manuf.	0.328***	0.323***	0.274***	0.261***
		(0.0185)	(0.0193)	(0.0272)	(0.0280)
Observations		127,440	127,440	127,440	127,440
FE		ns, js, st	nst, js	ns, js, st	nst, js
Mean Dep. Var		-5.968	-5.968	-5.968	-5.968
Mean Indep. Var		0.249	0.249	0.249	0.249
First Stage F		76.53	74.03	91.18	103.1
Implied σ^s		3.425	3.710	2.821	2.283
Implied ζ^s		2.628	2.585	1.340	1.226

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table presents the estimated elasticities of substitution across different sourcing origin countries (trade elasticities) and elasticities of substitution across MNEs within each origin country (MNE elasticities). Elasticities are estimated for a pool of all sectors. I allow the impact of other gravity variables to vary across sectors. Each column contains a different combination of fixed effects. Regressors and instruments are constructed according to Section 4.2. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Figure A.4: **Distributions of Shocks**

Description: This figure displays the sector-level distributions of the shocks that are backed out with model inversion in Section 4.

Table A.14: **Correlations of the MNE Productivity Shock with Domestic Productivity Shocks in the Headquarters and Host Country**

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Durable Manufacturing	Non-durable Manufacturing	Non-manufacturing	Durable Manufacturing	Non-durable Manufacturing	Non-manufacturing
	HQ Fixed Effect, Host Country Fixed Effect			OLS		
$\hat{A}^s_{ii}$	0.202***	0.00751***	0.201***	0.196***	0.00751***	0.201***
	(0.0122)	(0.00230)	(0.0134)	(0.0120)	(0.00230)	(0.0134)
$\hat{A}^s_{jj}$	0.457***	0.879***	0.569***	0.462***	0.879***	0.569***
	(0.0122)	(0.00230)	(0.0134)	(0.0120)	(0.00230)	(0.0134)
Observations	39,600	39,600	39,600	39,600	39,600	39,600
FE	l, i	l, i	l, i	NA	NA	NA
Mean Dep. Var	0.00561	0.00297	0.00783	0.00561	0.00297	0.00783
Mean HQ Prod. Chg	-0.00159	0.00275	0.00829	-0.00159	0.00275	0.00829
Mean Host Prod. Chg	-0.00159	0.00275	0.00829	-0.00159	0.00275	0.00829

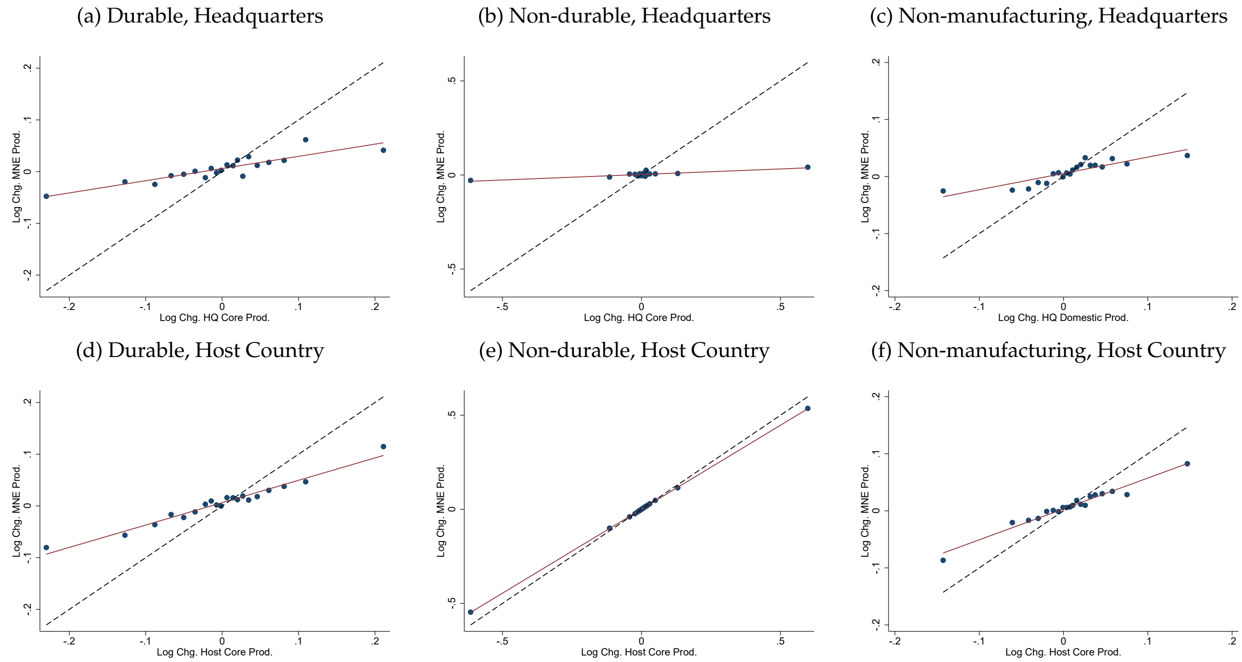
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table shows, by sector, the correlations between the MNE productivity shock and domestic productivity shocks in the headquarters and host country. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

A.6 Construct Upstream and Downstream Tariffs

I show how I compute the upstream and downstream tariffs that I use as instruments (for domestic firms' shares in exports) in Section 4.2. Consider country n. $t^s_{nj} = 1 + \tau^s_{nj}$, where

Figure A.5: **Correlations between Headquarters/Host Country Domestic Productivity Shocks and MNE Productivity Shocks**



Description: These figures plot, by sector, the correlations between the domestic productivity shocks in headquarters or host country with headquarters-host country-bilateral MNE productivity shocks. These are bin scatter plots: each point represents the average of a bin and there are 20 bins with equal sizes.

τ_{nj}^s denotes the tariff country n imposes on sector s products from j. Following Acemoglu et al. (2016) and Acemoglu et al. (2016), I define sector direct input coefficient matrix A_n of which $s - s'$ element, $a_n^{ss'}$, equals the following:

$$a_n^{ss'} = \frac{\text{Sales}_n^{s \leftarrow s'}}{\text{Sales}_n^s}.$$

Hence, $a_n^{ss'}$ measures the expenditure share sector s spends on sector s' in country n. The total input coefficient matrix, A_n^{tot} is the Leontif inverse of A_n:

$$A_n^{\text{tot}} = (I - A_n)^{-1},$$

of which the element $a_n^{ss',\text{tot}}$ measures total (direct + indirect) expenditure share sector s spends on sector s' in country n.

I construct the direct upstream tariff of country n sector s as follows:

$$t_{nj}^{s,\text{direct up}} = \frac{\sum_{s' \neq s} a_n^{ss'} t_{nj}^{s'}}{\sum_{s' \neq s} a_n^{ss'}}.$$

I construct the total upstream tariff of country n sector s as follows:

$$t_{nj}^{s,\text{total up}} = \frac{\sum_{s' \neq s} a_n^{ss',\text{tot}} t_{nj}^{s'}}{\sum_{s' \neq s} a_n^{ss',\text{tot}}}.$$

Now consider downstream tariffs. I define sector direct output coefficient matrix B_n of which $s' - s$ element, $b_n^{s's}$, equals the following:

$$b_n^{s's} = \frac{\text{Sales}_n^{s \to s'}}{\text{Sales}_n^s}.$$

Hence, $b_n^{s's}$ measures direct output share sector s sells to sector s' in country n. The total output coefficient matrix, B_n^{tot} is the Leontif inverse of B_n:

$$B_n^{\text{tot}} = (I - B_n)^{-1},$$

of which the element $b_n^{s's,\text{tot}}$ measures total (direct + indirect) output share sector s sells to sector s' in country n.

Construct the direct downstream tariff of country n sector s as follows:

$$t_{nj}^{s,\text{direct down}} = \frac{\sum_{s' \neq s} b_n^{s's} t_{nj}^{s'}}{\sum_{s' \neq s} b_n^{s's}}.$$

The total downstream tariff of country n sector s:

$$t_{nj}^{s,\text{total down}} = \frac{\sum_{s' \neq s} b_n^{s's,\text{tot}} t_{nj}^{s'}}{\sum_{s' \neq s} b_n^{s's,\text{tot}}}.$$

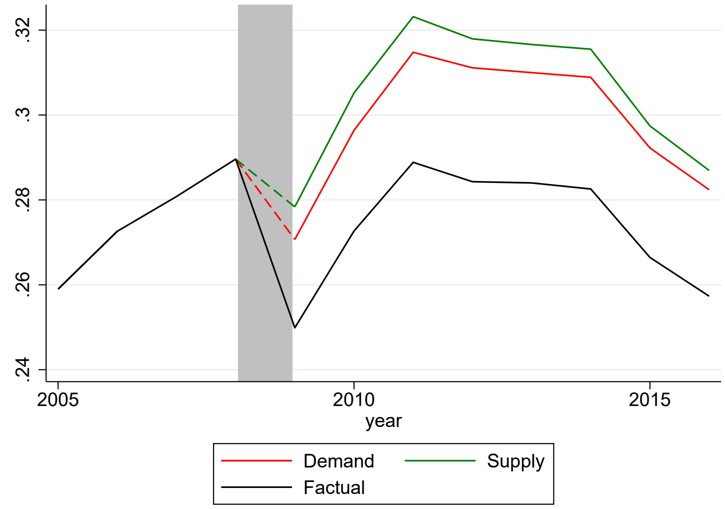
A.7 Simulations

Table A.15: **Impact of Shocks on Changes in Global Trade and MP, Model without MNEs**

	2008-2009		2009-2010		2014-2016	
	Trade	Trade (Percent)	Trade	Trade (Percent)	Trade	Trade (Percent)
Shocks	(1)	(2)	(3)	(4)	(5)	(6)
Domestic Productivity Shocks	–1.13%	28.31%	–0.00%	–0.22%	–0.62%	24.74%
Final Demand Shocks	–1.96%	49.31%	0.28%	12.18%	–0.24%	9.42%
All Shocks	–4.02%	100.00%	2.28%	100.00%	–2.53%	100.00%

Description: This table presents the impact of different kinds of shocks on how global trade and MP changed relative to global GDP in different periods in a model that does not have MP (see Section B.5).

Figure A.6: **Impact of Shocks on Global Trade Collapse, Model without MNEs**



Description: This figure plots the impact of different kinds of shocks on the global trade collapse during the Great Recession (2008-2009, shadowed years) in a model that does not have MP (see Section B.5). Dashed line segments indicate the impact of individual shock groups. Line segments after 2009 indicate counterfactual outcomes that started with counterfactual market shares (as a result of individual shock groups) and were influenced by actual shocks.

Table A.16: **Impact of Different MNE-specific Shocks on Global Trade and MP Collapse**

Shocks	Trade Collapse	Trade Collapse (Percent)	MP Collapse	MP Collapse (Percent)
	(1)	(2)	(3)	(4)
Sourcing Shocks	–0.54%	13.37%	0.18%	–9.43%
Selling Shocks	0.09%	–2.26%	0.57%	–29.07%
Relative Productivity Shocks	–1.19%	29.61%	–0.35%	18.10%
MNE Demand Shocks	–0.97%	24.11%	0.01%	–0.71%
MNE-specific Shocks	–0.39%	9.67%	–0.53%	27.32%
All Shocks	–4.02%	100.00%	–1.96%	100.00%

Description: This table presents the impact of different kinds of MNE-specific shocks on the global trade and MP collapse during the Great Recession. The global trade collapse is measured with the change in world trade to world GDP ratio. The global MP collapse is measured with the change in world MP (sales by MNE foreign affiliates) to world GDP ratio.

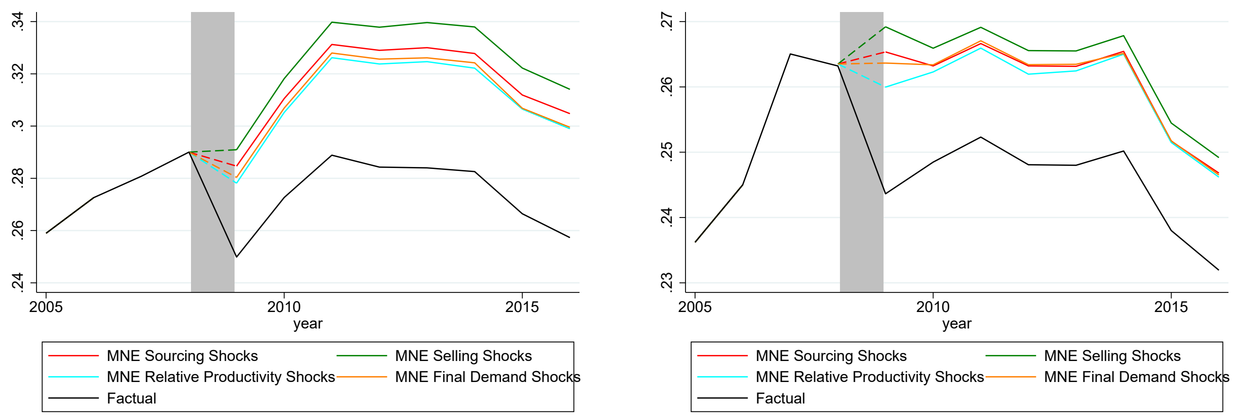
Table A.17: **Impact of Shocks on Global Trade Collapse and Global MP Collapse, Model without MNE Sourcing and Selling Frictions**

Shocks	Trade Collapse	Trade Collapse (Percent)	MP Collapse	MP Collapse (Percent)
	(1)	(2)	(3)	(4)
MNE-specific Shocks	0.07%	–5.99%	–0.92%	45.83%
Domestic Productivity Shocks	–1.01%	85.00%	–0.70%	34.59%
Final Demand Shocks	–0.42%	35.49%	–0.31%	15.31%
Supply Shocks	–0.27%	22.88%	–1.52%	75.45%
Demand Shocks	–0.39%	32.87%	–0.26%	12.70%
All Shocks	–1.19%	100.00%	–2.01%	100.00%

Description: This table presents the impact of different kinds of MNE-specific shocks on the global trade and MP collapse during the Great Recession in a model that does not have MNE sourcing and selling frictions. The global trade collapse is measured with the change in world trade to world GDP ratio. The global MP collapse is measured with the change in world MP (sales by MNE foreign affiliates) to world GDP ratio.

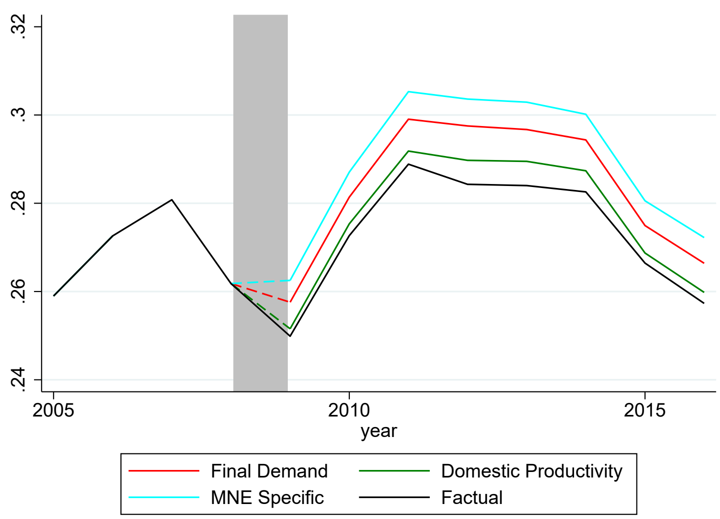
Figure A.7: **Impact of Different MNE-specific Shocks on Global Trade and MP Collapse**

(a) Trade Collapse (b) MP Collapse



Description: These figures plot the impact of different kinds of MNE-specific shocks on the global trade and MP collapse during the Great Recession (2008-2009, shadowed years). Dashed line segments indicate the impact of individual shock groups. Line segments after 2009 indicate counterfactual outcomes that started with counterfactual market shares (as a result of individual shock groups) and were influenced by actual shocks.

Figure A.8: **Impact of Shocks on Global Trade Collapse, Model without MNE Sourcing and Selling Frictions**



Description: This figure plots the impact of different kinds of shocks on the global trade collapse during the Great Recession (2008-2009, shadowed years) in a model that does not have MNE sourcing and selling frictions. Dashed line segments indicate the impact of individual shock groups. Line segments after 2009 indicate counterfactual outcomes that started with counterfactual market shares (as a result of individual shock groups) and were influenced by actual shocks.

Table A.18: **Impact of Different MNE-specific Shocks on Cross-country Variations in Trade collapse, MP collapse, and Welfare**

Shocks	Trade Collapse (1)	MP Collapse (2)	Welfare (3)
Sourcing Shocks	14.90%	1.07%	–0.72%
Selling Shocks	13.51%	9.35%	–2.38%
Relative Productivity Shocks	–5.18%	49.88%	11.07%
MNE Demand Shocks	1.77%	0.57%	1.86%
All MNE-specific Shocks	24.90%	64.10%	11.72%

Description: This table presents the impact of different MNE-specific shocks on the cross-country variation in the collapse of trade, MP, and welfare changes during the Great Recession. Country-level trade collapse is measured with the change in the average of its imports and exports relative to its GDP. Country-level MP collapse is measured with the change in the average of its inward MP (sales made by foreign affiliates hosted by this country) and its outward MP (sales made by the country's affiliates hosted by other countries) relative to its GDP. The share of cross-country variation explained by a group of shocks is calculated with Equation (26).

Table A.19: **Impact of Shocks on Cross-country Variations in Changes in Trade and Welfare, Model without MNEs**

	2008-2009		2009-2010		2014-2016	
	Trade	Welfare	Trade	Welfare	Trade	Welfare
Shocks	(1)	(2)	(3)	(4)	(5)	(6)
Domestic Productivity Shocks	25.55%	54.68%	11.52%	85.21%	13.78%	70.59%
Final Demand Shocks	–7.20%	26.42%	5.51%	12.67%	11.89%	13.30%

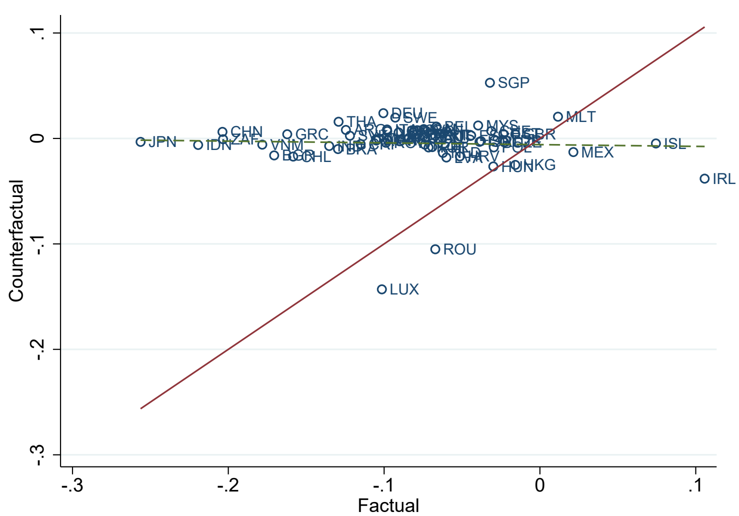
Description: This table presents impact of different kinds of shocks on the cross-country variation in changes in trade relative to GDP, changes in MP relative to GDP, and welfare changes. The country-level change in trade relative to GDP is measured with the change in the average of its imports and exports relative to its GDP. The country-level change in MP relative to GDP is measured with the change in the average of its inward MP (sales made by foreign affiliates hosted by this country) and its outward MP (sales made by the country's affiliates hosted by other countries) relative to its GDP. The share of cross-country variation explained by a group of shocks is calculated with Equation (26).

Table A.20: **Impact of Different Shocks on Cross-country Variations in Trade collapse, MP collapse, and Welfare, Model without MNE Sourcing and Selling Frictions**

Shocks	Trade Collapse (1)	MP Collapse (2)	Welfare (3)
MNE-specific Shocks	–0.45%	71.71%	8.47%
Domestic Productivity Shocks	34.51%	19.85%	57.48%
Final Demand Shocks	2.25%	0.09%	20.12%
Supply Shocks	29.71%	89.94%	57.66%
Demand Shocks	7.48%	7.92%	25.47%

Description: This table presents the impact of different kinds of shocks on the cross-country variation in the collapse of trade, MP, and welfare changes during the Great Recession in a model that does not have MNE sourcing and selling frictions. Country-level trade collapse is measured with the change in the average of its imports and exports relative to its GDP. Country-level MP collapse is measured with the change in the average of its inward MP (sales made by foreign affiliates hosted by this country) and its outward MP (sales made by the country's affiliates hosted by other countries) relative to its GDP. The share of cross-country variation explained by a group of shocks is calculated with Equation (26).

Figure A.9: **Impact of MNE-specific Shocks on Cross-country Variations in Trade collapse, Model without MNE Sourcing and Selling Frictions**



Description: This figure plots the impact of MNE-specific shocks on the cross-country variation in the collapse of trade. Country-level trade collapse is measured with the change in the average of its imports and exports relative to its GDP. The share of cross-country variation explained by a group of shocks is calculated with Equation (26). The green dashed line indicates the fitted regression line. The red line indicates the 45-degree line.

Table A.21: **Impact of Shocks on Global Trade and MP Recovery, 2009-2010**

Shocks	Trade	Trade (Percent)	MP	MP (Percent)
	(1)	(2)	(3)	(4)
MNE-specific Shocks	4.03%	177.01%	1.79%	369.86%
Domestic Productivity Shocks	0.01%	0.47%	–0.24%	–49.54%
Final Demand Shocks	0.24%	10.38%	0.15%	31.26%
Supply Shocks	2.89%	126.85%	0.83%	170.55%
Demand Shocks	0.24%	10.65%	0.16%	32.02%
All Shocks	2.28%	100.00%	0.49%	100.00%

Description: This table presents the impact of different kinds of shocks on how global trade and MP changed relative to global GDP from 2009 to 2010.

Figure A.10: **Importance of Shocks for Global Trade and MP Recovery, 2009-2010**

Description: These figures plot the impact of different kinds of shocks on the global trade and MP collapse recovery during 2009-2010. Dashed line segments indicate the impact of individual shock groups. Line segments after 2010 indicate counterfactual outcomes that started with counterfactual market shares (as a result of individual shock groups) and were influenced by actual shocks.

Table A.22: **Impact of Shocks on Global Trade and MP Decline, 2013-2016**

Shocks	Trade	Trade (Percent)	MP	MP (Percent)
	(1)	(2)	(3)	(4)
MNE-specific Shocks	–0.21%	8.14%	–1.50%	82.23%
Domestic Productivity Shocks	–0.52%	20.63%	–0.24%	12.92%
Final Demand Shocks	–0.13%	5.03%	–0.12%	6.45%
Supply Shocks	–2.07%	81.87%	–1.65%	90.22%
Demand Shocks	–0.07%	2.58%	–0.14%	7.72%
All Shocks	–2.53%	100.00%	–1.83%	100.00%

Description: This table presents the impact of different kinds of shocks on how global trade and MP changed relative to global GDP from 2013 to 2016.

Figure A.11: **Importance of Shocks for Global Trade and MP Decline, 2013-2016**

Description: These figures plot the impact of different kinds of shocks on the global trade and MP collapse decline during 2013-2016. Dashed line segments indicate the impact of individual shock groups.

Table A.23: **Impact of Shocks on Cross-country Variations in Changes in Trade, MP, and Welfare, 2009-2010**

Shocks	Trade Collapse (1)	MP Collapse (2)	Welfare (3)
MNE-specific Shocks	24.90%	64.10%	–12.94%
Domestic Productivity Shocks	28.72%	28.74%	99.33%
Final Demand Shocks	1.70%	0.63%	6.01%
Supply Shocks	24.46%	78.00%	89.31%
Demand Shocks	7.06%	9.91%	2.58%

Description: This table presents the impact of different kinds of shocks on the cross-country variation in trade, MP, and welfare changes during the trade and MP recovery from 2009 to 2010. Country-level trade collapse is measured with the change in the average of its imports and exports relative to its GDP. Country-level MP collapse is measured with the change in the average of its inward MP (sales made by foreign affiliates hosted by this country) and its outward MP (sales made by the country's affiliates hosted by other countries) relative to its GDP. The share of cross-country variation explained by a group of shocks is calculated with Equation (26).

Table A.24: **Impact of Shocks on Cross-country Variations in Changes in Trade, MP, and Welfare, 2014-2016**

Shocks	Trade Collapse	MP Collapse	Welfare
	(1)	(2)	(3)
MNE-specific Shocks	32.17%	79.52%	10.16%
Domestic Productivity Shocks	14.76%	5.80%	58.27%
Final Demand Shocks	8.75%	0.53%	23.05%
Supply Shocks	11.54%	94.08%	49.84%
Demand Shocks	9.28%	–1.21%	21.93%

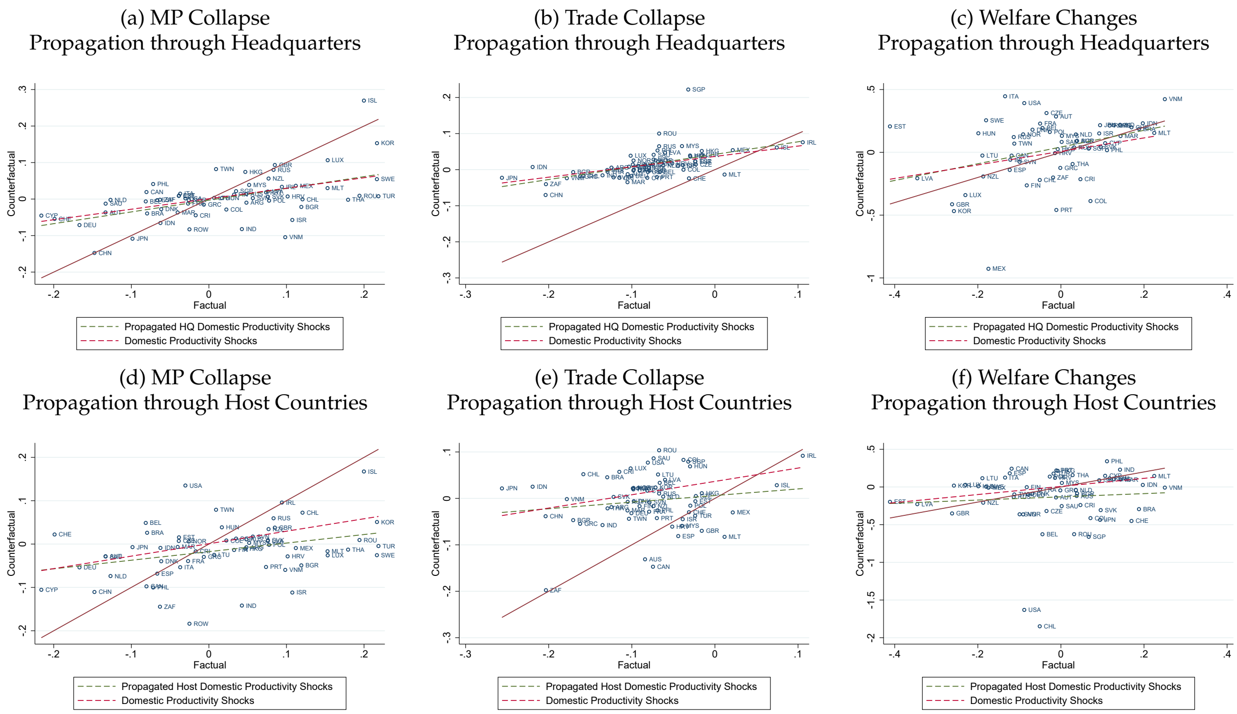
Description: This table presents the impact of different kinds of shocks on the cross-country variation in the collapse of trade, MP, and welfare changes during the trade and MP declines from 2013 to 2016. Country-level trade collapse is measured with the change in the average of its imports and exports relative to its GDP. Country-level MP collapse is measured with the change in the average of its inward MP (sales made by foreign affiliates hosted by this country) and its outward MP (sales made by the country's affiliates hosted by other countries) relative to its GDP. The share of cross-country variation explained by a group of shocks is calculated with Equation (26).

Table A.25: **Propagation of Domestic Productivity Shocks through MP Headquarters and Host Countries: Global Trade Collapse and MP Collapse**

Shocks	Trade	Trade (Percent)	MP	MP (Percent)
	(1)	(2)	(3)	(4)
Propagation through Headquarters	–1.53%	38.07%	–0.76%	39.00%
Propagation through Host Countries	–0.01%	0.13%	–0.22%	11.27%
Domestic Productivity Shocks	–1.09%	27.11%	–0.64%	32.65%
All Shocks	–4.02%	100.00%	–1.96%	100.00%

Description: This table presents the impact of domestic productivity shocks, these shocks propagated through MP headquarters, and these shocks propagated through MP host country linkages on the global trade and MP collapse during the Great Recession. The global trade collapse is measured with the change in world trade to world GDP ratio. The global MP collapse is measured with the change in world MP (sales by MNE foreign affiliates) to world GDP ratio.

Figure A.12: **Propagation of Domestic Productivity Shocks through MP Headquarters and Host Countries: Cross-country Variations in Trade Collapse, MP Collapse, and Welfare**



Description: These figures plot the impact of domestic productivity shocks, these shocks propagated through MP headquarters, and these shocks propagated through MP host country linkages, on the cross-country variation in the collapse of trade, MP, and welfare changes during the Great Recession. Country-level trade collapse is measured with the change in the average of its imports and exports relative to its GDP. Country-level MP collapse is measured with the change in the average of its inward MP (sales made by foreign affiliates hosted by this country) and its outward MP (sales made by the country's affiliates hosted by other countries) relative to its GDP. The share of cross-country variation explained by a group of shocks is calculated with Equation (26). The green dashed line indicates the fitted line of regressing the impact of propagated domestic productivity shocks on actual changes. The cranberry dashed line indicates the fitted line of regressing the impact of domestic productivity shocks on actual changes. Shocks that have higher explanatory power correspond to a steeper fitted line. The red line indicates the 45-degree line.

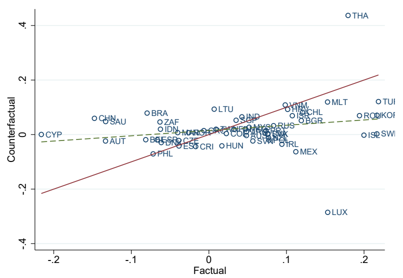
Table A.26: **Propagation of Domestic Productivity Shocks through MP Headquarters and Host Countries: Cross-country Variations in Changes in Trade, MP, and Welfare, 2009-2010**

Shocks	Trade Collapse (1)	MP Collapse (2)	Welfare (3)
Propagation through Headquarters	14.22%	26.24%	149.77%
Propagation through Host Countries	15.69%	18.61%	84.19%
Domestic Productivity Shocks	11.83%	20.16%	97.18%

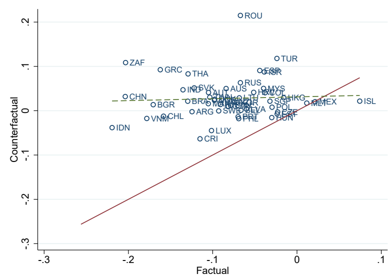
Description: This table presents the impact of domestic productivity shocks, these shocks propagated through MP headquarters, and these shocks propagated through MP host country linkages, on the cross-country variation in the collapse of trade, MP, and welfare changes during 2009-2010. Country-level trade collapse is measured with the change in the average of its imports and exports relative to its GDP. Country-level MP collapse is measured with the change in the average of its inward MP (sales made by foreign affiliates hosted by this country) and its outward MP (sales made by the country's affiliates hosted by other countries) relative to its GDP. The share of cross-country variation explained by a group of shocks is calculated with Equation (26).

Figure A.13: **Propagation of Domestic Productivity Shocks in Top Headquarters and Host Countries: Cross-country Variations in Trade Collapse, MP Collapse, and Welfare across Other Countries**

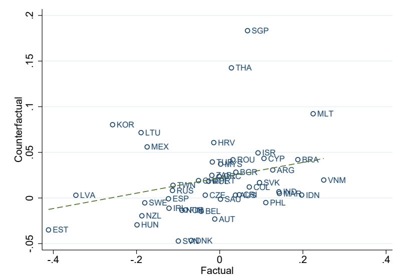
(a) MP Collapse
MNE-specific Shocks, Top 10 Headquarters



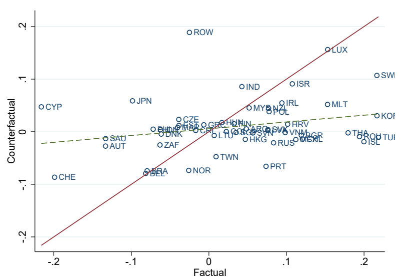
(b) Trade Collapse
MNE-specific Shocks, Top 10 Headquarters



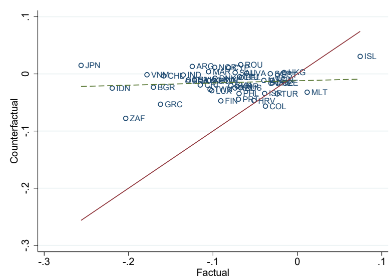
(c) Welfare Changes
MNE-specific Shocks, Top 10 Headquarters



(d) MP Collapse
MNE-specific Shocks, Top 10 Host Countries

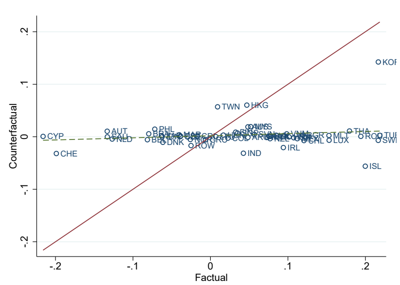


(e) Trade Collapse
MNE-specific Shocks, Top 10 Host Countries

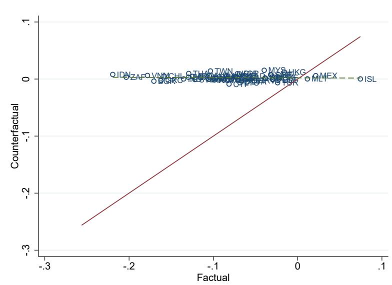


(f) Welfare Changes
MNE-specific Shocks, Top 10 Host Countries

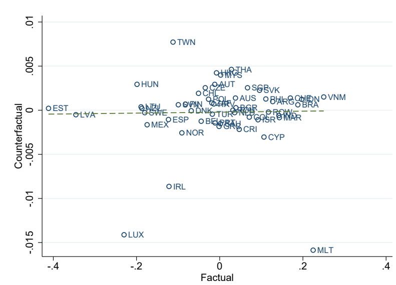
(g) MP Collapse
Domestic Productivity Shocks, Top 10 Exporters



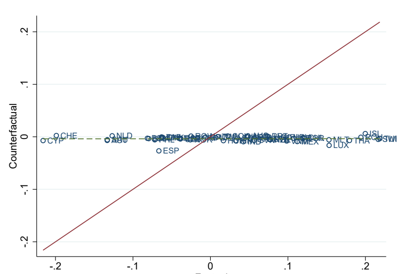
(h) Trade Collapse
Domestic Productivity Shocks, Top 10 Exporters



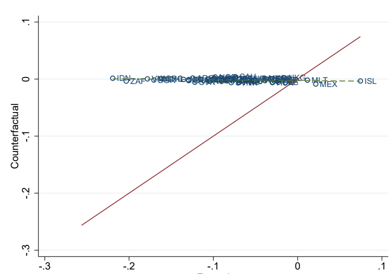
(i) Welfare Changes
Domestic Productivity Shocks, Top 10 Exporters



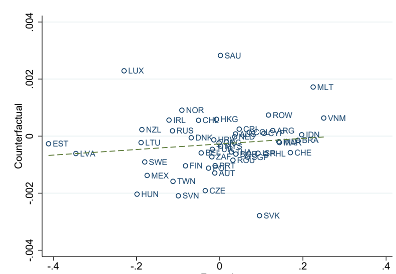
(j) MP Collapse
Final Demand Shocks, Top 10 Importers



(k) Trade Collapse
Final Demand Shocks, Top 10 Importers



(l) Welfare Changes
Final Demand Shocks, Top 10 Importers



Description: These figures plot the impact of the MNE-specific shocks in the top 10 headquarters and in the top 10 host countries, as well as domestic productivity shocks in the top 10 exporters and final demand shocks in the top 10 importers, on the cross-country variation in the collapse of trade, MP, and welfare changes during the Great Recession. Country-level trade collapse is measured with the change in the average of its imports and exports relative to its GDP. Country-level MP collapse is measured with the change in the average of its inward MP (sales made by foreign affiliates hosted by this country) and its outward MP (sales made by the country's affiliates hosted by other countries) relative to its GDP. The share of cross-country variation explained by a group of shocks is calculated with Equation (26). The green dashed line indicates the fitted line of regressing the impact of propagated domestic productivity shocks on actual changes. The cranberry dashed line indicates the fitted line of regressing the impact of domestic productivity shocks on actual changes. Shocks that have higher explanatory power correspond to a steeper fitted line. The red line indicates the 45-degree line.

Table A.27: **Propagation of Domestic Productivity Shocks through MP Headquarters and Host Countries: Cross-country Variations in Changes in Trade, MP, and Welfare, 2014-2016**

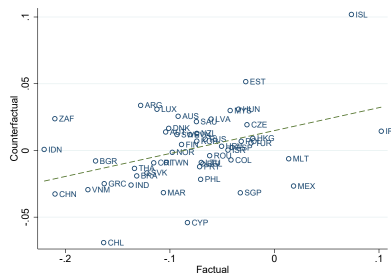
Shocks	Trade Collapse (1)	MP Collapse (2)	Welfare (3)
Propagation through Headquarters	18.09%	2.33%	118.47%
Propagation through Host Countries	13.12%	16.79%	125.07%
Domestic Productivity Shocks	14.76%	1.78%	69.04%

Description: This table presents the impact of domestic productivity shocks, these shocks propagated through MP headquarters, and these shocks propagated through MP host country linkages, on the cross-country variation in the collapse of trade, MP, and welfare changes during 2013-2016. Country-level trade collapse is measured with the change in the average of its imports and exports relative to its GDP. Country-level MP collapse is measured with the change in the average of its inward MP (sales made by foreign affiliates hosted by this country) and its outward MP (sales made by the country's affiliates hosted by other countries) relative to its GDP. The share of cross-country variation explained by a group of shocks is calculated with Equation (26).

Figure A.14: **Propagation of Domestic Productivity Shocks in Top Headquarters and Host Countries: Cross-country Variations in Trade Collapse, MP Collapse, and Welfare across Other Countries**

(a) Shocks in Top 10 Headquarters
Propagation through Headquarters
MP Collapse

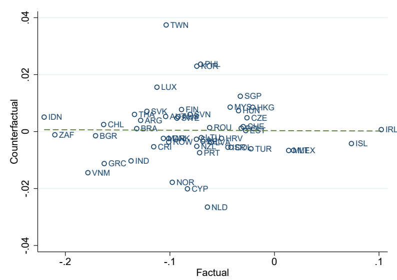
(b) Shocks in Top 10 Headquarters
Propagation through Headquarters
Trade Collapse



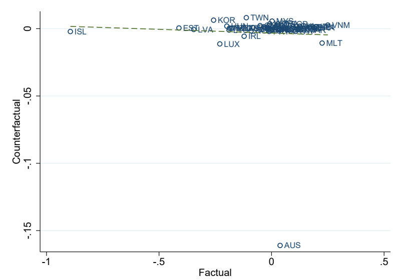
(c) Shocks in Top 10 Headquarters
Propagation through Headquarters
Welfare Changes

(d) Shocks in Top 10 Host Countries
Propagation through Host Countries
MP Collapse

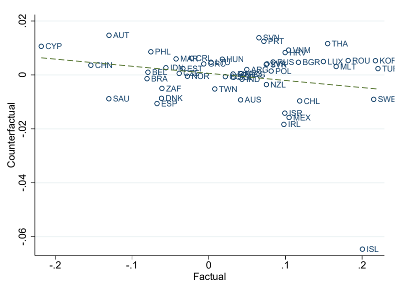
(e) Shocks in Top 10 Host Countries
Propagation through Host Countries
Trade Collapse



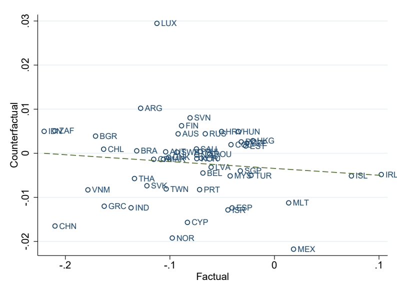
(f) Shocks in Top 10 Host Countries
Propagation through Host Countries
Welfare Changes



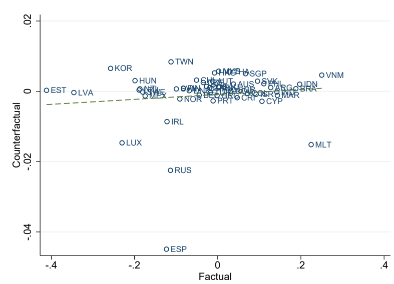
(g) Shocks in Top 10 Headquarters
No Propagation Through MP
MP Collapse



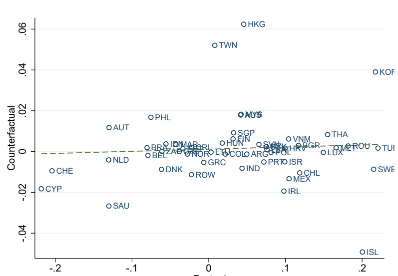
(h) Shocks in Top 10 Headquarters
No Propagation Through MP
Trade Collapse



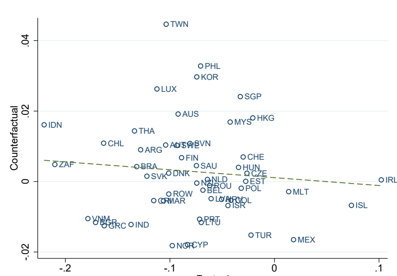
(i) Shocks in Top 10 Headquarters
No Propagation Through MP
Welfare Changes



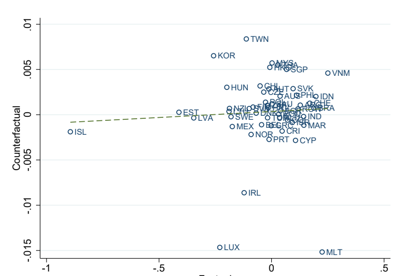
(j) Shocks in Top 10 Host Countries
No Propagation Through MP
MP Collapse



(k) Shocks in Top 10 Host Countries
No Propagation Through MP
Trade Collapse



(l) Shocks in Top 10 Host Countries
No Propagation Through MP
Welfare Changes



Description: These figures illustrate the impact of domestic productivity shocks in the top 10 headquarters countries and their propagation through MP headquarters and host country linkages on cross-country variation in trade, MP, and welfare changes during the Great Recession. Trade collapse is measured by changes in average imports and exports relative to GDP, while MP collapse is assessed by changes in inward and outward MP relative to GDP. Cross-country variation shares are calculated using Equation (26). The green dashed line represents the fitted line for the impact of propagated shocks, while the cranberry dashed line indicates the fitted line for the impact of direct shocks. A steeper fitted line signifies higher explanatory power.

B Theories and Derivations

B.1 A Micro-foundation for the Sourcing and Output Shares

In this section I derive a micro-foundation for the solution to the sourcing problem in Section 3.2. It builds on Eaton and Kortum (2002) and Ramondo and Rodríguez-Clare (2013). Assume an MNE produces its composite goods by combining a continuum of measure 1 of homogeneous product lines:

$$Q^s_{nm} = (\int_0^1 (Q^s_{nm}(\omega))^{\frac{\lambda-1}{\lambda}} d\omega)^{\frac{\lambda}{\lambda-1}}.$$

For each product line, it draws a random productivity shock, z^s_{nmji}, for all upstream host economies and technologies. Assume that sourcing MNEs make the sourcing decision independently. Assume z^s_{nmji} is distributed multivariate Frechet, with joint distribution:

$$F(\vec{z}^s_{nm}) = \exp(-(\sum_{j=1}^{N}(\sum_{i=1}^{N}(z^s_{nmji})^{-\frac{\theta}{1-\rho^s_1}})^{\frac{1-\rho^s_1}{1-\rho^s_2}})^{1-\rho^s_2}),$$

where ρ^s_1 governs the correlation between technologies, and ρ^s_2 governs the correlation between production locations. We allow the correlations to differ with respect to sectors. Consider the following special cases. Fix a source technology I. The probability of drawing technology shock z_{nmjI} for I equals, by taking $z_{nmji} \to \infty, \forall i \neq I$:

$$\tilde{F}(\{z_{nmjI}\}_{j=1}^N) = \exp(-(\sum_{j=1}^{N} z_{nmjI}^{-\frac{\theta}{1-\rho^s_2}})^{1-\rho^s_2}).$$

Therefore, the productivity shock draws for all production locations given a technology is still multivariate Frechet distribution with correlation ρ^s_2 across production locations. Now fix a source production location J. The probability of drawing technology shock z_{nmJi} for J is, taking $z_{nmji} \to \infty, \forall j \neq J$:

$$\tilde{F}(\{z_{nmJi}\}_{i=1}^N) = \exp(-(\sum_{i=1}^{N} z_{nmJi}^{-\frac{\theta}{1-\rho^s_1}})^{1-\rho^s_1}).$$

The productivity shock draws for all technologies given a production location is still multivariate Frechet distribution with correlation ρ^s_1 across production locations.

Denote the price for nm to get a unit of intermediate input from ji:

$$\frac{\tilde{H}^s_{ni}\tilde{h}^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}z^s_{nmji}}.$$

First, consider the probability that MNE nm's composite intermediate input price, P^s_{nm}, is no larger than p:

$$\begin{aligned} G^s_{nm}(p) &= 1 - F(\left\{z^s_{nmji} = \frac{H^s_{ni}h^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}p}\right\}_{i,j}) \\ &= 1 - \exp(-\Phi^s_{nm}p^{\theta}), \end{aligned}$$

where

$$\Phi^s_{nm} = (\sum_{j=1}^{N}(\sum_{i=1}^{N}(\frac{\tilde{H}^s_{ni}\tilde{h}^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}})^{-\frac{\theta}{1-\rho^s_1}})^{\frac{1-\rho^s_1}{1-\rho^s_2}})^{1-\rho^s_2}.$$

The probability that MNE nm sources from ji can be calculated as follows. First consider the marginal probability density of z^s_{nmji} (which is the partial derivative of $F(z^s_{nmji})$ with respect to z^s_{nmji}:

$$\begin{aligned} F_{ji}(z^s_{nmji}) = \theta(z^s_{nmji})^{-\frac{\theta}{1-\rho^s_1}-1}\left[\sum_{i=1}^{N}(z^s_{nmji})^{-\frac{\theta}{1-\rho^s_1}}\right]^{\frac{\rho^s_2-\rho^s_1}{1-\rho^s_2}} \left\{\sum_{j=1}^{N}\left[\sum_{i=1}^{N}(z^s_{nmji})^{-\frac{\theta}{1-\rho^s_1}}\right]^{\frac{1-\rho^s_1}{1-\rho^s_2}}\right\}^{-\rho^s_2} \\ \exp\left(\left\{\sum_{j=1}^{N}\left[\sum_{i=1}^{N}(z^s_{nmji})^{-\frac{\theta}{1-\rho^s_1}}\right]^{\frac{1-\rho^s_1}{1-\rho^s_2}}\right\}^{1-\rho^s_2}\right). \end{aligned}$$

Therefore,

$$F_{ji}(z^s_{nmj'i'} = \frac{\frac{H^s_{ni'}h^s_{mj'}k^s_{nj'}t^s_{nj'}\Theta^s_{j'i'}}{A^s_{j'i'}}}{\frac{H^s_{ni}h^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}}}z) = \theta z^{-\theta-1}\left[\sum_{i=1}^{N}(\frac{H^s_{ni'}h^s_{mj'}k^s_{nj'}t^s_{nj'}\Theta^s_{j'i'}}{A^s_{j'i'}})^{-\frac{\theta}{1-\rho^s_1}}\right]^{\frac{\rho^s_2-\rho^s_1}{1-\rho^s_2}}$$

$$\underbrace{\left\{\sum_{j=1}^{N}\left[\sum_{i=1}^{N}(\frac{H^s_{ni'}h^s_{mj'}k^s_{nj'}t^s_{nj'}\Theta^s_{j'i'}}{A^s_{j'i'}})^{-\frac{\theta}{1-\rho^s_1}}\right]^{\frac{1-\rho^s_1}{1-\rho^s_2}}\right\}^{-\rho^s_2}}_{(\Phi^s_{nm})^{-\frac{\rho^s_2}{1-\rho^s_2}}}(\frac{H^s_{ni}h^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}})^{-\frac{\theta\rho^s_1}{1-\rho^s_1}}$$

$$\exp(-\Phi^s_{nm}(\frac{H^s_{ni}h^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}})^{\theta}z^{-\theta}).$$

Integrating this from 0 to ∞ gives us the probability nm sources from ji. Note that

$$\int_{z=0}^{\infty}\theta z^{-\theta-1}\Phi^s_{nm}(\frac{H^s_{ni}h^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}})^{\theta}z^{-\theta}\exp(-\Phi^s_{nm}(\frac{H^s_{ni}h^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}})^{\theta}z^{-\theta})dz = 1.$$

Therefore,

$$\int_{z=0}^{\infty}F_{ji}(z^s_{nmj'i'}dz = \frac{\frac{H^s_{ni'}h^s_{mj'}k^s_{nj'}t^s_{nj'}\Theta^s_{j'i'}}{A^s_{j'i'}}}{\frac{H^s_{ni}h^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}}}z) = (\frac{H^s_{ni}h^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}})^{-\frac{\theta}{1-\rho^s_1}}$$

$$\left[\sum_{i=1}^{N}(\frac{H^s_{ni'}h^s_{mj'}k^s_{nj'}t^s_{nj'}\Theta^s_{j'i'}}{A^s_{j'i'}})^{-\frac{\theta}{1-\rho^s_1}}\right]^{\frac{\rho^s_2-\rho^s_1}{1-\rho^s_2}}(\Phi^s_{nm})^{-\frac{1}{1-\rho^s_2}}.$$

To acquire expenditure shares from quantity shares requires information about the conditional distribution of prices conditional on the sourcing decision. The probability that the price facing nm is no larger than p, and nm optimally sources ji, equal the following:

$$\int_{z=\frac{H^s_{ni}h^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}p}}^{\infty}F_{ji}(z^s_{nmj'i'} = \frac{\frac{H^s_{ni'}h^s_{mj'}k^s_{nj'}t^s_{nj'}\Theta^s_{j'i'}}{A^s_{j'i'}}}{\frac{H^s_{ni}h^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}}}z)dz = \left[\int_{z=0}^{\infty}F_{ji}(z^s_{nmj'i'} = \frac{\frac{H^s_{ni'}h^s_{mj'}k^s_{nj'}t^s_{nj'}\Theta^s_{j'i'}}{A^s_{j'i'}}}{\frac{H^s_{ni}h^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}}}z)dz\right]G^s_{nm}(p).$$

This implies that, the conditional price distribution is the same as the unconditional price distribution. Therefore, similar to Eaton and Kortum (2002), the current setting also yields the result that the quantity shares are the same as the expenditure shares.

Relabel $-\frac{\theta}{1-\rho_1^s} = 1-\zeta^s$ and $-\frac{\theta}{1-\rho_2^s} = 1-\sigma^s$. The expenditure share by nm on ji equals:

$$\pi^s_{nmji} = \underbrace{\frac{\sum_{i=1}^N \big(\frac{\tilde{H}^s_{ni}\tilde{h}^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}}\big)^{1-\zeta^s}\big)^{\frac{1-\sigma^s}{1-\zeta^s}}}{\sum_{j=1}^N \big(\sum_{i=1}^N \big(\frac{\tilde{H}^s_{ni}\tilde{h}^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}}\big)^{1-\zeta^s}\big)^{\frac{1-\sigma^s}{1-\zeta^s}}}}_{\pi^s_{nmj\cdot}} \underbrace{\frac{\big(\frac{\tilde{H}^s_{ni}\tilde{h}^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}}\big)^{1-\zeta^s}}{\sum_{i=1}^N \big(\frac{\tilde{H}^s_{ni}\tilde{h}^s_{mj}k^s_{nj}t^s_{nj}\Theta^s_{ji}}{A^s_{ji}}\big)^{1-\zeta^s}}}_{S^s_{n\cdot ji}},$$

which is exactly the same as the one in the main text.

B.2 Model in "Hats"

The model in "hats" is characterized by the following equations. The change in sourcing capability equals the following:

$$\hat{\Theta}^s_{li} = (\hat{w}_l)^{\gamma^s_l} \prod_{s'=1}^S (\hat{P}^{s'}_{li})^{\gamma^{ss'}_l}. \tag{B.1}$$

The change in MNE output share equals the following:

$$\hat{S}^s_{n\cdot ji} = \frac{(\frac{\hat{\Theta}^s_{ji}}{\hat{A}^s_{ji}})^{1-\zeta^s}\hat{H}_{ni}}{(\hat{P}^{s,p}_{nj})^{1-\zeta^s}},$$

where the change in the producer price index for producers hosted by country j selling to n equals the following:

$$(\hat{P}^{s,p}_{nj})^{1-\zeta^s} = \sum_{i=1}^N S^s_{n\cdot ji}(\frac{\hat{\Theta}^s_{ji}}{\hat{A}^s_{ji}})^{1-\zeta^s}\hat{H}_{ni}. \tag{B.2}$$

The change in MNE sourcing share equals:

$$\hat{\pi}^s_{nmj\cdot} = \frac{\hat{h}_{mj}(\hat{P}^{s,p}_{nj}\hat{k}^s_{nj}\hat{t}^s_{nj})^{1-\sigma^s}}{(\hat{P}^s_{nm})^{1-\sigma^s}},$$

where the change in MNE-specific composite goods price equals:

$$(\hat{P}^s_{nm})^{1-\sigma^s} = \sum_{j=1}^N \pi^s_{nmj\cdot}\hat{h}^s_{mj}(\hat{k}^s_{nj}\hat{t}^s_{nj}\hat{P}^{s,p}_{nj})^{1-\sigma^s}. \tag{B.3}$$

The change in MNE-bilateral specific sourcing share equals the following:

$$\hat{\pi}^s_{nmji} = \frac{\hat{h}_{mj}(\hat{P}^{s,p}_{nj}\hat{k}^s_{nj}\hat{t}^s_{nj})^{1-\sigma^s}}{(\hat{P}^s_{nm})^{1-\sigma^s}} \frac{(\frac{\hat{\Theta}^s_{ji}}{\hat{A}^s_{ji}})^{1-\zeta^s}\hat{H}_{ni}}{(\hat{P}^{s,p}_{nj})^{1-\zeta^s}} = \hat{\pi}^s_{nmj\cdot}\hat{S}^s_{n\cdot ji}.$$

The counterfactual MNE sourcing and output shares equal the following: $\pi^{s\prime}_{nmj\cdot} = \pi^s_{nmj\cdot}\hat{\pi}^s_{nmj\cdot}$, $\hat{S}^{s\prime}_{n\cdot ji} = S^s_{n\cdot ji}\hat{S}^s_{n\cdot ji}$, as well as $\pi^{s\prime}_{nmji} = \pi^s_{nmji}\hat{\pi}^s_{nmji}$.

The change in sectoral final expenditure share equals:

$$\hat{s}^s_n = \frac{\hat{\alpha}^s_n(\hat{P}^s_n)^{1-\lambda}}{(\hat{P}^c_n)^{1-\lambda}},$$

where the change in country n's consumer price index equals:

$$(\hat{P}^c_n)^{1-\lambda} = \sum_{s=1}^{S} s^s_n\hat{\alpha}^s_n(\hat{P}^s_n)^{1-\lambda}.$$

The counterfactual sectoral final expenditure share equals the following:

$$s^{s\prime}_n = s^s_n\hat{s}^s_n.$$

The change in sectoral final expenditure share on MNE-specific composite goods equals:

$$\hat{s}^s_{nm} = \frac{\hat{\alpha}^s_{nm}(\hat{P}^s_{nm})^{1-\delta^s}}{(\hat{P}^s_n)^{1-\delta^s}}.$$

This defines the sectoral final goods price: $(\hat{P}^s_n)^{1-\delta^s} = \sum_{m'=1}^{N}\alpha^s_{nm'}(P^s_{nm'})^{1-\delta^s}$.

The counterfactual sectoral final expenditure share on MNE-specific composite goods equals the following:

$$s^{s\prime}_{nm} = s^s_{nm}\hat{s}^s_{nm}.$$

The market clearing conditions for labor and composite intermediate input in the counterfactual equilibrium equal the following:

$$\hat{w}_j\hat{L}_jw_jL_j = w'_jL'_j = \sum_{s=1}^{S}\gamma^s_j\sum_{m=1}^{N}\sum_{n=1}^{N}\frac{X'^s_{nm}\pi'^s_{nmj\cdot}}{t'^s_{nj}},$$

and

$$X_{ji}^{\prime s} = I_j^{\prime} s_j^{s\prime} s_{ji}^{s\prime} + \sum_{s'=1}^{S} \gamma_j^{s's} \sum_{m=1}^{N} \sum_{n=1}^{N} \frac{X_{nm}^{\prime s'}}{t_{nj}^{\prime s'}} \pi_{nmji}^{\prime s'},$$

where the counterfactual household income equals:

$$I_n^{\prime} = w_n L_n \hat{w}_n \hat{L}_n + R_n^{\prime} + D_n^{\prime},$$

in which the counterfactual tariff revenue equal:

$$R_n^{\prime} = \sum_{s=1}^{S} \sum_{j=1}^{N} \sum_{m=1}^{N} X_{nm}^{\prime s} \pi_{nmj\cdot}^{\prime s} \frac{\tau_{nj}^{\prime s}}{t_{nj}^{\prime s}}.$$

In order to solve the counterfactual equilibrium, we have to know the baseline MNE sourcing shares, $\pi_{nmj\cdot}^{s}$, MNE output shares, $S_{n\cdot ji}^{s}$, sectoral final expenditure shares, s_j^s, and sectoral final expenditure shares on MNE-specific composite goods, s_{nm}^{s}. On top of that, we have to know the baseline labor income $w_j L_j$ and tariffs.

The shocks to the system of equations include: (1) MNE sourcing shocks, $\hat{h}_{mj}$, (2) MNE selling shocks, $\hat{H}_{ni}$, (3) MNE relative productivity shocks, $\frac{\hat{A}_{ji}^{s}}{\hat{A}_{jj}^{s}}$, (4) final demand shocks for MNEs, $\hat{\alpha}_{nm}^{s}$, (5) sectoral final demand shocks, $\hat{\alpha}_{n}^{s}$, (6) domestic productivity shocks, $\hat{A}_{jj}^{s}$, (7) non-tariff trade cost shocks, $\hat{k}_{nj}^{s}$, (8) tariff shocks, $\hat{t}_{nj}^{s}$, (9) labor endowment shocks, $\hat{L}_n$, as well as (10) trade deficit shocks, $D_n^{\prime}$.

Once we know all the variables above, the equilibrium is characterized by a set of prices, $\{\hat{w}_n\}$, $\left\{\hat{P}_{nj}^{s,p}\right\}$, $\left\{\hat{P}_{nm}^{s}\right\}$, such that the market clearing conditions hold for the counterfactual equilibrium.

B.3 Back out MNE Relative Productivity

I write a foreign affiliate's productivity relative to that of domestic firms in the same host country with its relative price of input divided by its relative price of output:

$$\frac{A_{ji}^{s}}{A_{jj}^{s}} = \frac{\Theta_{ji}^{s}}{\Theta_{jj}^{s}} \bigg/ \frac{\frac{\Theta_{ji}^{s}}{A_{jj}^{s}}}{\frac{\Theta_{jj}^{s}}{A_{jj}^{s}}}.$$

The denominator, $\frac{\frac{\Theta^s_{ji}}{A^s_{jj}}}{\frac{\Theta^s_{jj}}{A^s_{jj}}}$, can be derived from Equation (15), with knowledge about GO^s_{li}, T^s_{pl} and $S^s_{p\cdot ll}$ obtained from the data, ζ^s estimated in Section 4.2, and MNE selling efficiencies H^s_{pi} backed out in Section 4.1:

$$\frac{\frac{\Theta^s_{ji}}{A^s_{ji}}}{\frac{\Theta^s_{jj}}{A^s_{jj}}} = \left(\frac{GO^s_{ji}}{\sum_{p=1}^{N} T^s_{pj} S^s_{p\cdot jj} \frac{H^s_{pi}}{H^s_{pj}}}\right)^{\frac{1}{1-\zeta^s}}. \tag{B.4}$$

The numerator, $\frac{\Theta^s_{ji}}{\Theta^s_{jj}}$, equals the following:

$$\frac{\Theta^s_{ji}}{\Theta^s_{jj}} = \prod_{s'=1}^{S} \left(\frac{P^{s'}_{ji}}{P^{s'}_{jj}}\right)^{\gamma^{ss'}_i}, \tag{B.5}$$

where the relative price of composite intermediate input of foreign affiliates relative to local producers is computed as follows:

$$\frac{P^s_{ji}}{P^s_{jj}} = \left(\sum_{k=1}^{N} \pi^s_{jjk\cdot} \frac{h^s_{ik}}{h^s_{jk}}\right)^{\frac{1}{1-\sigma^s}}, \tag{B.6}$$

where $\pi^s_{jjk\cdot}$ is data and the MNE sourcing efficiency, h^s_{ik}, has been backed out in Section 4.1. Combining Equations (22), (B.4), (B.5) and (B.6), I get the MNE relative productivity, $\frac{A^s_{ji}}{A^s_{jj}}$, for all sectors and years.

B.4 Back out Domestic Productivity Shocks

I back out the domestic productivity shocks by solving a system of equations involving the shock itself and prices. We start with the change in sourcing shares of domestic firms:

$$\hat{\pi}^s_{nnj\cdot} = \frac{\hat{h}^s_{nj}(\hat{P}^{s,p}_{nj}\hat{k}^s_{nj}\hat{t}^s_{nj})^{1-\sigma^s}}{(\hat{P}^s_{nn})^{1-\sigma^s}},$$

in which the change in the producer price index equals:

$$(\hat{P}^{s,p}_{nj})^{1-\sigma^s} = \frac{(\hat{\Theta}^s_{jj})^{1-\sigma^s}}{(\hat{A}^s_{jj})^{1-\sigma^s}} \left(\frac{\hat{S}^s_{n\cdot jj}}{\hat{H}^s_{nj}}\right)^{\frac{1-\sigma^s}{\zeta^s-1}} = (\hat{\Theta}^s_{jj})^{1-\sigma^s} \left(\frac{\hat{H}^s_{nj}}{\hat{S}^s_{n\cdot jj}}\right)^{\frac{\sigma^s-1}{\zeta^s-1}} (\hat{A}^s_{jj})^{\sigma^s-1}. \tag{B.7}$$

Setting $n = j$ and inverting these two equations, I get:

$$\hat{A}^s_{jj} = (\hat{\pi}^s_{jjj\cdot})^{\frac{1}{\sigma^s - 1}} \frac{\hat{\Theta}^s_{jj}}{\hat{P}^s_{jj}} \left(\hat{S}^s_{j\cdot jj} \right)^{\frac{1}{\zeta^s - 1}}.$$

Furthermore, Equations (B.1), (B.2), and (B.3) show that changes in prices can be expressed as a function of changes in global shocks and wages. As a consequence, I get $2 \prod N \prod S$ equations for $2 \prod N \prod S$ unknowns: $\left\{ \hat{A}^s_{jj} \right\}$ and $\left\{ \hat{P}^s_{jj} \right\}$. By using this system of equations, I am able to solve $\hat{A}^s_{jj}$ and $\hat{P}^s_{jj}$ iteratively.

B.5 The Model without MNEs in "Hats"

In this model, the change in composite intermediate input price of country n's firms equal the following:

$$(\hat{P}^s_n)^{1-\sigma^s} = \sum_{l=1}^{N} \pi^s_{nl\cdot} (\hat{k}^s_{nl} \hat{t}^s_{nl} \frac{\hat{\Theta}^s_l}{\hat{A}^s_l})^{1-\sigma^s},$$

where the change in the sourcing capability is Cobb-Douglas in the change in wage and sectoral composite intermediate input prices:

$$\hat{\Theta}^s_l = (\hat{w}_l)^{\gamma^s_l} \prod_{s'=1}^{S} (\hat{P}^{s'}_l)^{\gamma^{ss'}_l}.$$

Therefore, the change in the expenditure share by country n on country l equals:

$$\hat{\pi}^s_{nl} = \frac{(\hat{k}^s_{nl} \hat{t}^s_{nl} \hat{P}^{s,p}_l)^{1-\sigma^s}}{(\hat{P}^s_n)^{1-\sigma^s}}.$$

Furthermore, the change in the final expenditure share equals the following:

$$\hat{s}^s_l = \frac{\hat{\alpha}^s_l (\hat{P}^s_l)^{1-\lambda}}{(\hat{P}^c_l)^{1-\lambda}},$$

with the change in the consumer price index equals:

$$(\hat{P}^c_l)^{1-\lambda} = \sum_{s=1}^{S} s^s_l \hat{\alpha}^s_l (\hat{P}^s_l)^{1-\lambda}.$$

The counterfactual sectoral final expenditure share equals the following:

$$\hat{s}_l^{s\prime} = s_l^s \hat{s}_l^s$$

The market clearing conditions for labor and composite intermediate input in the counterfactual equilibrium equal the following:

$$\hat{w}_l \hat{L}_l w_l L_l = w_l' L_l' = \sum_{s=1}^{S} \gamma_l^s \sum_{n=1}^{N} \frac{X_n'^s \pi_{nl\cdot}'^s}{t_{nl}'^s},$$

and

$$X_l'^s = I_l' s_l^{s\prime} + \sum_{s'=1}^{S} (1-\gamma_l^{s'}) \gamma_l^{s's} \sum_{n=1}^{N} \frac{X_n'^{s'}}{t_{nl}'^{s'}} \pi_{nl\cdot}'^{s'}.$$

where the counterfactual household income equals:

$$I_n' = w_n L_n \hat{w}_n \hat{L}_n + R_n' + D_n',$$

in which the counterfactual tariff revenue equals:

$$R_n' = \sum_{s=1}^{S} \sum_{l=1}^{N} \tau_{nl}'^s \frac{X_n'^s \pi_{nl\cdot}'^s}{t_{nl}'^s}.$$

The equilibrium is characterized by a set of prices, $\{\hat{w}_n\}$ and $\left\{\hat{P}_n\right\}$, such that the market clearing conditions hold for the counterfactual equilibrium.

B.6 The Model without MNE Sourcing and Selling Frictions in "Hats"

The change in sourcing capability equals the following:

$$\hat{\Theta}_j^s = (\hat{w}_j)^{\gamma_l^s} \prod_{s'=1}^{S} (\hat{P}_j^{s'})^{\gamma_l^{ss'}},$$

$\forall i$ headquarters in the host country j. Note that without heterogeneous MNE sourcing efficiencies, the composite goods price is not MNE-specific.

The change in the output shares of i's MNE in country j:

$$\hat{S}^s_{ji} = \frac{(\frac{\hat{\Theta}^s_i}{\hat{A}^s_{ji}})^{1-\zeta^s}}{(\hat{P}^{s,p}_j)^{1-\zeta^s}}.$$

Without heterogeneous MNE selling frictions, an MNE's output share in the host economy's outward trade flow is the same regardless of the destination.

The change in country j's producer price index equals the following:

$$(\hat{P}^{s,p}_j)^{1-\zeta^s} = \sum_{i=1}^{N} S^s_{ji}(\frac{\hat{\Theta}^s_j}{\hat{A}^s_{ji}})^{1-\zeta^s}$$

The change in the sourcing shares from country j, by any MNE hosted in n, equals:

$$\hat{\pi}^s_{nj} = \frac{(\hat{P}^{s,p}_j \hat{k}^s_{nj} \hat{t}^s_{nj})^{1-\sigma^s}}{(\hat{P}^s_n)^{1-\sigma^s}}.$$

Note that without heterogeneous MNE sourcing frictions, these sourcing shares are also not MNE-specific.

The change in the composite intermediate input price for all MNEs in country n equals:

$$(\hat{P}^s_n)^{1-\sigma^s} = \sum_{j=1}^{N} \pi^s_{nj\cdot}(\hat{k}^s_{nj} \hat{t}^s_{nj} \hat{P}^{s,p}_j)^{1-\sigma^s}.$$

The sourcing shares by any MNE in n, on an MNE headquartered in i, producing in j, equal the following:

$$\hat{\pi}^s_{nji} = \hat{\pi}^s_{nj\cdot} \hat{S}^s_{ji}$$

The counterfactual MNE sourcing and output shares are constructed as follows: $\hat{\pi}^{s\prime}_{nj\cdot} = \pi^s_{nj\cdot}\hat{\pi}^s_{nj\cdot}$, $\hat{S}^{s\prime}_{ji} = S^s_{ji}\hat{S}^s_{ji}$, as well as $\pi^{s\prime}_{nji} = \pi^s_{nji}\hat{\pi}^s_{nji}$.

The change in sectoral final expenditure share equals:

$$\hat{s}^s_n = \frac{\hat{\alpha}^s_n (\hat{P}^s_n)^{1-\lambda}}{(\hat{P}^c_n)^{1-\lambda}},$$

where the change in country n's consumer price index equals:

$$(\hat{P}_n^c)^{1-\lambda} = \sum_{s=1}^{S} s_n^s \hat{\alpha}_n^s (\hat{P}_n^s)^{1-\lambda}.$$

The counterfactual sectoral final expenditure share equals the following:

$$s_n^{s\prime} = s_n^s \hat{s}_n^s.$$

The change in sectoral final expenditure share on MNE-specific composite goods equals:

$$\hat{s}_{nm}^s = \hat{\alpha}_{nm}^s.$$

The counterfactual sectoral final expenditure share on MNE-specific composite goods equals the following:

$$s_{nm}^{s\prime} = s_{nm}^s \hat{s}_{nm}^s.$$

The market clearing conditions for labor and composite input in the counterfactual equilibrium are the following:

$$\hat{w}_j \hat{L}_j w_j L_j = \sum_{s=1}^{S} \gamma_j^s \sum_{n=1}^{N} \frac{X_n^{\prime s} \pi_{nj}^{\prime s}}{t_{nj}^{\prime s}},$$

and

$$X_j^{s\prime} = I_j^{\prime} s_j^{s\prime} + \sum_{s^{\prime}=1}^{S} \gamma_j^{s^{\prime} s} \sum_{n=1}^{N} \frac{X_n^{\prime s^{\prime}}}{t_{nj}^{\prime s^{\prime}}} \pi_{nj}^{\prime s^{\prime}},$$

where the counterfactual household income equals:

$$I_n^{\prime} = w_n L_n \hat{w}_n \hat{L}_n + R_n^{\prime} + D_n^{\prime},$$

in which the counterfactual tariff revenue equal:

$$R_n^{\prime} = \sum_{s=1}^{S} \sum_{j=1}^{N} \sum_{m=1}^{N} X_{nm}^{\prime s} \pi_{nmj}^{\prime s} \cdot \frac{\tau_{nj}^{\prime s}}{t_{nj}^{\prime s}}.$$

The equilibrium is characterized by a set of prices, $\{\hat{w}_n\}$, $\left\{\hat{P}_j^{s,p}\right\}$, $\left\{\hat{P}_n^s\right\}$, such that the market clearing conditions hold for the counterfactual equilibrium.