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Multinational Production and Global Shock Propagation during the Great Recession

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Multinational Production and Global Shock Propagation during the Great Recession

Abstract

Did multinational production (MP) exacerbate or mitigate the collapse of international trade during the Great Recession? What role did MP and trade links play in propagating economic shocks across countries? I resolve the “Multinationals’ Resilience Puzzle” during the Great Recession by documenting that while MP declined less than GDP in an average country, MP declined more in larger countries and GDP declined more in countries with a high MP intensity. Thus, MP declined as a percentage of GDP at the global level. To understand the sources of MP and trade collapse, I build a model of MP, trade, and sectoral linkages. The model highlights the frictions that multinational enterprises (MNEs) face when they source from and sell to countries other than their headquarters. These parameters determine MNEs’ vertical/horizontal-ness and govern the rich interactions between MP and trade. According to the model with MP, supply-side productivity shocks contributed to the collapse of trade almost as much as demand shocks. The majority of the collapse in MP (both globally and cross-country) was attributed to shocks that affected aggregate productivity and were specific to multinationals in a few key headquarters countries. The MP links significantly amplified the impact of these shocks on the rest of the world, which had a much greater impact than if the shocks had been propagated solely through trade.

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1 Introduction

While economists have recognized that multinational enterprises (MNEs) perform a large share of international trade (see, for example, [Bernard et al. 2009](#), [Antràs and Yeaple 2014](#), [Ramondo et al. 2015](#)), researchers and policy makers remain unaware of the role MNEs played in the collapse of international trade during the Great Recession.¹ Did multinational production (MP) exacerbate or mitigate the collapse of international trade? What role did MP and trade links play in propagating economic shocks across countries? Answers shed light on whether a country’s welfare changes were caused by external forces or internal causes, as well as whether trade or MP played a role in precipitating them.

In this paper, I begin by presenting and resolving the “Multinationals’ Resilience Puzzle” during the Great Recession. Figure 1 shows that from 2008 to 2009, global foreign affiliate sales by multinational enterprises (“global MP”) declined by 11 percent, while global trade declined by 12 percent (traditionally known as the “Great Trade Collapse”, see [Bems et al. 2013](#), among others), both relative to world GDP.² However, previous works, including [Alfaro and Chen \(2012\)](#), [Alvarez et al. \(2017\)](#), and [Kamal and Kroff \(2021\)](#), showed that MNEs were more resilient and suffered fewer sales declines compared to domestically owned firms during the Great Recession.

I resolve this puzzle by decomposing how global MP and GDP declined relative to GDP both within and between countries. I find that for an average country, MP declined less than GDP.³ However, MP declined more in larger countries and GDP declined more in countries with a high MP intensity. As a result of these differences between countries, MP as a percentage of GDP has declined globally. The collapse of global trade, on the other hand, occurred in almost all countries, and the within-country component accounted for the entire collapse.

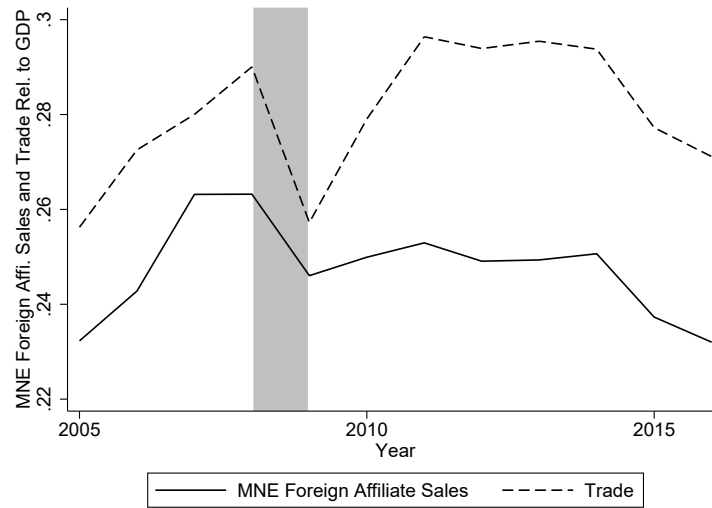
To understand the sources of the trade and MP collapse, I build a model which considers shocks affecting sectoral final demand, final demand for MNEs, productivity of domestic firms and foreign affiliates, as well as the costs of international trade and MP.

¹Specifically, [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).

²This 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](#)).

³I also find that in each country-sector, MP declined less than GDP.

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.

The model is designed to replicate the empirical fact that foreign affiliates engage in more imports and exports than domestic firms (in particular so with their headquarters), and that MP is more prevalent in durable manufacturing. Due to such close relationship between trade and MP, investigating the sources of the trade collapse while ignoring MP may overestimate the contribution by the sectoral final demand shocks, which were considered the dominant channel.⁴

The key feature of the model is that to conduct international trade, on top of the usual trade cost, MNEs face additional headquarters-trade partner specific frictions to source and sell the tradable output from and to non-headquarters countries.⁵ Firms (domestic or foreign-affiliated) use labor and MNE-specific, non-tradable composite goods from all sectors to produce the tradable output.⁶ The composite goods consist of the tradable output that MNEs source from all upstream host economies and MNEs. Having a nesting structure in the sourcing problem, the outer nest implies substitution across host economies and the inner nest implies substitution across MNEs within host economies. The price that the buying firm faces is a combination of the seller's factory gate price, tariff and non-tariff trade costs, the sourcing frictions (depending on the buyer's headquarters and the sourcing origin), as well as the selling frictions (depending on the seller's headquarters and the selling destination). The sourcing and selling frictions govern MNEs' vertical/horizontal-ness and explain the fact that affiliates engage in importing and ex-

⁴See, for example, [Bems et al. \(2010\)](#), [Eaton et al. \(2016\)](#), among others.

⁵A similar set of frictions is later examined in [Antràs et al. \(2022\)](#).

⁶These composite goods includes both physical goods and services.

porting more than local producers, and the headquarters countries affect where MNEs source from and sell to.

The key innovations—the MNE sourcing and selling frictions and the nesting structure—allow the model to be exactly matched to the data. In particular, the MNE sourcing and selling frictions match the model-implied MNE sourcing shares (the expenditure shares spent on a sourcing origin by a country’s domestic firms or foreign affiliates) and the model-implied MNE output shares (foreign affiliates or domestic firms’ shares of the host economy’s destination-specific trade flows) to their data counterparts. With the MNE sourcing and output shares, I conveniently compute the model counterfactuals.

I estimate key parameters and back out shocks in the model with the OECD Analytical Activities of Multinational Enterprises Database (henceforth, OECD AAMNE). The database covers sectoral, international trade and domestic sales by domestic firms and foreign affiliates. I develop a new method to estimate the sectoral trade elasticity and MNE elasticity (the elasticity of substitution across MNEs within the host economy). The core estimation equation is to regress the sourcing share of a destination country’s domestic firms on the bilateral tariff and the origin country’s destination-specific producer price index (all in logs), along with other controls. The producer price index can be inverted as a function of the share of domestic firms in the origin country’s destination-specific exports and the MNE elasticity. In order to identify the MNE elasticity, I use variations in this output share instrumented with the tariff imposed by the origin country on the sales destination (in the opposite direction of the original trade flow). These tariffs shift the costs of origin country’s domestic firms and foreign affiliates differently, leading to variations in their output shares. The trade elasticity is simultaneously estimated using the variation in the destination’s importing tariffs. The identifying assumption, as in [Head and Mayer \(2019\)](#), is that tariffs are exogenous to the unobserved factors in bilateral non-tariff trade barriers. The estimated trade and MNE elasticities are higher for the durable manufacturing sector (4.475 and 2.962) than they are for the non-durable manufacturing (3.020 and 1.578) and non-manufacturing sectors (3.020 and 1.539). Furthermore, the estimated sectoral MNE elasticities are smaller than the trade elasticities.

In order to investigate the causes of the MP and trade collapse, I use data and model inversion to back out the shocks exactly from the data. A total of four sets of moments are used for each sector: (1) MNE gross output of headquarter-host country pairs; (2) foreign affiliates’ host-country-origin-specific sourcing shares; (3) foreign affiliates’ host-country-destination-specific output shares; and (4) country-bilateral total trade.⁷ Using

⁷OECD AAMNE divides each country-bilateral trade flow only on the basis of whether the buyer and the seller are domestic or foreign. In this way, it provides statistics about trade based on all foreign affiliates

these moments, I am able to identify, for each sector, changes in the key structural parameters that relate to the productivity of MNEs and their ability to source from and sell to other countries. Since these shocks affect foreign affiliates differently from domestic firms and impact MNEs with different headquarters in different ways, I refer to them as the **MNE-specific shocks**. They include: (1) an MNE's productivity relative to domestic firms for headquarter-host country pairs (MNE relative productivity shocks); (2) headquarter-origin-specific MNE sourcing frictions (MNE sourcing shocks); (3) headquarter-destination-specific MNE selling frictions (MNE selling shocks). As a result of this procedure, I also obtain country-bilateral non-tariff trade barriers.⁸

In the next step, I estimate the elasticity of substitution among MNE-specific composite goods and across sectors in final use. To understand the roles of final demand shocks in the MP and trade collapses, I allow final demand consists of substitutable sectoral final goods, which are in turn composed of substitutable MNE-specific composite goods. To estimate the elasticity of substitution across MNE-specific composite goods, I regress sectoral final expenditure shares on foreign affiliates from different headquarters countries against their respective composite price indices (all in log changes). I instrument the MNE-specific composite price indices with the headquarters' domestic productivity shocks weighted according to the MNE's share of host country's gross output. I back out the last kind of **MNE-specific shocks** – (4) final demand shocks to MNEs – with these estimate elasticities and sectoral final expenditure shares on MNEs. To estimate the elasticity of substitution across sectoral final goods, I regress their shares on their respective prices (all in log changes). I instrument sectoral final goods prices by weighting the domestic productivity shocks in all foreign headquarters with their respective shares of gross output in the host country. I back out sectoral final demand shocks with this elasticity and sectoral shares in final demand.⁹

I find that these MNE-specific shocks were influenced by distances: if the two countries are located at a greater distance, MNEs' productivity and the final demand for them decreased more, while sourcing and selling frictions increased more. Nevertheless, such shocks are found to be less adverse when the headquarters had stronger pre-Recession trade and investment ties with the host nation (consistent with [Alfaro and Chen 2012](#)).

rather than by multinational corporations based in a specific headquarters country.

⁸MNE relative productivity, MNE sourcing and selling frictions, as well as non-tariff trade barriers, are all of dimensionality M^2 . I normalize local producers' relative productivity, MNE sourcing and selling frictions with the headquarter, as well as a country's non-tariff trade barriers with itself to 1. Then these parameters are point-identified.

⁹The identifying assumption of these elasticities is that domestic final demand shocks to (1) MNE-specific composite goods and (2) sectoral composite goods are uncorrelated with domestic productivity shocks in foreign headquarters.

To examine how a country's domestic productivity shocks propagate through MP linkages, I estimate the share of headquarters' productivity in the productivity of foreign affiliates. A foreign affiliate's productivity has both a headquarters' component and a host country's component, therefore it can change differently than domestic firms in both countries. Consequently, productivity shocks in one country propagate to other countries through MP networks. Based on changes in domestic sourcing shares, domestic-to-domestic sales shares, and country-level wage indices, I calculate the productivity shocks of domestic firms in each sector. To acquire the contribution of headquarters' productivity, I regress changes in MNE productivity (relative to domestic firms in the host country) on the difference between headquarters' domestic productivity and the domestic productivity of the host country. I find that the headquarters' productivity accounts for 6% (non-durable manufacturing sector) to 37% (durable manufacturing sector) of the foreign affiliate's productivity.

A first set of simulation findings focuses on the importance of shocks. MNE-specific shocks contributed 10% of global collapse in trade. Taking into account MP, supply side productivity shocks contributed almost as much (36%) as demand side forces (38%). In the absence of MP, almost all of the impact of MNE-specific shocks is likely to be misinterpreted as the impact of final demand shocks, resulting in the incorrect conclusion that final demand shocks were responsible for half of the global trade collapse. MNE-specific shocks, domestic productivity shocks, and final demand shocks all contributed substantially to the global MP collapse. These shocks contributed 27%, 33%, and 20%, respectively. Among the MNE-specific shocks I examined, the MNE relative productivity shocks contributed most to both the global trade and MP collapse.

To understand why some countries performed better during the Great Recession than others, I investigate the cross-country variation in country-level trade collapse, MP collapse, and welfare changes.¹⁰ MNE-specific shocks accounted for 22% of cross-country variation in trade collapse – almost as much as the impact of the domestic productivity shocks (which accounted for 29%).¹¹ Furthermore, they explained 12% of the variation in welfare across countries. Among the MNE-specific shocks, the MNE sourcing shocks contributed most to the cross-country variation in the trade collapse, while the MNE relative productivity shocks contributed most to the cross-country variation in the MP collapse. Furthermore, I show that the high trade intensity of MNEs (governed by the sourcing

¹⁰I measure a country's 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.

¹¹Nevertheless, final demand shocks were only responsible for 2% of the variation in trade collapse across nations.

and selling frictions) was the primary reason why shocks to MNEs affected the collapse of trade in terms of both cross-country differences as well as global totals.

In the second set of simulations, I examine the cross-border propagation of shocks. I find that domestic productivity shocks in a country can have significantly greater impact on the global economy if they can propagate through MP headquarters linkages - that is, when they affect the productivity of MNEs headquartered in the country. Through the MP headquarters linkages, the impact of domestic productivity shocks on the global trade collapse was increased by 40% and that on the global MP collapse was increased by 20%. The impact of domestic productivity shocks on the variations of trade collapse, MP collapse, and welfare changes across countries was also increased by 12%, 84%, and 45% when these shocks propagated through MP headquarters.

Through MP, shocks spread more widely than through international trade. MNE-specific shocks that impacted the top global MP headquarters had a significant influence on the MP collapse and welfare in other countries. In contrast, neither the domestic productivity shocks affecting top exporters nor the final demand shocks affecting top importers significantly impacted the trade collapse or welfare in other countries. As an example, the MNE-specific shocks which affected the top ten headquarters countries could explain 30% of the variation in MP collapse and 8% of the variation in welfare changes across other countries. The domestic productivity shocks in the top ten exporters countries, if they only propagated through trade, did not explain any of the variation in trade collapse or welfare changes in other countries. Conversely, if these domestic productivity shocks affected the top ten headquarters countries and propagated to other countries via MP headquarters linkages, they could explain 17% of the variation in trade collapse, 6% of the variation in MP collapse, and 4.5% of the variation in welfare across other countries.

As a result of these findings, while the collapse of trade occurred in almost all countries, the collapse of MP was concentrated in a few key headquarters countries and spread to the rest of the world. Such cross-border propagation effects contributed to the MP collapse, trade collapse, and welfare. It is important for global policymakers, in particular those in countries that host a large number of MP activities, to closely monitor these shocks in global MP headquarters.

This paper 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 that misses either of these frictions

will fail to capture the differences between MNEs from different headquarters in their sourcing and selling patterns, as measured by the MNE sourcing shares or output shares. Furthermore, I demonstrate that ignoring these sourcing and selling frictions will underestimate the effect of MNE-specific shocks on the collapse of trade.

This paper contributes to the literature on trade and MP collapse during the Great Recession. [Bems et al. \(2010\)](#), [Bems et al. \(2013\)](#), [Eaton et al. \(2016\)](#), [Alessandria et al. \(2010a\)](#), [Alessandria et al. \(2010b\)](#), among others, find that the decline in final demand for durable manufacturing, which is more trade intensive than other sectors, contributed the most to the global trade collapse. Fewer works study MNEs in the Great Recession. [Alfaro and Chen \(2012\)](#), [Alvarez et al. \(2017\)](#), and [Kamal and Kroff \(2021\)](#) examine the factors affecting the performance of MNEs during the Recession. [Biermann and Huber \(2019\)](#) study how bank lending cuts to headquarters affected German MNE businesses abroad. The two literatures examined the collapse of trade and MP separately. As MNEs play a critical role in international trade, I propose a framework to analyze how shocks to trade contribute to the collapse of MP and how shocks to MP contribute to the collapse of trade. I find that a significant portion of the trade collapse can be explained by shocks specific to MNEs, while final demand and domestic productivity shocks were also responsible for the decline in foreign affiliate sales.

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](#), [Alvarez et al. 2020](#), [Bilir and Morales 2020](#)) can result in economic shocks affecting other parts of the economy. I introduce a tractable framework that accounts for all these three channels. I find that the propagation through MP from the headquarters to foreign affiliates significantly amplified the impact of domestic productivity shocks in the top headquarters countries on trade, MP, and welfare in other countries. In the absence of such propagation through MP, domestic productivity shocks in the major exporting countries did not significantly affect other countries' trade collapse or welfare from purely trade propagation.

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

The main data source, OECD AAMNE ([Cadestin et al., 2018](#)), provides information about bilateral gross output and international trade by domestic/foreign firms, for 59 countries plus a constructed rest of the world.¹² OECD AAMNE consists of two data tables. The first features a complete matrix of MNE gross output by headquarters country, host country, and industry (a total of 34). The second extends the coverage by the OECD inter-country input-output database to all countries and sectors, then splits each cell into four according to whether the buyer or seller of each trade flow is a domestic firm or a foreign affiliate. OECD AAMNE covers the years 2005 to 2016.¹³

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 used in this paper.

The data is complemented with country-sector-level GDP data from the United Nations National Account Database. To measure the size of the labor forces of countries, I use data from the Penn World Table version 9.1 ([Lederman et al., 2017](#)).¹⁴ I further acquire country-bilateral variables, including distance, common language, contiguity from CEPII data ([Head et al. 2010](#), [Head and Mayer 2014](#)), and the latest global trade agreements information from [Head and Mayer \(2019\)](#).

Following [Eaton et al. \(2016\)](#), I measure country-level collapse of trade with changes in the average of a country's imports and exports relative to its GDP (between 2008 and 2009). Correspondingly, I define country-level collapse of MP with changes in the average of a country's inward and outward foreign affiliate sales relative to its GDP (between 2008 and 2009). A country's inward foreign affiliate sales refer to the sales of foreign affiliates

¹²OECD 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.

¹³OECD ICIO, a database that documents international trade between country-sector pairs. See [Ahmad et al. 2006](#).

¹⁴The variable I use is "Number of persons engaged (in millions)".

headquartered in other countries and operating in this country. A country's outward foreign affiliate sales refer to the sales of foreign affiliates headquartered in the country and operating in other countries.

2.2 Resolving the "Multinationals' Resilience Puzzle"

Figure 1 shows that, similar to the global trade collapse, world total sales by multinational foreign affiliates also declined as a share of world GDP. However, based on previous research, including [Alfaro and Chen \(2012\)](#), [Alvarez et al. \(2017\)](#), and [Kamal and Kroff \(2021\)](#), MNEs proved to be more resilient, and their sales declined less during the Great Recession than domestically owned firms. A comprehensive understanding of MNE performance during the Great Recession requires an explanation of these inconsistencies, which I refer to as the "Multinationals' Resilience Puzzle".

The "Multinationals' Resilience Puzzle" can be resolved with a between-country-within-country decomposition. This solution provides insight into the causes of the MP and trade collapses, as well as the mechanisms by which these shocks propagated across countries. Equation (1) decomposes the decline in world total MNE foreign affiliate sales relative to world GDP into three terms: (A) that summarizes whether MP declines more in larger countries; (B) that summarizes whether GDP declines more in countries with a higher intensity of MP; and (C) which is the within-country effect that refers to the average decline in MP relative to GDP across countries:

$$\begin{aligned}
& \frac{\sum_{i=1}^N MP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} - \frac{\sum_{i=1}^N MP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}} = \\
& N \underbrace{\text{cov}_i \left(\underbrace{\frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}}}_{\text{A}}, \underbrace{\frac{GDP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} + \frac{GDP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}}_{\text{B}} \right)}_{\text{Between-country Effects}} + N \underbrace{\text{cov}_i \left(\frac{GDP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} - \frac{GDP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}, \frac{MP_{i,2009}}{GDP_{i,2009}} + \frac{MP_{i,2008}}{GDP_{i,2008}} \right)}_{\text{B}} \\
& + \underbrace{\frac{1}{N} \sum_{i=1}^N \left(\frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}} \right)}_{\text{C: Within-country Effect}}, \tag{1}
\end{aligned}$$

where i denotes a country, N denotes the total number of countries, $MP_{i,t}$ denotes the average of country i 's inward and outward MP in year t , and $GDP_{i,t}$ denotes country i 's GDP in year t . The term A represents the covariance (over countries) between the country-level MP collapse and the time-average of countries' shares of world GDP (adjusted with the number of countries). The term B represents the covariance (over countries) between the changes in countries' shares of world GDP and the time-average of

countries' MP intensity (adjusted with the number of countries). The within-country effect equals the simple average of MP collapse across countries. The same decomposition for the global trade collapse can be conducted by replacing $MP_{i,t}$ with the average of country i 's imports and exports in year t .

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	-0.017 (78.6%)	-0.008 (39.6%)	0.004 (-18.1%)	-0.02 (100%)
Trade	0.009 (-23.2%)	-0.003 (6.5%)	-0.046 (116.7%)	-0.04 (100%)
I. Durable Manufacturing				
MP	-0.067 (228.8%)	-0.037 (125.0%)	0.074 (-253.8%)	-0.03 (100%)
Trade	0.049 (-52.9%)	-0.006 (6.1%)	-0.135 (146.8%)	-0.09 (100%)
II. Non-durable Manufacturing				
MP	-0.021 (48.4%)	-0.040 (94.1%)	0.018 (-42.5%)	-0.04 (100%)
Trade	0.010 (-18.7%)	-0.014 (24.9%)	-0.052 (93.8%)	-0.06 (100%)
III. Non-manufacturing				
MP	-0.012 (111.6%)	-0.007 (58.3%)	0.008 (-69.9%)	-0.01 (100%)
Trade	0.004 (-16.9%)	-0.002 (10.2%)	-0.024 (106.7%)	-0.02 (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.

Fact 1: While MP Declined More in Larger Countries and GDP Declined More in MP Intensive Countries, Trade Declines were Similar in All Countries.

Table 1 shows that MP declined more in larger countries during the Great Recession. As indicated by the term A, it accounted for 79% of the global MP decline during the Great Recession. Additionally, GDP declined more in MP intensive countries, and the term B contributed 40% of the global MP collapse. These two covariance terms accounted for the entire global MP collapse. Furthermore, according to the within-country term, MP is more resilient than GDP for an average country, resolving the puzzle.

These findings suggest that the MP collapse was concentrated in a few countries – likely the major headquarters and host countries. Since shocks that were specific to MP in these countries propagated to other countries, they likely contributed to the global MP collapse. Moreover, country-level aggregate shocks that caused MP intensive countries to decline more might also have contributed to the MP collapse.

While the MP collapse was heterogeneous across countries, most of the global trade collapse was “within-country” and similar across countries. Larger nations did not ex-

perience a greater decline in trade, nor did countries with a greater reliance on trade experience a significantly greater decline in GDP. For an average country, trade declined substantially more relative to GDP. This suggests that shocks that contributed to the collapse of global trade should have affected almost all countries.

Panels I.-III. of Table 1 show that both the “Multinationals’ Resilience Puzzle” and the difference between the MP and the trade collapse apply to all sectors. Table A.5 further decomposes the MP and trade declines in each country into three terms that denote (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. All “between-country” and “between-sector” effects contributed to the global MP collapse, which suggested that the MP collapse propagated strongly across countries and sectors. Additionally, for an average country and sector, MP is significantly more resilient than GDP. The global trade collapse, on the other hand, was largely the result of factors within countries and sectors. Table A.3 and A.4 conduct this decomposition for the post-Recession recovery and the trade and MP declines during the years 2013-2016.

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

Fact 2: On the Country Level, the Collapses of MP and Trade were Positively Correlated

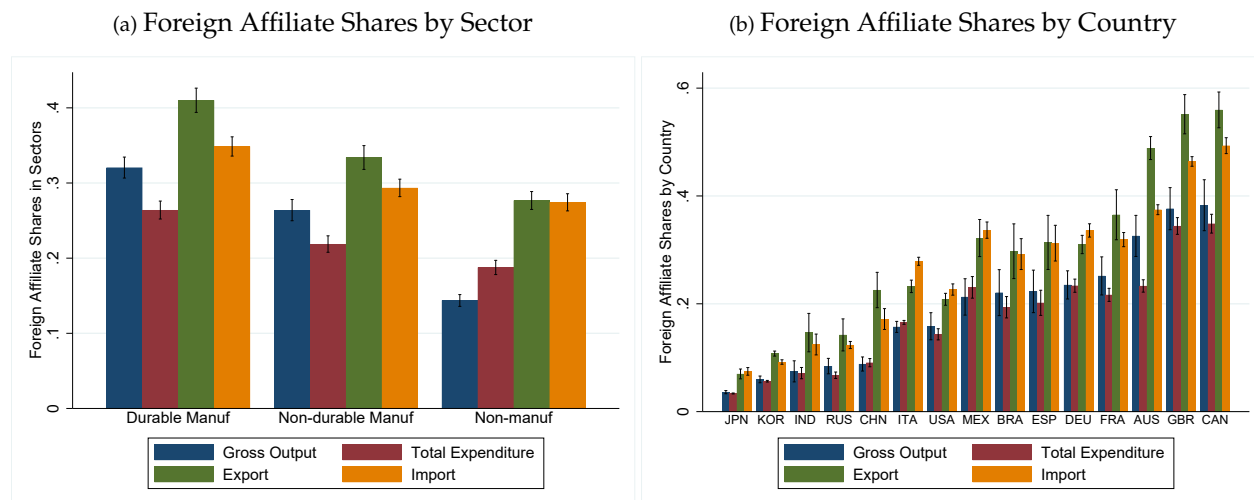
Figure 2 shows that the collapse of MP was positively correlated with the collapse of trade across countries.¹⁵ This suggests that shocks to MP might have contributed to the variations in trade across countries. Simultaneously, shocks to trade might have contributed to the variations in MP. Furthermore, the MP collapse was more heterogeneous across countries than the trade collapse. All but three countries experienced a collapse in trade, while in 28 of them (less than half) MP decreased relative to GDP. There were, however, some countries, such as Germany, where MP declined more than 20% in relation to GDP. It might be important for the rest of the global economy to consider the shocks that affected these countries. Figure A.1 shows that these relationships exist for each sector.

Fact 3: MNEs are More Intensive in the Durable Manufacturing Sector and International Trade

Figure 3a shows that MP activities are most intensive in the durable manufacturing

¹⁵Regressing the MP collapse on the trade collapse at the country level gives a coefficient of .504 and a standard error of 0.182.

Figure 3: Foreign Affiliate Shares by Sector and 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.

I investigate the relationship between MNE status and trade on the firm level. First, I show that the fact that MNEs participate more in both importing and exporting is robust to firm-level controls. Furthermore, I show that not only is it a foreign affiliate, but also the location of the firm’s headquarters has an effect on where it sources from and sells to. I take advantage of Chinese firm-level databases. They include the Annual Survey of Chinese Manufacturing (ASCM) Database, which covers firm-level business statistics; the Chinese Customs Records (CCR) Database, which covers all importing and exporting transactions by Chinese firms; and the Foreign-Invested Enterprise Survey in China (FIESC), which documents the ownership nationalities of all foreign affiliates in China.¹⁹

Building on the empirical strategy in Wang (2019) and presenting more details in Section A.3, I establish two facts for foreign affiliates’ importing decisions.²⁰ Conditional on firm-level characteristics, including employment, capital, intermediate input and TFP, foreign affiliates are 36 percentage points more likely to import, and they import 14 percentage points more relative to total sales than local firms (Table A.6).²¹ Conditional on importing and controlling for two-way fixed effects between the host economy and the importing origin, foreign affiliates on average are 13 percentage points more likely to

¹⁹Detailed information about these data sets are presented in Section A.3.

²⁰Wang (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.

²¹I also control for 2-digit industry fixed effects.

source from their headquarters. A one percent increase in the distance between the headquarters and the sourcing origin is associated with 0.3 percentage point decline in the probability of sourcing and 0.2% decline in importing values (Table A.7).

Based on these findings, MNEs face additional transaction frictions relating to global sourcing and exporting that are specific to their headquarters and trading partners, which is why the model counterparts are presented in Section 3.²² The MNE selling frictions related to exporting may reflect the additional cost of setting up and maintaining the distribution networks in a non-headquarters country, higher marketing cost due to less brand recognition, limited knowledge of consumer preferences, etc. The MNE sourcing frictions related to importing may include incompatibility between a country's technology and the input of other countries, different regulatory requirements, a lack of information about where and how to source from other countries, etc.

3 Model

The global economy consists of N countries 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. If the host economy n is different from the headquarters m , the firm is a foreign affiliate. Otherwise, it is a domestic firm. An MNE is defined by its headquarters m , host country n , and sector s . Firms use labor and MNE-specific composite goods from all sectors as inputs. All markets are competitive.²³

3.1 The Firm's Problem

Country m 's MNE in country n , sector s produces quantity y_{nm}^s of tradable output by combining labor with MNE-specific composite intermediate inputs from all sectors.²⁴

$$y_{nm}^s = A_{nm}^s \left(\frac{L_{nm}^s}{\gamma_n^s} \right)^{\gamma_n^s} \prod_{s'=1}^S \left(\frac{M_{nm}^{ss'}}{\gamma_n^{ss'}} \right)^{\gamma_n^{ss'}}. \quad (2)$$

²²Wang (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.

²³These 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 Alvarez et al. (2017), among others.

²⁴I assume technology and trade flow from right to left in the subscripts.

A_{nm}^s denotes the firm's productivity. The productivity varies with respect to both the headquarters as well as the host country.²⁵ I call the productivity of domestic firms, A_{nn}^s , the **domestic productivity**. I refer to an MNE's productivity relative to the host economy's domestic productivity, $\frac{A_{nm}^s}{A_{nn}^s}$, the **MNE relative productivity**. L_{nm}^s denotes labor hired by the MNE. $M_{nm}^{ss'}$ is non-tradable, MNE-specific composite goods of sector s' that are used to produce s output. The composite input price is MNE-specific and denoted with P_{nm}^s . The production function is constant return to scale with $\gamma_n^s + \sum_{s'=1}^S \gamma_n^{ss'} = 1$.²⁶ Accordingly, MNEs that operate in the same host country differ in terms of their TFP and the price of composite inputs that are specific to MNEs.

3.2 International Trade by MNEs

Assume the composite intermediate input takes the form of a nested-CES aggregate over global tradable output as follows:

$$Q_{nm}^s = \left[\sum_{j=1}^N \left(\sum_{i=1}^N (q_{nmji}^s)^{\frac{\zeta^s-1}{\zeta^s}} \right)^{\frac{\zeta^s}{\zeta^s-1} \frac{\sigma^s-1}{\sigma^s}} \right]^{\frac{\sigma^s}{\sigma^s-1}}. \quad (3)$$

The composite intermediate input is produced with a “love-of-variety” style production function and combines tradable output that the MNE sources from all upstream host economies and MNEs in a Dixit-Stiglitz fashion. The outer-nest models trade-offs between host countries with elasticity of substitution σ^s . Given a host country, the inner nest combines all MNEs that operate there with elasticity of substitution ζ^s . We call σ^s the **trade elasticity** and ζ^s the **MNE elasticity**. The tradable output is assumed to differ with respect to where it is produced and where the technology comes from. q_{nmji}^s denotes the quantity of it sold from an MNE headquartered in country i operating in j to an MNE headquartered in country m that operates in n .

The price paid by an MNE from country m that operates in n , to acquire a unit of output from an MNE from country i that operates in j equals the following:

$$\tilde{H}_{ni}^s \tilde{h}_{mj}^s k_{nj}^s t_{nj}^s \frac{\Theta_{ji}^s}{A_{ji}^s}. \quad (4)$$

$\Theta_{ji}^s = (w_j)^{\gamma_j^s} \prod_{s'=1}^S (P_{ji}^{s'})^{\gamma_j^{ss'}}$ denotes the selling MNE's input bundle cost (or, the sourcing

²⁵The same idea is considered by [Cravino and Levchenko \(2017\)](#), [Tintelnot \(2017\)](#), and others.

²⁶I assume that all MNEs in platform country n have the same input-output shares γ_n^s and $\gamma_n^{ss'}$ – the same assumption is used by [Alvarez \(2019\)](#).

capability) and $\frac{\Theta_{ji}^s}{A_{ji}^s}$ refers to its factory gate price charged for one unit of output. This follows from profit maximization and the perfect competition assumption. Trade flows from country j to country n face iceberg, **non-tariff trade barriers**, denoted with k_{nj}^s . Ad-valorem **tariffs** at rate τ_{nj}^s has to be paid to the buying MNE's country n , and $t_{nj}^s = 1 + \tau_{nj}^s$. Tariff revenues are then transferred to country n 's households for consumption. I assume the tariff barriers are multiplicative separable from the non-tariff trade barriers.²⁷ MNEs face additional iceberg frictions sourcing from and selling to non-headquarter countries. These frictions are assumed to be bilateral, MNE headquarter-trade partner specific. \tilde{h}_{mj}^s denotes the **MNE sourcing friction** for an MNE headquartered in country m to source from country j . \tilde{H}_{ni}^s denotes the **MNE selling friction** for an MNE headquartered in country i to sell to country n .²⁸

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:

$$S_{n \cdot ji}^s = \frac{H_{ni}^s \left(\frac{\Theta_{ji}^s}{A_{ji}^s} \right)^{1-\zeta^s}}{\sum_{k=1}^N H_{nk}^s \left(\frac{\Theta_{jk}^s}{A_{jk}^s} \right)^{1-\zeta^s}}. \quad (5)$$

Here I relabel $H_{ni}^s = (\tilde{H}_{ni}^s)^{1-\zeta^s}$. H_{ni}^s denotes the **MNE selling efficiency** - efficiency of MNEs headquartered in i to sell to country n . This is the object to be exactly backed out with data and model inversion in Section 4. I define country j 's producer price index for its shipment to n , $P_{nj}^{s,p}$, with the denominator of Equation (5): $(P_{nj}^{s,p})^{1-\zeta^s} = \sum_{k=1}^N H_{nk}^s \left(\frac{\Theta_{jk}^s}{A_{jk}^s} \right)^{1-\zeta^s}$. Country j 's producer price index for destination country n should be lower if the MNEs hosted by country j are more productive, have lower input prices, or are more efficient at selling to n .

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:

$$\pi_{nmj}^s = \frac{h_{mj}^s (k_{nj}^s t_{nj}^s P_{nj}^{s,p})^{1-\sigma^s}}{\sum_{l=1}^N h_{ml}^s (k_{nl}^s t_{nl}^s P_{nl}^{s,p})^{1-\sigma^s}}. \quad (6)$$

²⁷The same assumption is used by [Caliendo and Parro \(2015\)](#), among others.

²⁸Non-tariff trade barriers within a country, as well as MNEs' selling and sourcing frictions with the headquarters, are normalized to one: $k_{nn}^s = \tilde{H}_{ii}^s = \tilde{h}_{mm}^s = 1$.

Here I relabel $h_{mj}^s = (\tilde{h}_{mj}^s)^{1-\sigma^s}$. h_{mj}^s denotes the **MNE sourcing efficiency** - efficiency of MNEs headquartered in m to source from j . This is the object to be exactly backed out with data and model inversion in Section 4.²⁹ The composite intermediate input price index of the MNE from m operating in n can be defined with the following: $(P_{nm}^s)^{1-\sigma^s} = \sum_{l=1}^N h_{ml}^s (k_{nl}^s t_{nl}^s P_{nl}^{s,p})^{1-\sigma^s}$. 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).

The MNE sourcing and selling efficiencies determine the vertical/horizontal-ness of MNEs. Consider the following three cases. If $h_{mj}^s = 0, \forall j \neq m$, foreign affiliates can only source from their headquarters country m . MNEs in this category are forward-vertical – the headquarters is the exclusive supplier of input to the affiliates abroad. A forward-vertical MNE would be a distributor of a car manufacturer, for example, Toyota dealers in the United States that import cars exclusively from Japan. Another extreme case is $H_{ni}^s = 0, \forall n \neq i$. In this case, foreign affiliates only sell back to their headquarters. These MNEs are backward-vertical because the headquarters is the exclusive buyer of the foreign affiliates. Examples include Toyota's tire suppliers in Thailand that only provide tires to Japan. In the third extreme case, $h_{mj}^s = H_{ni}^s = 1, \forall m, n, j, i$. With this condition, foreign affiliates will have the same sourcing shares as the host country's domestic firms. Additionally, any destination's share of the foreign affiliates' total sales will equal to the same destination's share for the domestic firms within the host economy. As horizontal MNEs, they differ from domestic firms with respect to productivity but not with respect to trade patterns - where to source from and where to sell to.³⁰

²⁹Both the selling and sourcing efficiencies are relative to selling and buying with the MNE headquarters, with the normalization $H_{ii}^s = 1 \forall i$ and $h_{mm}^s = 1 \forall m$.

³⁰Compare a foreign affiliate headquartered in m and producing in n with a domestic firm in country n . With $h_{mj}^s = 1, \forall m, j$, the two producers have the same sourcing shares from any given origin country: $\pi_{nmj}^s = \pi_{nnj}^s, \forall m, n, j$. Next, compare a foreign affiliate headquartered in i and producing in j with country j 's domestic firms. With $H_{ni}^s = 1, \forall n, i$, MNEs have the same output shares in trade flows for any given destination: $S_{n.ji}^s = S_{j.ji}^s, \forall n$. Denote total sales from country j to any country n in sector s with T_{nj}^s . The gross output by the foreign affiliate headquartered in i and hosted by j equals $\sum_{n=1}^N T_{nj}^s S_{n.ji}^s$. The share of destination n in this MNE's total output equals: $\frac{T_{nj}^s S_{n.ji}^s}{\sum_{n=1}^N T_{nj}^s S_{n.ji}^s} = \frac{T_{nj}^s}{\sum_{n=1}^N T_{nj}^s}$, which is invariant to the MNE's headquarters and is the same regardless of whether it is a foreign affiliate.

Most MNEs in the real world mix features of forward-vertical, backward-vertical and horizontal MNEs.³¹ Therefore, the true values of the MNE sourcing and selling efficiencies are unlikely falling into any of the three cases. Heterogeneous MNE sourcing and selling efficiencies are necessary to explain why foreign affiliates engage more in both importing and exporting than domestic firms and trade more with the headquarters and the trade partners closer to their headquarters - patterns documented in Figure 3a and 3b and Section A.3. I will back out the sourcing and selling efficiencies exactly with data.

The 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:

$$\pi_{nmji}^s = \pi_{nmj}^s S_{n \cdot ji}^s.$$

3.3 The Consumer's Problem

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

$$U_n = \left(\sum_{s=1}^S (\alpha_n^s)^{\frac{1}{\lambda}} (C_n^s)^{\frac{\lambda-1}{\lambda}} \right)^{\frac{\lambda}{\lambda-1}}.$$

C_n^s denotes sector s final goods and λ denotes the elasticity of substitution across sectors. To understand the impact of sectoral final demand shocks on the collapses of trade and MP, I let α_n^s denote sectoral preferences and shocks to α_n^s refer to the **sectoral final demand shocks**.³² This implies that the sectoral final expenditure share equals the following:

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

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:

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

³¹See Yeaple (2003), Antràs and Yeaple (2014), Baldwin and Okubo (2014), Ramondo et al. (2016), among others.

³²I impose the normalization that $\alpha_n^s = 1$ for the non-manufacturing sector.

C_{nm}^s denotes MNE-specific composite goods in final use. δ^s denotes sectoral elasticities of substitution across different MNEs in final use. α_{nm}^s denotes the preference for MNEs by final consumers and shocks to α_{nm}^s refer to the **MNE final demand shocks**.³³ This implies that MNE nm 's share in country n sector s consumption bundle equals the following:

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

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

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:

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

3.4 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:

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

On the right-hand side, $\sum_{m=1}^N \frac{X_{nm}^s \pi_{nmj}^s}{t_{nj}^s}$ 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:

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

³³I impose the normalization that $\alpha_{nn}^s = 1$ for domestic firms' composite goods.

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).

3.5 Equilibrium in changes

To simulate counterfactuals, I take advantage of the “exact hat algebra” technique and rewrite the model variables in terms of changes relative to the baseline equilibrium. I denote the change in an variable x with $\hat{x} = \frac{x'}{x}$, where x is the level of the variable in the baseline equilibrium and x' is the level of the variable in the counterfactual equilibrium. The MNE sourcing and output shares, baseline tariffs, expenditure share on sectoral final goods, sectoral expenditure shares on MNE-specific composite goods, and household income contain sufficient information to characterize endogenous variables’ response to shocks. The model in “hats” is presented in Section B.2.³⁴

4 Model Inversion and Elasticity Estimation

Here I present the procedure to back out the frictions and shocks in the model and estimate the elasticities.

4.1 Back out MNE Sourcing and Selling Efficiencies

First, I calculate expenditures on MNE-specific composite goods, X_{nm}^s , using Equation (10), which is based on data on gross output at the MNE level, income at the country level, input-output coefficients, and final expenditure shares on sectors and MNEs. Next, since the trade flow from country j to country n equals the total expenditure by all MNEs in n on the tradable output from country j , I can establish the following relationship:

$$T_{nj}^s = \frac{\sum_{m=1}^N X_{nm}^s \pi_{nmj}^s}{t_{nj}^s} = \frac{\sum_{m=1}^N X_{nm}^s \pi_{nnj}^s \frac{\pi_{nmj}^s}{\pi_{nnj}^s}}{t_{nj}^s}. \quad (11)$$

³⁴This method reduces the data requirement for counterfactual analysis: I no longer need to know the levels of economic fundamentals such as the TFP or the non-tariff barriers, which are generally difficult to estimate.

In the second equality, I divide and multiply by domestic firms' expenditure share, π_{nmj}^s , which is known from the data. To express the ratio, $\frac{\pi_{nmj}^s}{\pi_{nmj}^s}$, in terms of the known variables, I manipulate the MNE sourcing shares expression as follows using Equation (6):

$$\frac{\pi_{nmj}^s}{\pi_{nmj}^s} = \frac{\frac{h_{mj}^s}{h_{nj}^s}}{\sum_{l=1}^N \pi_{nml}^s \frac{h_{ml}^s}{h_{nl}^s}}. \quad (12)$$

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

$$h_{nj}^s = \frac{\pi_{nmj}^s}{T_{nj}^s t_{nj}^s} \sum_{m=1}^N X_{nm}^s \frac{h_{mj}^s}{\sum_{l=1}^N \pi_{nml}^s \frac{h_{ml}^s}{h_{nl}^s}}. \quad (13)$$

With the backed-out MNE sourcing efficiencies and Equation (12), we can calculate the sourcing shares of any given MNE, π_{nmj}^s .

MNE selling efficiency is exactly backed out with the difference between domestic firms' shares of the host country's gross output and their shares of the host country's outward trade flows. Starting with domestic firms' output shares in Equation (5), I get:

$$\frac{1}{S_{n \cdot jj}^s} = \sum_{k=1}^N \frac{\left(\frac{\Theta_{jk}^s}{A_{jk}^s}\right)^{1-\zeta^s}}{\left(\frac{\Theta_{jj}^s}{A_{jj}^s}\right)^{1-\zeta^s}} \frac{H_{nk}^s}{H_{nj}^s}. \quad (14)$$

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

$$GO_{ji}^s = \sum_{n=1}^N T_{nj}^s S_{n \cdot ji}^s = \sum_{n=1}^N T_{nj}^s S_{n \cdot jj}^s \frac{S_{n \cdot ji}^s}{S_{n \cdot jj}^s} = \frac{\left(\frac{\Theta_{ji}^s}{A_{ji}^s}\right)^{1-\zeta^s}}{\left(\frac{\Theta_{jj}^s}{A_{jj}^s}\right)^{1-\zeta^s}} \sum_{n=1}^N T_{nj}^s S_{n \cdot jj}^s H_{ni}^s.$$

Here, the gross output of an MNE is equal to the sum of its sales to all markets. The MNE's sales to a destination are equal to the host country's total trade flow to that destination multiplied by the MNE's share of the trade flow. In the second equality I divide and multiply with domestic firms' output shares, $S_{n \cdot jj}^s$, which is known in the data. In the third equality I plug in the expression for MNE output shares, i.e., Equation (5). With this

I get:

$$\frac{\left(\frac{\Theta_{ji}^s}{A_{ji}^s}\right)^{1-\zeta^s}}{\left(\frac{\Theta_{jj}^s}{A_{jj}^s}\right)^{1-\zeta^s}} = \frac{GO_{ji}^s}{\sum_{p=1}^N T_{pj}^s S_{p \cdot jj}^s H_{pi}^s}. \quad (15)$$

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

$$H_{nj}^s = S_{n \cdot jj}^s \sum_{k=1}^N \frac{GO_{jk}^s}{\sum_{p=1}^N T_{pj}^s S_{p \cdot jj}^s \frac{H_{pk}^s}{H_{pj}^s}} H_{nk}^s. \quad (16)$$

With H_{ni}^s backed out, one may calculate the output shares of an arbitrary MNEs, $S_{n \cdot ji}^s$.³⁵

For each sector s , Equations (13) and (16) each have N^2 equations with N^2 unknowns—the MNE sourcing/selling efficiencies. Note in these equations h_{mj}^s 's and H_{ni}^s 's are identified up to a scale. Say $\{h_{mj}^s\}$ and $\{H_{ni}^s\}$ are a set of solutions to Equations (13) and (16). For any headquarters country m or i , if we multiply its sourcing or selling efficiencies with all countries by the same constant, the equations still hold. As a result, I normalize the sourcing and selling efficiency with the headquarter economy, h_{mm}^s and H_{ii}^s , to 1, which pins down the rest of the unknown parameters. Further note that 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.³⁶

Table A.10 shows that, for each sector and for the average of all sectors, the 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 the trader partner. These results are consistent with the empirical findings in Section 2.3.

I find that during the Great Recession, the MNE sourcing and selling shocks – year-on-year changes in the MNE sourcing and selling efficiencies \hat{h}_{mj}^s and \hat{H}_{ni}^s – are negatively correlated with the distance between the MNE headquarters and sourcing origin/selling destination (Columns 1 and 5 of Table 2). This shows that trade by MNEs with countries that are farther away from their headquarters was more adversely affected during the Great Recession. As a consequence, MNEs relied more on their headquarters as sourcing

³⁵Note that $S_{n \cdot ji}^s = S_{n \cdot jj}^s \frac{H_{ni}^s \left(\frac{\Theta_{ji}^s}{A_{ji}^s}\right)^{1-\zeta^s}}{H_{nj}^s \left(\frac{\Theta_{jj}^s}{A_{jj}^s}\right)^{1-\zeta^s}}$, where the ratio of factory gate prices is from Equation (15).

³⁶For each problem, I try different starting values and find they all converge to the same solution.

origins and exporting destinations. This suggests that, in addition to foreign investment (see, for example, [Alfaro et al. 2004](#) and [Forbes and Warnock 2012](#)), MNEs also retrenched sales to their headquarters during the Great Recession. I include the pre-Recession (year 2007) bilateral portfolio investment and trade between the headquarters and trade partners in Columns 2-4 for sourcing shocks and Columns 6-8 for selling shocks.³⁷ Consistent with [Alfaro and Chen \(2012\)](#), I find that strong pre-Recession linkages can alleviate the negative impact of the Great Recessions on international trade by MNEs. Even when other measures of linkages are included in the regression, the relationship with distance remains robust.

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*** (0.00479)	-0.0289*** (0.00483)	-0.0209*** (0.00553)	-0.0202*** (0.00554)	-0.0213*** (0.00520)	-0.0206*** (0.00525)	-0.0102* (0.00599)	-0.0100* (0.00600)
1 (legal)	0.0133*** (0.00516)	0.0119** (0.00519)	0.0114** (0.00519)	0.0103** (0.00521)	0.0102* (0.00545)	0.00958* (0.00549)	0.00822 (0.00547)	0.00790 (0.00550)
1 (contiguity)	0.0921*** (0.0125)	0.0929*** (0.0125)	0.0856*** (0.0126)	0.0868*** (0.0126)	0.0172 (0.0137)	0.0173 (0.0137)	0.00881 (0.0139)	0.00902 (0.0139)
1 (common lang.)	0.00978 (0.00966)	0.00829 (0.00967)	0.00706 (0.00968)	0.00598 (0.00969)	0.0423*** (0.0108)	0.0417*** (0.0108)	0.0394*** (0.0108)	0.0391*** (0.0108)
1 (trade agree.)	0.00160 (0.00882)	-0.000321 (0.00885)	-0.000615 (0.00884)	-0.00209 (0.00886)	0.0199** (0.00966)	0.0192** (0.00969)	0.0176* (0.00968)	0.0172* (0.00970)
log (Pre. Investment)		0.00108*** (0.000411)		0.000927** (0.000414)		0.000424 (0.000432)		0.000235 (0.000435)
log (Pre. Trade)			0.00960*** (0.00276)	0.00887*** (0.00277)			0.0107*** (0.00288)	0.0105*** (0.00290)
Observations	10,620	10,620	10,620	10,620	10,620	10,620	10,620	10,620
FE	ls,ls	ls,ls	ls,ls	ls,ls	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.

4.2 Estimate Trade and MNE Elasticities

Building on knowledge about the MNE sourcing and selling efficiencies, I take advantage of the market shares information and use variations in tariffs to estimate the trade and

³⁷I 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.

MNE elasticities. Start with a country's domestic firms' sourcing shares:

$$\pi_{nnj}^s = \frac{h_{nj}^s (P_{nj}^{s,p} k_{nj}^s t_{nj}^s)^{1-\sigma^s}}{(P_{nn}^s)^{1-\sigma^s}}. \quad (17)$$

On the right hand side, there is the MNE sourcing efficiency h_{nj}^s , tariff t_{nj}^s , the producer price index $P_{nj}^{s,p}$, and non-tariff barriers k_{nj}^s . The producer price is unknown. However, manipulating Equation (5), we may write it as a function of the factory gate price of domestic firms in the origin, $\frac{\Theta_{jj}^s}{A_{jj}^s}$, MNE selling efficiency H_{nj} , and the output share of domestic firms $S_{n,jj}^s$ in bilateral trade:

$$P_{nj}^{s,p} = \frac{\Theta_{jj}^s}{\underbrace{A_{jj}^s}_{B_j^s}} \left(\frac{S_{n,jj}^s}{\underbrace{H_{nj}^s}_{C_{nj}^s, \text{ adjusted output shares, data+model inversion}}} \right)^{\frac{1}{\zeta^s-1}}. \quad (18)$$

To collect notations I denote $B_j^s = \frac{\Theta_{jj}^s}{A_{jj}^s}$ and $C_{nj}^s = \frac{S_{n,jj}^s}{H_{nj}^s}$. I call C_{nj}^s the adjusted output share. C_{nj}^s is known because $S_{n,jj}^s$ is from data and H_{nj} is acquired in Section 4.1.

Plug Equation (18) into Equation (17) to eliminate the producer price:

$$\frac{\pi_{nnj}^s}{\underbrace{h_{nj}^s}_{D_{nj}^s, \text{ adjusted sourcing shares, data+calibration}}} = \frac{(C_{nj}^s)^{-\frac{\sigma^s-1}{\zeta^s-1}} (B_j^s k_{nj}^s t_{nj}^s)^{1-\sigma^s}}{(P_{nn}^s)^{1-\sigma^s}}. \quad (19)$$

The left-hand side is the sourcing share divided by the sourcing efficiency. To collect notations, I relabel the left-hand side D_{nj}^s and call it the adjusted sourcing shares. D_{nj}^s is known, with π_{nnj}^s from data and h_{nj}^s from model inversion. Equation (19) forms the basis of parameter estimation. The identification strategy for σ^s and ζ^s builds on [Head and Mayer \(2019\)](#). First, I assume k_{nj}^s takes the following form:

$$\log(k_{nj}^s) = \beta_1 \log(\text{dist}_{nj}) + \beta_2 \mathbf{1}(\text{contiguity}_{nj}) + \beta_3 \mathbf{1}(\text{common lang}_{nj}) + \beta_4 \mathbf{1}(\text{trade agreement}_{nj}) + FE_n^s + FE_j^s + \phi_{nj}^s. \quad (20)$$

The log of non-tariff barriers is assumed to be a linear function of log distances between: the importing and exporting countries; a dummy for whether the two countries share a border; a dummy for whether the two countries speak a common official language; and a dummy for whether the two countries sign a trade agreement. Additionally, origin and destination fixed effects are added to allow for [Vaugh \(2010\)](#)'s idea that rich and poor

countries face asymmetric trade costs. What cannot be controlled by the observables is left in the error term, ϕ_{nj}^s .

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

$$\begin{aligned} \log(D_{nj,t}^s) = & \frac{1-\sigma^s}{1-\zeta^s} \log(C_{nj,t}^s) + (1-\sigma^s) \log(t_{nj,t}^s) + \gamma_1^s \log(\text{dist})_{nj,t} + \gamma_2^s \mathbf{1}(\text{contiguity})_{nj,t} \\ & + \gamma_3^s \mathbf{1}(\text{common lang})_{nj,t} + \gamma_4^s \mathbf{1}(\text{trade agreement})_{nj,t} + FE_n^s + FE_j^s + FE_t^s + \epsilon_{nj,t}^s. \end{aligned} \quad (21)$$

Like [Head and Mayer \(2019\)](#), I assume tariff variation is not correlated with $\epsilon_{nj,t}^s$, which is the unobserved term in bilateral non-tariff frictions. Variation in tariffs is used to identify the trade elasticity, σ^s . Bilateral variation in adjusted output shares, $C_{nj,t}^s$, are used to identify $\frac{1-\sigma^s}{1-\zeta^s}$, which then gives ζ^s . I instrument $\log(C_{nj,t}^s)$ with the tariffs imposed on the destination n by the origin country j (in the reverse direction of the trade flow in the main regression) in its own, upstream and downstream sectors. Those instruments are relevant since n 's foreign affiliates in j import more from and export more to n than j 's domestic firms. A rise in the tariffs that j imposes on n raises the cost of n 's affiliates in j more than j 's domestic firms. This leads to a decline in n 's affiliates' shares in j and a rise in domestic firms' shares in the sales back to n . This, in turn, causes an increase in $\log(C_{nj,t}^s)$. Following [Acemoglu et al. \(2016\)](#), I use input-output shares to construct the upstream and downstream tariffs.³⁸

Table 3 shows that both trade elasticities and MNE elasticities are higher in the durable manufacturing sector than in the non-durable manufacturing and non-manufacturing sectors. Moreover, for all sectors, the trade elasticity is greater than the MNE elasticity - downstream MNEs' preferences for technologies are more heterogeneous than those of manufacturing countries (consistent with [Head and Mayer 2019](#)). These findings hold true regardless of how upstream and downstream tariffs are constructed (using 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).

³⁸See Section A.6 for more details.

Table 3: Estimated MNE and Trade Elasticities

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Durable Manufacturing	Non-durable Manufacturing	Non-manufacturing	Durable Manufacturing	Non-durable Manufacturing	Non-manufacturing
	Tariff Instruments with Direct Shares			Tariff Instruments with Total Shares		
$\log(C_{nj,t}^s)$	1.771* (1.100)	3.496*** (1.130)	2.717*** (0.454)	9.770*** (1.347)	6.048*** (2.244)	2.708*** (0.435)
$\log(n_{nj,t}^s)$	-3.475*** (0.559)	-2.020*** (0.398)	-1.464** (0.570)	-5.707*** (1.184)	-2.056*** (0.520)	-1.470*** (0.564)
$\log(\text{dist}_{nj,t})$	-1.043*** (0.0184)	-0.989*** (0.0120)	-1.301*** (0.0129)	-1.158*** (0.0299)	-0.974*** (0.0184)	-1.300*** (0.0128)
$1(\text{legal}_{nj,t})$	0.147*** (0.0236)	0.142*** (0.0121)	0.0616*** (0.0143)	0.299*** (0.0369)	0.147*** (0.0162)	0.0616*** (0.0143)
$1(\text{common lang}_{nj,t})$	0.332*** (0.0308)	0.266*** (0.0238)	0.0808*** (0.0270)	0.168*** (0.0573)	0.248*** (0.0334)	0.0808*** (0.0270)
$1(\text{contiguity}_{nj,t})$	0.154*** (0.0404)	0.286*** (0.0305)	0.665*** (0.0421)	-0.0558 (0.0765)	0.295*** (0.0402)	0.664*** (0.0417)
$1(\text{trade agree}_{nj,t})$	0.319*** (0.0182)	0.314*** (0.0197)	0.319*** (0.0227)	0.353*** (0.0426)	0.326*** (0.0271)	0.319*** (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.

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

A foreign affiliate's productivity relative to that of domestic firms in the same host country is equal to its relative price of input divided by its relative price of output:

$$\frac{A_{ji}^s}{A_{jj}^s} = \frac{\Theta_{ji}^s}{\Theta_{jj}^s} \bigg/ \frac{\frac{\Theta_{ji}^s}{A_{jj}^s}}{\frac{\Theta_{jj}^s}{A_{jj}^s}}. \quad (22)$$

In Section B.3, I show how I compute these relative prices with data on MNE gross output, trade flows, market shares, and the MNE sourcing and selling efficiencies that I backed out. Then I compute the year-on-year changes in MNE relative productivity, $\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}$. These are the MNE relative productivity shocks.

Table A.11 shows, by sector, the correlations between an MNE's productivity relative to domestic firms in the host country and gravity variables. It shows that (other things constant) multinational production involves a productivity loss and such loss increases in the distance between the headquarters and host countries.

During the Great Recession, MNE relative productivity shocks were also negatively correlated with the distance between the headquarters and the host country, as demonstrated by Table 4, similar to the patterns of MNE sourcing and selling shocks documented in Table 2. Columns 2-4 show that pre-Recession investment and trade flows were positively correlated with MNE relative productivity shocks (consistent with Alfaro and Chen

2012). This suggests that the MNEs that had a close proximity to their headquarters in terms of distance, investment, and trade were more resilient during the Great Recession.

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*** (0.00794)	-0.0326*** (0.00803)	-0.0199** (0.00923)	-0.0185** (0.00925)	-0.0841*** (0.0199)	-0.0828*** (0.0201)	-0.0406* (0.0231)	-0.0406* (0.0231)
1 (legal)	-0.000502 (0.00862)	-0.00288 (0.00867)	-0.00308 (0.00865)	-0.00491 (0.00869)	0.0133 (0.0213)	0.0122 (0.0214)	0.00560 (0.0214)	0.00557 (0.0215)
1 (contiguity)	-0.0158 (0.0209)	-0.0145 (0.0209)	-0.0260 (0.0211)	-0.0241 (0.0212)	0.0104 (0.0528)	0.0110 (0.0528)	-0.0186 (0.0533)	-0.0186 (0.0534)
1 (common lang.)	-0.0247 (0.0160)	-0.0270* (0.0160)	-0.0296* (0.0160)	-0.0312* (0.0161)	-0.0239 (0.0402)	-0.0250 (0.0402)	-0.0377 (0.0403)	-0.0378 (0.0404)
1 (trade agree.)	-0.0276* (0.0147)	-0.0305** (0.0147)	-0.0312** (0.0147)	-0.0333** (0.0147)	0.00286 (0.0369)	0.00151 (0.0370)	-0.00690 (0.0370)	-0.00694 (0.0371)
log (Pre. Investment)		0.00169** (0.000686)		0.00144** (0.000691)		0.000792 (0.00171)		2.14e-05 (0.00172)
log (Pre. Trade)			0.0152*** (0.00457)	0.0141*** (0.00461)			0.0425*** (0.0114)	0.0425*** (0.0115)
Observations	10,620	10,620	10,620	10,620	10,620	10,620	10,620	10,620
FE	ls,ls	ls,ls	ls,ls	ls,ls	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:

$$\frac{\pi_{nnj}^s}{\pi_{jjj}^s} = \frac{h_{nj}^s}{h_{jj}^s} \left(\frac{t_{nj}^s k_{nj}^s P_{nj}^{s,p}}{t_{jj}^s k_{jj}^s P_{jj}^{s,p}} \right)^{1-\sigma^s} \frac{1}{\sum_{p=1}^N \pi_{jjp}^s \frac{h_{np}^s}{h_{jp}^s} \left(\frac{t_{np}^s k_{np}^s P_{np}^{s,p}}{t_{jp}^s k_{jp}^s P_{jp}^{s,p}} \right)^{1-\sigma^s}}.$$

By plugging in the expression for producer price indices, $\frac{P_{nj}^{s,p}}{P_{jj}^{s,p}} = \frac{\left(\frac{H_{nj}}{S_{n \cdot jj}^s} \right)^{\frac{1}{1-\zeta^s}}}{\left(\frac{H_{jj}}{S_{j \cdot jj}^s} \right)^{\frac{1}{1-\zeta^s}}}$, and by guessing and verifying, I am able to obtain:

$$k_{nj}^s = \left(\frac{\pi_{nnj}^s}{\pi_{jjj}^s} \frac{h_{jj}^s}{h_{nj}^s} \right)^{\frac{1}{1-\sigma^s}} \frac{\left(\frac{H_{jj}}{S_{j \cdot jj}^s} \right)^{\frac{1}{1-\zeta^s}} t_{jj}^s}{\left(\frac{H_{nj}}{S_{n \cdot jj}^s} \right)^{\frac{1}{1-\zeta^s}} t_{nj}^s},$$

which is a function of known variables only. Therefore, shocks to trade costs are the year-on-year changes of k_{nj}^s .

I back out the domestic productivity shocks by solving a system of equations involving the shock itself 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:

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

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. By using this system of equations, I am able to solve \hat{A}_{jj}^s and \hat{P}_{jj}^s iteratively.³⁹

4.4 Estimate Headquarters' Share in MNE Productivity

I estimate, by sector, how headquarters contribute to MNE productivity. Studies such as Cravino and Levchenko (2017), Alvarez et al. (2020), and Bilir and Morales (2020) have found that productivity shocks at the headquarters affect an MNE's productivity. Hence, MNEs can propagate productivity shocks from the headquarters to host countries.

Following this literature, I assume MNE's productivity is Cobb-Douglas in the headquarters' productivity and the host country's productivity (multiplied by a country-bilateral term). As a result, MNE's productivity relative to domestic firms can be written as:

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

As I have known the values of MNE relative productivity shocks and domestic productivity shocks in both countries, I am able to run the following regression in order to identify ϕ^s – the headquarters' share of MNE productivity:

$$\log \left(\frac{\hat{A}_{ji,t}^s}{\hat{A}_{jj,t}^s} \right) = \phi^s \log \left(\frac{\hat{A}_{ii,t}^s}{\hat{A}_{jj,t}^s} \right) + FE_j^s + FE_i^s + \epsilon_{ji,t}^s. \quad (23)$$

As shown in Table 5, headquarters account for 37%, 6%, and 32% of an MNE's productivity in durable manufacturing, non-durable manufacturing, and non-manufacturing, respectively. Regardless of whether the fixed effects are included (Columns 1-3) or not (Columns 4-6), these results are robust.

³⁹See details in Section B.4.

Table 5: Estimated Headquarters' Share in MNE Productivity

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Durable Manufacturing	Non-durable Manufacturing	Non-manufacturing	Durable Manufacturing	Non-durable Manufacturing	Non-manufacturing
	HQ fixed effect, host country fixed effect			OLS		
$\log(\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s})$	0.372*** (0.00883)	0.0641*** (0.00168)	0.316*** (0.00996)	0.367*** (0.00864)	0.0640*** (0.00168)	0.312*** (0.00975)
Observations	39,600	39,600	39,600	39,600	39,600	39,600
FE	ji	ji	ji	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.

In Table A.14, I find that the shock to MNE productivity (derived by multiplying the host country's domestic productivity shock with the MNE relative productivity shock: $\hat{A}_{ji}^s = \hat{A}_{jj}^s \frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}$) is correlated with the domestic productivity shocks of both the headquarters and the host country. In this specification, I also find that the headquarters' contribution to MNE productivity is the smallest in the non-durable manufacturing sector (with or without fixed effect controls). Figure A.3 plots the correlations between the MNE productivity shocks and the domestic productivity shocks in the headquarters/host countries with bin scatter plots.

4.5 Estimate Final Demand Elasticities

I estimate the elasticity of substitution across MNE-specific composite goods in sectoral final demand with the following regression, which is the log change of Equation (8):

$$\log(\hat{\delta}_{nm,t}^s) = \tilde{\delta}^s \log(\hat{P}_{nm,t}^s) + FE_{n,t}^s + \epsilon_{nm,t}^s, \quad (24)$$

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

$$Instrument_{nm}^s = \frac{GO_{nm}^s}{\sum_{m=1}^N GO_{nm}^s} \hat{A}_{mm}^s.$$

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.

Column 1-4 of Table 6 show that the final demand elasticity for MNEs equals 3.167 for durable manufacturing, 2.170 for non-durable manufacturing, and 1.819 for non-manufacturing. The average across all sectors equals 2.479. Column 5-9 show that these estimates are robust to alternative fixed effect controls.

With the normalization that $\hat{\alpha}_{nm}^s = 1$, I back out the final demand shocks for MNE-

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

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Durable Manufacturing	Non-durable Manufacturing	Non-Manufacturing	All	Durable Manufacturing	Non-durable Manufacturing	Non-Manufacturing	All
log_p_nm	-2.167*** (0.388)	-1.170** (0.513)	-0.819** (0.414)	-1.479*** (0.273)	-3.280*** (0.520)	-1.425*** (0.473)	-0.874* (0.500)	-1.941*** (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.

specific composite goods:

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

Columns 5-8 of Table 4 show that during the Great Recession, a country's preference for a foreign MNE in final demand also decreased in the distance between this country and the foreign headquarters. However, such preference was strengthened by pre-Recession trade linkages between the two countries.

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

$$\log(s_{n,t}^s) = \tilde{\lambda} \log(P_{n,t}^s) + \Phi_{n,t} + \epsilon_{n,t}^s. \quad (25)$$

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

$$Instrument_n^s = \sum_{m \neq n} \frac{GO_{nm}^s}{\sum_{m=1}^N GO_{nm}^s} \hat{A}_{mm}^s.$$

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

With the normalization that $\hat{\alpha}_n^s = 1$ for the non-manufacturing sector, we back out the

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

VARIABLES	(1)	(2)	(3)	(4)
$\log(P_{n,t}^s)$	-0.582* (0.339)	-0.447** (0.216)	-4.746 (13.06)	0.0248*** (0.00920)
Observations	1,980	1,980	1,980	1,980
FE	nt	nt, s	NA	nt
Instrument	MNE productivity	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.

sectoral final demand shocks for other sectors:

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

In sum, in this section I discussed the procedures to back out the shocks in the model. I plot their distributions in Figure A.2. Table 8 shows that these shocks include MNE specific shocks (MNE relative productivity shocks, MNE final demand shocks, as well as MNE sourcing and selling shocks), traditional supply and demand shocks that were considered in the trade collapse literature – domestic productivity shocks and sectoral final demand shocks, as well as shocks to 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

Table 8: Categories of Shocks

	MNE-specific Shocks	Traditional Supply and Demand Shocks	Other Shocks
Supply Shocks	MNE Relative Productivity Shocks	Domestic Productivity Shocks	
Demand Shocks	MNE Final Demand Shocks	Sectoral Final Demand Shocks	
Other Shocks	MNE Sourcing Shocks MNE Selling Shocks		Trade Cost Shocks Labor Endowment Shocks Trade Deficit Shocks

Description: This table presents the shocks examined in the model and whether they belong to supply or demand shocks.

⁴⁰Based on this literature, these other shocks did not play a significant role in the global trade collapse. See, for example, Eaton et al. (2016).

⁴¹Other shocks, such as shocks to the trade cost or MNE’s sourcing and selling efficiencies, affect both supply and demand in this economy. Hence, I am not able to classify them as either supply or demand shock.

5 Simulations

In this section, I study the impact of MP on the global trade collapse and propagation of shocks. First, I examine the importance of different types of shocks. Next, I investigate how shocks propagated across countries.

5.1 Importance of Shocks

5.1.1 Global Trade and MP Collapse

Figure 4 shows the impact of different groups of shocks.⁴² During the Great Recession, sectoral final demand shocks, domestic productivity shocks, and MNE-specific shocks contributed 1.61 percentage points (40%), 1.09 percentage points (27%), and 0.39 percentage points (10%) of the global trade collapse.⁴³ Meanwhile, sectoral final demand shocks, domestic productivity shocks, and MNE-specific shocks contributed 0.40 percentage points (20%), 0.64 percentage points (33%), and 0.53 percentage points (27%) of the global MP collapse (Table 9).⁴⁴ Therefore, shocks that were important for the collapse of global trade also had a substantial impact on the collapse of MP, and vice versa.

Taking into account the role of MNEs in trade, supply shocks contributed to the collapse of global trade almost as much (36%) as demand shocks (38%). The reason is that MNE-specific shocks primarily affected supply rather than demand. On the other hand, the collapse of global MP was more caused by supply shocks than by demand shocks.

Table 9: Impact of Shocks on Global Trade Collapse and Global MP Collapse

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 presents the impact of different kinds of 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.

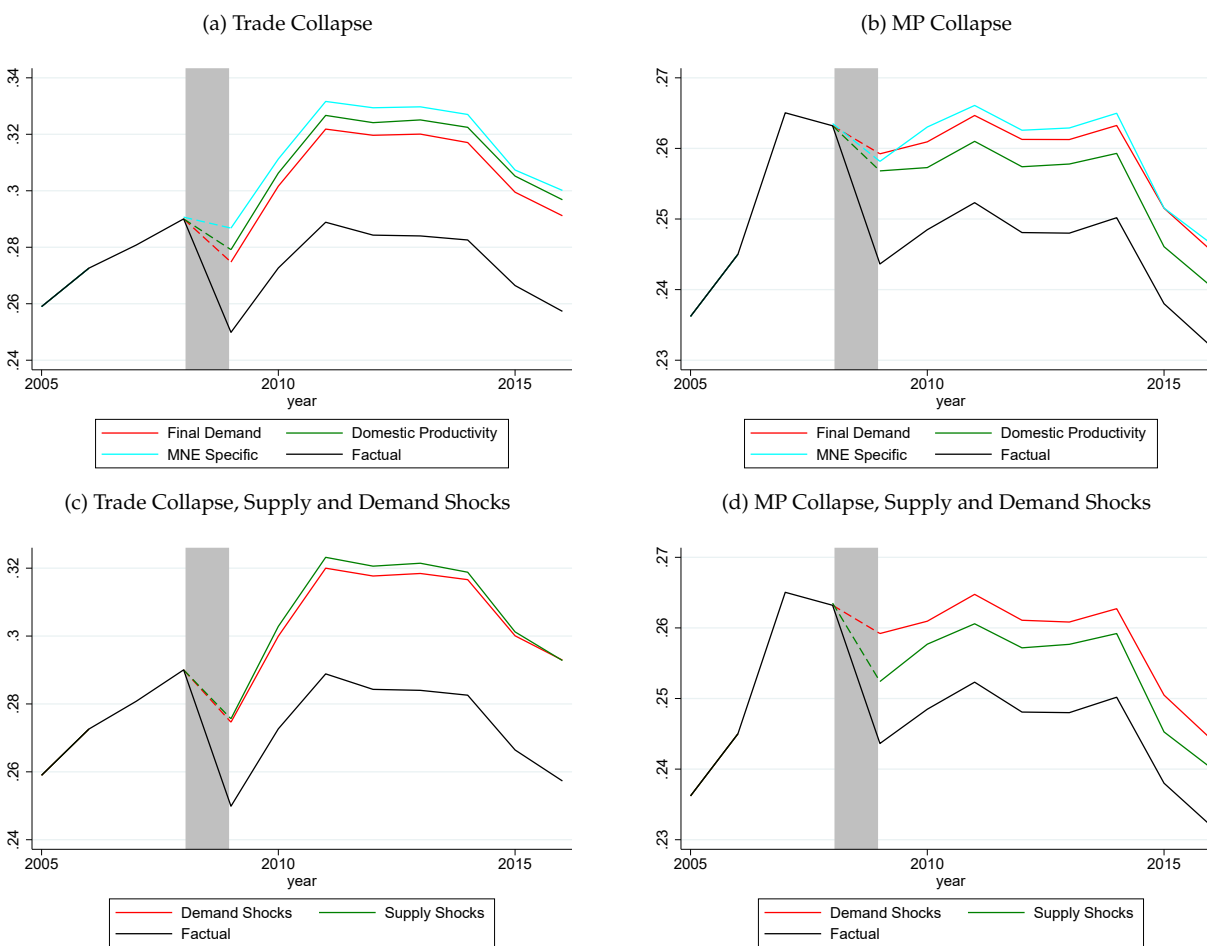
⁴²Dashed line segments indicate the impact of individual shock groups. Line segments after 2009 indicate counterfactual outcomes that start with counterfactual market shares (as a result of individual shock groups) and are influenced by actual shocks.

⁴³The global trade collapse is measured with the change in world trade to world GDP ratio.

⁴⁴The global MP collapse is measured with the change in world MP (sales by MNE foreign affiliates) to world GDP ratio.

A model without MNEs would incorrectly conclude that final demand shocks were responsible for half of the global trade collapse and contributed much more than supply shocks. Ignoring the role of MNEs in trade results in the impact of MNE-specific shocks on the global trade collapse being misinterpreted as the impact of final demand shocks (see Table A.15 and Figure A.4).⁴⁵

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



Description: These figures plot the impact of different kinds of 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.

Among the MNE-specific shocks I studied, MNE relative productivity shocks contributed the most to the collapse of both global trade and MP. MNE relative productivity shocks, MNE final demand shocks, and sourcing shocks all contributed to the global trade collapse by 1.19 percentage points (30%), 0.97 percentage points (24%), and 0.54 percentage points (13%) respectively. MNE relative productivity shocks also explained

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

0.35 percentage points (18%) of the global MP collapse (see Table A.16 and Figure A.5). The MNE-specific shocks that contributed to the collapse of global trade and MP were primarily caused by shocks to MNE relative productivity, and therefore had the greater effect on the supply side rather than demand side.

In a model where MNEs did not have a comparative advantage at sourcing and selling internationally, MNE-specific shocks did not significantly impact the global trade collapse. As a result of such a model, world trade would be increased by 0.07 percent in relation to world GDP due to MNE-specific shocks (see Table A.17 and Figure A.6).⁴⁶ This suggests that the high trade intensity of MNEs drove the simultaneous global trade and MP collapse.

5.1.2 Cross-country Variation

I investigate the impact of shocks on the cross-country variation of the collapse of trade, MP, and welfare changes during the Great Recession. Since I show in Section 2.2 that the MP collapse was heterogeneous across countries, it is important to understand why some countries performed better than others and what shocks contributed to these differences. In addition, this analysis provides insight into how shocks propagated across countries, which cannot be assessed based only on global totals. I build on the method used by Klenow and Rodriguez-Clare (1997), Alvarez et al. (2020), among others. Use $\log(\hat{y}_i)$ to denote the log change in country i 's variable of interest in the data, and $\log(\hat{x}_i)$ to denote the model counterpart from counterfactual simulation with a group of shocks. The following accounting identity holds:

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

where z_i denotes the contribution by other shocks. The fraction of cross-country variation in the variable of interest that can be explained by the shocks can be measured with:

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

This exactly equals the slope coefficient of regressing the counterfactual on the data.

Figure 5 shows that MNE-specific shocks contributed a significant share – 22% in terms of cross-country variation (see Table 10) – to the collapse of trade. They also ac-

⁴⁶In this model I set the sourcing and selling efficiencies with non-headquarters countries all to one: $h_{mj}^s \equiv H_{ni}^s \equiv 1$, 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.

counted for 70% of the variation across countries in the MP collapse. Additionally, it explained 12% of the variation in welfare across countries. MNE-specific shocks were the primary factor contributing to MP collapse heterogeneity across countries, and MP and trade collapses were positively correlated across countries, indicating that MNE-specific shocks contributed significantly to cross-country differences in trade collapses. Table A.18 shows that, in the model without MP, neither the domestic productivity shocks nor the final demand shocks were capable of absorbing the impact of MNE-specific shocks on the variations in the trade collapse across countries.

Although final demand shocks contributed most to the global total trade decline, they were not the primary source of heterogeneity in performances across countries. Domestic productivity shocks contributed 30% to the cross-country variation in the trade collapse. In contrast, the contribution by final demand shocks was limited, explaining only 2% of cross-country variation in the trade collapse. Consequently, supply shocks contributed more to these cross-country variations than demand shocks.

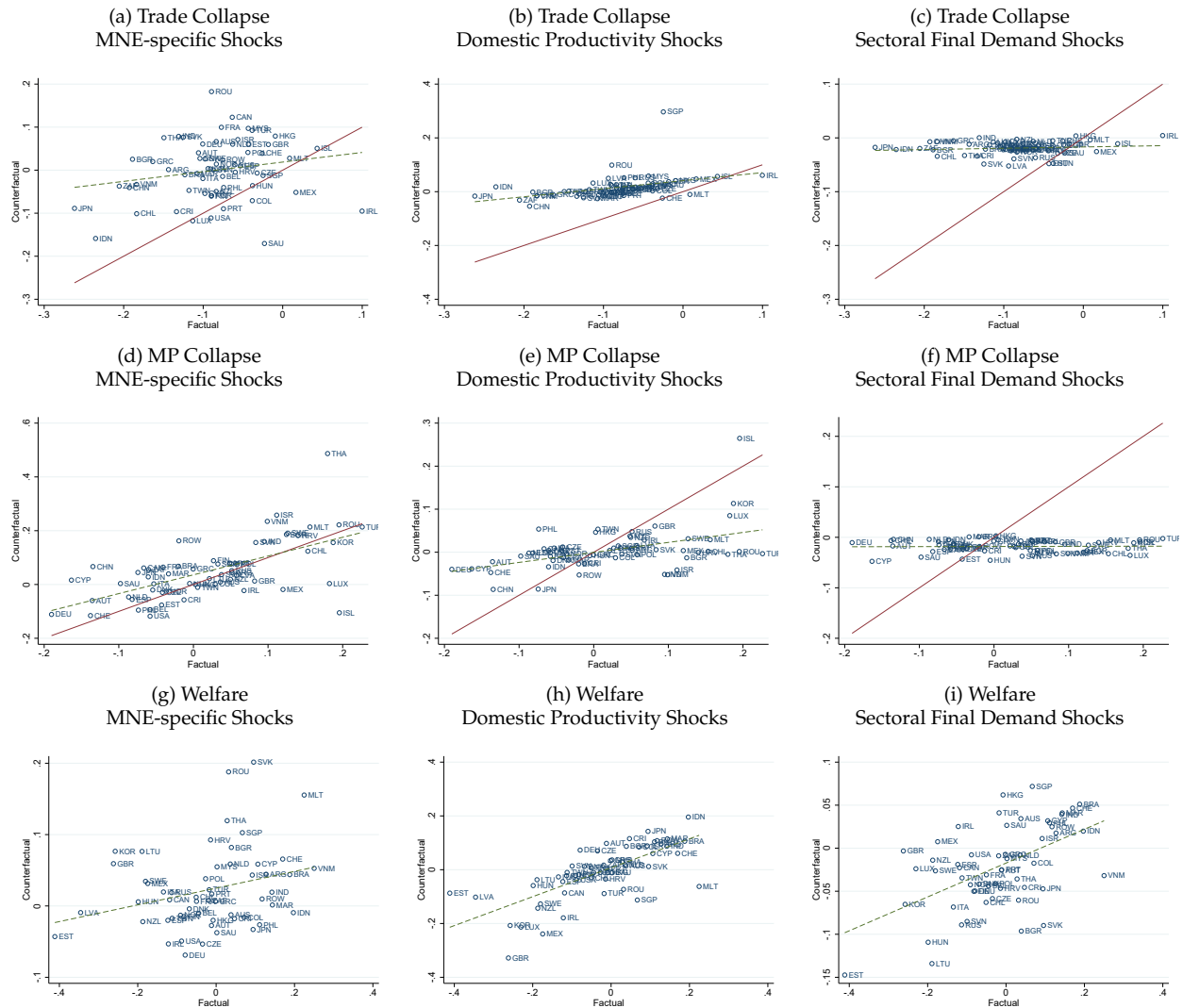
Table 10: Impact of Shocks on Cross-country Variations in Trade collapse, MP collapse, and Welfare

Shocks	Trade Collapse (1)	MP Collapse (2)	Welfare (3)
MNE-specific Shocks	22.42%	69.82%	11.72%
Domestic Productivity Shocks	29.89%	23.23%	53.75%
Final Demand Shocks	2.44%	0.27%	19.66%
Supply Shocks	20.90%	73.30%	58.31%
Demand Shocks	8.25%	9.14%	27.76%
All Shocks	100.00%	100.00%	100.00%

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. 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.20 shows that, in a model that does not having sourcing and selling frictions facing MNEs, MNE-specific shocks was not able to explain the cross-country variation in the trade collapse (explaining -0.4%). Consequently, this confirms the findings in Section 5.1.1 concerning the global trade collapse, and once again implies that the high trade intensity of MNEs were the primary cause of why shocks to them affected the collapse of trade.

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



Description: These figures plot 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. 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 regression line. The red line indicates the 45-degree line.

5.1.3 Impact of Shocks in Other Periods

After the Great Recession, global trade recovered. In 2010, the ratio of global trade to global GDP returned to 0.29 from 0.25 in 2009. Table A.21 and Figure A.8 show that MNE-specific shocks were the main source of this recovery. In contrast, neither the domestic productivity shocks nor the final demand shocks contributed significantly to the recovery of trade. MNE-specific shocks alone would also restore the MP-to-GDP ratio to its pre-Recession level. However, domestic productivity shocks and final demand shocks did

not contribute to the recovery, and in fact, reduced global MP as a percentage of GDP. As a result, global MP did not recover to its pre-Recession level.

These findings suggest (in accordance with the decomposition results in Table A.3) that after the Great Recession, MP recovered relative to GDP in an average country.⁴⁷ This helped the rebound of trade. However, due to the sluggish economic recovery in many countries that were MP intensive (particularly in European countries), MP never returned to the pre-Recession level.⁴⁸

From 2013 onwards, both world trade and MP declined in relation to GDP again. Table A.4 and Figure A.9 show that all shocks contributed to these declines and there was no a single shock that played the major role (consistent with the decomposition findings in Table A.4).⁴⁹ This period was characterized by a lack of growth in the euro-zone, a crisis in emerging market economies like Brazil and Russia, as well as weak demand for global commodities.⁵⁰ Furthermore, for an average country, MNEs performed worse than domestic firms. All these factors contributed to the declines in both trade and MP.

5.2 Propagation of Shocks

I study how MP linkages amplified the impact of domestic productivity shocks in MP headquarters on the trade and MP collapses. Additionally, I examine how shocks that affected the top global MP headquarters influenced other countries through MP and trade.

5.2.1 Propagation of Domestic Productivity Shocks through MP

Domestic productivity shocks in headquarters countries affect the productivity of an MNE headquartered there compared to the MNE's host country's domestic firms (see Section 4.4). In this regard, and due to the propagation effect, domestic productivity shocks contributed to the shocks specific to MNEs. Since I document in Section 5.1 that MNE-specific shocks contributed significantly to the collapses of trade, MP, and welfare, in this section I study how such propagation effect increased the impact of domestic productivity shocks.

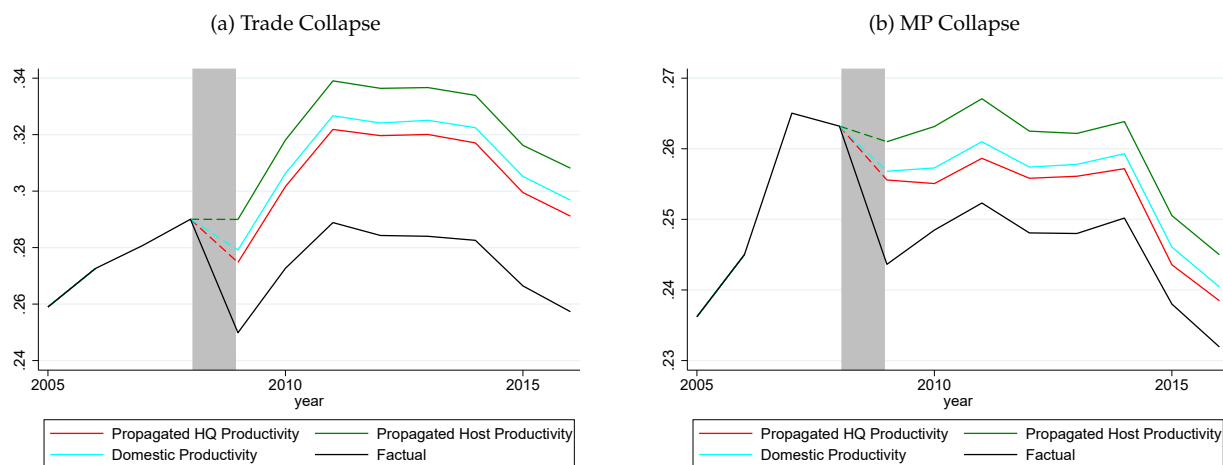
⁴⁷Table A.23 shows the impact of shocks on the cross-country variations in trade, MP, and welfare changes from 2009 to 2010.

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

⁴⁹Table A.24 shows the impact of shocks on the cross-country variations in trade, MP, and welfare changes from 2013 to 2016.

⁵⁰See, for example, Constantinescu et al. (2016).

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



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 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 6 and Table A.25 show 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% to 1.53 percentage points or 38%). 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 that headquartered in these countries. The propagation effect intensified the effects of domestic productivity shocks on the collapse of trade since the important MP headquarters were also those that were negatively affected by these shocks. 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% to 0.76 percentage points or 39%).

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 12%, 84%, and 45% (Table 11 and Figure A.10). 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 these impacts 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	33.49%	42.80%	82.69%
Propagation through Host Countries	12.81%	16.30%	24.73%
Domestic Productivity Shocks	29.89%	23.23%	57.01%

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 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).

5.2.2 MNE-specific Shocks in the Top Headquarters

I investigate whether shocks spread more widely through MP than through international trade. As such, I study the impact of MNE-specific shocks that affected the top headquarters on the rest of the global economy. As a comparison, I also investigate the domestic productivity shocks that affected the top exporters and the sectoral final demand shocks in the top importers.

Table 12 and Figure A.11 show that the MNE-specific shocks in the top ten global headquarters of MP contributed 30% of the variation in MP collapse and 8% of the variation in welfare changes across the other fifty countries.⁵¹ MNE-specific shocks in the top ten host countries explained, in terms of cross-country variation, 9% of the variation of the MP collapse and 2% of the welfare changes. In contrast, neither did the domestic productivity shocks in the top ten exporters nor did the sectoral final demand shocks in the top ten importers significantly affect the trade collapse, MP collapse, or welfare in other countries.⁵²

⁵¹Table 10 shows that all MNE-specific shocks contributed 12%.

⁵²As 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.

These findings suggest that, through MP, shocks spread more widely than through international trade. In the case of MP, the collapse was concentrated in a few countries – the major global headquarters – and the shocks that affected these countries had a significant effect on the rest of the world. Countries that do not supply a large amount of outward MP, such as China and India, may receive a large amount of inward MP from major MP headquarters, such as the United States. As a result, these inward MP activities and the welfare of the host country are subject to shocks specific to MNEs in the important headquarters. Contrary to this, almost all countries experienced a collapse in trade. As imports and exports are largely balanced for each country, it is likely that countries that do not export or import a great deal will also not import or export a lot. In order to rationalize such global collapse of trade, shocks that affected almost all countries were necessary, since shocks that affected the top global exporters and importers were unlikely to affect countries that traded less.

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)
Top 10 Headquarters	29.69%	4.43%	8.43%
Top 10 Host Countries	8.84%	2.12%	2.32%
Domestic Productivity Shocks in Top 10 Exporters	1.91%	-1.00%	0.05%
Final Demand Shocks in Top 10 Importers	0.13%	-1.71%	0.10%

Description: This table presents 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).

5.2.3 Propagation of Domestic Productivity Shocks in the Top Headquarters

Despite the fact that domestic productivity shocks in a subset of countries didn’t significantly affect the rest of the world if they propagated through only trade, they could have a significant impact on the trade and welfare of other countries if they propagated through MP headquarters linkages. Figure 7 and Table A.28 show that, if domestic productivity shocks in the top ten global headquarters propagated through their headquarters linkages, they lead to significant cross-country variation (17% of the factual level) in the collapse of trade. These propagated shocks also explained 6% and 4% of the cross-country variation in the MP collapse and welfare changes.

In contrast, the domestic productivity shocks in the top host countries did not signifi-

cantly affected the other countries even if they propagated through MP host country linkages (consistent with findings in Section 5.2.1). Similar to what I have found in Section 5.2.2, if these domestic productivity shocks in the top headquarters and host countries did not propagate through MP (i.e., they propagated through only trade), they did not significantly affect the trade collapse, MP collapse, or welfare in other countries.

6 Conclusion

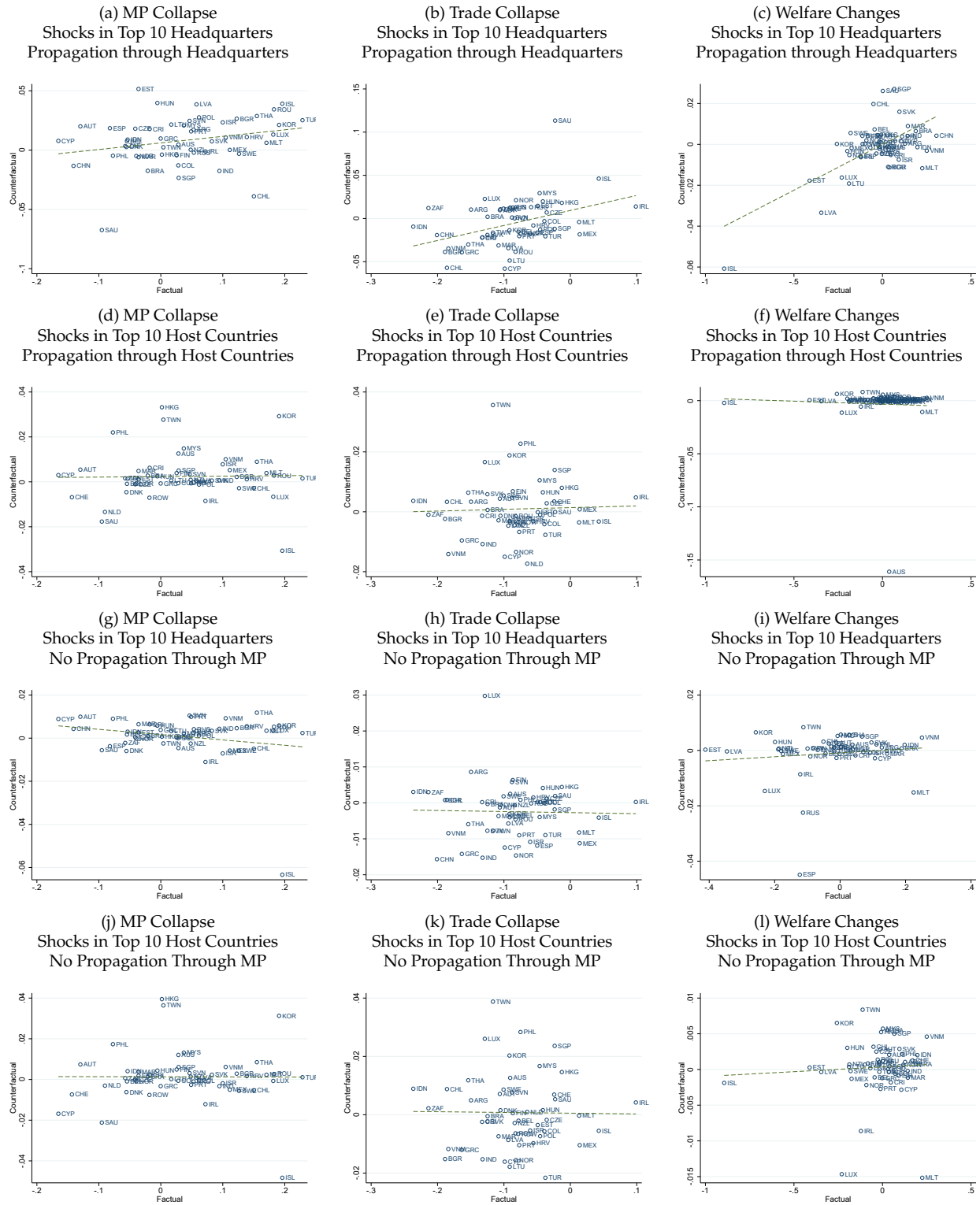
In this paper, I demonstrate that shocks to MNEs accounted for a significant share of the collapse of trade during the Great Recession, both in terms of global totals and cross-country variations. The linkages between MP headquarters and the rest of the world significantly amplified the impact of the shocks in these headquarters on the rest of the world, in terms of the trade and MP collapses and welfare.

I start with resolving the “Multinationals’ Resilience Puzzle”. Using a within-country-between-country decomposition, I find that while for an average country (and average country-sector) MNEs were more resilient than GDP, MP declined more in larger countries and GDP declined more in MP intensive countries. These heterogeneities across countries lead to the global collapse of MP. Furthermore, I document that MNEs are more intensive in the durable manufacturing sector and in international trade, and that they import and export more with their headquarters and countries that are close to their headquarters.

To disentangle the mechanisms, I build a model of the global economy that takes into consideration trade, MP, sectoral input-output linkages. I account for the additional barriers that MNEs face when sourcing from and selling to non-headquarters countries. This innovation, in addition to the nesting structure of the MNE’s sourcing problem, allows the model to match exactly to the OECD AAMNE Database and replicate the empirical facts. I introduce new methods of estimating the model’s elasticities, including the trade elasticities, the MNE elasticities, the substitution elasticities across sectors and across MNEs in final consumption, and the headquarters’ shares of productivity within an MNE.

Simulating the model, I find that shocks that are specific to MNEs contributed significantly to the collapse of trade. Thus, supply-side productivity shocks contributed almost as much to the global trade collapse as demand shocks. By ignoring MP, researchers may misinterpret shocks to MNEs as shocks to final demand and exaggerate the impact of demand side forces. Additionally, I demonstrate that high trade intensity of MNEs was the primary reason why shocks to MNEs affected the trade collapse.

Figure 7: Propagation of Domestic Productivity Shocks in Top Headquarters and Host Countries: Cross-country Variations in Trade Collapse, MP Collapse, and Welfare across Other Countries



Description: These figures plot 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). The green dashed line indicates the fitted line of regressing the impact of propagated domestic productivity shocks on actual changes. The red 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.

I find that MP headquarters linkages substantially increased the impact of shocks in the headquarters countries on the global economy. The impact of domestic productivity shocks increased if such shocks also affected the countries' MNEs in other countries. MNE-specific shocks in the top headquarters countries significantly affected other countries, while neither domestic productivity shocks in the top exporters nor final demand shocks in the top importers did. If, however, domestic productivity shocks in the top headquarters countries propagated through MP headquarters links, then those shocks had a substantial impact on trade collapse and welfare in other countries.

This framework gives us insights about the role that international trade by MNEs plays in propagating shocks across countries and sectors, which has implications for countries' welfare. When a country's policy makers monitor external shocks, they should also monitor shocks that hit foreign headquarters with substantial MP activities in the local economy. During the Great Recession, these shocks were more important for domestic welfare than shocks to trade. FDI/MP-friendly policies should be considered an important policy instrument that promotes trade. These policies are useful today, particularly given the intensifying tariffs wars between countries. Ignoring the MP margin will lead to misunderstanding of the sources of welfare changes and, thus, incorrect policies.

Other than the Great Recession, this framework has interesting applications to other policy contexts featuring strong adjustments in both margins of openness. There are numerous examples, such as the trade and technology wars between the United States and China, the lockdown of important headquarters and host countries during the COVID crisis, and the signing and exiting of 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.

A.1 Other Decomposition Results

Table A.3: 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	0.008 (165.5%)	-0.006 (-115.4%)	0.002 (49.8%)	0.00 (100%)
Trade	-0.006 (-26.8%)	0.000 (0.5%)	0.029 (126.3%)	0.02 (100%)
A. Durable Manufacturing				
MP	-0.048 (288.4%)	-0.012 (74.3%)	0.044 (-262.7%)	-0.02 (100%)
Trade	0.007 (10.5%)	-0.005 (-8.5%)	0.062 (98.0%)	0.06 (100%)
B. Non-durable Manufacturing				
MP	0.022 (276.6%)	-0.018 (-227.5%)	0.004 (50.9%)	0.01 (100%)
Trade	-0.015 (-42.9%)	-0.007 (-19.7%)	0.058 (162.6%)	0.04 (100%)
C. Non-manufacturing				
MP	0.010 (280.1%)	-0.004 (-119.9%)	-0.002 (-60.2%)	0.00 (100%)
Trade	-0.004 (-33.7%)	0.000 (1.5%)	0.016 (132.2%)	0.01 (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.4: 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%)	-0.02 (100%)
Trade	-0.015 (57.4%)	-0.005 (17.3%)	-0.007 (25.3%)	-0.03 (100%)
A. Durable Manufacturing				
MP	-0.039 (-295.1%)	-0.016 (-121.6%)	0.069 (516.7%)	0.01 (100%)
Trade	-0.068 (174.6%)	-0.015 (37.5%)	0.043 (-112.1%)	-0.04 (100%)
B. Non-durable Manufacturing				
MP	-0.019 (66.8%)	-0.025 (87.2%)	0.015 (-54.1%)	-0.03 (100%)
Trade	-0.035 (98.0%)	-0.022 (61.5%)	0.021 (-59.5%)	-0.04 (100%)
C. Non-manufacturing				
MP	-0.004 (21.9%)	-0.004 (21.5%)	-0.011 (56.7%)	-0.02 (100%)
Trade	-0.007 (26.4%)	-0.004 (16.3%)	-0.015 (57.2%)	-0.03 (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.

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:

$$\begin{aligned}
& \frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}} = \frac{\sum_{s=1}^S MP_{i,2009}^s}{\sum_{s=1}^S GDP_{i,2009}^s} - \frac{\sum_{s=1}^S MP_{i,2008}^s}{\sum_{s=1}^S GDP_{i,2008}^s} \\
& S \text{cov}_s \left(\underbrace{\frac{MP_{i,2009}^s}{GDP_{i,2009}^s} - \frac{MP_{i,2008}^s}{GDP_{i,2008}^s}}_{\text{C.1}}, \underbrace{\frac{\frac{GDP_{i,2009}^s}{\sum_{s=1}^S GDP_{i,2009}^s} + \frac{GDP_{i,2008}^s}{\sum_{s=1}^S GDP_{i,2008}^s}}{2}}_{\text{C.2}} \right) + S \text{cov}_s \left(\underbrace{\frac{GDP_{i,2009}^s}{\sum_{s=1}^S GDP_{i,2009}^s} - \frac{GDP_{i,2008}^s}{\sum_{s=1}^S GDP_{i,2008}^s}}_{\text{C.2}}, \underbrace{\frac{\frac{MP_{i,2009}^s}{GDP_{i,2009}^s} + \frac{MP_{i,2008}^s}{GDP_{i,2008}^s}}{2}}_{\text{C.1}} \right) \\
& \underbrace{\hspace{10em}}_{\text{Between-country Effects}} \\
& + \underbrace{\frac{1}{S} \sum_{s=1}^S \left(\frac{MP_{i,2009}^s}{GDP_{i,2009}^s} - \frac{MP_{i,2008}^s}{GDP_{i,2008}^s} \right)}_{\text{C.3: Within-country Effect}}. \tag{A.1}
\end{aligned}$$

Here, S denotes the total number of sectors. $MP_{i,t}^s$ denotes the average of inward and outward MP in country i , sector s , and year t . $GDP_{i,t}^s$ 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. $C.1: \frac{1}{N} \sum_{n=1}^N S \text{cov}_s \left(\frac{MP_{i,2009}^s}{GDP_{i,2009}^s} - \frac{MP_{i,2008}^s}{GDP_{i,2008}^s}, \frac{\frac{GDP_{i,2009}^s}{\sum_{s=1}^S GDP_{i,2009}^s} + \frac{GDP_{i,2008}^s}{\sum_{s=1}^S GDP_{i,2008}^s}}{2} \right);$
4. $C.2: \frac{1}{N} \sum_{n=1}^N S \text{cov}_s \left(\frac{GDP_{i,2009}^s}{\sum_{s=1}^S GDP_{i,2009}^s} - \frac{GDP_{i,2008}^s}{\sum_{s=1}^S GDP_{i,2008}^s}, \frac{\frac{MP_{i,2009}^s}{GDP_{i,2009}^s} + \frac{MP_{i,2008}^s}{GDP_{i,2008}^s}}{2} \right);$
5. $C.3: \frac{1}{N} \sum_{n=1}^N \frac{1}{S} \sum_{s=1}^S \left(\frac{MP_{i,2009}^s}{GDP_{i,2009}^s} - \frac{MP_{i,2008}^s}{GDP_{i,2008}^s} \right).$

Table A.5 presents the decomposition results.

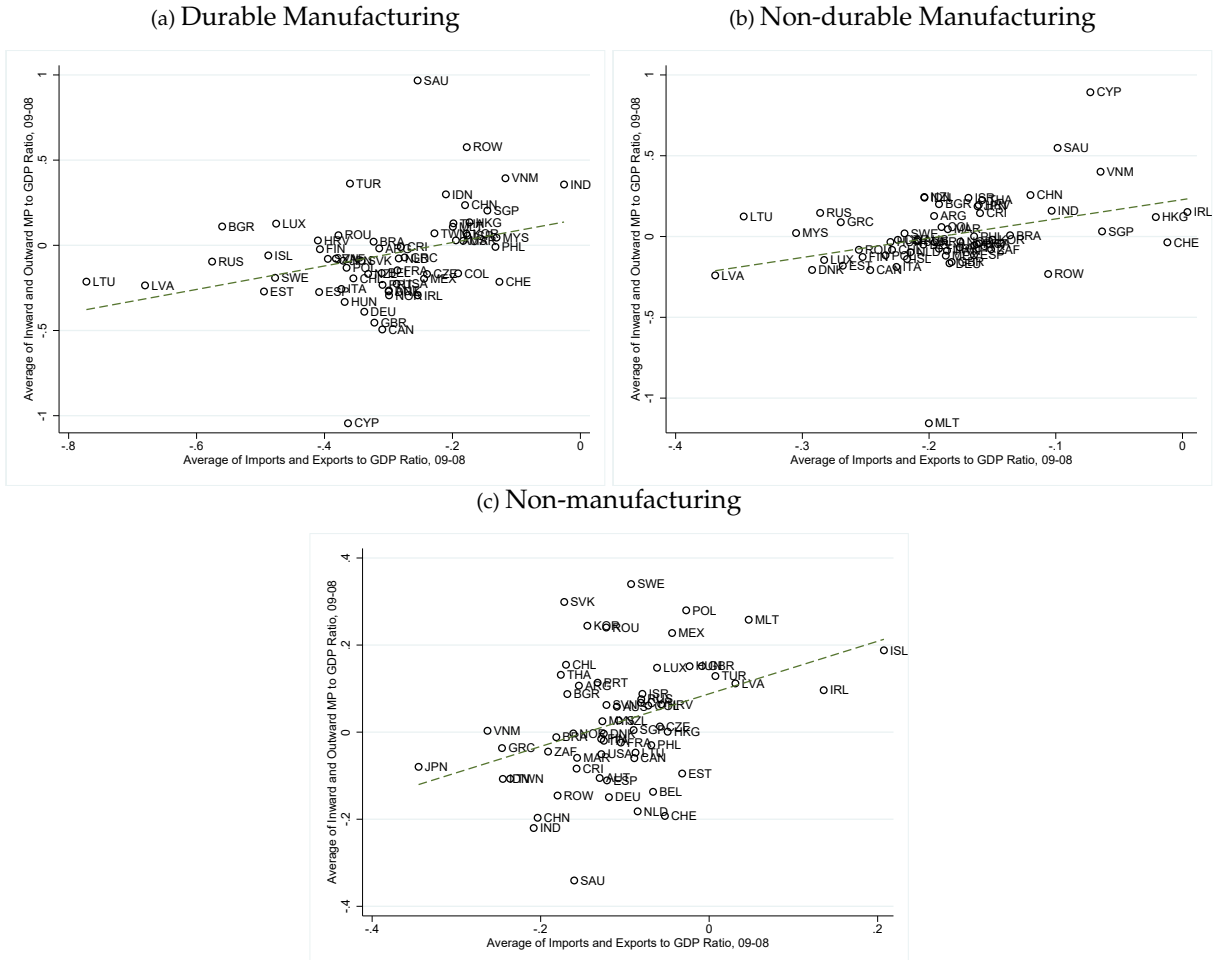
Table A.5: Decomposition of Changes in Global MP and Trade

	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	-0.017 (78.6%)	-0.008 (39.6%)	-0.020 (91.9%)	-0.010 (45.8%)	0.033 (-155.9%)	-0.02 (100%)
Trade	0.009 (-23.2%)	-0.003 (6.5%)	0.035 (-89.5%)	-0.011 (27.7%)	-0.070 (178.5%)	-0.04 (100%)
2009-2010						
MP	0.008 (165.5%)	-0.006 (-115.4%)	-0.016 (-331.3%)	0.003 (66.9%)	0.015 (314.3%)	0.00 (100%)
Trade	-0.006 (-26.8%)	0.000 (0.5%)	-0.022 (-97.0%)	0.006 (24.7%)	0.045 (198.6%)	0.02 (100%)
2013-2016						
MP	-0.006 (40.3%)	-0.005 (30.3%)	-0.027 (170.8%)	-0.002 (11.0%)	0.024 (-152.4%)	-0.02 (100%)
Trade	-0.015 (57.4%)	-0.005 (17.3%)	-0.024 (91.4%)	0.001 (-3.3%)	0.017 (-62.8%)	-0.03 (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.

A.2 Other Empirical Findings

Figure A.1: MP and Trade Collapses were Positively Correlated at the Country Level for Each Sector



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 .688 and a standard error of .253 for durable manufacturing, a coefficient of 1.193 and a standard error of .415 for non-durable manufacturing, and a coefficient of .604 and a standard error of .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 local producers 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, 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: $\log\left(\frac{\text{Imp}_f}{\text{Sales}_f}\right)$.

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.

Next I show that conditional on importing, foreign affiliates source more from their

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

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

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

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

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

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:

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

where S_f denotes whether the firm 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: $\log\left(\frac{\text{Exp}_f}{\text{Sales}_f}\right)$.

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)
	$\mathbf{1}(\text{Exp})_f$	$\frac{\text{Exp}_f}{\text{Sales}_f}$	$\log\left(\frac{\text{Exp}_f}{\text{Sales}_f}\right)$
$\mathbf{1}(\text{Foreign subsidiary})_f$	0.338*** (0.0122)	0.254*** (0.0313)	0.962*** (0.0705)
$\log(\text{emp}_f)$	0.0314*** (0.00293)	0.0407*** (0.00903)	0.259*** (0.0459)
$\log(\text{cap}_f)$	0.00953*** (0.00270)	-0.00346 (0.00269)	-0.170*** (0.0331)
$\log(\text{interm}_f)$	0.0194*** (0.00234)	-0.0213** (0.00813)	-0.323*** (0.0436)
$\log(\text{TFP}_f)$	0.00185 (0.00234)	-0.00307 (0.00292)	-0.336*** (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:

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

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

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	$n \neq i$
	$\mathbf{1}(x_{f,n-CN_i} > 0)$	$\mathbf{1}(x_{f,n-CN_i} > 0)$	$\log(x_{f,n-CN_i})$	$\log(x_{f,n-CN_i})$
$\mathbf{1}(n = i)$	0.124*** (0.0244)		1.613*** (0.157)	
$\mathbf{1}(\text{common lang.})_{ni}$		-0.00128** (0.000509)		-0.0538*** (0.00535)
$\mathbf{1}(\text{contiguity})_{ni}$		-0.000465 (0.000593)		0.125 (0.0857)
$\mathbf{1}(\text{contiguity})_{ni}$		0.00540** (0.00234)		-0.0331 (0.0935)
$\mathbf{1}(\text{legal})_{ni}$		0.00130 (0.000850)		0.0718 (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
1($i = j$)	0.918*** (0.0159)	0.737*** (0.0169)	0.758*** (0.0176)	0.804*** (0.0117)	0.348*** (0.0220)	0.428*** (0.0215)	0.391*** (0.0258)	0.389*** (0.0151)
log (dist)	-0.146*** (0.00362)	-0.188*** (0.00383)	-0.100*** (0.00399)	-0.144*** (0.00265)	-0.0190*** (0.00500)	-0.0374*** (0.00488)	-0.00906 (0.00586)	-0.0218*** (0.00342)
1 (legal)	0.0325*** (0.00416)	0.0496*** (0.00440)	0.0291*** (0.00459)	0.0371*** (0.00305)	0.00654 (0.00575)	-0.000117 (0.00561)	-0.00156 (0.00673)	0.00162 (0.00393)
1 (contiguity)	0.0657*** (0.0103)	0.129*** (0.0109)	0.175*** (0.0114)	0.123*** (0.00756)	0.0365** (0.0143)	0.160*** (0.0139)	0.116*** (0.0167)	0.104*** (0.00974)
1 (common lang.)	0.0546*** (0.00780)	0.0491*** (0.00826)	0.0694*** (0.00860)	0.0577*** (0.00572)	-0.0348*** (0.0108)	0.0192* (0.0105)	-0.00840 (0.0126)	-0.00802 (0.00737)
1 (trade agree.)	-0.00744 (0.00628)	0.0428*** (0.00665)	0.0392*** (0.00693)	0.0249*** (0.00461)	-0.00162 (0.00868)	0.0143* (0.00847)	0.0450*** (0.0102)	0.0192*** (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
1($i = j$)	3.860*** (0.0843)	17.38*** (0.324)	4.606*** (0.127)	8.617*** (0.145)
log (dist)	-0.917*** (0.0192)	-3.739*** (0.0737)	-2.134*** (0.0288)	-2.263*** (0.0330)
1 (legal)	0.228*** (0.0220)	1.500*** (0.0847)	0.556*** (0.0331)	0.761*** (0.0379)
1 (contiguity)	1.473*** (0.0546)	7.034*** (0.210)	2.224*** (0.0821)	3.577*** (0.0939)
1 (common lang.)	0.647*** (0.0413)	1.301*** (0.159)	0.739*** (0.0621)	0.896*** (0.0711)
1 (trade agree.)	-0.326*** (0.0332)	-1.215*** (0.128)	-0.558*** (0.0500)	-0.700*** (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)	(2)	(3)	(4)	(5)	(6)
	Durable Manufacturing Tariff Instruments with Direct Shares	Non-durable Manufacturing Tariff Instruments with Direct Shares	Non-manufacturing	Durable Manufacturing Tariff Instruments with Total Shares	Non-durable Manufacturing Tariff Instruments with Total Shares	Non-manufacturing
$\log(C_{nj,t}^s)$	2.737** (1.184)	4.278*** (1.474)	2.559*** (0.472)	9.005*** (1.081)	9.293** (4.412)	2.389*** (0.447)
$\log(t_{nj,t}^s)$	-3.697*** (0.560)	-1.849*** (0.502)	-1.898*** (0.646)	-4.069*** (1.106)	-1.099 (0.974)	-2.040*** (0.627)
$\log(\text{dist}_{nj,t})$	-1.055*** (0.0211)	-0.986*** (0.0130)	-1.299*** (0.0129)	-1.153*** (0.0265)	-0.961*** (0.0280)	-1.298*** (0.0126)
$1(\text{legal}_{nj,t})$	0.166*** (0.0253)	0.143*** (0.0126)	0.0613*** (0.0138)	0.284*** (0.0312)	0.154*** (0.0217)	0.0610*** (0.0136)
$1(\text{common lang}_{nj,t})$	0.312*** (0.0330)	0.261*** (0.0255)	0.0817*** (0.0260)	0.184*** (0.0498)	0.224*** (0.0488)	0.0823*** (0.0256)
$1(\text{contiguity}_{nj,t})$	0.130*** (0.0438)	0.288*** (0.0316)	0.657*** (0.0412)	-0.0368 (0.0669)	0.305*** (0.0518)	0.649*** (0.0402)
$1(\text{trade agree}_{nj,t})$	0.330*** (0.0200)	0.316*** (0.0222)	0.315*** (0.0226)	0.355*** (0.0389)	0.348*** (0.0426)	0.317*** (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

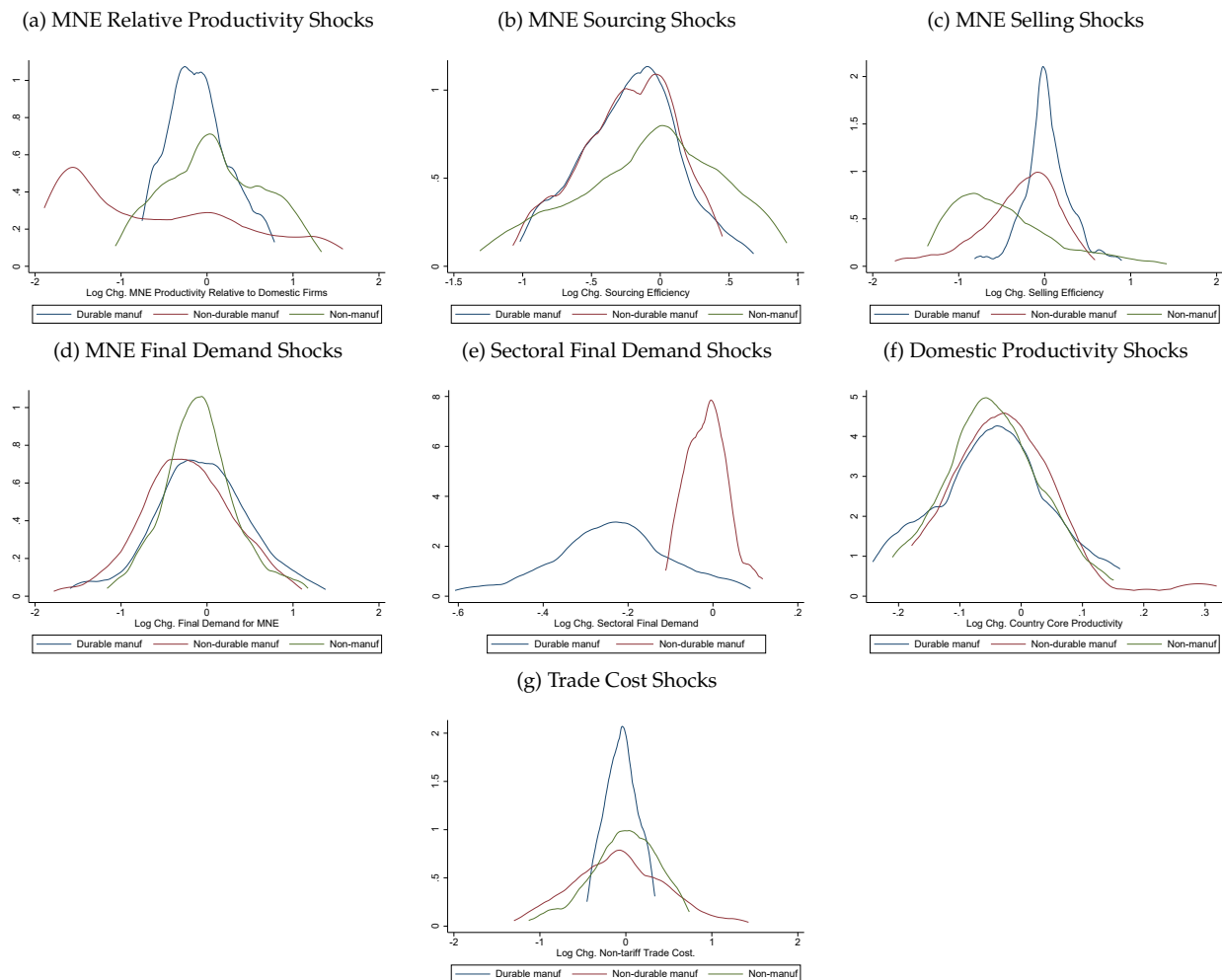
VARIABLES	(1)	(2)	(3)	(4)
	Tariffs Instrumented with Direct Shares	Tariffs Instrumented with Direct Shares	Tariffs Instrumented with Total Shares	Tariffs Instrumented with Total Shares
$\log(C_{nj,t}^s)$	1.490*** (0.467)	1.710*** (0.499)	5.349*** (0.645)	5.688*** (0.636)
$\log(t_{nj,t}^s)$	-2.425*** (0.247)	-2.710*** (0.312)	-1.821*** (0.365)	-1.283*** (0.443)
$\log(\text{dist}_{nj,t}) \#$	Durable Manuf.	-1.041*** (0.0119)	-1.040*** (0.0126)	-1.098*** (0.0173)
	Non-durable Manuf.	-0.999*** (0.0100)	-0.998*** (0.00997)	-0.979*** (0.0147)
	Non-manuf.	-1.290*** (0.0104)	-1.290*** (0.0108)	-1.321*** (0.0153)
$1(\text{legal}_{nj,t}) \#$	Durable Manuf.	0.142*** (0.0144)	0.146*** (0.0146)	0.215*** (0.0208)
	Non-durable Manuf.	0.137*** (0.0114)	0.138*** (0.0113)	0.146*** (0.0169)
	Non-manuf.	0.0596*** (0.0113)	0.0600*** (0.0112)	0.0658*** (0.0168)
$1(\text{common lang}_{nj,t}) \#$	Durable Manuf.	0.339*** (0.0233)	0.334*** (0.0234)	0.261*** (0.0342)
	Non-durable Manuf.	0.281*** (0.0216)	0.279*** (0.0215)	0.250*** (0.0318)
	Non-manuf.	0.0855*** (0.0214)	0.0851*** (0.0212)	0.0728** (0.0317)
$1(\text{contiguity}_{nj,t}) \#$	Durable Manuf.	0.162*** (0.0313)	0.158*** (0.0315)	0.0626 (0.0459)
	Non-durable Manuf.	0.279*** (0.0289)	0.279*** (0.0286)	0.293*** (0.0428)
	Non-manuf.	0.607*** (0.0359)	0.618*** (0.0364)	0.785*** (0.0520)
$1(\text{trade agree}_{nj,t}) \#$	Durable Manuf.	0.328*** (0.0179)	0.336*** (0.0181)	0.370*** (0.0267)
	Non-durable Manuf.	0.297*** (0.0179)	0.293*** (0.0184)	0.331*** (0.0271)
	Non-manuf.	0.328*** (0.0185)	0.323*** (0.0193)	0.274*** (0.0272)
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.2: 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

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Durable Manufacturing	Non-durable Manufacturing	Non-manufacturing	Durable Manufacturing	Non-durable Manufacturing	Non-manufacturing
	HQ Fixed Effect, Host Country Fixed Effect			OLS		
\hat{A}_i^d	0.202*** (0.0122)	0.00751*** (0.00230)	0.201*** (0.0134)	0.196*** (0.0120)	0.00751*** (0.00230)	0.201*** (0.0134)
\hat{A}_{ij}^s	0.457*** (0.0122)	0.879*** (0.00230)	0.569*** (0.0134)	0.462*** (0.0120)	0.879*** (0.00230)	0.569*** (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

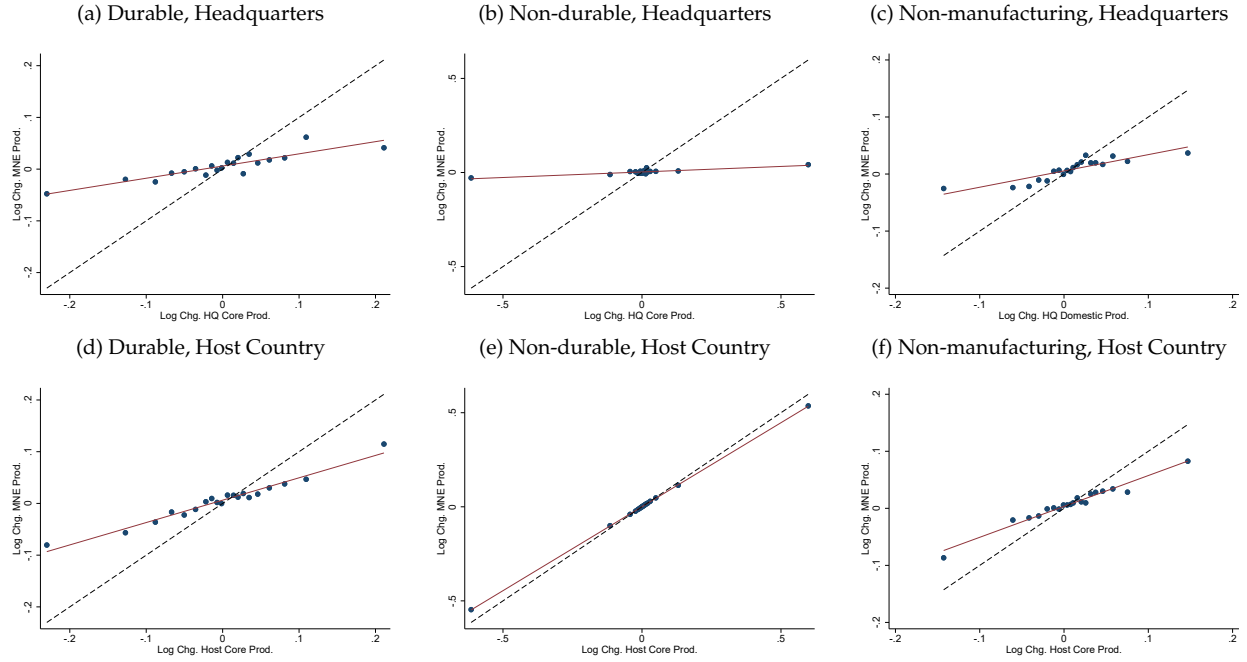
*** p<0.01, ** p<0.05, * p<0.1

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 . $t_{nj}^s = 1 + \tau_{nj}^s$, where

Figure A.3: 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:

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

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 :

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

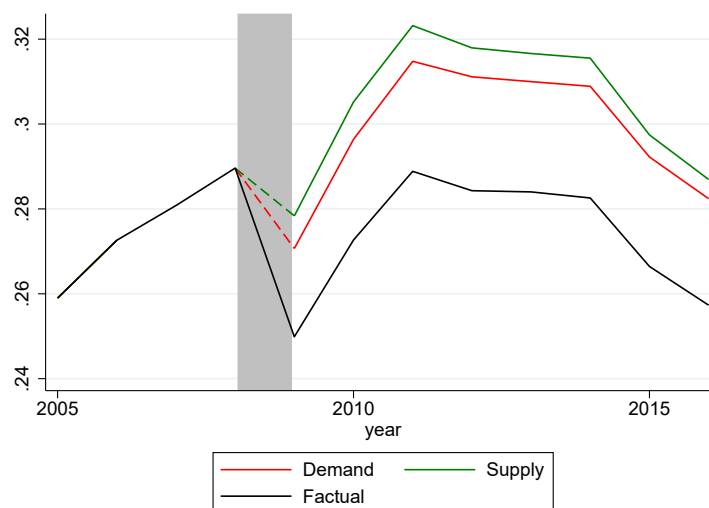
A.7 Simulations

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

Shocks	2008-2009		2009-2010		2014-2016	
	Trade (1)	Trade (Percent) (2)	Trade (3)	Trade (Percent) (4)	Trade (5)	Trade (Percent) (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.4: 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%

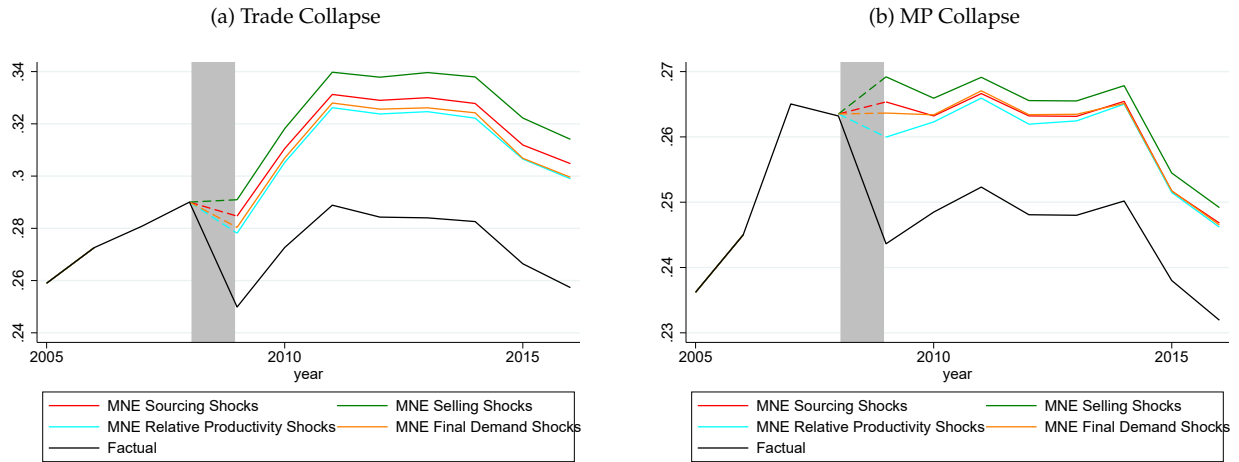
Description: This table presents the impact of different kinds of MNE-specific shocks on the global trade and MP collapse during the Great Recession. The global trade collapse is measured with the change in world trade to world GDP ratio. The global MP collapse is measured with the change in world MP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

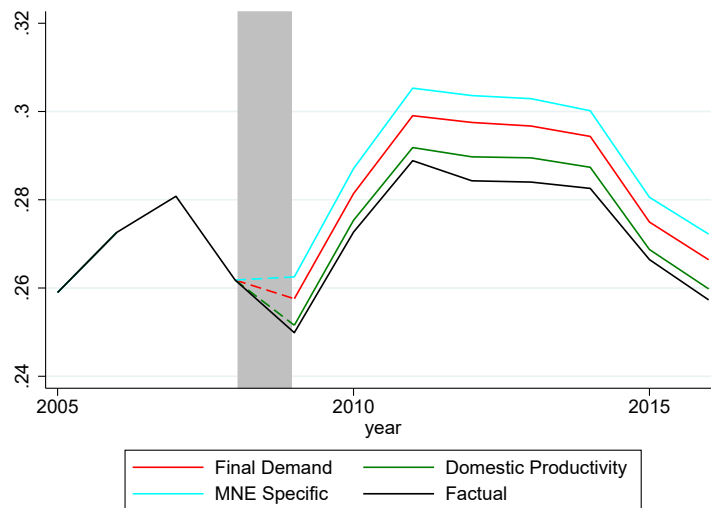
Description: This table presents the impact of different kinds of MNE-specific shocks on the global trade and MP collapse during the Great Recession in a model that does not have MNE sourcing and selling frictions. The global trade collapse is measured with the change in world trade to world GDP ratio.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

Figure A.5: Impact of Different MNE-specific Shocks on Global Trade and 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.6: 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 Shocks on Cross-country Variations in Changes in Trade and Welfare, Model without MNEs**

Shocks	2008-2009		2009-2010		2014-2016	
	Trade (1)	Welfare (2)	Trade (3)	Welfare (4)	Trade (5)	Welfare (6)
Domestic Productivity Shocks	23.90%	54.68%	9.90%	85.21%	13.98%	70.59%
Final Demand Shocks	-4.78%	26.42%	4.19%	12.67%	11.49%	13.30%
All Shocks	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

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.19: **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	14.11%	0.77%	-0.72%
Selling Shocks	12.88%	12.77%	-2.38%
Relative Productivity Shocks	-8.18%	49.99%	11.07%
MNE Demand Shocks	1.12%	0.67%	1.86%
All MNE-specific Shocks	22.42%	69.82%	11.72%

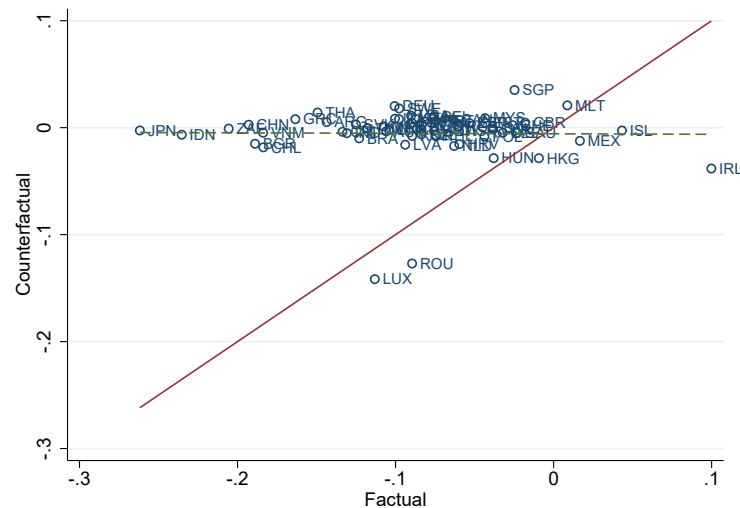
Description: This table presents the impact of different MNE-specific shocks on the cross-country variation in the collapse of trade, MP, and welfare changes during the Great Recession. Country-level trade collapse is measured with the change in the average of its imports and exports relative to its 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.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%
All Shocks	100.00%	100.00%	100.00%

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.7: Impact of Shocks Cross-country Variations in Trade collapse, Model without MNE Sourcing and Selling Frictions



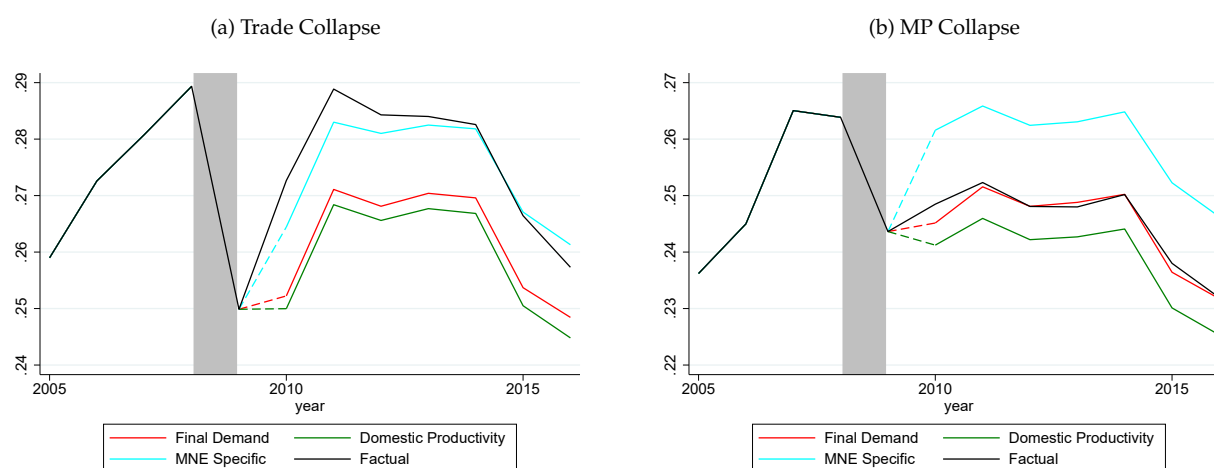
Description: This figure plots the impact of MNE-specific shocks on the cross-country variation in the collapse of trade. Country-level trade collapse is measured with the change in the average of its imports and exports relative to its GDP. The share of cross-country variation explained by a group of 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.8: Importance of Shocks for Global Trade and MP Recovery, 2009-2010



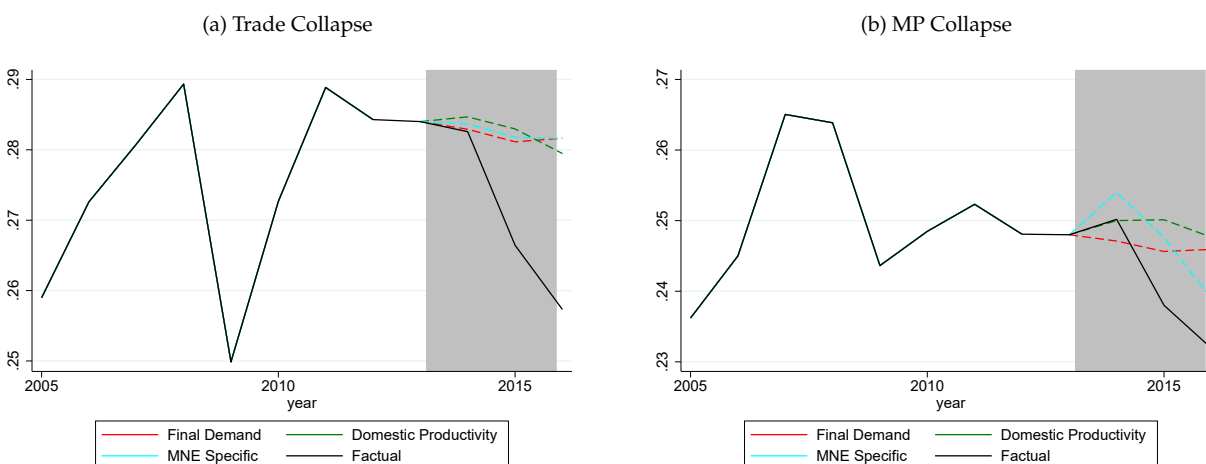
Description: These figures plot the impact of different kinds of shocks on the global trade and MP collapse recovery during 2009-2010. Dashed line segments indicate the impact of individual shock groups. Line segments after 2010 indicate counterfactual outcomes that started with counterfactual market 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.9: 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	22.42%	69.82%	-12.94%
Domestic Productivity Shocks	29.89%	23.23%	99.33%
Final Demand Shocks	2.44%	0.27%	6.01%
Supply Shocks	20.90%	73.30%	89.31%
Demand Shocks	8.25%	9.14%	2.58%
All Shocks	100.00%	100.00%	100.00%

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 (1)	MP Collapse (2)	Welfare (3)
MNE-specific Shocks	31.69%	77.74%	10.16%
Domestic Productivity Shocks	12.51%	1.51%	58.27%
Final Demand Shocks	8.76%	0.74%	23.05%
Supply Shocks	45.21%	84.46%	49.84%
Demand Shocks	8.40%	-1.64%	21.93%
All Shocks	100.00%	100.00%	100.00%

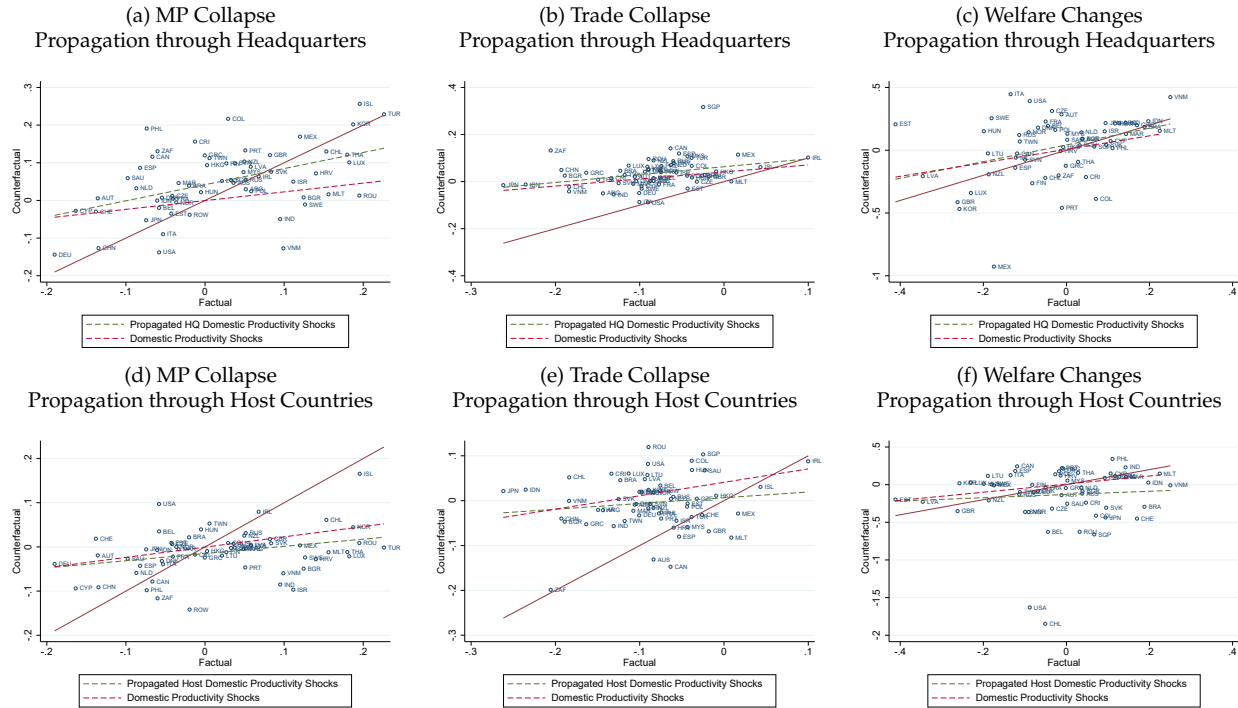
Description: This table presents the impact of different kinds of shocks on the cross-country variation in the collapse of trade, MP, and welfare changes during the trade and MP declines from 2013 to 2016. Country-level trade collapse is measured with the change in the average of its imports and exports 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 (1)	Trade (Percent) (2)	MP (3)	MP (Percent) (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.10: Propagation of Domestic Productivity Shocks through MP Headquarters and Host Countries: Cross-country Variations in Trade Collapse, MP Collapse, and Welfare



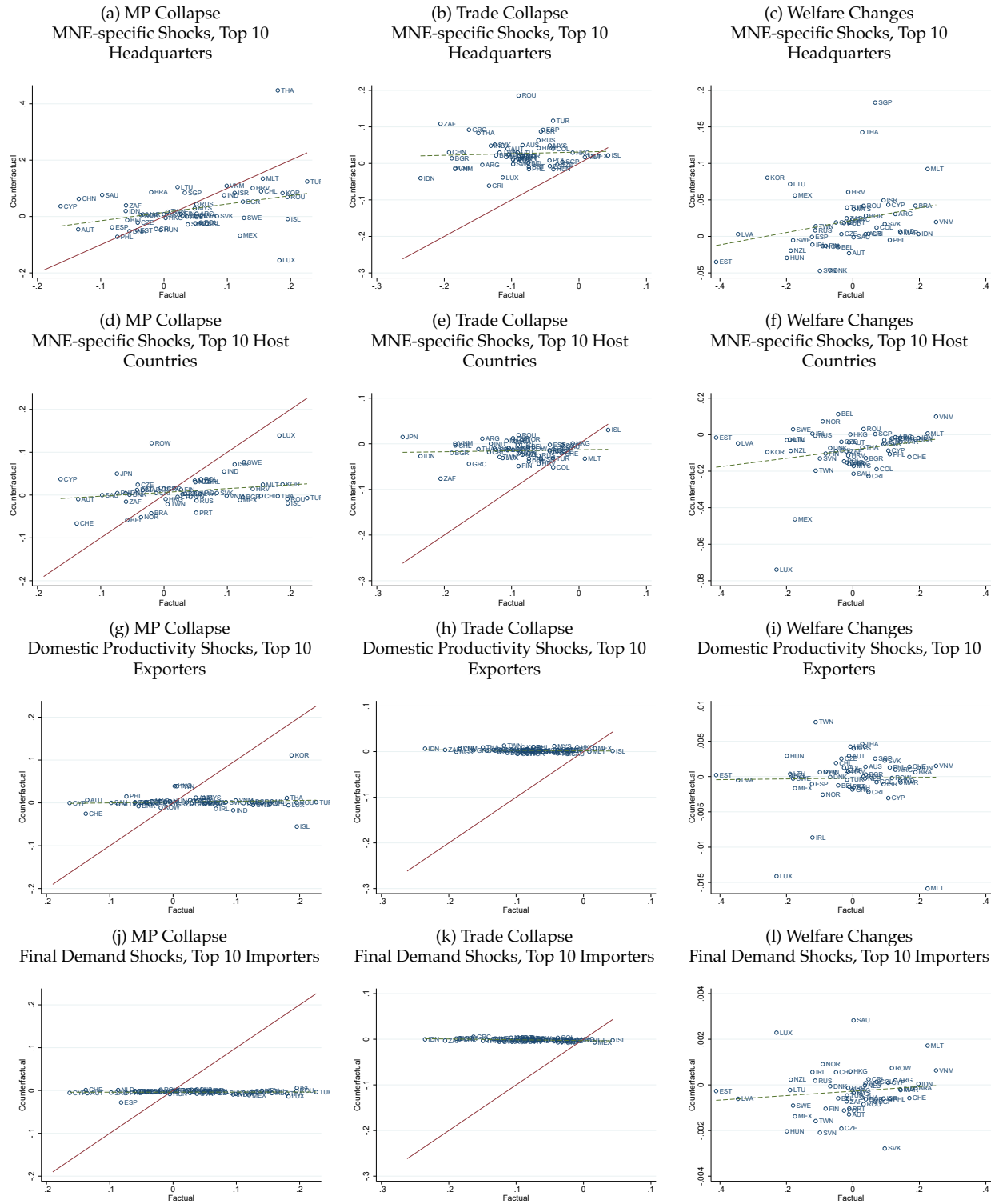
Description: These figures plot the impact of domestic productivity shocks, these shocks propagated through MP headquarters, and these shocks propagated through MP host country linkages, on the cross-country variation in the collapse of trade, MP, and welfare changes during the Great Recession. Country-level 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	15.47%	19.84%	149.77%
Propagation through Host Countries	14.27%	12.60%	84.19%
Domestic Productivity Shocks	10.41%	14.47%	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.11: Propagation of Domestic Productivity Shocks in Top Headquarters and Host Countries: Cross-country Variations in Trade Collapse, MP Collapse, and Welfare across Other Countries



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	17.19%	1.32%	118.47%
Propagation through Host Countries	13.90%	16.97%	125.07%
Domestic Productivity Shocks	15.66%	1.08%	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).

Table A.28: 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	17.40%	5.53%	4.48%
Domestic Productivity Shocks in Top 10 Headquarters	-0.30%	-2.46%	0.13%
Propagation of Domestic Productivity Shocks in Top 10 Host Countries	0.57%	0.22%	0.40%
Domestic Productivity Shocks in Top 10 Host Countries	-0.25%	-0.06%	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).

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:

$$Q_{nm}^s = \left(\int_0^1 (Q_{nm}^s(\omega))^{\frac{\lambda-1}{\lambda}} d\omega \right)^{\frac{\lambda}{\lambda-1}}.$$

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

$$F(z_{nm}^s) = \exp\left(-\left(\sum_{j=1}^N \left(\sum_{i=1}^N (z_{nmji}^s)^{-\frac{\theta}{1-\rho_1^s}}\right)^{\frac{1-\rho_1^s}{1-\rho_2^s}}\right)^{1-\rho_2^s}\right),$$

where ρ_1^s governs the correlation between technologies, and ρ_2^s 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 $z_{nmji} \rightarrow \infty, \forall i \neq I$:

$$\tilde{F}(\{z_{nmjI}\}_{j=1}^N) = \exp\left(-\left(\sum_{j=1}^N z_{nmjI}^{-\frac{\theta}{1-\rho_2^s}}\right)^{1-\rho_2^s}\right).$$

Therefore, the productivity shock draws for all production locations given a technology is still multivariate Fréchet distribution with correlation ρ_2^s across production locations. Now fix a source production location J . The probability of drawing technology shock z_{nmJi} for J is, taking $z_{nmji} \rightarrow \infty, \forall j \neq J$:

$$\tilde{F}(\{z_{nmJi}\}_{i=1}^N) = \exp\left(-\left(\sum_{i=1}^N z_{nmJi}^{-\frac{\theta}{1-\rho_1^s}}\right)^{1-\rho_1^s}\right).$$

The productivity shock draws for all technologies given a production location is still multivariate Fréchet distribution with correlation ρ_1^s across production locations.

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

$$\frac{\tilde{H}_{ni}^s \tilde{h}_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s z_{nmji}^s}.$$

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

$$\begin{aligned} G_{nm}^s(p) &= 1 - F\left(\left\{z_{nmji}^s = \frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s p}\right\}_{i,j}\right) \\ &= 1 - \exp(-\Phi_{nm}^s p^\theta), \end{aligned}$$

where

$$\Phi_{nm}^s = \left(\sum_{j=1}^N \left(\sum_{i=1}^N \left(\frac{\tilde{H}_{ni}^s \tilde{h}_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s}\right)^{-\frac{\theta}{1-\rho_1^s}}\right)^{\frac{1-\rho_1^s}{1-\rho_2^s}}\right)^{1-\rho_2^s}.$$

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

$$\begin{aligned} F_{ji}(z_{nmji}^s) &= \theta (z_{nmji}^s)^{-\frac{\theta}{1-\rho_1^s}-1} \left[\sum_{i=1}^N (z_{nmji}^s)^{-\frac{\theta}{1-\rho_1^s}} \right]^{\frac{\rho_2^s - \rho_1^s}{1-\rho_2^s}} \left\{ \sum_{j=1}^N \left[\sum_{i=1}^N (z_{nmji}^s)^{-\frac{\theta}{1-\rho_1^s}} \right]^{\frac{1-\rho_1^s}{1-\rho_2^s}} \right\}^{-\rho_2^s} \\ &\quad \exp \left(\left(\left\{ \sum_{j=1}^N \left[\sum_{i=1}^N (z_{nmji}^s)^{-\frac{\theta}{1-\rho_1^s}} \right]^{\frac{1-\rho_1^s}{1-\rho_2^s}} \right\}^{1-\rho_2^s} \right) \right). \end{aligned}$$

Therefore,

$$\begin{aligned}
F_{ji}(z_{nmj'i'}^s = \frac{\frac{H_{ni'}^s h_{mj'}^s k_{nj'}^s t_{nj'}^s \Theta_{j'i'}^s}{A_{j'i'}^s}}{\frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s}} z) &= \theta z^{-\theta-1} \left[\sum_{i=1}^N \left(\frac{H_{ni'}^s h_{mj'}^s k_{nj'}^s t_{nj'}^s \Theta_{j'i'}^s}{A_{j'i'}^s} \right)^{-\frac{\theta}{1-\rho_1^s}} \right]^{\frac{\rho_2^s - \rho_1^s}{1-\rho_2^s}} \\
&\underbrace{\left\{ \sum_{j=1}^N \left[\sum_{i=1}^N \left(\frac{H_{ni'}^s h_{mj'}^s k_{nj'}^s t_{nj'}^s \Theta_{j'i'}^s}{A_{j'i'}^s} \right)^{-\frac{\theta}{1-\rho_1^s}} \right]^{\frac{1-\rho_1^s}{1-\rho_2^s}} \right\}^{-\rho_2^s}}_{(\Phi_{nm}^s)^{-\frac{\rho_2^s}{1-\rho_2^s}}} \left(\frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s} \right)^{-\frac{\theta \rho_1^s}{1-\rho_1^s}} \\
&\exp(-\Phi_{nm}^s \left(\frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s} \right)^\theta z^{-\theta}).
\end{aligned}$$

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

$$\int_{z=0}^{\infty} \theta z^{-\theta-1} \Phi_{nm}^s \left(\frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s} \right)^\theta z^{-\theta} \exp(-\Phi_{nm}^s \left(\frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s} \right)^\theta z^{-\theta}) dz = 1.$$

Therefore,

$$\begin{aligned}
\int_{z=0}^{\infty} F_{ji}(z_{nmj'i'}^s = \frac{\frac{H_{ni'}^s h_{mj'}^s k_{nj'}^s t_{nj'}^s \Theta_{j'i'}^s}{A_{j'i'}^s}}{\frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s}} z) dz &= \left(\frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s} \right)^{-\frac{\theta}{1-\rho_1^s}} \\
&\left[\sum_{i=1}^N \left(\frac{H_{ni'}^s h_{mj'}^s k_{nj'}^s t_{nj'}^s \Theta_{j'i'}^s}{A_{j'i'}^s} \right)^{-\frac{\theta}{1-\rho_1^s}} \right]^{\frac{\rho_2^s - \rho_1^s}{1-\rho_2^s}} (\Phi_{nm}^s)^{-\frac{1}{1-\rho_2^s}}.
\end{aligned}$$

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:

$$\int_{z=\frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s p}}^{\infty} F_{ji}(z_{nmj'i'}^s = \frac{\frac{H_{ni'}^s h_{mj'}^s k_{nj'}^s t_{nj'}^s \Theta_{j'i'}^s}{A_{j'i'}^s}}{\frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s}} z) dz = \left[\int_{z=0}^{\infty} F_{ji}(z_{nmj'i'}^s = \frac{\frac{H_{ni'}^s h_{mj'}^s k_{nj'}^s t_{nj'}^s \Theta_{j'i'}^s}{A_{j'i'}^s}}{\frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s}} z) dz \right] G_{nm}^s(p).$$

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:

$$\pi_{nmji}^s = \frac{\sum_{i=1}^N \left(\frac{\tilde{H}_{ni}^s \tilde{h}_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s} \right) 1 - \zeta^s}{\underbrace{\sum_{j=1}^N \left(\sum_{i=1}^N \left(\frac{\tilde{H}_{ni}^s \tilde{h}_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s} \right) 1 - \zeta^s \right)}_{\pi_{nmj}^s}} \frac{\left(\frac{\tilde{H}_{ni}^s \tilde{h}_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s} \right) 1 - \zeta^s}{\underbrace{\sum_{i=1}^N \left(\frac{\tilde{H}_{ni}^s \tilde{h}_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s} \right) 1 - \zeta^s}_{S_{n \cdot ji}^s}},$$

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:

$$\hat{\Theta}_{li}^s = (\hat{w}_l)^{\gamma_l^s} \prod_{s'=1}^S (\hat{P}_{li}^{s'})^{\gamma_l^{s'}}. \quad (\text{B.1})$$

The change in MNE output share equals the following:

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

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

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

The change in MNE sourcing share equals:

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

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

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

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

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

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

The change in sectoral final expenditure share equals:

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

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:

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

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

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

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

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

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

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

$$\hat{w}_j \hat{L}_j w_j L_j = w'_j L'_j = \sum_{s=1}^S \gamma_j^s \sum_{m=1}^N \sum_{n=1}^N \frac{X_{nm}^{I_s} \pi_{nmj}^{I_s}}{t_{nj}^{I_s}},$$

and

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

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 equal:

$$R'_n = \sum_{s=1}^S \sum_{j=1}^N \sum_{m=1}^N X_{nm}^{ts} \pi_{nmj}^{ts} \frac{\tau_{nj}^{ts}}{t_{nj}^{ts}}.$$

In order to solve the counterfactual equilibrium, we have to know the baseline MNE sourcing shares, π_{nmj}^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 .

Once we know all the variables above, the equilibrium is characterized by a set of prices, $\{\hat{w}_n\}$, $\{\hat{P}_{nj}^{s,p}\}$, $\{\hat{P}_{nm}^s\}$, 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, $\frac{\Theta_{ji}^s}{\Theta_{jj}^s}$, can be derived from Equation (15), with knowledge about GO_{li}^s , T_{pl}^s and $S_{p,ll}^s$ obtained from the data, ζ^s estimated in Section 4.2, and MNE selling efficiencies H_{pi}^s backed out in Section 4.1:

$$\frac{\Theta_{ji}^s}{\Theta_{jj}^s} = \left(\frac{GO_{ji}^s}{\sum_{p=1}^N T_{pj}^s S_{p,jj}^s \frac{H_{pi}^s}{H_{pj}^s}} \right)^{\frac{1}{1-\zeta^s}}. \quad (\text{B.4})$$

The numerator, $\frac{\Theta_{ji}^s}{\Theta_{jj}^s}$, equals the following:

$$\frac{\Theta_{ji}^s}{\Theta_{jj}^s} = \prod_{s'=1}^S \left(\frac{P_{ji}^{s'}}{P_{jj}^{s'}} \right)^{\gamma_i^{s's'}}, \quad (\text{B.5})$$

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

$$\frac{P_{ji}^s}{P_{jj}^s} = \left(\sum_{k=1}^N \pi_{jjk}^s \frac{h_{ik}^s}{h_{jk}^s} \right)^{\frac{1}{1-\sigma^s}}, \quad (\text{B.6})$$

where π_{jjk}^s is data and the MNE sourcing efficiency, h_{ik}^s , has been backed out in Section 4.1. Combining Equations (22), (B.4), (B.5) and (B.6), I get the MNE relative productivity, $\frac{A_{ji}^s}{A_{jj}^s}$, 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:

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

in which the change in the producer price index equals:

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

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

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

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: $\{\hat{A}_{jj}^s\}$ and $\{\hat{P}_{jj}^s\}$. By using this system of equations, I am able to solve \hat{A}_{jj}^s and \hat{P}_{jj}^s 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:

$$(\hat{P}_n^s)^{1-\sigma^s} = \sum_{l=1}^N \pi_{nl}^s (\hat{k}_{nl}^s \hat{t}_{nl}^s \frac{\hat{\Theta}_l^s}{\hat{A}_l^s})^{1-\sigma^s},$$

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

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

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

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

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

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

with the change in the consumer price index equals:

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

The counterfactual sectoral final expenditure share equals the following:

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

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

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

and

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

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:

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

The equilibrium is characterized by a set of prices, $\{\hat{w}_n\}$ and $\{\hat{P}_n\}$, 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:

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

$\forall i$ 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 :

$$\hat{S}_{ji}^s = \frac{\left(\frac{\hat{\Theta}_i^s}{\hat{A}_{ji}^s}\right)^{1-\zeta^s}}{\left(\hat{P}_j^{s,p}\right)^{1-\zeta^s}}.$$

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:

$$\left(\hat{P}_j^{s,p}\right)^{1-\zeta^s} = \sum_{i=1}^N S_{ji}^s \left(\frac{\hat{\Theta}_j^s}{\hat{A}_{ji}^s}\right)^{1-\zeta^s}$$

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

$$\hat{\pi}_{nj}^s = \frac{\left(\hat{P}_j^{s,p} \hat{k}_{nj}^s \hat{t}_{nj}^s\right)^{1-\sigma^s}}{\left(\hat{P}_n^s\right)^{1-\sigma^s}}.$$

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:

$$\left(\hat{P}_n^s\right)^{1-\sigma^s} = \sum_{j=1}^N \pi_{nj}^s \cdot \left(\hat{k}_{nj}^s \hat{t}_{nj}^s \hat{P}_j^{s,p}\right)^{1-\sigma^s}.$$

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

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

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

The change in sectoral final expenditure share equals:

$$\hat{s}_n^s = \frac{\hat{\alpha}_n^s \left(\hat{P}_n^s\right)^{1-\lambda}}{\left(\hat{P}_n^c\right)^{1-\lambda}},$$

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:

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

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:

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

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

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

and

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

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 equal:

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

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