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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

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## Abstract

Using a new database on global multinational production (MP), I document that world multinational enterprise (MNE) sales declined as sharply as trade during the Great Recession. This collapse was driven by MNEs from a few key headquarters countries, associated with steeper GDP declines in MP-intensive countries. MNEs amplified the trade collapse because their overall sales fell while they maintained higher trade intensity than domestic firms. In a calibrated quantitative model with flexible vertical and horizontal MNE structures, international trade, and input-output linkages, I show that supply shocks contributed more to the trade collapse than demand shocks, as productivity shocks disproportionately affected trade-intensive MNEs. MNE productivity shocks contributed over half of global GDP decline during the Great Recession. MP linkages significantly amplified the impact of headquarters-country domestic productivity shocks on global GDP, MP, and trade.

*Keywords:* Multinational Production, International Trade, Great Recession

*JEL:* F12

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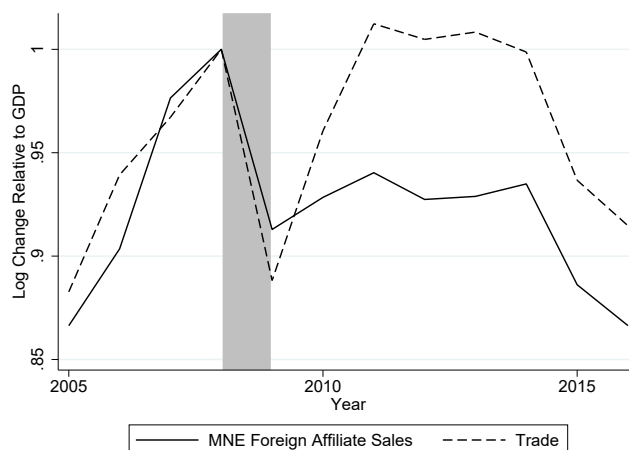
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# 1. Introduction

Economists acknowledge the importance of multinational enterprises (MNEs) for global output and trade, yet their performance during the Great Recession and contribution to the “Great Trade Collapse” remain poorly understood.<sup>1</sup> A fundamental question persists: Were MNEs more resilient than domestic firms? While Alfaro and Chen (2012), Alviarez et al. (2017), and Kamal and Kroff (2021) concluded that MNE sales declined less than domestic firms, Figure 1, however, shows that global MNE sales and trade each plunged by about 10% relative to GDP.<sup>2</sup> Two further questions remain: How did multinational production (MP) contribute to the trade collapse? Did MNEs propagate shocks from their headquarters countries (typically advanced economies severely affected by the Great Recession) to other countries and amplify the global GDP decline?

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



*Notes:* The figure illustrates how global foreign affiliate sales and international trade both declined relative to world GDP during the Great Recession (2008-2009). The data is normalized to 2008 levels, so the figure reflects changes in multinational production (MP) sales and trade relative to GDP compared to 2008. The data source is OECD Analytical Activities of Multinationals (OECD AAMNE) Database.

I start with addressing the “Multinationals’ Resilience Puzzle,” which questions why global MP declined more than GDP, despite prior studies finding MNE resilience compared to domestic firms.

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

<sup>2</sup>This paper refers to the Great Recession as the period between 2008 and 2009. The ratio of world aggregate trade to world GDP fell from 0.29 to 0.26. The ratio of world total foreign affiliate sales to world GDP fell from 0.26 to 0.24. As a benchmark, world real GDP dropped by 1.4% (World Bank). Measures of global MNE foreign affiliate sales, trade, and GDP are acquired from the OECD Analytical Activities of Multinational Enterprises Database (Cadestin et al., 2019). See Levchenko et al. (2010), among others, for a review of the literature on the Great Trade Collapse.

30 With a new decomposition formula, I find that while MP performance was particularly negative  
31 in a few large economies, with GDP falling more in countries intensive in MP, MP declined *less*  
32 than GDP for an average country or country-sector. Previous studies only discovered this average  
33 resilience. Such cross-country heterogeneity explains the global MP decline, despite MNE resilience  
34 in an average country, and contrasts the widespread trade collapse observed in almost all countries.

35 MP amplified the trade collapse because their global sales declined and MNEs are more trade  
36 intensive than domestic firms, even though their trade intensity did not decline relative to domestic  
37 firms. Using a difference-in-differences approach, I find that MNE trade declined *more* than  
38 domestic firm's trade during the Great Recession. However, once controlling for overall MNE sales  
39 growth, MNE trade declined *less* than domestic firms' trade. This shows that MNEs contributed  
40 to the trade collapse through their overall sales decline and high trade intensity, not a declining  
41 MNE trade-to-sales ratio relative to domestic firms.

42 Productivity shock propagation through MNEs across countries rationalizes these empirical  
43 patterns. During the Great Recession, adverse productivity shocks originating in key headquarters  
44 countries spread through MNEs, decreasing MP in large headquarters and host countries and  
45 reducing GDP there due to MP's sharp decline. As MNEs are more trade-intensive, they also  
46 contributed to the trade collapse without a decline in trade intensity.

47 To formalize and quantify these effects, I develop a model of MP and global value chains.  
48 Households consume sectoral composite goods produced by domestic firms and MNEs, and derive  
49 utility from consumption and leisure, causing labor supply to slope upward. To produce tradable  
50 output, firms use labor and composite goods from all sectors. These composite goods are sourced  
51 from different countries and firms of different ownership within each country.

52 The key model feature is MNEs' heterogeneous efficiencies in sourcing inputs and selling out-  
53 puts across different countries. These sourcing and selling efficiencies are headquarters-trade  
54 partner-bilateral, multiplying with standard bilateral international trade costs between exporter  
55 and importer host countries. They determine MNE's vertical/horizontal-ness and explain two  
56 empirical facts: (1) MNEs' higher trade intensity compared to domestic firms, and (2) how head-  
57 quarters countries influence MNEs' sourcing and selling locations.

58 I calibrate model shocks with the new OECD Analytical Activities of Multinational Enterprises

(OECD AAMNE) Database. In particular, I find MNE productivity declined relative to domestic firms, driving the MP collapse. Furthermore, their sourcing and selling efficiencies declined for non-headquarters and distant countries. These shocks made MNEs more vertical, increasing their trade reliance on headquarters and reducing local sourcing and selling. Consequently, MNE trade intensity displayed resilience during the Great Recession. Leveraging calibrated shocks, I develop new methods to estimate various model elasticities: short-run substitution elasticity across countries and MNEs within a country; headquarters' share in foreign affiliates' productivity; final demand elasticities for sectors and MNEs; and labor supply elasticity.

The model finds that supply-side productivity shocks contributed more to the trade collapse than demand shocks. In contrast, trade-only models or those with only horizontal MNEs (without heterogeneous sourcing and selling efficiencies) find demand shocks more influential, as was found in the previous trade collapse literature. In the MP model, supply shocks explained 68% of the trade collapse, while demand shocks explained 44%.<sup>3</sup> In contrast, in the trade-only model and the model with only horizontal MNEs, demand shocks each accounted for 33%, while supply shocks contributed 8% and 21%.

Using cross-industry variations and a decomposition similar to Levchenko et al. (2010) and Levchenko et al. (2011), I identify key sector characteristics driving the filtered demand and supply shocks. My model predicts supply-side policies (targeting high-inventory, trade-intensive, and upstream sectors) would lead to greater trade recovery. In contrast, trade-only or horizontal-MNE models predict demand-side policies (targeting capital-intensive, skill-intensive, and less contract-intensive sectors) would yield greater trade recovery.

Productivity shocks affecting MNEs (relative to domestic firms) accounted for over half of global GDP change during the Great Recession, highlighting MNEs' macroeconomic importance.<sup>4</sup> Trade intensity, sector upstreamness, and trade credit are primary drivers of MNE productivity shocks. A model without MNEs underestimates the gains from policies targeting these industry

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<sup>3</sup>Extending the model to incorporate a CES production function, international capital flow and risk sharing, and MNE entry and exit yields qualitatively similar conclusions.

<sup>4</sup>While this number may initially appear large, its intuition is the following: From 2008 to 2009, world GDP declined by 1.4%, while MP declined 9% more than GDP. Furthermore, MNE foreign affiliate sales constituted 12.5% of world total output in 2007. Consequently, the approximate contribution of MP to world GDP decline, without accounting for general equilibrium effects, is calculated as:  $\frac{12.5\% \times 10.4\%}{(1-12.5\%) \times 1.4\% + 0.125 \times 10.4\%} = 51\%$ .

84 margins by two-thirds on global trade and by half on global GDP.

85 Applying the within-between country decomposition to model simulated data, I find that  
86 the “Multinationals’ Resilience Puzzle” can be rationalized by the transmission of productivity  
87 shocks from key headquarters to host countries through MNEs. They generated greater decline  
88 in MP relative to GDP in larger countries, greater decrease of GDP in MP-intensive countries,  
89 and resilience of MP relative to GDP in an average country. However, final demand shocks or  
90 domestic productivity shocks, if they only propagated through trade, are unable to account for  
91 these patterns. MP linkages significantly amplified the effects of productivity shocks in important  
92 headquarters on GDP, MP, and trade across other countries.

93 This paper contributes to the literature on MNE performance during the Great Recession. Prior  
94 works, including Alfaro and Chen (2012); Alvarez et al. (2017); Kamal and Kroff (2021) find MNE  
95 sales more resilient than host country domestic firms, but their sales declined with headquarters’  
96 GDP decline (also supported by Basco et al. 2023). Biermann and Huber (2019) and Bena et al.  
97 (2022) investigate shock transmission from headquarters and key subsidiaries to other subsidiaries.  
98 The paper also links to the extensive trade collapse literature, where works by Alessandria et al.  
99 (2010a,b); Bems et al. (2010); Levchenko et al. (2010); Eaton et al. (2016) attribute the trade  
100 collapse primarily to declining demand in the trade-intensive durable manufacturing sector.

101 Despite extensive literature on trade collapse, consensus on basic MP facts during the Great  
102 Recession—including MNE resilience—has not been reached. Prior work analyzed trade and MP  
103 collapse patterns separately. This paper studies empirically and quantitatively the impact of MP  
104 on the trade collapse. Accounting for trade intensive MNEs shifts trade collapse’s primary driver  
105 from demand to supply. To mitigate the trade collapse, models without MNEs predict demand-  
106 side policies, while the MNE model highlights supply policies’ importance. Trade-only models also  
107 underestimate MNE-targeting policies’ impact on trade and GDP.

108 This paper contributes to the literature that studies the propagation of shocks across regions  
109 and sectors. Previous studies have found trade linkages (e.g., Kehoe and Ruhl 2008; Di Giovanni  
110 et al. 2018; Huo et al. 2019; Bonadio et al. 2021), input-output connections (e.g., Caliendo and  
111 Parro 2015; Caliendo et al. 2017; Baqaee and Farhi 2019a,b; Foerster et al. 2019), and MNE  
112 headquarters-host country relationships (e.g., Cravino and Levchenko 2017; Alvarez et al. 2020;



113 Bilir and Morales 2020) can propagate economic shocks to other parts of the economy. I introduce  
114 a tractable framework integrating all three channels. MP linkages amplified key headquarters’  
115 domestic productivity shocks’ impact on other countries’ GDP, MP, and trade compared to prop-  
116 agation only through sectoral linkages and trade.

117 This paper extends the theoretical literature of multinational production. It combines Caliendo  
118 and Parro (2015) with Ramondo and Rodríguez-Clare (2013) and introduce headquarters-dependent  
119 sourcing and selling efficiencies. It presents a parsimonious yet realistic model of global value chains  
120 with flexible vertical/horizontal MNE structure. It extends Ramondo and Rodríguez-Clare (2013)  
121 and Arkolakis et al. (2018) to incorporate sector linkages and the MNEs’ sourcing and selling  
122 efficiencies with non-headquarters countries. It introduces MNE sourcing efficiency and input-  
123 output linkages into Head and Mayer (2019) and Wang (2019), and it introduces both efficiencies  
124 into Alvarez (2019). Ignoring these features will not capture realistic MNE vertical/horizontal  
125 structure and underestimates MNE productivity shocks’ impact on trade collapse and GDP.

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

## 130 **2. Data and Empirical Facts**

131 This section first describes the datasets. Next, I document the following facts: (1) The MP  
132 collapse was driven by a few large countries, and GDP declined more in MP-intensive countries;  
133 however, MP was more resilient than GDP for an average country during the Great Recession.  
134 (2) Trade and MP collapse were positively correlated at the country level. (3) MNEs contributed  
135 to the trade collapse because overall MNE sales declined and MNEs are more trade-intensive  
136 than domestic firms, not due to a decline in MNE trade intensity (trade-to-sales ratio) relative  
137 to domestic firms. (4) MNEs are more intensive in durable manufacturing, and engage more in  
138 trade, particularly with their headquarters and those proximate to their headquarters.

140 As far as I am aware, this is the first academic study that uses the new OECD AAMNE  
 141 database.<sup>5</sup> The database covers output and trade for domestic/foreign firms across 59 countries  
 142 and a constructed rest of the world for 2005 to 2016.<sup>6</sup> It comprises two data tables. The first  
 143 presents a complete matrix of MNE gross output, defined by headquarters country, host country,  
 144 and industry (34 total). The second extends the OECD inter-country input-output database  
 145 (OECD ICIO) to cover all countries and sectors and disaggregates each cell into four based on  
 146 whether a trade flow’s buyer or seller is a domestic firm or a foreign affiliate.<sup>7</sup> Section Appendix A.1  
 147 presents other datasets used in this paper.

148 Following Eaton et al. (2016), I measure country-level trade collapse using growth in a country’s  
 149 average imports and exports relative to its GDP, and country-level MP collapse using growth in  
 150 a country’s average inward and outward foreign affiliate sales relative to its GDP.<sup>8</sup> In order to  
 151 compare with Eaton et al. (2016), I use the same sector classification, collapsing the 34 industries  
 152 in the OECD AAMNE into three: durable manufacturing, nondurable manufacturing, and non-  
 153 manufacturing.<sup>9</sup>

## 154 *2.2. Resolving the “Multinationals’ Resilience Puzzle”*

155 Despite previous research (e.g., Alfaro and Chen 2012; Alviarez et al. 2017; Kamal and Kroff  
 156 2021) documenting MNE sales resilience compared to domestic firms during the Great Recession,  
 157 Figure 1 sharply contrasts this. It shows global MP plunged relative to GDP comparably to the  
 158 trade collapse.<sup>10</sup> To reconcile this inconsistency, which I call the “Multinationals’ Resilience Puz-  
 159 zle,” I conduct a within-between country decomposition, summarized in the following proposition:

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<sup>5</sup>OECD AAMNE highly correlates with MNE sales data previously used in the literature. Figure Appendix A.1a shows high correlation with the headquarters-host country-sector level MNE sales data collected by Alviarez (2019) when aggregated to their sector classification and averaged across 2003-2012, as Alviarez (2019) only reports the time-average statistics. Figure Appendix A.1b also shows high correlation with headquarters-sector level sales by foreign MNEs in the US from the US Bureau of Economic Analysis (US BEA). Ramondo et al. (2015) and Arkolakis et al. (2018) used this US BEA data.

<sup>6</sup>Table Appendix A.1 shows the countries in OECD AAMNE.

<sup>7</sup>OECD ICIO is a database documenting trade between country-sector pairs. See Ahmad et al. (2006).

<sup>8</sup>Inward foreign affiliate sales represent sales of foreign affiliates headquartered elsewhere. Outward foreign affiliate sales represent sales of foreign affiliates headquartered in the country and operating abroad.

<sup>9</sup>Table Appendix A.2 lists the industries in OECD AAMNE and their mappings to the broad sectors.

<sup>10</sup>Figure Appendix A.2 confirms these patterns are consistent across all sectors, suggesting sectoral composition is not the only driving force.

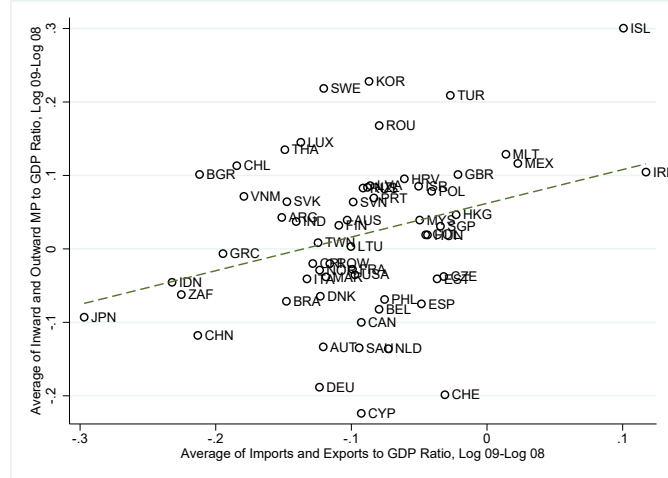
Figure 2: **Global MP and Trade Collapse During the Great Recession**

(a) 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
<b>All</b>				
MP	-0.020 (114.1%)	-0.008 (48.7%)	0.011 (-62.8%)	-0.017 (100%)
Trade	0.008 (-23.5%)	-0.002 (6.3%)	-0.038 (117.2%)	-0.032 (100%)
<b>I. Durable Manufacturing</b>				
MP	-0.045 (262.7%)	-0.033 (190.4%)	0.061 (-353.1%)	-0.017 (100%)
Trade	0.048 (-75.0%)	-0.004 (5.8%)	-0.108 (169.2%)	-0.064 (100%)
<b>II. Non-durable Manufacturing</b>				
MP	-0.010 (28.4%)	-0.034 (93.2%)	0.008 (-21.6%)	-0.037 (100%)
Trade	0.008 (-19.3%)	-0.012 (31.5%)	-0.034 (87.8%)	-0.039 (100%)
<b>III. Non-manufacturing</b>				
MP	-0.013 (108.5%)	-0.007 (54.8%)	0.008 (-63.3%)	-0.012 (100%)
Trade	0.005 (-22.3%)	-0.002 (8.9%)	-0.024 (113.4%)	-0.022 (100%)

*Notes:* 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.

(b) Country-Level Correlation of MP and Trade Collapse



*Notes:* This figure displays, on the country level, (1) average inward/outward affiliate sales growth and GDP growth difference; and (2) average imports/exports growth and GDP growth difference between 2008 and 2009. Regressing the MP collapse on the trade collapse at the country level gives a coefficient of 0.52 and a standard error of 0.21. The data source is OECD Analytical Activities of Multinationals (OECD AAMNE) Database.

**Proposition 1.** The change in the global MP-to-GDP ratio decomposes into two cross-country effects: (A) MP declined more in higher-GDP countries; (B) GDP declined more in MP-intensive countries; and one within-country effect: (C) the average country-level change of MP relative to GDP. See Equation (1):<sup>11</sup>

<sup>11</sup>In Equation (1),  $i$  represents a country,  $N$  is the total number of countries,  $MP_{i,t}$  denotes the average of country  $i$ 's inward and outward MP in year  $t$ , and  $GDP_{i,t}$  is country  $i$ 's GDP in year  $t$ . Term A quantifies the

$$\begin{aligned}
& \frac{\sum_{i=1}^N MP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} - \frac{\sum_{i=1}^N MP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}} \\
&= N \text{cov}_i \underbrace{\left( \frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}}, \frac{\frac{GDP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} + \frac{GDP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}}{2} \right)}_{\text{A: MP Declined More in Larger Countries}} \\
&+ N \text{cov}_i \underbrace{\left( \frac{GDP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} - \frac{GDP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}, \frac{\frac{MP_{i,2009}}{GDP_{i,2009}} + \frac{MP_{i,2008}}{GDP_{i,2008}}}{2} \right)}_{\text{B: GDP Declined More in More MP Intensive Countries}} + \underbrace{\frac{1}{N} \sum_{i=1}^N \left( \frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}} \right)}_{\text{C: Average MP Decline across Countries}}. \tag{1}
\end{aligned}$$

Table 2a presents the decomposition results and establishes the following fact:

**Fact 1.** *MP declined more in higher-GDP countries, while GDP fell more in MP-intensive countries. However, MP showed greater resilience than GDP in an average country.*

The MP collapse displayed greater cross-country heterogeneity than the trade collapse.<sup>12</sup> Its decline was driven entirely by MP decline in large, key headquarters countries and GDP decline in MP-intensive countries, despite MP rising relative to GDP in an average country. In contrast, the trade collapse was widespread in nearly all countries, with the within-country term fully accounting for the world total. Figure 2b, which plots country-level MP collapse against trade collapse, proves this pattern. This pattern prevails across all sectors, from manufacturing to service.

Previous works finding MNE resilience typically employed a regression approach that only uncovered average firm or sector resilience across countries. Hence, they mostly ignored the cross-country heterogeneity and failed to document the global MP collapse.<sup>13</sup>

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covariance between country-level MP collapse and the time-average of countries' shares of world GDP (adjusted for  $N$  countries). Term B captures the covariance between changes in countries' shares of world GDP and the time-average of countries' MP intensity (also adjusted for  $N$  countries). The within-country effect represents the average MP collapse across countries. To decompose the global trade collapse,  $MP_{i,t}$  is replaced with the average of country  $i$ 's imports and exports in year  $t$ . Proof is in Section Appendix A.2.

<sup>12</sup>Table Appendix A.3 further decomposes the within-country term from Equation 1 into its within-country-between-sector and within-country-within-sector components. The table shows that the within-country-between-sector term contributed to the MP collapse, even though MNE sales declined much less than GDP for an average country-sector. In contrast, the trade collapse was entirely driven by the within-country-within-sector term. The technical details are presented in Sector Appendix A.2.

<sup>13</sup>These studies typically consider an unweighted regression:  $y_{f,i,t} = \beta \mathbb{1}(\text{Great Recession}_t) \times \text{MNE}_f + FE_f + FE_t + \epsilon_{f,i,t}$ . Here,  $f$  denotes a firm or sector,  $i$  a country, and  $t$  a year.  $\mathbb{1}(\text{Great Recession}_t)$  is an indicator for the Great Recession, and  $\text{MNE}_f$  for whether firm  $f$  is an MNE or if the sector has higher MNE intensity.  $FE_f$  and  $FE_t$  are firm/sector and time fixed effects.

177 The next two facts examine how MNEs affected the trade collapse:

178 **Fact 2.** *Figure 2b demonstrates a positive correlation between MP and trade collapses across*  
 179 *countries, suggesting that shocks to MNEs contributed to the trade collapse.*<sup>14</sup>

180 Using an event study approach, I disentangle two potential channels through which MP con-  
 181 tributed to the trade collapse:

182 **Fact 3.** *MP amplified the trade collapse because MNE sales declined more than GDP globally and*  
 183 *MNEs have higher trade intensity (trade-to-sales ratio). However, MNEs' trade intensity did not*  
 184 *decline relative to domestic firms.*

185 First, I show that MNE imports and exports declined more than domestic firms and amplified  
 186 the trade collapse during the Great Recession. I use the OECD AAMNE trade-by-ownership  
 187 database, which provides trade value  $T_{nmji,t}^s$  from country  $j$  firms (domestic:  $i = D$ , or foreign:  
 188  $i = F$ ) to country  $n$  firms (domestic:  $m = D$ , or foreign:  $m = F$ ) across sectors  $s$  and years  $t$ :

$$\begin{aligned} \log(T_{nmji,t}^s) &= \sum_{k=2006}^{2012} \beta_k^{imp} \mathbb{I}\{t = k\} \times \mathbb{I}\{n \neq j\} + \sum_{k=2006}^{2012} \gamma_k^{imp} \mathbb{I}\{t = k\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{m = F\} + \delta_{nmji}^s + \delta_t^s + \epsilon_{nmji,t}^s, \\ \log(T_{nmji,t}^s) &= \sum_{k=2006}^{2012} \beta_k^{exp} \mathbb{I}\{t = k\} \times \mathbb{I}\{n \neq j\} + \sum_{k=2006}^{2012} \gamma_k^{exp} \mathbb{I}\{t = k\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{i = F\} + \delta_{nmji}^s + \delta_t^s + \epsilon_{nmji,t}^s, \end{aligned}$$

where  $m, i \in \{D, F\}$ .

(2)

189 The term  $\mathbb{I}\{t = k\} \times \mathbb{I}\{n \neq j\}$  interacts a cross-border trade dummy with time, capturing the  
 190 overall trade collapse.  $\mathbb{I}\{t = k\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{m = F\}$  and  $\mathbb{I}\{t = k\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{i = F\}$   
 191 further interact it with the importer's ( $m$ ) or exporter's ( $i$ ) MNE status. These effects quantify  
 192 how MNE imports and exports declined relative to domestic firms. While I examine two terms'  
 193 effects individually, I report the results when both terms are included in Table Appendix A.4.

194 Figures 3a and 3b show that MNE trade declined more than domestic firms' trade during the  
 195 Great Recession, with two potential channels: (1) MNEs' overall sales declined relative to domestic  
 196 firms while they have higher trade intensity (confirmed later in Fact 4 and 5), and (2) MNE trade

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<sup>14</sup>Figures Appendix A.3 and Appendix A.4 confirm the relationship holds across sectors and for all years in OECD AAMNE.

intensity itself declined relative to domestic firms. To disentangle these channels, I consider the following regression:

$$\begin{aligned}
\log(T_{nmji,t}^s) &= \sum_{k=2006}^{2012} \beta_k^{imp} \mathbb{I}\{t = k\} \times \mathbb{I}\{n \neq j\} + \sum_{k=2006}^{2012} \theta_k^{imp} \mathbb{I}\{t = k\} \times \mathbb{I}\{m = F\} \\
&\quad + \sum_{k=2006}^{2012} \gamma_k^{imp} \mathbb{I}\{t = k\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{m = F\} + \delta_{nmji}^s + \delta_t^s + \epsilon_{nmji,t}^s, \\
\log(T_{nmji,t}^s) &= \sum_{k=2006}^{2012} \beta_k^{exp} \mathbb{I}\{t = k\} \times \mathbb{I}\{n \neq j\} + \sum_{k=2006}^{2012} \theta_k^{exp} \mathbb{I}\{t = k\} \times \mathbb{I}\{i = F\} \\
&\quad + \sum_{k=2006}^{2012} \gamma_k^{exp} \mathbb{I}\{t = k\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{i = F\} + \delta_{nmji}^s + \delta_t^s + \epsilon_{nmji,t}^s,
\end{aligned} \tag{3}$$

where  $m, i \in \{D, F\}$ .

I include an additional interaction term,  $\mathbb{I}\{t = k\} \times \mathbb{I}\{m = F\}$  or  $\mathbb{I}\{t = k\} \times \mathbb{I}\{i = F\}$ : time dummy interacted with buyer's ( $m$ ) and seller's ( $i$ ) firm type (domestic or MNE). This term captures overall sales by domestic firms and MNEs. Once this term is controlled, the terms  $\mathbb{I}\{t = k\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{m = F\}$  and  $\mathbb{I}\{t = k\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{i = F\}$  capture whether MNE trade intensity (trade relative to sales) declined more than domestic firms.

Figures 3c and 3d show that MNEs contributed to the trade collapse due to declining overall sales and higher trade intensity, whereas their trade intensity remained more resilient than domestic firms. The coefficient for overall MNE sales is negative and significant; once this term is included, MNE trade increased relative to domestic firms, suggesting resilient trade intensity. Section Appendix A.3 presents difference-in-differences regressions that estimate the time-averaged effect and report more robustness tests.

I present additional cross-sectional facts about MNEs, with details in Section Appendix A.4:

**Fact 4.** *MNEs are more intensive in the durable manufacturing and international trade.*

**Fact 5.** *MNEs import and export more intensively with their headquarters countries and countries closer to their headquarters.*

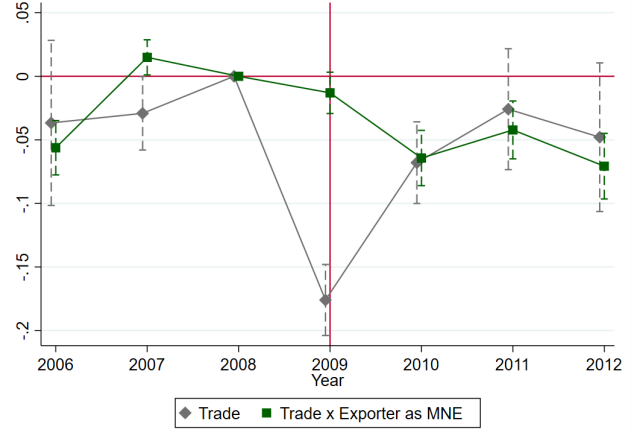
*Discussion.* Adverse domestic productivity shocks from major headquarters countries, propagating through MNEs across countries, can explain these empirical patterns. The Great Recession stemmed from a financial and real estate crisis in the United States that spread to other advanced economies' financial sectors. As MNEs rely on headquarters' financing (Biermann and Huber, 2019;

Figure 3: **Effect of Great Recession on Trade by Domestic Firms and MNEs**

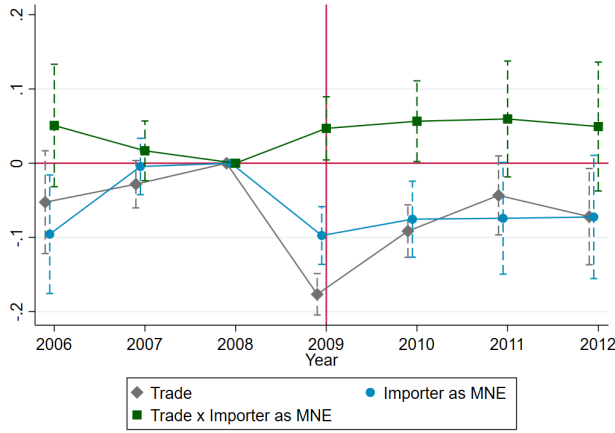
(a) MNE Imports Declined More Than Domestic Firm Imports



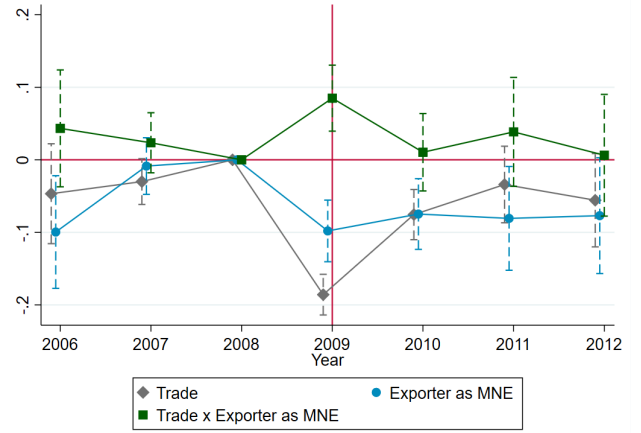
(b) MNE Exports Declined More Than Domestic Firm Exports



(c) Conditional on MNE Sales, MNE Imports Showed Resilience



(d) Conditional on MNE Sales, MNE Exports Showed Resilience



Notes: Panel (a) and (b) display the coefficients and 90% confidence interval from Equation (2). Panel (c) and (d) display the coefficients and 90% confidence interval from Equation (3). The vertical red line refers to year 2009. Standard errors are clustered at the importer country-importer firm type-exporter country-exporter firm type-sector ( $nmijst$ ) level. The year 2008 is the omitted reference quarter. The regression is weighted on sum of pre-period trade value ( $\sum_{t=2006}^{2008} T_{nmji,t}^s$ ).

Bena et al., 2022), these shocks negatively impacted MNE performance from advanced economies (often key headquarters and host countries) and decreased GDP in these MP-intensive countries (explaining the two cross-country terms in Equation 1). Productivity shocks to trade-intensive MNEs likely contributed to the trade collapse and augmented productivity shocks' overall role in it.<sup>15</sup> Prior works, which concluded demand shocks outweighed productivity shocks for the trade collapse, did not account for those specifically affecting MNEs. My quantitative analysis will use a model of MNEs and global value chains to re-evaluate whether demand or supply shocks were more crucial for the trade collapse.

<sup>15</sup>Quantitatively, demand shocks for MNEs did not significantly reduce their sales.

### 3. Model

The model integrates Caliendo and Parro (2015) with Ramondo and Rodríguez-Clare (2013). It features a global economy with  $N$  countries and  $S$  sectors. Its agents include households, firms/MNEs, and governments. Households consume and supply labor. Firms produce with host country labor and composite goods, which they source from different upstream countries and firms from different headquarters within each upstream country. All markets are competitive.<sup>16</sup> The government collects labor income taxes and tariffs and rebate the revenues to households.

#### 3.1. Household's Problem

Household utility maximization builds on Huo et al. (2019).<sup>17</sup> Households derive utility from consumption and leisure. They receive income from work (after a government labor income tax), tariff revenues, lump-sum rebate of the labor income tax, and foreign transfers:

$$\begin{aligned}
 \max_{C_{nm}^s, L_n^s} \quad & C_n - \sum_{s=1}^S \frac{\psi}{1+\psi} (L_n^s)^{\frac{1+\psi}{\psi}}, \\
 \text{s.t.} \quad & C_n = \left( \sum_{s=1}^S (\alpha_n^s)^{\frac{1}{\lambda}} (C_n^s)^{\frac{\lambda-1}{\lambda}} \right)^{\frac{\lambda}{\lambda-1}}, \\
 & C_n^s = \left( \sum_{m=1}^N (\alpha_{nm}^s)^{\frac{1}{\delta}} (C_{nm}^s)^{\frac{\delta-1}{\delta}} \right)^{\frac{\delta}{\delta-1}}, \\
 & P_n C_n \equiv \sum_{s=1}^S \sum_{m=1}^N P_{nm}^s C_{nm}^s = \sum_{s=1}^S (\xi_n^s)^{\frac{1}{\psi}} w_n^s L_n^s + R_n + T_n + D_n \equiv I_n, \\
 & T_n = \sum_{s=1}^S \left[ 1 - (\xi_n^s)^{\frac{1}{\psi}} \right] w_n^s L_n^s.
 \end{aligned} \tag{4}$$

Country  $n$ 's consumption ( $C_n$ ) is a Constant Elasticity of Substitution (CES) function of sectoral goods ( $C_n^s$ ), with an elasticity of substitution  $\lambda$  across sectors  $s$ . Within each sector, consumption is a CES function of MNE-specific composite goods ( $C_{nm}^s$ ) from firms with different headquarters with an elasticity of substitution  $\delta$ .  $P_{nm}^s$  denotes *MNE-specific composite goods price*.

For income,  $L_n^s$  represents country-sector level labor supply, with wage denoted by  $w_n^s$ . The labor supply elasticity is  $\psi$ , and  $\left[ 1 - (\xi_n^s)^{\frac{1}{\psi}} \right]$  defines the labor income tax rate.<sup>18</sup> Additional terms

<sup>16</sup>These assumptions follow from Ramondo and Rodríguez-Clare (2013), Eaton et al. (2016), Cravino and Levchenko (2017), and Alviarez et al. (2017).

<sup>17</sup>This setup conveniently generates an upward-sloping labor supply function, as in Greenwood et al. (1988). Alternatively, Bonadio et al. (2021) and De Souza and Li (2022) produce a positive labor supply elasticity by assuming that each household chooses the sector that maximizes their utility.

<sup>18</sup>For clarity and following works like Huo et al. (2019) and Bonadio et al. (2021), I assume these elasticities are



include  $R_n$  for tariff revenue,  $T_n$  for the lump-sum labor income tax rebate, and  $D_n$  for foreign transfers (positive  $D_n$  means a trade deficit).

Equation (4) leads to the following sectoral labor supply function, as in Huo et al. (2019), as well as final expenditure shares on sectors and MNEs:<sup>19</sup>

$$\begin{aligned} L_n^s &= \xi_n^s \left[ \frac{w_n^s}{P_n^s} \right]^\psi, \\ s_n^s &= \frac{\alpha_n^s (P_n^s)^{1-\lambda}}{\sum_{s'=1}^S \alpha_n^{s'} (P_n^{s'})^{1-\lambda}}, \\ s_{nm}^s &= \frac{\alpha_{nm}^s (P_{nm}^s)^{1-\delta}}{\sum_{m'=1}^N \alpha_{nm'}^s (P_{nm'}^s)^{1-\delta}}. \end{aligned} \quad (5)$$

### 3.2. Firm's Problem

In country  $n$ , sector  $s$ , country  $m$ 's MNE produces tradable output  $y_{nm}^s$  by combining labor and MNE-specific composite goods from all sectors:<sup>20</sup>

$$y_{nm}^s = A_{nm}^s \left( \frac{L_{nm}^s}{\gamma_n^s} \right)^{\gamma_n^s} \prod_{s'=1}^S \left( \frac{M_{nm}^{ss'}}{\gamma_n^{ss'}} \right)^{\gamma_n^{ss'}}. \quad (6)$$

MNEs in the same host country differ in both their productivity  $A_{nm}^s$  and MNE-specific composite input prices. MNEs hire labor  $L_{nm}^s$  and use non-tradable, MNE-specific composite goods  $M_{nm}^{ss'}$  from sector  $s'$  for producing  $s$  output. The price of  $M_{nm}^{ss'}$  is the MNE-specific composite goods price  $P_{nm}^{s'}$ , as defined in Equation (4). Production exhibits constant returns to scale with  $\gamma_n^s + \sum_{s'=1}^S \gamma_n^{ss'} = 1$ .<sup>21</sup>

The composite goods are produced with a “love-of-variety” function, combining tradable output from upstream host countries and MNEs in each host country. The outer nest captures trade-offs between countries at an elasticity of substitution  $\sigma$  (*trade elasticity*). The inner nest combines all MNEs within a country at an elasticity  $\zeta$  (*MNE elasticity*):

$$Q_{nm}^s = \left[ \sum_{j=1}^N \left( \sum_{i=1}^N (q_{nmji}^s)^{\frac{\zeta-1}{\zeta}} \right)^{\frac{\zeta}{\zeta-1} \frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}. \quad (7)$$

The price paid by an MNE from country  $m$ , operating in  $n$ , for a unit of output from an MNE

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constant across sectors.

<sup>19</sup>Based on properties of the CES function,  $P_n^s = \left( \sum_{m=1}^N \alpha_{nm}^s (P_{nm}^s)^{1-\delta} \right)^{\frac{1}{1-\delta}}$  and  $P_n^s = \left( \sum_{s=1}^S \alpha_n^s (P_n^s)^{1-\lambda} \right)^{\frac{1}{1-\lambda}}$ . The following normalization is imposed:  $\alpha_n^s = 1$  for non-manufacturing sector and  $\alpha_{nn}^s = 1$  for domestic firms' composite goods.

<sup>20</sup>Technology and trade flow from right to left in the subscripts.

<sup>21</sup>I assume that all MNEs in host country  $n$  have the same input-output shares  $\gamma_n^s$  and  $\gamma_n^{ss'}$  – the same assumption is used by Alvarez (2019).

259 in country  $i$ , operating in  $j$ , is:

$$\tilde{H}_{ni}^s \tilde{h}_{mj}^s k_{nj}^s t_{nj}^s \frac{\Theta_{ji}^s}{A_{ji}^s}. \quad (8)$$

260 The selling MNE's input bundle cost is represented by  $\Theta_{ji}^s = (w_j^s)^{\gamma_j^s} \prod_{s'=1}^S (P_{ji}^{s'})^{\gamma_j^{ss'}}$ .<sup>22</sup> Trade  
 261 between countries  $j$  and  $n$  incurs both iceberg, *non-tariff trade barriers* ( $k_{nj}^s$ ), and ad-valorem  
 262 *tariffs* at rate  $\tau_{nj}^s$ , with  $t_{nj}^s = 1 + \tau_{nj}^s$ .

263 Departing from prior works, I assume MNEs face headquarters-trade partner-specific iceberg  
 264 frictions sourcing from and selling to non-headquarters countries.  $\tilde{h}_{mj}^s$  represents the *MNE sourcing*  
 265 *friction* for an MNE headquartered in country  $m$  that sources inputs from country  $j$ .  $\tilde{H}_{ni}^s$  denotes  
 266 the *MNE selling friction* for an MNE headquartered in country  $i$  that sells to country  $n$ .<sup>23</sup>

267 *MNE Output Shares and Sourcing Shares*. They critically differentiate international trade pat-  
 268 terns of MNEs from domestic firms.<sup>24</sup> The *MNE output shares* refer to a selling MNE's share  
 269 (headquartered in  $i$  and operating in  $j$ ) in trade from host country  $j$  to destination  $n$ , as follows:

$$S_{nji}^s = \frac{H_{ni}^s \left( \frac{\Theta_{ji}^s}{A_{ji}^s} \right)^{1-\zeta}}{\sum_{k=1}^N H_{nk}^s \left( \frac{\Theta_{jk}^s}{A_{jk}^s} \right)^{1-\zeta}}. \quad (9)$$

270 I relabel  $H_{ni}^s = \left( \tilde{H}_{ni}^s \right)^{1-\zeta}$ , which represents the *MNE selling efficiency* for MNEs headquartered  
 271 in country  $i$  selling to country  $n$ . Country  $j$ 's producer price index for shipments to  $n$ ,  $P_{nj}^{s,p}$ , is  
 272 defined by the denominator of Equation (9) as:  $(P_{nj}^{s,p})^{1-\zeta} = \sum_{k=1}^N H_{nk}^s \left( \frac{\Theta_{jk}^s}{A_{jk}^s} \right)^{1-\zeta}$ .<sup>25</sup>

273 The *MNE sourcing shares* represent a buying MNE's (headquartered in  $m$  and operating in  
 274  $n$ ) expenditure share on origin country  $j$ . They are the outer-nest shares and equal:

$$\pi_{nmj}^s = \frac{h_{mj}^s (k_{nj}^s t_{nj}^s P_{nj}^{s,p})^{1-\sigma}}{\sum_{l=1}^N h_{ml}^s (k_{nl}^s t_{nl}^s P_{nl}^{s,p})^{1-\sigma}}. \quad (10)$$

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<sup>22</sup>Consequently, the factory gate price per unit of output becomes  $\frac{\Theta_{ji}^s}{A_{ji}^s}$ , based on profit maximization and perfect competition assumptions.

<sup>23</sup>Non-tariff trade barriers within a country, as well as MNEs' selling and sourcing frictions with the headquarters, are normalized to one:  $k_{nn}^s = \tilde{H}_{ii}^s = \tilde{h}_{mm}^s = 1$ .

<sup>24</sup>As an alternative to the nested-CES setup, Section Appendix B.1 builds on Ramondo and Rodríguez-Clare (2013) to develop a micro-foundation for the MNE sourcing problem. The downstream MNE draws correlated productivity shocks for upstream host countries and upstream MNEs and source from the lowest-cost supplier. It yields the same market shares as in Equations (9) and (10).

<sup>25</sup>A lower  $P_{nj}^{s,p}$  indicates higher productivity, lower input prices, or greater selling efficiency for MNEs hosted by country  $j$  selling to destination  $n$ .

I relabel  $h_{mj}^s = \left(\tilde{h}_{mj}^s\right)^{1-\sigma}$ , which represents the *MNE sourcing efficiency* for MNEs headquartered in country  $m$  sourcing from  $j$ .<sup>26</sup> The MNE-specific composite goods price is defined as:  $(P_{nm}^s)^{1-\sigma} = \sum_{l=1}^N h_{ml}^s (k_{nl}^s t_{nl}^s P_{nl}^{s,p})^{1-\sigma}$ . This MNE will face lower composite goods price if country  $n$  has lower trade barrier and producer price index, or if country  $m$ 's MNE is more efficient at global sourcing.

*Sourcing and Selling Efficiencies Determine the MNE's Vertical/Horizontal Structure.* Consider three cases: (1) Forward-vertical MNEs source exclusively from their headquarters  $m$  (i.e.,  $h_{mj}^s = 0, \forall j \neq m$ ). For example, Toyota dealers in the US importing cars solely from Japan; (2) Backward-vertical MNEs sell exclusively to their headquarters (i.e.,  $H_{ni}^s = 0, \forall n \neq i$ ). For example, Toyota's tire suppliers in Thailand providing tires solely to Japan; and (3) Horizontal MNEs (i.e.,  $h_{mj}^s = H_{ni}^s = 1, \forall m, n, j, i$ ) have identical sourcing and sales shares as domestic firms. They differ from domestic firms only in productivity, not in their sourcing and selling patterns.<sup>27</sup>

In reality, most MNEs exhibit a mix of forward-vertical, backward-vertical, and horizontal characteristics.<sup>28</sup> Thus, the true values of MNE sourcing and selling efficiencies are unlikely to fall strictly into any of these three cases and need to be calibrated using data.

*MNE-Bilateral Expenditure Shares.* Expenditure share of an MNE from country  $m$  operating in  $n$ , on the output from one from  $i$  operating in  $j$ , equals the following:

$$\pi_{nmji}^s = \pi_{nmj}^s S_{nji}^s. \quad (11)$$

*Equilibrium in Levels and Changes.* I present the market clearing conditions in Section Appendix B.2. The model is solved in changes using the “exact hat algebra” technique. MNE sourcing and output shares, baseline tariffs, final goods expenditure shares and household income sufficiently characterize model response to shocks (see Section Appendix B.3).

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<sup>26</sup>Both 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  $h_{mm}^s = 1 \forall m$ .

<sup>27</sup>These efficiencies can also explain foreign affiliates' greater import/export engagement than domestic firms, alongside their higher trade with headquarters and proximate countries.

<sup>28</sup>See Yeaple (2003), Antràs and Yeaple (2014), Baldwin and Okubo (2014), Ramondo et al. (2016), among others.

296 By integrating Caliendo and Parro (2015) with Ramondo et al. (2015), the model presents a  
 297 parsimonious yet realistic treatment of MNEs and global supply chains. The model incorporates  
 298 input-output linkages and accounts for headquarters' influence on MNEs' international trade de-  
 299 cisions. As intermediate goods constitute the majority of trade, input-output linkages are crucial  
 300 for understanding how various shocks drove the trade collapse. MNEs' international trade deci-  
 301 sions, governed by headquarters sourcing and selling efficiencies, match the model with empirical  
 302 data showing: (1) MNEs are more trade-intensive than domestic firms, and (2) MNEs trade more  
 303 intensively with their headquarters and countries proximate to their headquarters. These features  
 304 are critical for how MNEs impacted the trade collapse.

305 In the next paragraphs, I outline how the model can incorporate endogenous international  
 306 capital flows and MNE entry and exit into production and trade.<sup>29</sup> While these extensions enrich  
 307 the model, they don't change MNEs' role in the trade collapse or broader macroeconomic outcomes.

308 *International Capital Flows.* Households in different countries trade state-contingent bonds to  
 309 borrow and save for consumption smoothing.<sup>30</sup> The utility function in Equation (4) is modified  
 310 as follows, where households maximize their lifetime utility by choosing labor, consumption, and  
 311 state-contingent bonds each period:

$$\begin{aligned} & \max_{C_{n,t}, L_{n,t}^s, Q_n(s_{t+1}|s_t)} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \log \left( C_{n,t} - \sum_{s=1}^S \frac{\psi}{1+\psi} (L_{n,t}^s)^{\frac{1+\psi}{\psi}} \right) \\ \text{s.t. } & P_{n,t} C_{n,t} + \sum_{s_{t+1}} p(s_{t+1}|s_t) Q_n(s_{t+1}|s_t) = \sum_{s=1}^S (\xi_{n,t}^s)^{\frac{1}{\psi}} w_{n,t}^s L_{n,t}^s + R_{n,t} + T_{n,t} + Q_n(s_t|s_{t-1}). \end{aligned} \quad (12)$$

312 To create a consumption smoothing motive, we assume per-period utility equals log of the previous  
 313 utility function in Equation (4). The international capital market is complete, featuring an asset  
 314 that pays one unit of monetary income for each history-dependent state  $s_t$ . Denote its current  
 315 holding as  $Q_n(s_t|s_{t-1})$  and price of next period's bond  $p(s_{t+1}|s_t)$ . Other variables in Equation (12)  
 316 maintain the definitions in Equation (4).

317 Proposition Appendix B.1 shows that the solution to Problem (12) is as follows:<sup>31</sup>

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<sup>29</sup>A more straightforward extension replaces the Cobb-Douglas production function with a CES function, discussed in Section Appendix B.6.

<sup>30</sup>See Backus et al. (1992), and recent works including Caselli et al. (2020) and Feng et al. (2024).

<sup>31</sup>See Section Appendix B.7 for additional analytical details.

$$P_{n,t}C_{n,t} = \frac{\lambda_n}{\sum_{n=1}^N \lambda_n} \sum_{n=1}^N \left( \frac{1}{1+\psi} \sum_{s=1}^S (\xi_{n,t}^s)^{\frac{1}{\psi}} w_{n,t}^s L_{n,t}^s + R_{n,t} + T_{n,t} \right) + \frac{\psi}{1+\psi} \sum_{s=1}^S (\xi_{n,t}^s)^{\frac{1}{\psi}} w_{n,t}^s L_{n,t}^s.$$

Through saving and borrowing, households can hedge  $\frac{1}{1+\psi}$  of their labor income and all their transfer income  $R_{n,t}$  and  $T_{n,t}$ .  $\lambda_n$  represents the inverse of country  $n$ 's marginal utility of income. For their hedged income, they receive a share  $\frac{\lambda_n}{\sum_{n=1}^N \lambda_n}$  of global income, which reduces their exposure to country-idiosyncratic shocks and country-idiosyncratic shocks disproportionately affect large countries (those with lower marginal utility of income).<sup>32</sup>

*MNE Entry and Exit in Production and Trade.* I introduce these features by combining Arkolakis et al. (2018) and Caliendo and Parro (2015). Following the spirit of the baseline model, I also incorporate input-output linkages and headquarters-dependent marginal and fixed costs for MNEs' sourcing and selling with non-headquarters countries. See Section Appendix B.8 for details.

A key takeaway is the following MNE-bilateral sourcing share, the counterpart of Equation (11) of the baseline model:

$$\pi_{nmji}^s = \frac{M_{ji}^s \pi_{nmj}^{s,\text{firm}} S_{nji}^{s,\text{firm}} [t_{nj}^s F_{nmji}^s]^{\frac{\zeta-\kappa}{1-\kappa}}}{\sum_{j=1}^N \sum_{i=1}^N M_{ji}^s \pi_{nmj}^{s,\text{firm}} S_{nji}^{s,\text{firm}} [t_{nj}^s F_{nmji}^s]^{\frac{\zeta-\kappa}{1-\kappa}}}, \quad (13)$$

in which firm-level sourcing and output shares,  $S_{nji}^{s,\text{firm}}$  and  $\pi_{nmj}^{s,\text{firm}}$  have the same expressions as in Equations (9) and (10).  $M_{ji}^s$  denotes the measure of firms from  $i$  operating in  $j$ , reflecting MNE entry and exit into production. The term  $[t_{nj}^s F_{nmji}^s]^{\frac{\zeta-\kappa}{1-\kappa}}$  captures the fixed cost an MNE from country  $i$  in  $j$  faces selling to an MNE from country  $m$  in  $n$ .<sup>33</sup>

Equation (13) shows that aggregate sourcing by MNEs (from  $m$  operating in  $n$ ) from other MNEs (from  $i$  operating in  $j$ ) increases under three cases: (1) each individual MNE is more likely to do so, indicated by a greater  $\pi_{nmj}^{s,\text{firm}} S_{nji}^{s,\text{firm}}$ ; (2) a greater measure of MNEs from  $i$  is producing in  $j$  (higher  $M_{ji}^s$ ); or (3) such sourcing faces lower fixed trade costs or headquarters-dependent fixed MNE sourcing and selling frictions (lower  $[t_{nj}^s F_{nmji}^s]^{\frac{\zeta-\kappa}{1-\kappa}}$ ).

<sup>32</sup> $\lambda_n$  does not have the time subscript because, as I show in Section Appendix B.7, their relatives across countries do not change over time. In this model, current account deficit,  $D_{n,t}$ , arises endogenously:  $D_{n,t} = P_{n,t}C_{n,t} - \left( \sum_{s=1}^S (\xi_{n,t}^s)^{\frac{1}{\psi}} w_{n,t}^s L_{n,t}^s + R_{n,t} + T_{n,t} \right)$ .

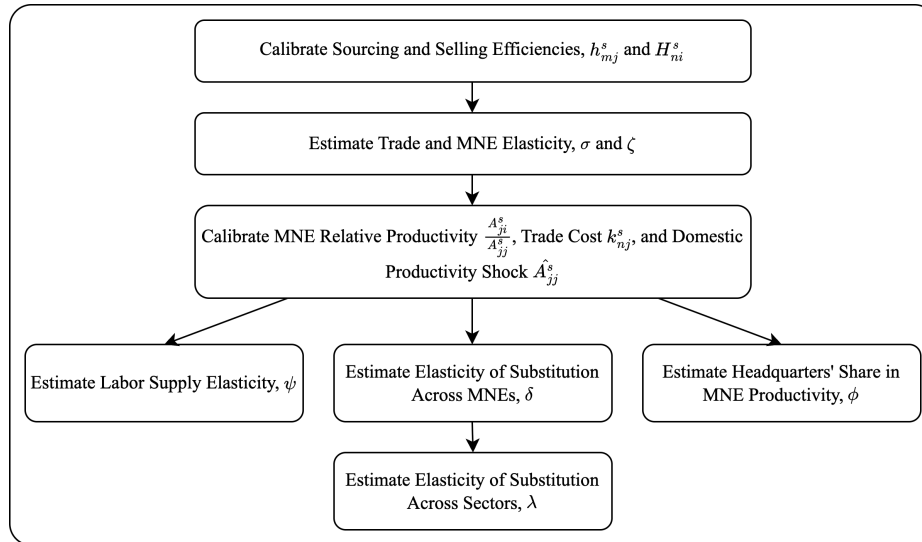
<sup>33</sup>In this model,  $\kappa$  is the elasticity of substitution across firms and  $\frac{\kappa}{\kappa-1}$  is the firm markup. It is required that  $1 < \kappa < \zeta < \sigma$ .

Compared to the baseline model, the extension with firm entry and exit does not change a shock's category (productivity, final demand, or MNE); instead, it decomposes the aggregate shocks identified with the baseline model into intensive and extensive margins. As shown in Proposition Appendix B.4, the baseline model's MNE productivity shock combines firm productivity and the measure of MNEs in the extended model. Baseline trade cost and MNE sourcing and selling efficiencies combine the extended model's trade cost, sourcing, and selling efficiencies on the firm level, with the fixed trade, sourcing, and selling costs.

#### 4. Shock Calibration and Model Validation

Figure 4 outlines the model's shock calibration and parameter estimation procedure. First, I calibrate MNE sourcing and selling efficiencies exactly with the OECD AAMNE data. Next, using this information, I estimate the trade and MNE elasticity. With these elasticities and MNE output data, I calibrate MNE productivity relative to domestic firms, trade cost, and domestic productivity shock. Using MNE productivity shock, I create exogenous variations to estimate the remaining elasticities: headquarters' share in MNE productivity, elasticity of substitution across MNEs within a sector and across sectors, and labor supply elasticity. Finally, with all estimated elasticities, I invert the model for the remaining shocks.

Figure 4: **Procedure to Calibrate Model Shocks and Estimate Elasticities**



Notes: This flow chart outlines the model's shock calibration and elasticity estimation procedure.

Section 4.1 presents the model shock calibration, focusing on MNE sourcing and selling effi-

ciencies (details in Section Appendix C.1). Section 4.2 discusses the performance of shocks during the Great Recession (details in Section Appendix C.3). Section 4.3 briefly discusses how the model elasticities are estimated (details in Section Appendix C.4). Section 4.4 presents numerous model validations with data that has not been used in the calibration (details in Section Appendix C.10).

#### 4.1. Model Shock Calibration

*MNE Sourcing and Selling Efficiencies.* Their calibration requires an involved process because OECD AAMNE lacks direct information on sourcing or selling activities for MNEs from an arbitrary headquarters. Instead, available data includes only headquarters-host country total output, along with sourcing and selling values by domestic firms and *all* MNEs.

I develop a new method to exactly calibrate MNE sourcing and selling efficiencies based on OECD AAMNE without any estimation of model elasticities. I calibrate MNE sourcing efficiency based on the difference between sourcing shares by foreign affiliates and domestic firms.<sup>34</sup> Note

that  $\frac{\pi_{nmj}^s}{\pi_{nnj}^s} = \frac{\frac{h_{mj}^s}{h_{nj}^s}}{\sum_{l=1}^N \pi_{nml}^s \frac{h_{ml}^s}{h_{nl}^s}}$ . Plug this into the equation that equates a country's total imports with the sum of imports by all firms in the country,  $T_{nj}^s = \frac{\sum_{m=1}^N X_{nm}^s \pi_{nmj}^s}{t_{nj}^s} = \frac{\sum_{m=1}^N X_{nm}^s \pi_{nnj}^s \frac{\pi_{nmj}^s}{\pi_{nnj}^s}}{t_{nj}^s}$ .<sup>35</sup> I derive the system of equations with which I solve  $h_{nj}^s$  and compute any MNE sourcing share,  $\pi_{nmj}^s$ .<sup>36</sup>

$$h_{nj}^s = \frac{\pi_{nnj}^s}{T_{nj}^s t_{nj}^s} \sum_{m=1}^N X_{nm}^s \frac{h_{mj}^s}{\sum_{l=1}^N \pi_{nml}^s \frac{h_{ml}^s}{h_{nl}^s}}. \quad (14)$$

I calibrate MNE selling efficiency using the difference between domestic firms' share in host country gross output and their share in host country exports. Specifically,  $GO_{ji}^s = \sum_{n=1}^N T_{nj}^s S_{nji}^s =$

$\sum_{n=1}^N T_{nj}^s S_{njj}^s \frac{S_{nji}^s}{S_{njj}^s} = \left( \frac{\Theta_{ji}^s}{A_{ji}^s} \right)^{1-\zeta} \sum_{n=1}^N T_{nj}^s S_{njj}^s H_{ni}^s$ .<sup>37</sup> As a result,  $\left( \frac{\Theta_{ji}^s}{A_{ji}^s} \right)^{1-\zeta} = \frac{GO_{ji}^s}{\sum_{p=1}^N T_{pj}^s S_{pjj}^s H_{pi}^s}$ . Plug this into the definition for  $S_{njj}^s$ , Equation (9), I obtain the system of equations to calibrate  $H_{nj}^s$ .<sup>38</sup>

<sup>34</sup>I calibrate MNE sourcing and selling efficiencies for all sectors and years available in OECD AAMNE.

<sup>35</sup> $T_{nj}^s$  denotes import by country  $n$  from  $j$  and  $X_{nm}^s$  country  $n$ 's expenditure on MNE- $m$  specific composite goods.

<sup>36</sup>Note that  $\pi_{nmj}^s = \pi_{nnj}^s \frac{\frac{h_{mj}^s}{h_{nj}^s}}{\sum_{l=1}^N \pi_{nml}^s \frac{h_{ml}^s}{h_{nl}^s}}$ .

<sup>37</sup> $GO_{ji}^s$  denotes total output by MNEs from  $i$  operating in  $j$ .

<sup>38</sup>For each sector  $s$ , Equations (14) and (15) have  $N^2$  equations with  $N^2$  unknowns. In these equations,  $h_{mj}^s$  and  $H_{ni}^s$  are identified up to a scale. If we multiply the sourcing or selling efficiencies of any headquarters country  $m$  or  $i$  with all countries by the same constant, the equations still hold. Consequently, I normalize the sourcing and selling efficiency with the headquarter economy,  $h_{mm}^s$  and  $H_{ii}^s$ , to 1, which fixes the remaining parameters. For each problem, I try different starting values and find they all converge to the same solution. With calibrated  $H_{nj}^s$ ,

$$H_{nj}^s = S_{njj}^s \sum_{k=1}^N \frac{GO_{jk}^s}{\sum_{p=1}^N T_{pj}^s S_{pjj}^s \frac{H_{pk}^s}{H_{pj}^s}} H_{nk}^s. \quad (15)$$

374 In Section Appendix C.1, I detail the calibration of the other model shocks: MNE productivity  
 375 relative to domestic firms (*MNE Relative Productivity Shocks*,  $\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}$ ), trade costs ( $\hat{k}_{nj}^s$ ), shocks to  
 376 domestic firm productivity ( $\hat{A}_{jj}^s$ ), sectoral and MNE final demand ( $\hat{\alpha}_n^s$  and  $\hat{\alpha}_{nm}^s$ ), and labor supply  
 377 ( $\hat{\xi}_n^s$ ). Note that a variable with a hat denotes its change over time:  $\hat{x} = \frac{x'}{x}$ , where  $x$  denotes the  
 378 variable in the current period and  $x'$  in the next period.

379 *Compute GDP in the Model with Calibrated Shocks.* A country's GDP change is computed as the  
 380 sum of contributions by domestic productivity shocks ( $\hat{A}_{jj}^s$ ), MNE relative productivity shocks  
 381 ( $\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}$ ), and labor supply changes ( $\hat{L}_j^s$ ), according to the following equation:<sup>39</sup>

$$\log(\widehat{GDP}_j) = \sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji}^s}{\sum_{s=1}^S w_j^s L_j^s} \log(\hat{A}_{jj}^s) + \sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji}^s}{\sum_{s=1}^S w_j^s L_j^s} \log\left(\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}\right) + \sum_{s=1}^S \frac{w_j^s L_j^s}{\sum_{s=1}^S w_j^s L_j^s} \log(\hat{L}_j^s). \quad (16)$$

382 Section Appendix C.2 shows that, using a variance decomposition approach, domestic productivity  
 383 shocks explain 51% of GDP changes across all countries and years, MNE relative productivity  
 384 shocks explain 42%, and factor supply accounts for 7%. During the Great Recession, domestic  
 385 productivity shocks explain 46% of GDP changes across countries, MNE relative productivity  
 386 shocks explain 39%, and factor supply contributes 14%.

#### 387 4.2. Model Shock Performance During the Great Recession

388 *During the Great Recession, MNEs Experienced Productivity Decrease and Became More Vertical*  
 389 *(Which Increased Their Trade Intensity).* Regressing calibrated shocks on gravity variables, I  
 390 find that MNE productivity decreased, which contributed to the MP collapse. MNE sourcing and  
 391 selling efficiencies with non-headquarters countries also declined, which made MNEs more vertical.  
 392 This led to greater MNE trade intensity compared to domestic firms and supports Fact 3, as MNEs

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I can also calculate the output share of an arbitrary MNE.

<sup>39</sup>For expositional clarity, this paper focuses on GDP as the macroeconomic outcome. The implications of MNEs and various shocks on other macroeconomic well-being measures, such as consumer welfare, are qualitatively similar. Equation (16) is derived in Section Appendix C.2. Notably, Baqaee and Farhi (2019a) derived a similar formula that does not include MNEs.



gained a comparative advantage in sourcing and selling with headquarters while domestic firms increased local sourcing and selling. Furthermore, pre-Recession trade and MP linkages, along with deep trade agreements with headquarters, mitigated MNE productivity and trade losses. Section Appendix C.3 details these analysis.

*Classify Shocks as Supply or Demand.* To revisit the trade collapse literature, I classify shocks as either supply or demand (Table 1). Supply shocks include MNE relative productivity ( $\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}$ ), domestic productivity ( $\hat{A}_{jj}^s$ ), and labor supply ( $\hat{\xi}_n^s$ ) shocks. Demand shocks include final demand shocks for sectors ( $\hat{\alpha}_n^s$ ) and MNEs ( $\hat{\alpha}_{nm}^s$ ). Previous works focused on domestic productivity and labor supply shocks as supply shocks, and sectoral final demand shocks as demand shocks, and ignored shocks differentially affecting MNEs and domestic firms.

Table 1: **Classify Shocks as Supply or Demand**

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

*Notes:* This table displays the shocks studied in the model and classifies them as either supply or demand shocks.

*Both Demand and Supply Shocks Decreased More for Manufacturing Sectors..* Figure Appendix C.1 shows that most shocks—sectoral final demand ( $\hat{\alpha}_n^s$ ), domestic productivity ( $\hat{A}_{jj}^s$ ), labor supply ( $\hat{\xi}_n^s$ ), and MNE relative productivity ( $\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}$ )—all decreased more for manufacturing than for non-manufacturing. A trade-only model likely misinterprets the source of trade collapse: it would treat the decline in input demand by manufacturing MNEs (due to their productivity decrease) as a decline in manufacturing’s final demand.

### 4.3. Elasticity Estimation

I develop a novel method to jointly estimate the MNE and trade elasticities, using a model-implied regression equation and variations in MP shares and tariffs. These estimations leverage 2005-2016 trade and MP data from OECD AAMNE. Controlling for origin-destination-sector fixed effects, I identify short-run elasticities using time variation. I instrument MP shares and tariffs with applied MFN tariffs, following Boehm et al. (2023).

I estimate headquarters' share in MNE productivity by regressing shocks to MNE productivity relative to domestic firms on the difference in headquarters and host country domestic productivity shocks. I develop new instruments with MNE headquarters productivity shocks to estimate final demand elasticities (for sectors and MNEs) and labor supply elasticity. These instruments generate exogenous variations in host country prices and labor demand.

Section Appendix C.4 shows the estimation of trade and MNE elasticities. Section Appendix C.6 presents the estimation of the headquarters' share in MNE productivity. Section Appendix C.7 details the estimation methods for final demand elasticities for MNEs within a sector and across sectors. Labor supply elasticity is estimated in Section Appendix C.8.

*Impact of Trade and MNE Elasticity Estimation Errors on Other Parameter Estimates.* Figure 4 shows that estimation errors for  $\sigma$  and  $\zeta$  affect the estimation of all other parameters, the calibration of most shocks (except MNE sourcing and selling efficiencies), and ultimately the quantitative results. To account for this, I make 300 independent draws of  $\sigma$  and  $\zeta$  from their asymptotic distribution (Column 1 of Table Appendix C.8). For each draw, I estimate, calibrate, and run a full model simulation.

Table 2 summarizes the baseline estimates-other elasticities' values when  $\sigma$  and  $\zeta$  are at their estimated means. Figure Appendix C.2 displays the distributions of these estimated elasticities relative to their baselines.

Table 2: **Estimated Parameters**

Parameter	Definition	Value	Estimation Method
$\sigma$	Trade Elasticity	3.10	Section Appendix C.4
$\zeta$	MNE Elasticity	2.71	Section Appendix C.4
$\phi$	Headquarters' Share in MNE Productivity	0.23	Section Appendix C.6
$\delta$	Elasticity of Substitution across MNEs within Sector	2.73	Section Appendix C.7
$\lambda$	Sectoral Final Demand Elasticity	1.81	Section Appendix C.7
$\psi$	Labor Supply Elasticity	0.61	Section Appendix C.8
$\mu$	Elasticity of Substitution across Inputs	High Value: 0.67 Low Value: 0.1	Section Appendix B.6 presents the extended model with CES production function. High value comes from De Souza and Li (2022) and low value is from De Souza et al. (2024).

*Notes:* This table displays estimated parameter values and estimation methods under the baseline calibration where  $\sigma$  and  $\delta$  take their mean values.

#### 4.4. Model Validation

Section Appendix C.10 conducts several model validation exercises with data that has not been used in the calibration. First, I show that the calibrated MNE sourcing and selling efficiencies

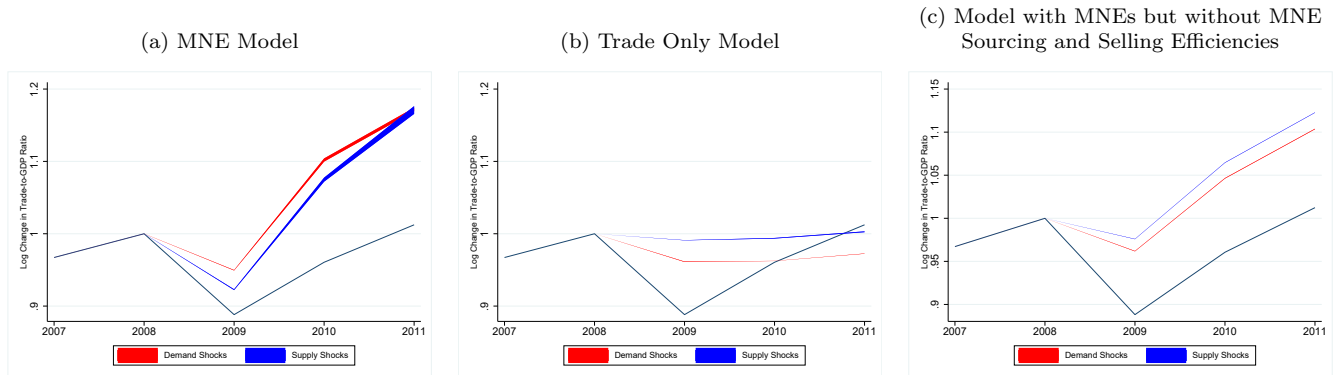
and productivity all follow gravity, consistent with Fact 5. Second, the model closely matches inter-MNE trade, the data for which not used in calibration. Third, the model implied GDP (Equation 16) accurately matches year-over-year GDP growth and GDP growth during the Great Recession in the actual data. Fourth, the model replicates the contribution by MNEs to the trade collapse, Fact 3. Finally, the model replicates the correlation between a country's GDP and its MNE sales, confirming that headquarters shocks propagate to host countries through MNEs.

## 5. Quantitative Analysis

With MNEs more adversely affected by productivity shocks and higher MNE trade intensity, the trade-only model under-predicts productivity shocks' impact on the trade collapse.<sup>40</sup> I first present the importance of supply and demand shocks for trade collapse in MP and trade-only models. I then highlight MNE shocks' large contribution to GDP. Next, I examine the impact of policies targeting supply or demand. Finally, I show how MP amplified the propagation of shocks across countries.

### 5.1. Importance of Shocks

Figure 5: **MP Model Concludes that Supply Shocks Contributed More to the Trade Collapse than Demand Shocks**



Notes: This figure shows the impact of demand and supply shocks on the trade collapse in different models: (a) the baseline model with MP, (b) the model with only trade but no MP, and (c) MP model without sourcing and selling efficiencies. The area represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

MP Model Predicts that Supply Shocks Contributed More to Trade Collapse than Demand Shocks.

Figure 5a shows that in the model with MNE, supply shocks (blue) contributed more to the trade

<sup>40</sup>This intuition is formalized in Section Appendix D.2 with an extension of the decomposition in Section 2.2.

collapse than demand shocks (red).<sup>41</sup> In contrast, Figure 5b shows that in the model without MP, demand shocks had a greater impact on the trade collapse than supply shocks, same as previous literature.<sup>42</sup>

Figure 5c shows demand shocks contributed more to trade collapse in the MNE model without sourcing/selling efficiencies, similar to a trade-only model. Here, MNEs are entirely *horizontal* and have trade patterns identical to domestic firms; consequently, their productivity shocks do not significantly affect trade.

As robustness tests, Figure Appendix D.1 shows that supply shocks consistently contributed more to the trade collapse than demand across various extended MP model specifications. These specifications include: (1) CES production functions; (2) international capital flows and risk sharing; and (3) firm entry and exit into production and trade.<sup>43</sup>

Figure Appendix D.2 shows a further counterfactual: if calibrated supply shocks had not hit the global economy, trade would have recovered more in the baseline MP model. Trade-only models or MNE models without sourcing and selling efficiencies would attribute greater trade recovery to the absence of demand shocks.<sup>44</sup>

*Impact of Different Shocks on GDP, MP, Trade.* Table Appendix D.8 shows that shocks affecting MNE productivity relative to domestic firms individually explained 66% of global GDP decline during the Great Recession.<sup>45</sup> This impact is comparable to domestic productivity shocks, which

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<sup>41</sup>The model computes outcomes after 2009 by using its predicted counterfactual 2009 level as the initial value and applying factual shocks after 2009.

<sup>42</sup>Quantitatively, Table Appendix D.4 shows demand shocks explained 44% of the trade collapse in the baseline MNE model, 33% in the trade-only model, and 33% in the MNE model without sourcing and selling efficiencies. Supply shocks explained 68% of the trade collapse in the baseline MNE model, 8% in the trade-only model, and 21% in the MNE model without sourcing and selling efficiencies. Overall, supply shocks consistently contributed more to global GDP decline than demand shocks during the Great Recession.

<sup>43</sup>Quantitatively, across all extended MNE models, demand shocks accounted for about 45% of the trade collapse, while supply shocks' contributed from 45% to 90% (Table Appendix D.5). In the model with international capital flows, supply shocks contributed less to the trade collapse due to international risk sharing, compared to other MNE models. Despite this, supply shocks still affected trade collapse by a magnitude higher than demand shocks.

<sup>44</sup>Table Appendix D.6 shows that removing demand shocks would have increased 2009's global trade by 2-4% relative to global GDP, recovering 18-32% of the Great Recession's trade loss. In trade-only models or MNE models without sourcing and selling efficiencies, removing supply shocks would increase 2009's global trade by only 1% relative to global GDP, recovering just 8% of the trade loss. However, in the baseline MNE model, removing supply shocks would have increased 2009's global trade by 7% relative to global GDP, recovering a substantial 60% of the trade loss. Table Appendix D.7 further shows that the baseline MNE model's high contribution of supply shocks to trade is robust across other extended MNE models.

<sup>45</sup>Table Appendix D.9 shows that MNE relative productivity shocks contributed a lower share to global GDP in the MNE model without sourcing and selling efficiencies, at 23%. These shocks contributed to global GDP by a

individually accounted for 70%.<sup>46</sup> In contrast, final demand and labor supply shocks did not significantly contribute to global GDP.<sup>47</sup>

An intuition underlies the large effect of MNE productivity shocks on GDP: From 2008 to 2009, world GDP declined by 1.4% with MP fell 9% more than GDP. Given foreign affiliate sales constituted 12.5% of world output in 2007, MP's approximate contribution to world GDP (excluding general equilibrium effects) is calculated as:  $\frac{12.5\% \times 10.4\%}{(1-12.5\%) \times 1.4\% + 0.125 \times 10.4\%} = 51\%$ . This large effect is also supported by the variance decomposition exercise of GDP change into different supply shocks and find MNEs contributed about 40% (Equation 16).

As supply shocks include both domestic and MNE productivity shocks, they collectively impacted the trade and MP collapse more than demand. Table Appendix D.8 shows that, for the trade collapse, demand shocks accounted for 44%, domestic productivity shocks for 43%, and MNE productivity shocks for 51%.<sup>48</sup> For the MP collapse, demand shocks accounted for 41%, domestic productivity shocks for 71%, and MNE relative productivity shocks for 37%. Consequently, the MP collapse was also predominantly supply-driven.<sup>49</sup>

Figure Appendix D.4 shows that shocks to MNE sourcing and selling efficiencies *increased* trade and MP relative to GDP. As these efficiencies declined for non-headquarters countries, MNEs trade more with headquarters and became more vertical, while domestic firms increased local sourcing and selling. MNE trade hence exhibited greater resilience than domestic firms' trade.

*Relate Shocks to Economic Indicators and Policies.* To link model shocks with actual economic indicators and inform policy, I conduct a variance decomposition exercise similar to Levchenko et al. (2010) and Levchenko et al. (2011). Using cross-6-digit NAICS sector variations from US NBER CES data, I regress filtered sectoral demand shocks, domestic productivity shocks,

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magnitude similar to the baseline MNE model (60% to 70%) in other extended MNE models.

<sup>46</sup>The individual impact of MNE relative productivity shock and domestic productivity shock add up to more than 100% because more productive domestic firms would reduce the impact of shocks to MNEs.

<sup>47</sup>This finding is consistent with the macroeconomic business accounting literature, particularly Brinca et al. (2016), who, when comparing the Great Recession to previous ones, found smaller global labor wedge effect but a larger effect of the efficiency wedge on GDP.

<sup>48</sup>Table Appendix D.9 shows that MNE relative productivity shocks contributed a significantly smaller share (13%) to the trade collapse in the MNE model without sourcing and selling efficiencies. In contrast, these shocks explained 40% to 50% of the trade collapse in other extended MNE models.

<sup>49</sup>Table Appendix D.9 also shows that these productivity shocks had similar effects on the MP collapse in extended MNE models.

and MNE productivity shocks on a comprehensive set of sectoral characteristics (see Table 3). With the estimated coefficients, I then construct each sector characteristic’s importance for the calibrated shocks.<sup>50</sup>

Table 3: **Industry Characteristics’ Predictive Power for Demand, Domestic Productivity, and MNE Relative Productivity Shocks**

Shock Type	Asset Tang.	Capital Inten.	Contract Inten.	Exter. Fin. Depen.	Interm. Inten.	Inven. Ratio	Skill Inten.	Trade Credit Inten.	Trade Inten.	Upstream	Demand Policies	Supply Policies	MNE Policies
Demand	0.015	<i>0.290</i>	<i>0.305</i>	-0.000	0.087	0.042	<i>0.145</i>	0.060	0.051	0.001	0.741	0.095	0.113
Domestic Prod.	-0.033	0.006	-0.000	0.000	0.062	<i>0.441</i>	0.019	0.017	<i>0.119</i>	<i>0.366</i>	0.025	0.926	0.503
MNE Prod.	-0.029	0.134	0.029	0.063	0.000	-0.004	0.007	<i>0.166</i>	<i>0.377</i>	<i>0.254</i>	0.171	0.627	0.798

*Notes:* This table presents the predictive power of various industry characteristics for demand, domestic productivity, and MNE relative productivity shocks. These sector characteristics include: include sectoral asset tangibility, capital intensity, contract intensity, external finance dependence, intermediate input intensity, inventory ratio, skill intensity, trade credit intensity, and sector upstreamness. Their contributions, computed using Equation Appendix D.2, sum to one across all characteristics. Demand policies aim to mitigate firm performance differences related to variations in capital intensity, skill intensity, and low-contract-intensity. These policies mitigate 74.1% of actual demand shocks, 2.5% of domestic productivity shocks, and 17.1% of MNE relative productivity shocks. Supply policies address firm performance differences stemming from variations in inventories, trade intensity, and upstreamness. They mitigate 92.6% of domestic productivity shocks, 9.5% of demand shocks, and 62.7% of MNE relative productivity shocks. MNE policies target firm performance differences linked to variations in trade intensity, trade-credit intensity, and upstreamness. They reduce MNE relative productivity shocks by 79.8%, demand shocks by 11.3%, and domestic productivity shocks by 50.3%.

Table 3 identifies *capital intensity*, *skill intensity*, and *contract intensity* as the most important sector characteristics for final demand shock, explaining 29%, 15%, and 30% of cross-sector variation.<sup>51</sup> For supply shock, *inventory intensity*, *trade intensity*, and *sector upstreamness* are most important, accounting for 44%, 12%, and 37% of cross-sector variation.<sup>52</sup> For MNE relative productivity shock, *trade intensity*, *sector upstreamness*, and *trade credit intensity* are key, explaining 38%, 25%, and 17% of cross-sector variation.<sup>53</sup>

*Supply, Demand, and MNE Policies.* I define *demand policies* as mitigating firm performance differences from variations in capital, skill, and contract intensity; *supply policies* as targeting variations in inventories, trade intensity, and upstreamness; and *MNE policies* as targeting trade intensity, trade-credit intensity, and upstreamness.<sup>54</sup>

<sup>50</sup>I leave details of the decomposition to Section Appendix D.1.

<sup>51</sup>Table Appendix D.1 shows that capital- and skill-intensive sectors had larger declines in final demand, consistent with Levchenko et al. 2010 and others finding larger final demand shocks in durable manufacturing. In contrast, sectors with higher contract intensity had smaller demand declines, supporting findings by Rauch (1999) and Nunn (2007) on the resilience of relationship-specific trade.

<sup>52</sup>Table Appendix D.2 shows that sectors with higher inventory intensity, trade intensity, and upstreamness experienced larger declines in domestic productivity. This suggests that financially constrained sectors with greater inventory holdings were more vulnerable during the Great Recession (Manova et al., 2015). Trade-intensive and upstream sectors faced greater productivity losses due to supply chain disruptions.

<sup>53</sup>Table Appendix D.3 shows that MNEs had a comparative advantage over domestic firms in sectors with higher trade intensity and greater trade credit needs, consistent with cross-country evidence in Section Appendix C.3 and findings by Alfaro and Chen (2012). However, MNEs in more upstream sectors experienced larger productivity declines relative to domestic firms.

<sup>54</sup>Demand policies mitigate 74.1% of actual demand shocks, 2.5% of domestic productivity shocks, and 17.1% of MNE relative productivity shocks. Supply policies mitigate 92.6% of domestic productivity shocks, 9.5% of demand

Figure Appendix D.3 shows that in the MNE model, supply policies lead to a greater trade recovery during the Great Recession, whereas demand policies lead to a greater trade recovery in the trade-only model.<sup>55</sup> Table Appendix D.10 shows the baseline MNE model predicts supply policies would have increased 2009 global GDP by 1.75%, fully recovering the Great Recession’s GDP loss. In contrast, the trade-only model under-predicts supply policies’ impact on global GDP by half and predict a mere 63% recovery of global GDP loss, as they did not account for the positive impact of supply policies on MNEs.

MNE policies, which could have boosted MNE performance relative to domestic firms in less trade-intensive, less trade-credit-intensive, and more upstream sectors, would have increased 2009 global trade to GDP ratio by 5%, recovering 44% of the Great Recession’s trade loss (Table Appendix D.12). They would also have increased 2009 world GDP by 1.2%, recovering 89% of the Great Recession’s GDP loss.<sup>56</sup> In contrast, trade-only model and model without MNE sourcing and selling efficiencies significantly underestimated the effects on trade (by two thirds) and GDP.

## 5.2. Propagation of Shocks

This section studies how domestic productivity shocks from top headquarters countries, propagating through MP, amplified their effects on the global economy during the Great Recession. I compare three scenarios: (1) domestic productivity shocks from top 10 headquarters propagating through MP and trade; (2) domestic productivity shocks from these headquarters propagating only through trade (i.e., not affecting MNEs’ productivity in other countries); and (3) final demand shocks from these headquarters propagating through trade.

When domestic productivity shocks propagate through MP, they affect headquarters country’s

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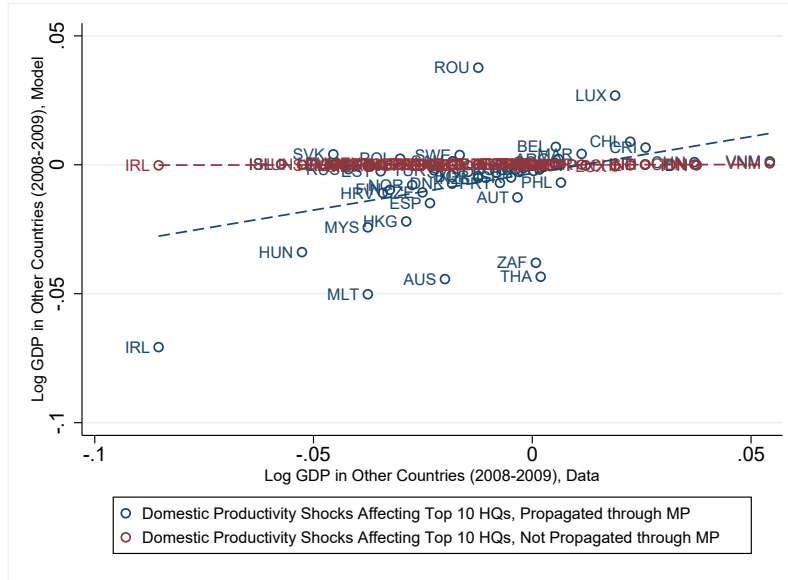
shocks, and 62.7% of MNE relative productivity shocks. MNE policies eliminate MNE relative productivity shocks by 79.8%, demand shocks by 11.3%, and domestic productivity shocks by 50.3%.

<sup>55</sup>Quantitatively, Table Appendix D.10 shows that demand policies would have increased world trade by about 3% relative to GDP and mitigated 20-30% of the Great Recession’s trade loss in both the baseline MNE model and the trade-only model. However, the two models predict drastically different consequences for supply policies. The baseline MNE model finds supply policies would have increased world trade by 6% relative to GDP, recovering 53% of the trade loss. In contrast, the trade-only model predicts supply policies would have increased the world trade-to-GDP ratio by only 2.5%, smaller than demand policies’ effect in this model. Table Appendix D.11 also shows that except for the MNE model without sourcing and selling efficiencies, in all other extended MNE models, supply policies contributed more to trade recovery than demand shocks.

<sup>56</sup>Table Appendix D.13 shows that MNE policies could have significantly boosted global trade and GDP across other extended MNE models, with a magnitude quantitatively similar to the baseline MNE model.

526 MNE productivity relative to host country's domestic firms as follows:  $\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s} = \left( \frac{\hat{A}_{ii}^s}{\hat{A}_{jj}^s} \right)^\phi$ .<sup>57</sup> Con-  
 527 sequently, as headquarters' efficiency decreased during the Great Recession, so did their MNEs'  
 528 performance, leading to declines in GDP, MP, and trade in host countries.

Figure 6: **Propagation through MP Amplified the Effect of Top Headquarters' Domestic Productivity Shocks on Other Countries' GDP**



Notes: This figure shows the impact of top 10 headquarters' domestic productivity shocks on GDP across other countries during the Great Recession under two scenarios: (1) propagation through both MP and trade; and (2) propagation solely through trade. Actual data is presented on the horizontal axis, while model-simulated outcomes for each scenario appear on the vertical axis. The dashed line is the fitted regression line. These results reflect the baseline calibration. Their confidence intervals are presented in Table Appendix D.14.

529 Figure 6 shows that domestic productivity shocks from important headquarters, when propa-  
 530 gated through MP linkages (blue), substantially affected GDP in other countries and explained a  
 531 significant fraction of observed cross-country GDP variations.<sup>58</sup> Conversely, if these shocks only  
 532 propagated through trade, their impact on GDP changes in other countries was minimal compared  
 533 to observed GDP variations.

534 Table Appendix D.14 confirms these findings: Top 10 headquarters' domestic productivity  
 535 shocks, when propagated through MP, explained 29% of GDP growth, 19% of MP-to-GDP ra-  
 536 tio growth, and 5% of trade-to-GDP ratio growth across other countries. In contrast, domestic

<sup>57</sup>Following Cravino and Levchenko (2017); Alviarez et al. (2020); Bilir and Morales (2020), I assume that the MNE productivity is Cobb-Douglas in the headquarters domestic productivity and host country productivity:  $\hat{A}_{ji}^s = \left( \hat{A}_{ii}^s \right)^\phi \left( \hat{A}_{jj}^s \right)^{1-\phi} \hat{\gamma}_{ji}^s$ , with  $\phi$  denoting headquarters' share in MNE productivity and estimated in Section Appendix C.6.

<sup>58</sup>Figure Appendix D.5 shows the impact of domestic productivity shocks from top 10 headquarters (1) propagated through both MP and trade or (2) propagated through only trade, on MP and trade in other countries.



productivity shocks propagated through trade only, or final demand shocks propagated through trade, barely affected other countries' GDP, MP, or trade variations.

Table 4: **Global MP and Trade Collapse Decomposition: Between-country and Within-country Components in Data and Different Shock Scenarios**

	MP/Trade Declined More in Larger Countries		GDP Declined More in MP/Trade Intensive Countries		Within-country		Total
Scenarios	Level (p.p.)	Share (%)	Level (p.p.)	Share	Level (p.p.)	Share	Level (p.p.)
MP Collapse							
<i>Data</i>	-1.958	114.1	-0.835	48.7	1.077	-62.8	-1.716
Domestic Productivity Shocks in Top 10 HQs	-0.336	73.0	-0.076	16.3	0.055	10.7	-0.357
Prop. through MP	[-0.347, -0.324]	[66.0, 80.0]	[-0.083, -0.069]	[9.8, 22.8]	[0.012, 0.098]	[-2.6, 24.0]	[-0.393, -0.321]
Domestic Productivity Shocks in Top 10 HQs	-0.270	6.9	-0.054	-15.1	0.032	108.3	-0.292
Not Prop. through MP	[-0.345, -0.196]	[-62.4, 76.1]	[-0.096, -0.011]	[-64.9, 34.6]	[-0.262, 0.327]	[-10.7, 227.2]	[-0.489, -0.095]
Final Demand Shocks in Top 10 HQs	-0.020	11.8	0.004	-6.1	-0.190	94.3	-0.206
	[-0.026, -0.014]	[2.4, 21.2]	[-0.008, 0.016]	[-10.3, -1.9]	[-0.247, -0.133]	[88.9, 99.7]	[-0.247, -0.165]
Trade Collapse							
<i>Data</i>	0.753	-23.5	-0.202	6.3	-3.751	117.2	-3.201
Domestic Productivity Shocks in Top 10 HQs	0.242	-33.0	-0.126	12.2	-0.912	120.8	-0.796
Prop. through MP	[0.221, 0.262]	[-34.1, -31.9]	[-0.194, -0.057]	[10.8, 13.7]	[-0.987, -0.838]	[118.5, 123.0]	[-0.879, -0.714]
Domestic Productivity Shocks in Top 10 HQs	-0.045	-44.1	-0.299	30.1	0.072	114.0	-0.271
Not Prop. through MP	[-0.735, 0.645]	[-44.9, -43.3]	[-0.345, -0.252]	[28.8, 31.4]	[-1.702, 1.847]	[112.1, 115.8]	[-1.437, 0.895]
Final Demand Shocks in Top 10 HQs	0.422	-42.5	-0.136	5.3	-1.390	137.2	-1.104
	[0.324, 0.520]	[-44.8, -40.2]	[-0.327, 0.056]	[1.4, 9.2]	[-1.655, -1.126]	[131.0, 143.3]	[-1.130, -1.077]

*Notes:* This table presents the decomposition of changes in global trade-to-GDP and MP-to-GDP ratios from 2008 to 2009 across various scenarios. These include: factual data; domestic productivity shocks in top 10 headquarters (both propagated and not propagated through MP); and final demand shocks in top 10 importers. As shown by the decomposition formula in Equation (1), the first component measures MP/trade decrease in larger countries. The second measures GDP decline in high MP/trade intensity countries. The third measures the contribution of cross-country average changes in MP and trade as a proportion of GDP. “Level” shows each component’s contribution to global MP and trade declines in percentage points, while “Share” denotes its contribution share to overall global declines. Numbers in hard brackets represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ . Since “Share” represents each component’s average share across simulations, its value does not exactly equal the ratio of the average “Level” to the average “Total” (both averaged across simulations).

*MP-Propagated Domestic Productivity Shocks Were Key to the “MNE Resilience Puzzle”.* Table 4 presents a within-between country decomposition of MP and trade collapse from model simulations (compared to data) under these three scenarios. The scenario with domestic productivity shocks from top 10 headquarters, propagated through MP, produces a decomposition resembling the data: MP declines in larger countries, GDP declines in MP-intensive countries, and MNE sales resilience in an average country. Conversely, domestic productivity or final demand shocks, if propagated solely through trade, failed to generate the cross-country heterogeneity critical for the MP collapse.

Table 4 also shows that, similar to final demand shocks, domestic productivity shocks from top 10 headquarters propagated through MP caused a significant decrease in trade relative to GDP in an average country, while producing little cross-country variation in the trade collapse. In contrast, domestic productivity shocks propagated through only trade did not significantly reduce global trade or trade collapse in an average country. This once more highlights that MNE productivity shocks contributed significantly to the trade collapse.

## 552 6. Conclusion

553 Despite prior research arguing MNE sales showed greater resilience than domestic firms during  
554 the Great Recession, I find global MP plunged by a magnitude similar to the well-known trade  
555 collapse. To resolve this inconsistency (the “MNE Resilience Puzzle”), I conduct a within-between  
556 country decomposition. This decomposition shows the MP collapse arose from substantial MP  
557 declines in key headquarters countries and GDP declines in MP-intensive countries, though MP  
558 was more resilient than GDP for an average country. Prior works, by only uncovering average  
559 resilience, overlooked this important cross-country heterogeneity. I document that MP contributed  
560 to the trade collapse through overall declines in MP sales and MNEs’ higher trade intensity, rather  
561 than a decline in MNE trade intensity.

562 Adverse productivity shocks from key headquarters that disproportionately impacted MNEs  
563 generated cross-country heterogeneity critical for the MP collapse and, via MNEs’ higher trade  
564 intensity, amplified their impact on the trade collapse. My calibrated quantitative model of MP  
565 and global value chains, with flexible vertical/horizontal MNE structures, finds supply shocks  
566 outweighed demand shocks in trade collapse. This holds for other extended MNE models with  
567 realistically calibrated MNE trade intensity. In contrast, trade-only or horizontal-MNE models find  
568 demand shocks more influential. The MNE model predicts supply-side policies (targeting high-  
569 inventory, trade-intensive, and upstream sectors) would lead to greater trade recovery, whereas  
570 models without realistic MNEs suggest policies targeting demand.

571 Productivity shocks affecting MNEs contributed over half of global GDP change during the  
572 Great Recession. Policies boosting MNE performance relative to domestic firms in less trade-  
573 intensive, less trade-credit-intensive, and upstream sectors could significantly increase GDP. Mod-  
574 els lacking realistic MNEs significantly underestimate these policies’ positive effects on trade and  
575 GDP. Applying the within-between country decomposition to model-simulated data confirms that  
576 productivity shock propagation through MP was critical for the “MNE Resilience Puzzle.”

577 This analysis highlights international trade by MNEs as a crucial channel for propagating  
578 shocks across countries and sectors, affecting macroeconomic outcomes. Ignoring the MP margin  
579 can lead to misinterpretations of GDP changes and flawed policies.

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# Online Appendix

## (for online publication only)

### Multinational Production and Global Shock Propagation during the Great Recession

by Haishi Li

#### Appendix A. Data Appendix

##### *Appendix A.1. Countries, Sectors, and Aggregate Patterns of MP and Trade Collapse*

The OECD AAMNE data is supplemented with other macroeconomics statistics.<sup>59</sup> They include country-sector-level GDP from the UN National Account Database. Country-sector level employment from the International Labor Organization (ILO), OECD, World Bank, and World Input-Output Database (WIOD). To analyze how various sector characteristics influence supply and demand shocks driving the MP and trade collapse, and to inform policy, I collect US NAICS 6-digit level data. This includes: output, input, employment, and price from the NBER-CES Manufacturing Industry Database; foreign affiliate sales by industry from US BEA; and numerous measures of sectoral financial constraints (e.g., inventory intensity, external finance intensity, trade credit intensity) and other sectoral production and trade characteristics.

*Employment Data.* To gather country-sector level employment data and estimate labor supply elasticities, I combine information from four sources: the International Labor Organization (ILO), OECD, World Bank, and WIOD. WIOD is prioritized as it provides comprehensive employment and wage data for 40 countries across various sectors from 2000 to 2014. For countries not covered by WIOD, I use the other three sources, which only provide aggregate manufacturing employment. To disaggregate this to the sector level, I allocate sectoral employment within aggregate manufacturing based on proportional sectoral exports. For example, for country  $i$ , observing total

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<sup>59</sup>Standard country-bilateral variables (e.g., distance, common language, and contiguity, trade agreement) come from CEPII (Head et al. 2010).

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

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

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

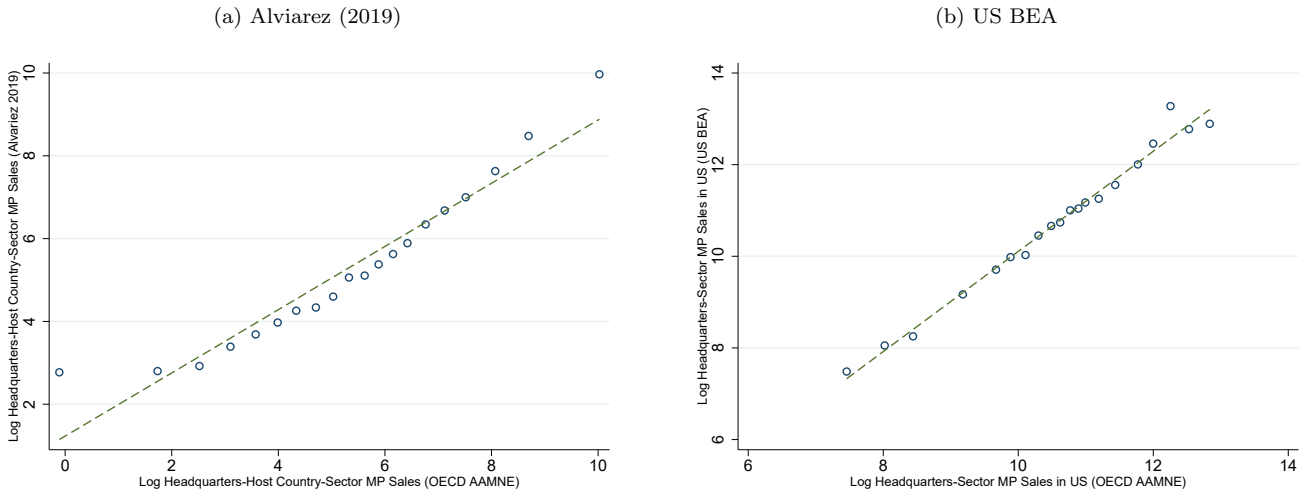
Table Appendix A.2: **Industries in the OECD AAMNE Database**

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

*Notes:* 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.

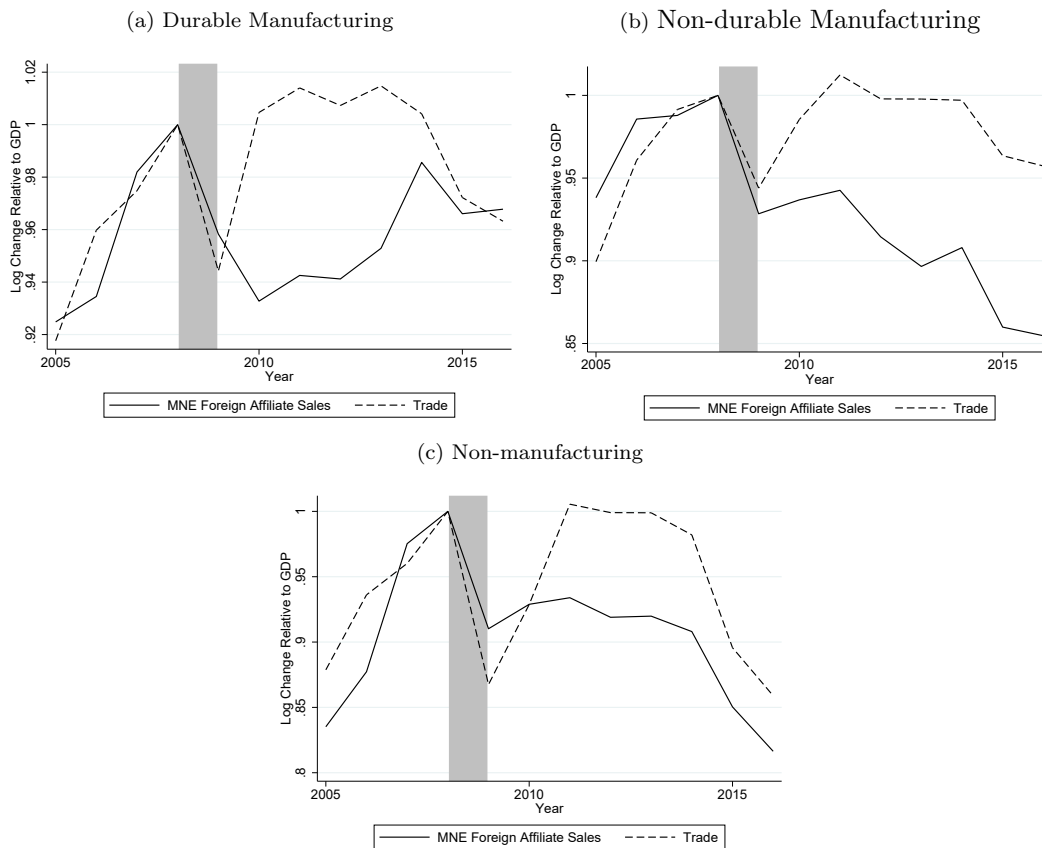
- 729 manufacturing employment  $L_i^{mfg}$ , I infer employment in a specific manufacturing sector  $s$ ,  $L_i^s$ , by
- 730 assuming  $L_i^s = \frac{EXP_i^s}{EXP_i^{mfg}} \times L_i^{mfg}$ .

Figure Appendix A.1: OECD AAMNE Gross Output Data Correlates Highly with Alvarez (2019) and US BEA Data



*Notes:* Figure Appendix A.1a presents the correlation between log headquarters-host country-sector level MNE gross output from OECD AAMNE and Alvarez (2019). I aggregate OECD AAMNE data to Alvarez (2019)'s sector classification and average it over 2005-2012, as Alvarez (2019) only reports this time average. The two data has a correlation of 0.80. Figure Appendix A.1b presents the correlation between log headquarters-sector level sales by foreign MNEs in the US, as reported in OECD AAMNE and by US BEA. I aggregate the US BEA sectors to OECD AAMNE classification, using common years from 2007-2016. These two data correlates at 0.97. To avoid clutter, I present the binscatter plots with 20 equally sized bins.

Figure Appendix A.2: Global MP and Trade Collapse in the Great Recession by Sector



*Notes:* The figure shows, by sector, that global foreign affiliate sales and international trade both declined relative to world GDP during the Great Recession (2008-2009). The data is normalized to 2008 levels, so the figure reflects changes in multinational production (MP) sales and trade relative to GDP compared to 2008. The data source is OECD Analytical Activities of Multinationals (OECD AAMNE) Database.

*Granular Sector Statistics and Characteristics.* I acquire NAICS 6-digit level foreign affiliate sales and employment data for the US from US BEA statistics. Since US BEA only provides this data at the NAICS 3-digit level, I disaggregate it by proportionally allocating 3-digit values using corresponding 6-digit output and employment information from NBER-CES. For a 6-digit sector  $s$  within a 3-digit sector  $S$ , the disaggregation formulas are:  $VA_{MNE}^s = \frac{VA_{nberces}^s}{VA_{nberces}^S} \times VA_{MNE}^S$  and  $L_{MNE}^s = \frac{L_{nberces}^s}{L_{nberces}^S} \times L_{MNE}^S$ , where  $VA$  represents value added and  $L$  represents employment.

I obtain sectoral output, value added, employment, and price data for the US from the NBER-CES Manufacturing Industry Database. I gather sector-level measures of financial constraints (external finance dependence, inventory ratio, asset tangibility, and trade credit intensity) from Rajan and Zingales (1995), Manova et al. (2015), and Li et al. (2024). Capital and skill intensity come from Pierce and Schott (2018); contract intensity from Rauch (1999) and Nunn (2007); and sector upstreamness from Antràs et al. (2012). I compute sector trade and intermediate use intensity using US data for 2007. All data is then concorded to the NAICS 6-digit level using the concordance from Pierce and Schott (2012).

## Appendix A.2. Other Decomposition Results

*Proof of Proposition 1.* The goal is to prove a decomposition formula that decomposes the change in the global MP-to-GDP ratio into two between-country terms: (A) MP declined more in larger countries; (B) GDP declined more in MP-intensive countries; and one within-country term: (C) average country-level change of MP relative to GDP:

$$\begin{aligned}
& \frac{\sum_{i=1}^N MP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} - \frac{\sum_{i=1}^N MP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}} \\
&= N_{\text{cov}_i} \underbrace{\left( \frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}}, \frac{\frac{GDP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} + \frac{GDP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}}{2} \right)}_{\text{A: MP Declined More in Larger Countries}} \\
&+ N_{\text{cov}_i} \underbrace{\left( \frac{GDP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} - \frac{GDP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}, \frac{\frac{MP_{i,2009}}{GDP_{i,2009}} + \frac{MP_{i,2008}}{GDP_{i,2008}}}{2} \right)}_{\text{B: GDP Declined More in More MP Intensive Countries}} + \underbrace{\frac{1}{N} \sum_{i=1}^N \left( \frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}} \right)}_{\text{C: Average Change of MP Relative to GDP Across Countries}}.
\end{aligned}$$

750 Term A on the right hand side equals the following:

$$\begin{aligned}
& N_{\text{cov}_i} \left( \frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}}, \frac{\frac{GDP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} + \frac{GDP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}}{2} \right) \\
&= \sum_{i=1}^N \left( \frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}} \right) \frac{\frac{GDP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} + \frac{GDP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}}{2} - \frac{1}{N} \sum_{i=1}^N \left( \frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}} \right) \\
&= \frac{1}{2} \frac{\sum_{i=1}^N MP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} - \frac{1}{2} \frac{\sum_{i=1}^N MP_{i,2009} \frac{GDP_{i,2008}}{GDP_{i,2009}}}{\sum_{i=1}^N GDP_{i,2008}} + \frac{1}{2} \frac{\sum_{i=1}^N MP_{i,2008} \frac{GDP_{i,2009}}{GDP_{i,2008}}}{\sum_{i=1}^N GDP_{i,2009}} - \frac{1}{2} \frac{\sum_{i=1}^N MP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}} \\
&\quad - \frac{1}{N} \sum_{i=1}^N \left( \frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}} \right).
\end{aligned}$$

751 Term B on the right hand side equals the following:

$$\begin{aligned}
& N_{\text{cov}_i} \left( \frac{GDP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} - \frac{GDP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}, \frac{\frac{MP_{i,2009}}{GDP_{i,2009}} + \frac{MP_{i,2008}}{GDP_{i,2008}}}{2} \right) \\
&= \frac{1}{2} \frac{\sum_{i=1}^N MP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} - \frac{1}{2} \frac{\sum_{i=1}^N MP_{i,2008} \frac{GDP_{i,2009}}{GDP_{i,2008}}}{\sum_{i=1}^N GDP_{i,2009}} + \frac{1}{2} \frac{\sum_{i=1}^N MP_{i,2009} \frac{GDP_{i,2008}}{GDP_{i,2009}}}{\sum_{i=1}^N GDP_{i,2008}} - \frac{1}{2} \frac{\sum_{i=1}^N MP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}.
\end{aligned}$$

752 Adding up all terms on the right hand side, we get Equation (1). ■

753 *Decomposing Within-country Effect into Between-sector and Within-sector Terms.* I further de-  
754 compose the within-country effect from Equation (1) into three terms: (C.1) MP/trade decline in  
755 larger sectors; (C.2) sectoral GDP decline in MP/trade intensive sectors; and (C.3) the cross-sector  
756 average of MP/trade decline relative to GDP:

$$\begin{aligned}
& \frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}} = \frac{\sum_{s=1}^S MP_{i,2009}^s}{\sum_{s=1}^S GDP_{i,2009}} - \frac{\sum_{s=1}^S MP_{i,2008}^s}{\sum_{s=1}^S GDP_{i,2008}^s} \\
&= \underbrace{S_{\text{cov}_s} \left( \frac{MP_{i,2009}^s}{GDP_{i,2009}^s} - \frac{MP_{i,2008}^s}{GDP_{i,2008}^s}, \frac{\frac{GDP_{i,2009}^s}{\sum_{s=1}^S GDP_{i,2009}^s} + \frac{GDP_{i,2008}^s}{\sum_{s=1}^S GDP_{i,2008}^s}}{2} \right)}_{\text{C.1: MP Declined More in Larger Sectors}} \\
&\quad + \underbrace{S_{\text{cov}_s} \left( \frac{GDP_{i,2009}^s}{\sum_{s=1}^S GDP_{i,2009}^s} - \frac{GDP_{i,2008}^s}{\sum_{s=1}^S GDP_{i,2008}^s}, \frac{\frac{MP_{i,2009}^s}{GDP_{i,2009}^s} + \frac{MP_{i,2008}^s}{GDP_{i,2008}^s}}{2} \right)}_{\text{C.2: GDP Declined More in More MP Intensive Sectors}} + \underbrace{\frac{1}{S} \sum_{s=1}^S \left( \frac{MP_{i,2009}^s}{GDP_{i,2009}^s} - \frac{MP_{i,2008}^s}{GDP_{i,2008}^s} \right)}_{\text{C.3: Average Change of MP Relative to GDP across Sectors (Appendix A.1)}}.
\end{aligned}$$

757  $S$  denotes the number of sectors.  $MP_{i,t}^s$  denotes the average of inward and outward MP in country  
758  $i$ , sector  $s$ , and year  $t$ .  $GDP_{i,t}^s$  denotes country  $i$ , sector  $s$ ' GDP in year  $t$ .

759 The complete decomposition of global MP and trade collapses involves five terms: between-

country, within-country-between-sector, and within-country-within-sector:

$$\begin{aligned}
1. \quad A: & N\text{cov}_i \left( \frac{MP_{i,2009}}{GDP_{i,2009}} - \frac{MP_{i,2008}}{GDP_{i,2008}}, \frac{\frac{GDP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} + \frac{GDP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}}{2} \right); \\
2. \quad B: & N\text{cov}_i \left( \frac{GDP_{i,2009}}{\sum_{i=1}^N GDP_{i,2009}} - \frac{GDP_{i,2008}}{\sum_{i=1}^N GDP_{i,2008}}, \frac{\frac{MP_{i,2009}}{GDP_{i,2009}} + \frac{MP_{i,2008}}{GDP_{i,2008}}}{2} \right); \\
3. \quad C.1: & \frac{S}{N} \sum_{n=1}^N \text{cov}_s \left( \frac{MP_{i,2009}^s}{GDP_{i,2009}^s} - \frac{MP_{i,2008}^s}{GDP_{i,2008}^s}, \frac{\frac{GDP_{i,2009}^s}{\sum_{s=1}^S GDP_{i,2009}^s} + \frac{GDP_{i,2008}^s}{\sum_{s=1}^S GDP_{i,2008}^s}}{2} \right); \\
4. \quad C.2: & \frac{S}{N} \sum_{n=1}^N \text{cov}_s \left( \frac{GDP_{i,2009}^s}{\sum_{s=1}^S GDP_{i,2009}^s} - \frac{GDP_{i,2008}^s}{\sum_{s=1}^S GDP_{i,2008}^s}, \frac{\frac{MP_{i,2009}^s}{GDP_{i,2009}^s} + \frac{MP_{i,2008}^s}{GDP_{i,2008}^s}}{2} \right); \\
5. \quad C.3: & \frac{1}{N} \frac{1}{S} \sum_{n=1}^N \sum_{s=1}^S \left( \frac{MP_{i,2009}^s}{GDP_{i,2009}^s} - \frac{MP_{i,2008}^s}{GDP_{i,2008}^s} \right).
\end{aligned}$$

Table Appendix A.3 presents the decomposition results.

**Table Appendix A.3: Global MP and Trade Change Decomposition: Cross-Country, Within-Country-Between-Sector, and Within-Country-Within-Sector Components**

	MP/Trade Declined More in Larger Countries	GDP Declined More in MP/Trade Intensive Countries	Within Country MP/Trade Declined More in Larger Sectors	Within Country GDP Declined More in MP/Trade Intensive Sectors	Within Country Within Sectors	Total
MP	-0.020 (114.1%)	-0.008 (48.7%)	-0.012 (68.8%)	-0.003 (17.2%)	0.026 (-148.8%)	-0.017 (100%)
Trade	0.008 (-23.5%)	-0.002 (6.3%)	0.023 (-72.0%)	-0.005 (16.1%)	-0.055 (173.1%)	-0.032 (100%)

*Notes:* This table presents the decomposition of changes in global trade-to-GDP and MP-to-GDP ratios for three periods: the Great Recession (2008-2009), the post-Recession recovery (2009-2010), and the later trade and MP decline (2013-2016). The decomposition formula, detailed in Equation (1) and (Appendix A.1), yields five components: (1) MP/trade decrease in larger countries; (2) GDP decline in high MP/trade intensity countries; (3) average country-level MP/trade decline in larger sectors; (4) average country-level sectoral GDP decline in high MP/trade intensity sectors; and (5) the contribution of cross-country, cross-sector simple average. Numbers outside brackets indicate each term's magnitude, while those inside denote its percentage contribution.

### Appendix A.3. Contribution of MP to Trade Collapse

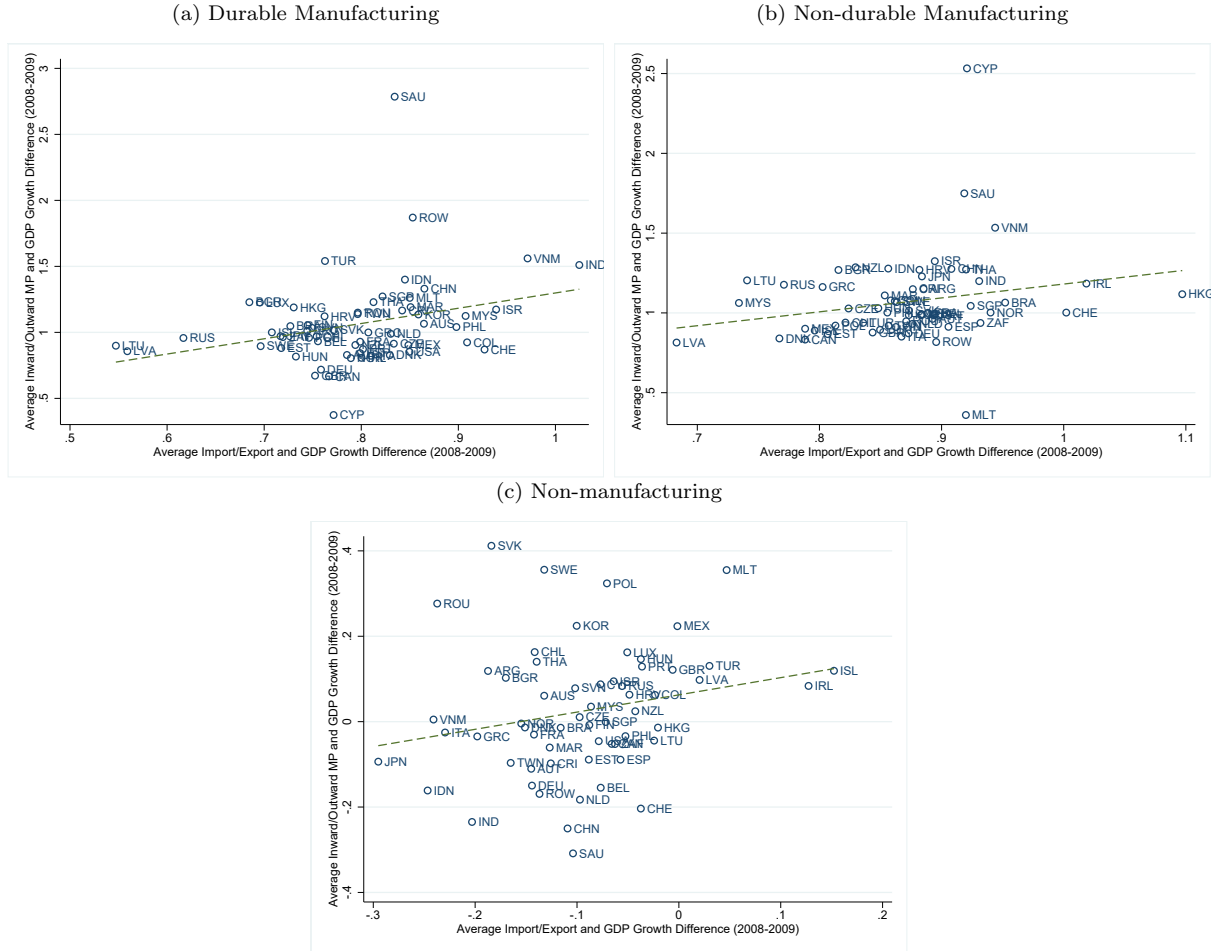
This section conducts a difference-in-differences analysis on the impact of MP on the trade collapse. Similar to the event studies in Section 2.3, I first show that trade by MNEs declined more than domestic firms. Next, I show that once overall sales by MNEs are controlled for, MNE trade was more resilient than domestic firms.

$$\begin{aligned}
\log(T_{nmji,t}^s) &= \beta^{imp} \mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} \\
&\quad + \gamma^{imp} \mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{m = F\} + \delta_{nmji}^s + \delta_t + \epsilon_{nmji,t}^s, \\
\log(T_{nmji,t}^s) &= \beta^{exp} \mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} \\
&\quad + \gamma^{exp} \mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{i = F\} + \delta_{nmji}^s + \delta_t + \epsilon_{nmji,t}^s,
\end{aligned} \tag{Appendix A.2}$$

where  $m, i \in \{D, F\}$ .

On the left-hand side,  $T_{nmji,t}^s$  denotes trade flow from country  $j$ 's firms (domestic:  $i = D$ , or foreign affiliates:  $i = F$ ) to country  $n$ 's firms (domestic:  $m = D$ , or foreign affiliates:  $m = F$ )

Figure Appendix A.3: **MP and Trade Collapses were Positively Correlated at the Country Level for Each Sector**



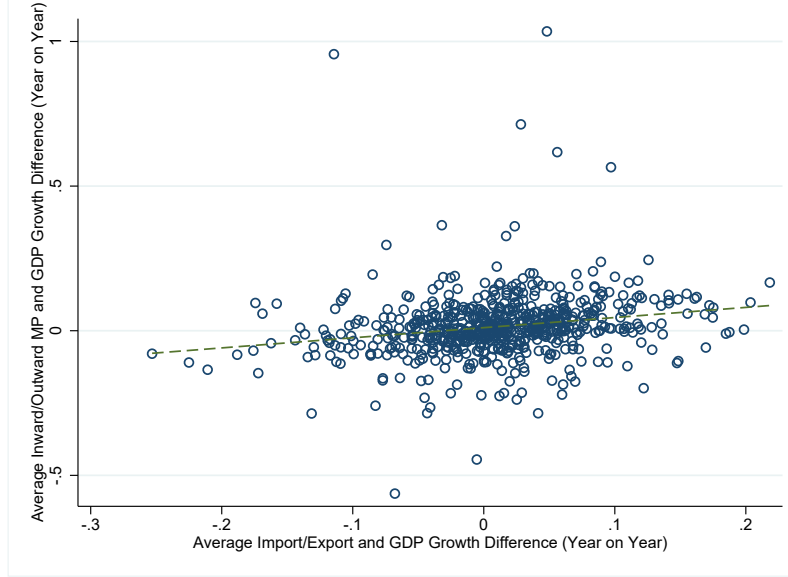
Notes: This figure displays, on the country level and for each sector, (1) average inward/outward affiliate sales growth and GDP growth difference; and (2) average imports/exports growth and GDP growth difference between 2008 and 2009. Regressing the MP collapse on the trade collapse at the country level gives a coefficient of 1.15 and a standard error of 0.48 for durable manufacturing, a coefficient of 0.87 and a standard error of 0.52 for non-durable manufacturing, and a coefficient of 0.40 and a standard error of 0.23 for non-manufacturing. The data source is OECD Analytical Activities of Multinationals (OECD AAMNE) Database.

across sectors ( $s$ ) and years ( $t$ ). The term  $\mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\}$  interacts a cross-border trade dummy with a time dummy for 2009, capturing the overall trade collapse. Subsequent terms,  $\mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{m = F\}$  and  $\mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{i = F\}$ , further interact this with the importer's ( $m$ ) or exporter's ( $i$ ) MNE status. These effects quantify how MNE imports and exports declined relative to domestic firms.

Column 1 of Table Appendix A.4 shows the trade collapse during the Great Recession. Columns 2 and 3 show that MNE imports and exports declined more significantly than those by domestic firms during the Great Recession, which shows that MP contributed to the trade collapse.

To disentangle two potential channels: (1) MNE overall sales declined and they are more intensive in trade than domestic firms, and (2) MNE trade intensity (trade to overall sales ratio)

Figure Appendix A.4: **Positive Correlations between Annual Country-level MP-to-GDP and Trade-to-GDP Ratio Changes**



Notes: This figure displays, on the country level, (1) average inward/outward affiliate sales growth and GDP growth difference; and (2) average imports/exports growth and GDP growth difference. Regressing the MP collapse on the trade collapse yields a coefficient of 0.35 and a standard error of 0.07. The data source is the OECD Analytical Activities of Multinationals (OECD AAMNE) Database.

declined relative to domestic firms, I consider the following regression:

$$\begin{aligned}
 \log(T_{nmji,t}^s) = & \beta^{imp} \mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} + \theta^{imp} \mathbb{I}\{t = 2009\} \times \mathbb{I}\{m = F\} \\
 & + \gamma^{imp} \mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{m = F\} + \delta_{nmji}^s + \delta_t + \epsilon_{nmji,t}^s, \\
 \log(T_{nmji,t}^s) = & \beta^{exp} \mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} + \theta^{exp} \mathbb{I}\{t = 2009\} \times \mathbb{I}\{i = F\} \\
 & + \gamma^{exp} \mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{i = F\} + \delta_{nmji}^s + \delta_t + \epsilon_{nmji,t}^s,
 \end{aligned}
 \tag{Appendix A.3}$$

where  $m, i \in \{D, F\}$ .

Compared to Equation (Appendix A.2), I include additional terms  $\mathbb{I}\{t = 2009\} \times \mathbb{I}\{m = F\}$  and  $\mathbb{I}\{t = 2009\} \times \mathbb{I}\{i = F\}$  to capture the overall sales decline by MNEs. Columns 4 and 5 of Table Appendix A.4 reveal that, once these terms are controlled, MNE trade was more resilient than domestic firms' trade. These findings demonstrate MP contributed to the trade collapse through MNEs' overall trade declines, not through a fall in MNE trade intensity. Columns 6 and 7 pool MNE import and export effects, confirming the robustness of previous findings.

#### Appendix A.4. Cross-sectional Facts about Multinational Production

Figure Appendix A.5a shows that MP is most intensive in durable manufacturing sector. Foreign affiliates account for 14% of gross output in non-manufacturing sector, 27% in non-durable



Table Appendix A.4: **Impact of MNEs on Trade Collapse**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$\log(T_{nmji,t}^s)$						
$\mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\}$	-0.1680*** (0.0193)	-0.1521*** (0.0196)	-0.1614*** (0.0197)	-0.1625*** (0.0210)	-0.1709*** (0.0208)	-0.1459*** (0.0201)	-0.1632*** (0.0222)
$\mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{m = F\}$		-0.0566*** (0.0104)		0.0386 (0.0309)		-0.0563*** (0.0103)	0.0273 (0.0304)
$\mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{i = F\}$			-0.0205** (0.0104)		0.0732** (0.0338)	-0.0196* (0.0103)	0.0613* (0.0336)
$\mathbb{I}\{t = 2009\} \times \mathbb{I}\{m = F\}$				-0.0952*** (0.0291)			-0.0836*** (0.0286)
$\mathbb{I}\{t = 2009\} \times \mathbb{I}\{i = F\}$					-0.0937*** (0.0321)		-0.0809** (0.0320)
$n \times m \times j \times i \times s$ FE	✓	✓	✓	✓	✓	✓	✓
$t$ FE	✓	✓	✓	✓	✓	✓	✓
Observations	125316	125316	125316	125316	125316	125316	125316

Notes: This table reports the regression results of Equations (Appendix A.3) and (Appendix A.2). The regression is weighted on sum of pre-period trade value ( $\sum_{t=2006}^{2008} T_{nmji,t}^s$ ). Robust standard errors clustered at the importer country-importer firm type-exporter country-exporter firm type-sector ( $nmjis$ ) level are displayed in parentheses. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ . The sample is restricted to year 2007, 2008 and 2009.

manufacturing sector, and 33% in durable manufacturing sector.<sup>60</sup>

Figure Appendix A.5b shows that foreign affiliates account for higher shares in exports and imports than in gross output and intermediate input expenditure.<sup>61</sup> For an average country and sector, foreign affiliates account for 8.2% higher shares in imports than expenditure on intermediate input and 9.8% higher shares in exports than gross output.<sup>62</sup>

To supplement these analysis, I further investigate the relationship between MNE status and trade on the firm level. I take advantage of Chinese firm-level databases, including the Annual Survey of Chinese Manufacturing Database for business statistics, China Customs Records Database for import/export transactions, and the Foreign-Invested Enterprise Survey Database for owner-

<sup>60</sup>In addition to visualization with Figure Appendix A.5a, I also consider the following regressions:

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

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

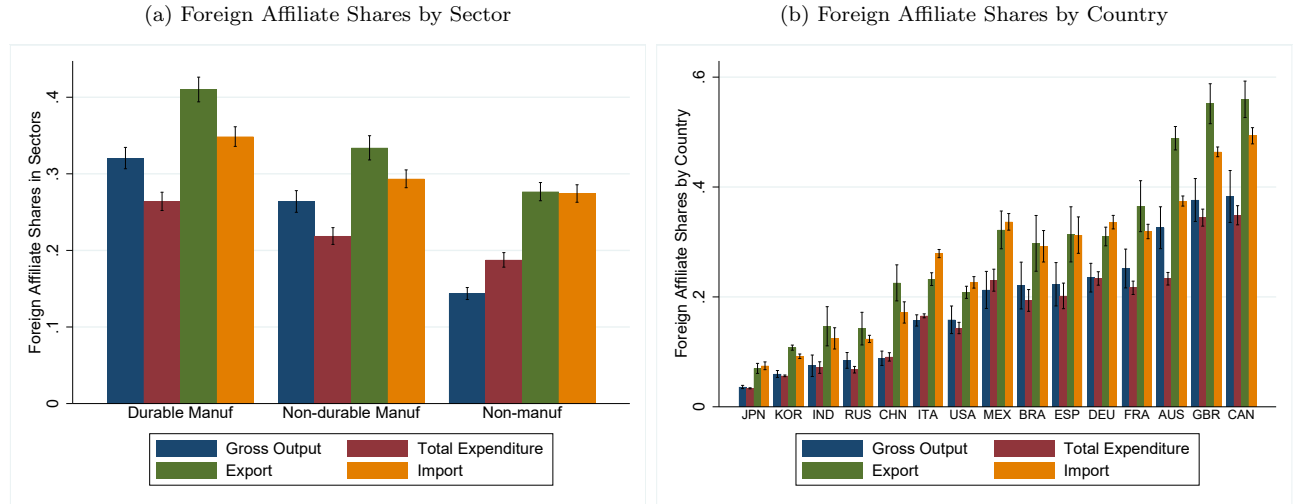
<sup>61</sup>These statistics are presented for the top ten countries in terms of GDP (in 2007) for the purpose of visualization.

<sup>62</sup>I consider the following regression:

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

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

Figure Appendix A.5: **Foreign Affiliate Shares by Sector and Country**



*Notes:* 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.

ship nationalities of foreign affiliates in China. Adopting the empirical strategy from Wang (2019), I establish two key facts regarding foreign affiliates' importing and exporting decisions: First, even accounting for firm-level characteristics, foreign affiliates are significantly more likely to trade and trade in greater volumes than domestic firms. Second, when controlling for firm and trade partner fixed effects (importing origin/exporting destination), foreign affiliates are significantly more likely to source from or sell to their headquarters and proximate countries.

These findings suggest MNEs encounter headquarters- and trading partner-specific transaction frictions in global sourcing and exporting, as modeled in Section 3. MNE selling frictions may stem from factors such as distribution network costs, marketing expenses, or limited consumer preference knowledge to approach markets different than their headquarters. MNE sourcing frictions could arise from technology incompatibility, regulatory differences, or insufficient information on global sourcing options in countries further away from their headquarters.

My first empirical finding is that, accounting for firm-level characteristics, foreign affiliates are significantly more likely to import and import more than domestic firms. I regress import behavior (a dummy for importing, and the share of imported intermediate input in total sales, both in level and log forms) on the firm's foreign affiliate status. Controls include the firm's employment, capital, intermediate input, TFP, and 2-digit industry fixed effects:

$$S_f = \beta_1 \mathbb{1}(\text{Foreign subsidiary}_f) + \beta_2 \log(\text{Emp}_f) + \beta_3 \log(\text{Cap}_f) + \beta_4 \log(\text{Interm}_i) + \beta_5 \log(\text{TFP}_f) + FE_{s(f)} + \epsilon_f,$$

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

Table Appendix A.5 reveals a strong positive correlation between foreign affiliate status and a firm's import activity, including both the importing decision and the share of imported intermediate input in total sales. On average, foreign affiliates are 36% more likely to import (Column 1). They show a 14 percentage point higher share of imports in total sales (Column 2) and are 187 percent more likely to have positive imports (Column 3).

Table Appendix A.5: **Conditional on Firm-level Characteristics, Foreign Affiliates Import More**

	(1)	(2)	(3)
	$\mathbb{1}(\text{Imp})_f$	$\frac{\text{Imp}_f}{\text{Sales}_f}$	$\log\left(\frac{\text{Imp}_f}{\text{Sales}_f}\right)$
$\mathbb{1}(\text{Foreign subsidiary})_f$	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)
$\log(\text{Interm}_i)$	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)
2-digit sector FE	✓	✓	✓
Observations	139613	139613	16518

*Notes:* The table shows the correlation between importing and foreign affiliate status. Total Factor Productivity (TFP) is estimated with the Olley and Pakes (1996) method. 2-digit sector fixed effect is controlled. I exclude the state-owned firms, processing traders and firms in the exporting zones. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Next, I show that, conditional on importing, foreign affiliates (headquartered in country  $m$  and operating in China) source more from their headquarters and from countries proximate to their headquarters ( $j$ ). For dependent variables, I use an import dummy for origin country  $j$  and the corresponding import values. I regress these on whether the importing origin is the headquarters and the distance between  $m$  and  $j$ . I also include controls for common language, common border, and common legal origin shared by  $m$  and  $j$ . Origin fixed effects account for bilateral trade costs

Table Appendix A.6: **Conditional on Importing, Foreign Affiliates Import More from the Headquarters and the Origin Countries Closer to the Headquarters**

	(1) Full sample $\mathbb{1}(x_{f,mj} > 0)$	(2) $m \neq j$ $\mathbb{1}(x_{f,mj} > 0)$	(3) Full sample $\log(x_{f,mj})$	(4) $m \neq j$ $\log(x_{f,mj})$
$\mathbb{1}(m = j)$	0.130*** (0.0244)		2.456*** (0.214)	
$\log(\text{Dist}_{mj})$		-0.00278*** (0.000579)		-0.192*** (0.0361)
$\mathbb{1}(\text{Common Lang}_{mj})$		0.000317 (0.000610)		0.0861 (0.136)
$\mathbb{1}(\text{Contiguity}_{mj})$		0.0127*** (0.00317)		0.162 (0.152)
$\mathbb{1}(\text{Legal}_{mj})$		0.000428 (0.000915)		-0.0610 (0.0851)
$f$ FE	✓	✓	✓	✓
$j$ FE	✓	✓	✓	✓
Observations	3889704	3889704	25428	25428

*Notes:* The table shows conditional on importing, the correlation 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. Standard errors are clustered on the headquarter-origin level. Firm and sourcing origin fixed effects are controlled. 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). \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

from the sourcing origin to China, while firm fixed effects control for potentially confounding firm characteristics. Thus, variation is captured within firm, across the foreign affiliate's headquarters and different sourcing origins. The regression specification is:

$$S_{f,mj} = \beta_1 \mathbb{1}(m = j) + \beta_2 \log(\text{Dist}_{mj}) + \beta_3 \mathbb{1}(\text{Common Lang}_{mj}) + \beta_4 \mathbb{1}(\text{Contiguity}_{mj}) + \beta_5 \mathbb{1}(\text{Legal}_{mj}) + \delta_f + \zeta_j + \epsilon_{f,mj},$$

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

Table Appendix A.6 shows that, conditional on importing, foreign affiliates are, on average, 13 percentage points more likely to source from their headquarters (Column 1), and source 246% more from headquarters than non-headquarters (Column 3). Columns 2 and 4 indicate that a one percent increase in distance between the headquarters and sourcing origin is associated with a 0.3 percentage point decline in sourcing probability and a 0.2% decline in importing values.

Tables Appendix A.7 and Appendix A.8 present counterpart results for exports: foreign af-

845 filiates are more likely to export and export greater values than domestic firms. Conditional on  
846 exporting, they export more to their headquarters and countries proximate to their headquarters.

Table Appendix A.7: **Conditional on Firm-level Characteristics, Foreign Affiliates Export More**

	(1)	(2)	(3)
	$\mathbb{1}(\text{Exp})_f$	$\frac{\text{Exp}_f}{\text{Sales}_f}$	$\log\left(\frac{\text{Exp}_f}{\text{Sales}_f}\right)$
$\mathbb{1}(\text{Foreign subsidiary})_f$	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)
$\log(\text{Interm}_i)$	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)
2-digit sector FE	✓	✓	✓
Observations	139613	139613	19569

*Notes:* The table shows the correlation between exporting and foreign affiliate status. Total Factor Productivity (TFP) is estimated with the Olley and Pakes (1996) method. 2-digit sector fixed effect is controlled. I exclude the state-owned firms, processing traders and firms in the exporting zones. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix A.8: **Conditional on Exporting, Foreign Affiliates Export More to the Headquarters and the Destination Countries Closer to the Headquarters**

	(1)	(2)	(3)	(4)
	Full sample $\mathbb{1}(x_{f,ni} > 0)$	$n \neq i$ $\mathbb{1}(x_{f,ni} > 0)$	Full sample $\log(x_{f,ni})$	$n \neq i$ $\log(x_{f,ni})$
$\mathbb{1}(n = i)$	0.124*** (0.0244)		1.613*** (0.157)	
$\log(\text{Dist}_{ni})$		-0.00128** (0.000509)		-0.0538*** (0.00535)
$\mathbb{1}(\text{Common Lang}_{ni})$		-0.000465 (0.000593)		0.125 (0.0857)
$\mathbb{1}(\text{Contiguity}_{ni})$		0.00540** (0.00234)		-0.0331 (0.0935)
$\mathbb{1}(\text{Legal}_{ni})$		0.00130 (0.000850)		0.0718 (0.0548)
$f$ FE	✓	✓	✓	✓
$n$ FE	✓	✓	✓	✓
Observations	3889704	3889704	25428	25428

*Notes:* The table shows conditional on exporting, the correlation 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 exporting destination and the headquarters. Standard errors are clustered on the headquarter-destination level. Firm and export destination fixed effects are controlled. 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). \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

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

849 In this section I derive a micro-foundation for the sourcing problem in Section Appendix A.8.  
 850 It builds on Eaton and Kortum (2002) and Ramondo and Rodríguez-Clare (2013). Assume a  
 851 downstream MNE from country  $m$  located in country  $n$  produces its composite goods with a  
 852 continuum of measure one products:

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

853 For each product, it draws a random productivity shock,  $z_{nmji}^s$  for all upstream host countries  
 854 and headquarters. Assume  $z_{nmji}^s$  is distributed multivariate Fréchet, with joint distribution:

$$F(z_{nmji}^s) = \exp \left( - \left( \sum_{j=1}^N \left( \sum_{i=1}^N (z_{nmji}^s)^{-\frac{\theta}{1-\rho_1}} \right)^{\frac{1-\rho_1}{1-\rho_0}} \right)^{1-\rho_0} \right),$$

855 where  $\rho_1$  governs the correlation across technologies, and  $\rho_0$  governs the correlation across pro-  
 856 duction locations.

857 Similar to Ramondo et al. (2015), the marginal distribution is also Fréchet. Fix a source  
 858 technology  $I$ . The cumulative distribution function (CDF) of drawing technology shock  $z_{nmjI}$  for  
 859  $I$  equals, by taking  $z_{nmji} \rightarrow \infty, \forall i \neq I$ :

$$F(\{z_{nmjI}\}_{j=1}^N) = \exp \left( - \left( \sum_{j=1}^N z_{nmjI}^{-\frac{\theta}{1-\rho_0}} \right)^{1-\rho_0} \right).$$

860 Therefore, the productivity draws for all host countries given a headquarters is still multivariate  
 861 Fréchet with correlation  $\rho_0$  across production locations.

862 Now fix a host country  $J$ . The CDF of drawing technology shock  $z_{nmJi}$  for  $J$  is, taking  
 863  $z_{nmji} \rightarrow \infty, \forall j \neq J$ :

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

864 The productivity shock draws for all technologies given a production location is still multivariate  
865 Fréchet with correlation  $\rho_1$  across headquarters.

866 The price for the downstream MNE from  $m$  in  $n$  to get a unit of intermediate input from the  
867 upstream MNE  $ji$ , whose productivity is  $z_{nmji}^s$ , equals:

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

868 To derive the sourcing shares, first consider the probability that MNE  $nm$ 's composite goods  
869 price,  $P_{nm}^s$ , is no larger than  $p$ :

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

870 where

$$\Phi_{nm}^s = \left(\sum_{j=1}^N \left(\sum_{i=1}^N \left(\frac{\tilde{H}_{ni}^s \tilde{h}_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s}\right)^{-\frac{\theta}{1-\rho_1}}\right)^{\frac{1-\rho_1}{1-\rho_0}}\right)^{1-\rho_0}.$$

871 The probability that MNE  $nm$  sources from  $ji$  is calculated as follows. Consider the probability  
872 density function of  $z_{nmji}^s$  as the partial derivative of  $F(z_{nmji}^s)$  with respect to  $z_{nmji}^s$ :

$$\begin{aligned} F_{ji}(z_{nmji}^s) &= \theta (z_{nmji}^s)^{-\frac{\theta}{1-\rho_1}-1} \left[\sum_{i=1}^N (z_{nmji}^s)^{-\frac{\theta}{1-\rho_1}}\right]^{\frac{\rho_0-\rho_1}{1-\rho_0}} \left\{\sum_{j=1}^N \left[\sum_{i=1}^N (z_{nmji}^s)^{-\frac{\theta}{1-\rho_1}}\right]^{\frac{1-\rho_1}{1-\rho_0}}\right\}^{-\rho_0} \\ &\quad \exp\left(\left\{\sum_{j=1}^N \left[\sum_{i=1}^N (z_{nmji}^s)^{-\frac{\theta}{1-\rho_1}}\right]^{\frac{1-\rho_1}{1-\rho_0}}\right\}^{1-\rho_0}\right). \end{aligned}$$

873 Therefore, the probability that  $z_{nmji}^s = z$  and  $ji$  is the least costly supplier is the following:

$$\begin{aligned}
& F_{ji} \left( z_{nmj'i'} = \frac{\frac{H_{ni'}^s h_{mj'}^s k_{nj'}^s t_{nj'}^s \Theta_{j'i'}^s}{A_{j'i'}^s}}{\frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s}} z \right) \\
&= \theta z^{-\theta-1} \left[ \sum_{i=1}^N \left( \frac{H_{ni'}^s h_{mj'}^s k_{nj'}^s t_{nj'}^s \Theta_{j'i'}^s}{A_{j'i'}^s} \right)^{-\frac{\theta}{1-\rho_1}} \right]^{\frac{\rho_0-\rho_1}{1-\rho_0}} \underbrace{\left\{ \sum_{j=1}^N \left[ \sum_{i=1}^N \left( \frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s} \right)^{-\frac{\theta}{1-\rho_1}} \right]^{\frac{1-\rho_1}{1-\rho_0}} \right\}^{-\rho_0}}_{(\Phi_{nm}^s)^{-\frac{\rho_0}{1-\rho_0}}} \\
& \left( \frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s} \right)^{-\frac{\theta \rho_1}{1-\rho_1}} \exp \left( -\Phi_{nm}^s \left( \frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s} \right)^\theta z^{-\theta} \right).
\end{aligned}$$

874 Integrating this from 0 to  $\infty$  gives us the probability  $nm$  sources from  $ji$ . Note that

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

875 Therefore,

$$\begin{aligned}
& \int_{z=0}^{\infty} F_{ji} \left( z_{nmj'i'} = \frac{\frac{H_{ni'}^s h_{mj'}^s k_{nj'}^s t_{nj'}^s \Theta_{j'i'}^s}{A_{j'i'}^s}}{\frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s}} z \right) \\
&= \left( \frac{H_{ni}^s h_{mj}^s k_{nj}^s t_{nj}^s \Theta_{ji}^s}{A_{ji}^s} \right)^{-\frac{\theta}{1-\rho_1}} \left[ \sum_{i=1}^N \left( \frac{H_{ni'}^s h_{mj'}^s k_{nj'}^s t_{nj'}^s \Theta_{j'i'}^s}{A_{j'i'}^s} \right)^{-\frac{\theta}{1-\rho_1}} \right]^{\frac{\rho_0-\rho_1}{1-\rho_0}} (\Phi_{nm}^s)^{-\frac{1}{1-\rho_0}}.
\end{aligned}$$

876 To derive expenditure shares from this probability requires information about the distribution of  
877 prices conditional on the sourcing decision. The probability that the price facing  $nm$  is no higher  
878 than  $p$ , and  $nm$  optimally sources  $ji$ , equal the following:

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

879 This implies that, the conditional price distribution is the same as the unconditional price distri-  
880 bution. 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  $-\frac{\theta}{1-\rho_1} = 1 - \zeta$  and  $-\frac{\theta}{1-\rho_0} = 1 - \sigma$ . The expenditure share by  $nm$  on  $ji$  equals:

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

which is the same as the one in the text.

## Appendix B.2. Market Clearing Conditions

The labor market clearing condition in  $j$  is the following:

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

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 composite goods equals the following:

$$X_{ji}^s = I_j s_j^s s_{ji}^s + \sum_{s'=1}^S \gamma_j^{s'} \sum_{m=1}^N \sum_{n=1}^N \frac{X_{nm}^{s'}}{t_{nj}^{s'}} \pi_{nmji}^{s'}. \quad (\text{Appendix B.2})$$

The equilibrium is defined by a set of global prices, including wage  $\{w_n\}$ , producer price index  $\{P_{nj}^{s,p}\}$ , and composite goods price  $\{P_{nm}^s\}$ , such that the MNE sourcing and output shares follow Equation (9) and (10), the final expenditure shares follow Equations (5), and labor and composite goods markets clear, following Equations (Appendix B.1) and (Appendix B.2).

## Appendix B.3. Solving Model in Changes

The change in sourcing capability equals the following:

$$\hat{\Theta}_{ji}^s = (\hat{w}_j^s)^{\gamma_j^s} \prod_{s'=1}^S \left( \hat{P}_{ji}^{s'} \right)^{\gamma_j^{ss'}}. \quad (\text{Appendix B.3})$$

897 The change in MNE output share equals the following:

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

898 where the change in the producer price index for country  $j$  firms selling to  $n$  is the following:

$$\left( \hat{P}_{nj}^{s,p} \right)^{1-\zeta} = \sum_{i=1}^N S_{nji}^s \left( \frac{\hat{\Theta}_{ji}^s}{\hat{A}_{ji}^s} \right)^{1-\zeta} \hat{H}_{ni}. \quad (\text{Appendix B.4})$$

899 The change in MNE sourcing share equals:

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

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

$$\left( \hat{P}_{nm}^s \right)^{1-\sigma} = \sum_{j=1}^N \pi_{nmj}^s \hat{h}_{mj}^s \left( \hat{k}_{nj}^s \hat{t}_{nj}^s \hat{P}_{nj}^{s,p} \right)^{1-\sigma}. \quad (\text{Appendix B.5})$$

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

$$\hat{\pi}_{nmji}^s = \hat{\pi}_{nmj}^s \hat{S}_{nji}^s.$$

902 The counterfactual MNE sourcing and output shares equal the following:  $\pi_{nmj}^{s'} = \pi_{nmj}^s \hat{\pi}_{nmj}^s$ ,

903  $\hat{S}_{nji}^{s'} = S_{nji}^s \hat{S}_{nji}^s$ , as well as  $\pi_{nmji}^{s'} = \pi_{nmji}^s \hat{\pi}_{nmji}^s$ .

904 The change in sectoral final expenditure share equals:

$$\hat{s}_n^s = \frac{\hat{\alpha}_n^s \left( \hat{P}_n^s \right)^{1-\lambda}}{\left( \hat{P}_n^s \right)^{1-\lambda}}, \quad (\text{Appendix B.6})$$

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

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

906 The counterfactual sectoral final expenditure share equals the following:

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

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

$$\hat{s}_{nm}^s = \frac{\hat{\alpha}_{nm}^s (\hat{P}_{nm}^s)^{1-\delta}}{(\hat{P}_n^s)^{1-\delta}}. \quad (\text{Appendix B.7})$$

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

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

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

911 The market clearing condition for labor in the counterfactual equilibrium is the following:

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

912 where the change in labor supply equals:

$$\hat{L}_j^s = \hat{\xi}_j^s \left[ \frac{\hat{w}_j^s}{\hat{P}_j} \right]^\psi. \quad (\text{Appendix B.8})$$

913 Market clearing condition for composite goods is the following:

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

914 where counterfactual household income equals:

$$I_n' = \sum_{s=1}^S (\xi_n^s \hat{\xi}_n^s)^{\frac{1}{\psi}} w_n^s L_n^s \hat{w}_n^s \hat{L}_n^s + R_n' + D_n' + T_n', \quad (\text{Appendix B.9})$$

915 in which counterfactual tariff revenue equals:

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

916 and labor income tax rebate equals the following:

$$T'_n = \sum_{s=1}^S \left[ 1 - (\xi_n^{s'})^{\frac{1}{\psi}} \right] w_n^{s'} L_n^{s'}.$$

917 In order to solve the counterfactual equilibrium, we have to know the baseline MNE sourcing  
 918 share,  $\pi_{nmj}^s$ , MNE output share,  $S_{nji}^s$ , sectoral final expenditure share,  $s_j^s$ , and final expenditure  
 919 share on MNE-specific composite goods,  $s_{nm}^s$ . On top of that, we have to know the baseline labor  
 920 income  $w_j L_j$ , labor supply parameter  $\xi_n^s$ , and tariffs.

921 The shocks to the system of equations include: (1) MNE sourcing shock,  $\hat{h}_{mj}$ , (2) MNE selling  
 922 shock,  $\hat{H}_{ni}$ , (3) MNE relative productivity shock,  $\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}$ , (4) labor supply shock,  $\hat{\xi}_n^s$ , (5) final demand  
 923 shock for MNEs,  $\hat{\alpha}_{nm}^s$ , (6) sectoral final demand shock,  $\hat{\alpha}_n^s$ , (6) domestic productivity shock,  $\hat{A}_{jj}^s$ ,  
 924 (8) non-tariff trade cost shock,  $\hat{k}_{nj}^s$ , (9) tariff shock,  $\hat{t}_{nj}^s$ , as well as (10) trade deficit shock,  $D'_n$ .  
 925 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  
 926 clearing conditions hold for the counterfactual equilibrium.

#### 927 *Appendix B.4. The Model without MNEs in Changes*

928 The change in country  $n$ 's composite goods price equals the following:

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

929 where the change in sourcing capability is Cobb-Douglas in wage and sectoral composite goods  
 930 price:

$$\hat{\Theta}_j^s = (\hat{w}_j^s)^{\gamma_j^s} \prod_{s'=1}^S \left( \hat{P}_j^{s'} \right)^{\gamma_j^{ss'}}.$$

931 The change in the expenditure share by country  $n$  on country  $l$  equals:

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

932 The change in the final expenditure share equals the following:

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

933 with the change in the consumer price index equal:

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

934 The counterfactual sectoral final expenditure share equals the following:

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

935 The labor market clearing condition in the counterfactual equilibrium equals the following:

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

936 The change in labor supply equals:

$$\hat{L}_j^s = \hat{\xi}_j^s \left[ \frac{\hat{w}_j^s}{\hat{P}_j} \right]^\psi.$$

937 The market clearing condition for composite goods in the counterfactual equilibrium equals the  
938 following:

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

939 where the counterfactual household income equals:

$$I_n' = \sum_{s=1}^S \left( \xi_n^s \hat{\xi}_n^s \right)^{\frac{1}{\psi}} w_n^s L_n^s \hat{w}_n^s \hat{L}_n^s + R_n' + D_n' + T_n',$$

940 in which the counterfactual tariff revenue equals:

$$R_n' = \sum_{s=1}^S \sum_{j=1}^N \tau_{nj}^{s'} \frac{X_n^{s'} \pi_{nj}^{s'}}{t_{nj}^{s'}}.$$

941 and the labor income tax rebate equals the following:

$$T'_n = \sum_{s=1}^S \left[ 1 - (\xi_n^{s'})^{\frac{1}{\psi}} \right] w_n^{s'} L_n^{s'}.$$

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

#### 944 *Appendix B.5. The Model without MNE Sourcing and Selling Frictions in Changes*

945 The change in sourcing capability equals the following:

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

946 Note that without heterogeneous MNE sourcing efficiencies, the composite goods price is not  
947 MNE-specific.

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

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

949 Without heterogeneous MNE selling frictions, an MNE's share in host country's exports is the  
950 same regardless of the destination. The change in country  $j$ 's producer price index equals the  
951 following:

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

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

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

953 Without heterogeneous MNE sourcing frictions, the sourcing share is also not MNE-specific.

954 The change in the composite goods price for all MNEs in country  $n$  equals:

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

955 The sourcing share by any MNE in  $n$ , on an MNE headquartered in  $i$ , producing in  $j$ , equals

the following:

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

The counterfactual MNE sourcing and output shares are constructed as follows:  $\hat{\pi}_{nj}^{s'} = \pi_{nj}^s \hat{\pi}_{nj}^s$ ,  $\hat{S}_{ji}^{s'} = S_{ji}^s \hat{S}_{ji}^s$ , as well as  $\pi_{nji}^{s'} = \pi_{nji}^s \hat{\pi}_{nji}^s$ . The other equations in this model are the same as in Section Appendix B.3.

### Appendix B.6. Model with CES Production Function

The Cobb-Douglas production function from Section Appendix A.8 can be extended to incorporate a non-unitary elasticity of substitution across inputs, as follows:

$$y_{nm}^s = A_{nm}^s \left( (b_{nm}^s)^{\frac{1}{\mu}} (L_{nm}^s)^{\frac{\mu-1}{\mu}} + \sum_{s'=1}^S (b_{nm}^{ss'})^{\frac{1}{\mu}} (M_{nm}^{ss'})^{\frac{\mu-1}{\mu}} \right)^{\frac{\mu}{\mu-1}},$$

where  $\mu$  denotes the elasticity of substitution across inputs.  $b_n^s$  and  $b_n^{ss'}$  denote labor- and composite goods-augmenting technology. It implies the following input shares on labor and composite goods:  $\gamma_{nm}^s = \frac{b_{nm}^s (w_n^s)^{1-\mu}}{(\Theta_{nm}^s)^{1-\mu}}$  and  $\gamma_{nm}^{ss'} = \frac{b_{nm}^{ss'} (P_{nm}^{s'})^{1-\mu}}{(\Theta_{nm}^{ss'})^{1-\mu}}$ , in which  $(\Theta_{nm}^s)^{1-\mu} = b_{nm}^s (w_n^s)^{1-\mu} + \sum_{s'=1}^S b_{nm}^{ss'} (P_{nm}^{s'})^{1-\mu}$ . Other equations in this model are the same as in the baseline model.

*Calibration and Counterfactuals.* For  $\mu$ , we calibrate to two values from the literature: a high value of 0.67 (De Souza and Li, 2022) and a low value of 0.1 (Bonadio et al., 2021; De Souza and Li, 2022). We can then invert the input shares to acquire the labor- and composite goods-augmenting technologies with the model in changes:

$$\hat{b}_{nm}^s = \frac{\hat{\gamma}_{nm}^s (\hat{\Theta}_{nm}^s)^{1-\mu}}{(\hat{w}_n^s)^{1-\mu}},$$

$$\hat{b}_{nm}^{ss'} = \frac{\hat{\gamma}_{nm}^{ss'} (\hat{\Theta}_{nm}^{ss'})^{1-\mu}}{(\hat{P}_{nm}^{s'})^{1-\mu}}.$$

Due to data availability, and consistent with the baseline model, we assume  $\hat{\gamma}_{nm}^s \equiv \hat{\gamma}_n^s$  and  $\hat{\gamma}_{nm}^{ss'} \equiv \hat{\gamma}_n^{ss'}$  for all  $m$ . Prices  $\hat{w}_n^s$ ,  $\hat{P}_{nm}^s$ , and  $\hat{\Theta}_{nm}^s$  are taken from the baseline model.

To compute counterfactuals, the market clearing conditions should be modified as follows whereas other equations are the same as Section Appendix B.3. For labor:

$$\hat{w}_j^s \hat{L}_j^s w_j^s L_j^s = w_j^{s'} L_j^{s'} = \sum_{i=1}^N \gamma_{ji}^s \hat{\gamma}_{ji}^s \sum_{m=1}^N \sum_{n=1}^N \frac{X_{nm}^{s'} \pi_{nmj}^{s'}}{t_{nj}^{s'}},$$

975 where  $\hat{\gamma}_{ji}^s$  is the change of labor input share:

$$\hat{\gamma}_{ji}^s = \frac{\hat{b}_{ji}^s (\hat{w}_j^s)^{1-\mu}}{(\hat{\Theta}_{ji}^s)^{1-\mu}}.$$

976 Market clearing condition for composite goods is as follows:

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

977 where  $\hat{\gamma}_{ji}^{s's}$  is the change of input-output share:

$$\hat{\gamma}_{ji}^{s's} = \frac{\hat{b}_{ji}^{s's} (\hat{P}_{ji}^s)^{1-\mu}}{(\hat{\Theta}_{ji}^{s'})^{1-\mu}}.$$

## 978 *Appendix B.7. International Capital Flows*

979 I extend the baseline model, which assumed exogenous current account imbalance, to incor-  
 980 porate endogenous international borrowing and lending. I assume that the international capital  
 981 market is complete, where households in different countries trade state-contingent bonds to smooth  
 982 their consumption over time.<sup>63</sup> The household's lifetime utility maximization problem is:

$$\begin{aligned} & \max_{C_{n,t}, L_{n,t}^s, Q_n(s_{t+1}|s_t)} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \log \left( C_{n,t} - \sum_{s=1}^S \frac{\psi}{1+\psi} (L_{n,t}^s)^{\frac{1+\psi}{\psi}} \right) \\ & \text{s.t. } P_{n,t} C_{n,t} + \sum_{s_{t+1}} p(s_{t+1}|s_t) Q_n(s_{t+1}|s_t) = \sum_{s=1}^S (\xi_{n,t}^s)^{\frac{1}{\psi}} w_{n,t}^s L_{n,t}^s + R_{n,t} + T_{n,t} + Q_n(s_t|s_{t-1}). \end{aligned} \quad (\text{Appendix B.10})$$

983 We assume per-period utility equals log of the previous utility function in Equation (4) to create  
 984 a consumption smoothing motive. Households maximize their lifetime utility by choosing labor,  
 985 consumption, and state-contingent bonds each period. A state-contingent bond pays one unit of  
 986 monetary income upon the realization of state  $s_t$ . Denote its current holding as  $Q_n(s_t|s_{t-1})$  and

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<sup>63</sup>See Backus et al. (1992), and recent works including Caselli et al. (2020) and Feng et al. (2024).



987 price of next period's bond  $p(s_{t+1}|s_t)$ . Other variables in Equation (12) maintain the definitions  
 988 in Equation (4).

989 **Proposition Appendix B.1.** The solution to Problem (Appendix B.10) is the following:

$$P_{n,t}C_{n,t} = \frac{\lambda_n}{\sum_{n=1}^N \lambda_n} \sum_{n=1}^N \left( \frac{1}{1+\psi} \sum_{s=1}^S (\xi_{n,t}^s)^{\frac{1}{\psi}} w_{n,t}^s L_{n,t}^s + R_{n,t} + T_{n,t} \right) + \frac{\psi}{1+\psi} \sum_{s=1}^S (\xi_{n,t}^s)^{\frac{1}{\psi}} w_{n,t}^s L_{n,t}^s. \quad (\text{Appendix B.11})$$

990 *Proof of Proposition Appendix B.1.* The Euler Equation is the following:

$$\frac{1}{\lambda_{n,t}(s_t)} = \frac{1}{p(s_{t+1}|s_t)} \frac{1}{\lambda_{n,t+1}(s_{t+1}|s_t)}, \quad (\text{Appendix B.12})$$

991 where  $\lambda_{n,t}(s_t)$  denotes country  $n$ 's discounted inverse marginal utility of income in state  $s_t$ .<sup>64</sup>  
 992 It shows the intertemporal tradeoff: if the household consumes today, they get marginal utility  
 993  $\frac{1}{\lambda_{n,t}(s_t)}$ , which should equal to the marginal utility from buying the bond for  $s_{t+1}$  and consume the  
 994 return in that state. Given a complete international capital market with state-contingent bonds  
 995 for all future states  $s_{t+1}$ , the Euler Equation holds for each future state.

996 Equation (Appendix B.12) shows that the growth of marginal utility of consumption is equal-  
 997 ized across countries:  $\frac{\lambda_{n,t+1}(s_{t+1}|s_t)}{\lambda_{n,t}(s_t)} = \frac{1}{p(s_{t+1}|s_t)}$  and  $\lambda_{n,t}(s_t) = \prod_{r=1}^t \frac{1}{p(s_r|s_{r-1})} \lambda_{n,0}(s_0)$ . The relative of  
 998 every two countries' marginal utility of consumption is invariant of time and history, since:

$$\frac{\lambda_{n,t}(s_t)}{\lambda_{m,t}(s_t)} = \frac{\lambda_{n,0}(s_0)}{\lambda_{m,0}(s_0)}.$$

999 As a result, we can normalize these marginal utilities and denote  $\lambda_{n,t}(s_t) \equiv \lambda_n$ . Furthermore,  
 1000 according to definition of  $\lambda_n$ :

$$\frac{1}{P_{n,t} \left( C_{n,t} - \sum_{s=1}^S \frac{\psi}{1+\psi} (L_{n,t}^s)^{\frac{1+\psi}{\psi}} \right)} = \frac{\beta^t}{\lambda_n} \cdot \forall n$$

1001 As a result,

$$P_{n,t} \left( C_{n,t} - \sum_{s=1}^S \frac{\psi}{1+\psi} (L_{n,t}^s)^{\frac{1+\psi}{\psi}} \right) = \frac{\lambda_n}{\sum_{n=1}^N \lambda_n} \sum_{n=1}^N P_{n,t} \left( C_{n,t} - \sum_{s=1}^S \frac{\psi}{1+\psi} (L_{n,t}^s)^{\frac{1+\psi}{\psi}} \right).$$

---

<sup>64</sup>  $\frac{1}{\lambda_{n,t}(s_t)}$  is the Lagrangian multiplier on state  $s_t$ 's budget constraint.

1002 Hence,

$$\begin{aligned}
P_{n,t}C_{n,t} = & \frac{\lambda_n}{\sum_{n=1}^N \lambda_n} \left( \sum_{n=1}^N \sum_{s=1}^S (\xi_{n,t}^s)^{\frac{1}{\psi}} w_{n,t}^s L_{n,t}^s + R_{n,t} + T_{n,t} - \sum_{n=1}^N P_{n,t} \sum_{s=1}^S \frac{\psi}{1+\psi} (L_{n,t}^s)^{\frac{1+\psi}{\psi}} \right) \\
& + P_{n,t} \sum_{s=1}^S \frac{\psi}{1+\psi} (L_{n,t}^s)^{\frac{1+\psi}{\psi}}
\end{aligned}$$

1003 Finally, substitute in the labor supply function, or  $P_{n,t} (L_{n,t}^s)^{\frac{1}{\psi}} = (\xi_{n,t}^s)^{\frac{1}{\psi}} w_{n,t}^s$ , I get Proposition  
1004 Appendix B.1. ■

1005 Proposition Appendix B.1 shows that, through saving and borrowing, households can hedge  
1006  $\frac{1}{1+\psi}$  of their labor income and all transfer income  $R_{n,t}$  and  $T_{n,t}$ . For their hedged income,  
1007 they receive a share  $\frac{\lambda_n}{\sum_{n=1}^N \lambda_n}$  of global income income, which reduces their exposure to country-  
1008 idiosyncratic shocks. Country-idiosyncratic shocks disproportionately affect large countries (with  
1009 lower marginal utility of income and higher  $\lambda_n$ ). The remaining labor income,  $\frac{\psi}{1+\psi} \sum_{s=1}^S (\xi_{n,t}^s)^{\frac{1}{\psi}} w_{n,t}^s L_{n,t}^s$ ,  
1010 cannot be hedged.

1011 In this model, current account deficit,  $D_{n,t}$ , arises endogenously:

$$D_{n,t} = P_{n,t}C_{n,t} - \left( \sum_{s=1}^S (\xi_{n,t}^s)^{\frac{1}{\psi}} w_{n,t}^s L_{n,t}^s + R_{n,t} + T_{n,t} \right) \quad (\text{Appendix B.13})$$

1012 *Calibration and Counterfactuals.* I calibrate  $\lambda_n$  such that the current account deficit implied by  
1013 Equations (Appendix B.11) and (Appendix B.13) matches the factual level in the initial year. To  
1014 compute counterfactuals, Equation (Appendix B.9) in the baseline model needs to be replaced  
1015 with Equation (Appendix B.11) and other equations remain the same.

## 1016 *Appendix B.8. A Model with Entry, Exit, Input-Output Linkages, and MNE Sourcing and Selling* 1017 *Efficiencies*

1018 I introduce a model featuring heterogeneous domestic firms and MNEs and their entry and exit  
1019 into production and trade. Firms incur both fixed and marginal costs for production and trade.  
1020 Specifically, trading involves a marginal trade cost and a fixed marketing cost. Furthermore,  
1021 sourcing from and selling to non-headquarters countries incurs an additional marginal cost and  
1022 a fixed market access cost. These sourcing and selling marginal and fixed costs depend on firm  
1023 headquarters I maintain input-output linkages from the baseline model. In the next sections, I  
1024 first present the model, then describe its calibration and compute counterfactuals.

Extending the model to include heterogeneous firms does not change my main quantitative findings; it only changes how the shocks should be interpreted. In the baseline model, the identified shocks should be viewed as aggregate shocks, including both intensive-margin firm-level shocks and extensive-margin adjustments. The baseline-identified MNE-specific productivity combines MNE firm-level productivity and the measure of firms. The previously identified trade cost includes both firm-level marginal trade costs and fixed marketing costs. MNE sourcing and selling efficiencies combine firm-level efficiencies with fixed market access costs.

### Appendix B.8.1. Model Setup and Propositions

I follow Arkolakis et al. (2018) to incorporate heterogeneous firms from a given headquarters and operating in a given country and sector (as contrast to the baseline model where these firms are represented by a representative firm). Similar to Arkolakis et al. (2018), I account for the fixed marketing cost to approach customers and entry cost. The model extends Arkolakis et al. (2018) to include input-output linkages and fixed cost of international sourcing and selling by MNEs.<sup>65</sup>

As in the baseline model, we start with the downstream firm's problem. MNEs from country  $m$  operating in country  $n$  sector  $s$  produces their composite goods by combining a measure of intermediate input, each defined with a product  $\omega$  and having elasticity of substitution  $\kappa > 1$  across products:

$$Q_{nm}^s = \left( \int_{\omega=0}^1 Q_{nm}^s(\omega)^{\frac{\kappa-1}{\kappa}} d\omega \right)^{\frac{\kappa}{\kappa-1}}.$$

For each product  $\omega$ , the downstream MNE sources from the least expensive supplier, which can be a firm from any headquarters country  $i$  operating in host country  $j$  and having firm-idiosyncratic productivity  $z_{ji}^s$ .<sup>66</sup> These productivity follows a multi-variate Pareto distribution:

$$\Pr(Z_{ji}^s \leq z_{ji}^s) = 1 - \left[ \sum_{j=1}^N \left( \sum_{i=1}^N z_{ji}^{-\theta} \right)^{\frac{1}{1-\rho_0}} \right]^{1-\rho_0}.$$

<sup>65</sup>In Arkolakis et al. (2018), all MNEs from a given host country face the same fixed marketing cost to access a particular destination country. This cost is also common to all buying firms in the destination. In contrast, my model allows this cost to depend not only on the origin and destination countries but also on the headquarters of both the selling and buying MNEs. This assumption is more realistic in the presence of global value chains, as the sourcing and selling decisions of one MNE can differ from another's, depending on their headquarters.

<sup>66</sup>Same as in the baseline model, a firm with  $i = j$  is a domestic firm.

1045 The distribution has correlation  $\rho_0 \in [0, 1)$  across host countries. For example, if a US firm  
 1046 is more productive at producing a product in US, it will be more productive at producing this  
 1047 product in China. For a given host country, the distribution is independent across headquarters.  
 1048 Like in Arkolakis et al. (2018), this distribution has support  $z_{ji} \geq \tilde{T}^{\frac{1}{\theta}}$ , where  $\tilde{T} \equiv N^{1-\rho_0}$ .

1049 To connect these parameters to those used in the baseline model, I relabel  $1 - \zeta \equiv -\theta$  where  
 1050  $\zeta$  refers to elasticity of substitution across headquarters and  $1 - \sigma \equiv -\frac{\theta}{1-\rho_0}$  where  $\sigma$  refers to  
 1051 elasticity of substitution across host countries. We assume that  $\sigma > \zeta > \kappa$ , which also follows  
 1052 Arkolakis et al. (2018). The productivity distribution can be rewritten as follows:

$$\Pr(Z_{ji}^s \leq z_{ji}^s) = 1 - \left[ \sum_{j=1}^N \left( \sum_{i=1}^N z_{ji}^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}} \right]^{\frac{1-\zeta}{1-\sigma}}. \quad (\text{Appendix B.14})$$

1053 Assume that upstream firms engage in monopolistic competition to sell to the downstream com-  
 1054 posite goods bundle. Hence, they charge a markup  $\frac{\kappa}{\kappa-1}$  over the *marginal cost* of producing and  
 1055 selling output. This *marginal cost*,  $c_{nmji}^s$ , equals the following:

$$c_{nmji}^s = \underbrace{\frac{\Theta_{ji}^s k_{nj}^{s, \text{firm}} t_{nj}^s \tilde{h}_{mj}^{s, \text{firm}} \tilde{H}_{ni}^{s, \text{firm}}}{A_{ji}^{s, \text{firm}}}}_{\equiv \Phi_{nmji}^s} \frac{1}{z_{ji}^s}, \quad (\text{Appendix B.15})$$

1056 where we label the *cost index* (the deterministic component of the seller's marginal cost) of an  
 1057 MNE from country  $i$  in country  $j$  to sell to an MNE from country  $m$  in country  $n$  with  $\Phi_{nmji}^s$ .  
 1058 Like before, the product function is Cobb-Douglas in labor and inputs from all sectors. Hence, the  
 1059 input cost of the selling MNE,  $\Theta_{ji}^s = (w_j^s)^{\gamma_n^s} \prod_{s'=1}^S (P_{ji}^{s'})^{\gamma_n^{ss'}}$ , where  $w_j^s$  denotes the wage in country  
 1060  $j$ -sector  $s$ , and  $P_{ji}^{s'}$  denotes the MNE-specific composite goods price for MNEs from country  $i$   
 1061 operating in country  $j$ -sector  $s'$ .  $\gamma_n^s$  and  $\gamma_n^{ss'}$  denote input-output coefficients.

1062 We denote firm-level marginal trade cost with  $k_{nj}^{s, \text{firm}}$ , which differentiates from the aggregate  
 1063 trade cost identified with the baseline model.  $t_{nj}^s$  denotes one plus the tariff that country  $n$  imposes  
 1064 on sector  $s$  imports from country  $j$ .  $\tilde{h}_{mj}^{s, \text{firm}}$  and  $\tilde{H}_{ni}^{s, \text{firm}}$  denote firm-level sourcing frictions faced by  
 1065 MNEs from country  $m$  when they source from country  $j$  and firm-level selling frictions faced by  
 1066 MNEs from country  $i$  when they sell to country  $n$ .  $A_{ji}^{s, \text{firm}}$  refers to the firm-level, deterministic  
 1067 component of MNE productivity. It differs from the MNE TFP identified in the baseline model,  
 1068 which, as I will show later, includes both the firm-level productivity and the measure of MNEs.

The following lemmas are presented to characterize the decision problems of MNEs:

**Lemma Appendix B.1.** *The cutoff marginal cost where the MNE from  $i$  operating in  $j$  is indifferent between selling or not selling to MNE from  $m$  operating in  $n$ :*

$$c_{nmji}^{s*} = \frac{\kappa - 1}{\kappa} P_{nm}^s (X_{nm}^s)^{\frac{1}{\kappa-1}} [\kappa t_{nj}^s P_{nm}^s F_{nmji}^s]^{\frac{1}{1-\kappa}}, \quad (\text{Appendix B.16})$$

where  $F_{nmji}^s$  denotes the fixed marketing cost of an MNE from  $i$  operating in  $j$  to sell to an MNE from  $m$  operating in  $n$ , which is paid in units of the buyer's composite goods (with price  $P_{nm}^s$ ).

*Proof of Lemma Appendix B.1.* The profit of an MNE from  $i$  operating in  $j$  that is indifferent between selling to or not selling to MNEs from  $m$  operating in  $n$  should have their variable profit equal to the fixed marketing cost:

$$\frac{1}{t_{nj}^s} \frac{1}{\kappa} \left( \frac{\kappa}{\kappa - 1} c_{nmji}^s \right)^{1-\kappa} (P_{nm}^s)^{\kappa-1} X_{nm}^s = P_{nm}^s F_{nmji}^s. \quad (\text{Appendix B.17})$$

Manipulating this equation, we get Equation (Appendix B.16). ■

**Lemma Appendix B.2.** *The distribution of the marginal cost for MNEs from  $i$  operating in  $j$  selling to MNEs from  $m$  in  $n$  equals the following:*

$$\begin{aligned} & \Pr(C_{nmj'i'}^s \geq c, C_{nmji}^s = c) \\ &= (\zeta - 1) \left[ \sum_{j=1}^N \left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}} \right]^{\frac{1-\zeta}{1-\sigma}} \frac{\left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}}}{\sum_{j=1}^N \left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}}} \frac{(\Phi_{nmji}^s)^{1-\zeta}}{\sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta}} (c)^{\zeta-2}. \end{aligned} \quad (\text{Appendix B.18})$$

This density distribution requires that the selling MNE from  $i$  in  $j$  has marginal cost  $c$  and those from other headquarters or operating in other host countries have higher marginal cost, such that those from  $i$  in  $j$  become the least costly supplier.

*Proof of Lemma Appendix B.2.* As  $c_{nmji}^s = \frac{\Phi_{nmji}^s}{z_{ji}^s}$ , and  $\{z_{ji}^s\}$  follows the distribution in Equation (Appendix B.14),  $\{c_{nmji}^s\}$  follows the following multi-variate Pareto distribution:

$$\Pr(C_{nmji}^s \geq c_{nmji}^s) = \Pr\left(Z_{ji}^s \leq \frac{\Phi_{nmji}^s}{c_{nmji}^s}\right) = 1 - \left[ \sum_{j=1}^N \left( \sum_{i=1}^N \left( \frac{\Phi_{nmji}^s}{c_{nmji}^s} \right)^{-\theta} \right)^{\frac{1}{1-\rho_0}} \right]^{1-\rho_0}$$

1085 Taking derivative with respect to  $c_{nmji}^s$ , we get the marginal distribution:

$$\begin{aligned} \Pr(C_{nmj'i'}^s \geq c_{nmj'i'}^s, C_{nmji}^s = c_{nmji}^s) &= (\zeta - 1) \left[ \sum_{j=1}^N \left( \sum_{i=1}^N \left( \frac{\Phi_{nmji}^s}{c_{nmji}^s} \right)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}} \right]^{\frac{1-\zeta}{1-\sigma}} \\ &\quad \frac{\left( \sum_{i=1}^N \left( \frac{\Phi_{nmji}^s}{c_{nmji}^s} \right)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}}}{\sum_{j=1}^N \left( \sum_{i=1}^N \left( \frac{\Phi_{nmji}^s}{c_{nmji}^s} \right)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}}} \frac{(\Phi_{nmji}^s)^{1-\zeta}}{\sum_{i=1}^N \left( \frac{\Phi_{nmji}^s}{c_{nmji}^s} \right)^{1-\zeta}} (c_{nmji}^s)^{\zeta-2} \end{aligned}$$

1086 Setting all  $c_{nmji}^s$ 's to  $c$ , we get Equation (Appendix B.18). ■

1087 **Proposition Appendix B.2.** *The measure of MNEs from  $i$  in  $j$  selling to MNEs from  $m$  in  $j$*   
 1088 *is related to these sales as follows:*

$$M_{nmji}^s = \frac{\zeta - \kappa}{(\zeta - 1)\kappa} \frac{1}{t_{nj}^s P_{nm}^s F_{nmji}^s} x_{nmji}^s. \quad (\text{Appendix B.19})$$

1089 *This equation shows that the measure of MNEs from  $i$  in  $j$  selling to MNEs from  $m$  in  $n$*   
 1090 *increases with aggregate sales between the two groups of MNEs. Tariffs and fixed marketing costs*  
 1091 *deter entry and reduce the measure of these MNEs.*

1092 *As a consequence of Equation (Appendix B.19), the fixed cost payment by MNEs from  $i$  in  $j$*   
 1093 *selling to MNEs from  $m$  in  $j$  is proportional to the sales:  $P_{nm}^s F_{nmji}^s M_{nmji}^s = \frac{\zeta - \kappa}{(\zeta - 1)\kappa} \frac{1}{t_{nj}^s} x_{nmji}^s$ .*

1094 *Proof of Proposition Appendix B.2.* The measure of firms from  $i$  in  $j$  selling to firms from  $m$  in  
 1095  $n$  equals their total measure multiplied by the integration from zero marginal cost to the cutoff  
 1096 marginal cost,  $c_{nmji}^{s*}$ . The integration uses the marginal cost distribution for MNEs from  $i$  operating  
 1097 in  $j$  selling to MNEs from  $m$  in  $n$ , Lemma (Appendix B.2):

$$\begin{aligned} M_{nmji}^s &= M_{ji} \int_0^{c_{nmji}^{s*}} \Pr(C_{nmj'i'}^s \geq c, C_{nmji}^s = c) dc \\ &= M_{ji} \frac{\left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}}}{\sum_{j=1}^N \left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}}} \frac{(\Phi_{nmji}^s)^{1-\zeta}}{\sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta}} \left[ \sum_{j=1}^N \left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}} \right]^{\frac{1-\zeta}{1-\sigma}} \\ &\quad \left( \frac{\kappa - 1}{\kappa} P_{nm}^s [\kappa t_{nj}^s P_{nm}^s F_{nmji}^s]^{\frac{1}{1-\kappa}} \right)^{\zeta-1}. \end{aligned}$$

1098 Sales by firms from  $i$  in  $j$  selling to firms from  $m$  in  $n$  equal the following, where we again integrate  
 1099 the marginal cost of the selling firm from zero to the cutoff:

$$\begin{aligned}
x_{nmji}^s &= M_{ji}^s (P_{nm}^s)^{\kappa-1} X_{nm}^s \int_0^{c_{nmji}^{s*}} \left( \frac{\kappa}{\kappa-1} c \right)^{1-\kappa} \Pr(C_{nmj'i'}^s \geq c, C_{nmji}^s = c) dc \\
&= M_{ji}^s (\zeta-1) \left[ \sum_{j=1}^N \left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}} \right]^{\frac{1-\zeta}{1-\sigma}} \frac{\left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}}}{\sum_{j=1}^N \left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}}} \\
&\quad \frac{(\Phi_{nmji}^s)^{1-\zeta}}{\sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta}} \left( \frac{\kappa}{\kappa-1} \right)^{1-\kappa} (P_{nm}^s)^{\kappa-1} X_{nm}^s \int_0^{c_{nmji}^{s*}} (c)^{\zeta-1-\kappa} dc \\
&= M_{ji}^s (\zeta-1) \left[ \sum_{j=1}^N \left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}} \right]^{\frac{1-\zeta}{1-\sigma}} \frac{\left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}}}{\sum_{j=1}^N \left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}}} \\
&\quad \frac{(\Phi_{nmji}^s)^{1-\zeta}}{\sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta}} \left( \frac{\kappa}{\kappa-1} \right)^{1-\kappa} (P_{nm}^s)^{\kappa-1} X_{nm}^s \frac{1}{\zeta-\kappa} \left( \frac{\kappa-1}{\kappa} P_{nm}^s (X_{nm}^s)^{\frac{1}{\kappa-1}} [\kappa t_{nj}^s P_{nm}^s F_{nmji}^s]^{\frac{1}{1-\kappa}} \right)^{\zeta-\kappa} \\
&= \left( \frac{\kappa}{\kappa-1} \right)^{1-\zeta} \frac{\zeta-1}{\zeta-\kappa} \kappa^{\frac{\zeta-\kappa}{1-\kappa}} M_{ji}^s \left[ \sum_{j=1}^N \left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}} \right]^{\frac{1-\zeta}{1-\sigma}} \pi_{nmj}^{s,\text{firm}} S_{nji}^{s,\text{firm}} (P_{nm}^s)^{\zeta-1+\frac{\zeta-\kappa}{1-\kappa}} \\
&\quad (X_{nm}^s)^{\frac{\zeta-1}{\kappa-1}} [t_{nj}^s F_{nmji}^s]^{\frac{\zeta-\kappa}{1-\kappa}}.
\end{aligned}$$

(Appendix B.20)

Combining these two Equations, we get Proposition (Appendix B.2). In Equation (Appendix B.20),

I introduce firm-level sourcing shares and output shares,  $\pi_{nmj}^{s,\text{firm}}$  and  $S_{nji}^{s,\text{firm}}$ . In particular,

$$S_{nji}^{s,\text{firm}} = \frac{H_{ni}^{s,\text{firm}} \left( \frac{\Theta_{ji}^s}{A_{ji}^{s,\text{firm}}} \right)^{1-\zeta}}{\sum_{i=1}^N H_{ni}^{s,\text{firm}} \left( \frac{\Theta_{ji}^s}{A_{ji}^{s,\text{firm}}} \right)^{1-\zeta}}, \quad (\text{Appendix B.21})$$

and

$$\pi_{nmj}^{s,\text{firm}} = \frac{h_{mj}^{s,\text{firm}} (P_{nj}^{s,p,\text{firm}} k_{nj}^{s,\text{firm}} t_{nj}^s)^{1-\sigma}}{(P_{nm}^{s,\text{firm}})^{1-\sigma}}, \quad (\text{Appendix B.22})$$

where  $P_{nj}^{s,p,\text{firm}}$  is the firm-level producer price index for firms in country  $j$  selling to country  $n$

and equals the following:

$$(P_{nj}^{s,p,\text{firm}})^{1-\zeta} = \sum_{i=1}^N H_{ni}^{s,\text{firm}} \left( \frac{\Theta_{ji}^s}{A_{ji}^{s,\text{firm}}} \right)^{1-\zeta}.$$

1105

■

**Lemma Appendix B.3.** *The composite goods price index of an MNE from  $m$  operating in  $n$ ,*

*$P_{nm}^s$ , equals the following:*

1107

$$(P_{nm}^s)^{1-\zeta-\frac{\zeta-\kappa}{1-\kappa}} = \left(\frac{\kappa}{\kappa-1}\right)^{1-\zeta} \frac{\zeta-1}{\zeta-\kappa} \kappa^{\frac{\zeta-\kappa}{1-\kappa}} \left[ \sum_{j=1}^N \left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}} \right]^{\frac{1-\zeta}{1-\sigma}} (X_{nm}^s)^{\frac{\zeta-\kappa}{\kappa-1}} \quad (\text{Appendix B.23})$$

$$\left( \sum_{j=1}^N \sum_{i=1}^N M_{ji}^s \pi_{nmj}^{s,\text{firm}} S_{nji}^{s,\text{firm}} [t_{nj}^s F_{nmji}^s]^{\frac{\zeta-\kappa}{1-\kappa}} \right).$$

1108 *Proof of Lemma Appendix B.3.* The price index is a CES aggregator of the prices of all firms  
 1109 that sell to these MNEs. For each selling MNE from  $i$  operating in  $j$ , integration should run  
 1110 from marginal cost equal to zero to marginal cost equal to  $c_{nmji}^{s*}$ . Again plug in the marginal cost  
 1111 distribution for these MNEs, Equation (Appendix B.2):

$$(P_{nm}^s)^{1-\kappa} = \sum_{j=1}^N \sum_{i=1}^N M_{ji}^s \int_{c=0}^{c_{nmji}^{s*}} \left(\frac{\kappa}{\kappa-1}c\right)^{1-\kappa} \Pr(C_{nmji}^s \geq c, C_{nmji}^s = c) dc$$

$$= \left(\frac{\kappa}{\kappa-1}\right)^{1-\kappa} (\zeta-1) \left[ \sum_{j=1}^N \left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}} \right]^{\frac{1-\zeta}{1-\sigma}} \left( \sum_{j=1}^N \sum_{i=1}^N M_{ji}^s \pi_{nmj}^{s,\text{firm}} S_{nji}^{s,\text{firm}} \int_{c=0}^{c_{nmji}^{s*}} c^{\zeta-1-\kappa} dc \right)$$

$$= \left(\frac{\kappa}{\kappa-1}\right)^{1-\zeta} \frac{\zeta-1}{\zeta-\kappa} \kappa^{\frac{\zeta-\kappa}{1-\kappa}} \left[ \sum_{j=1}^N \left( \sum_{i=1}^N (\Phi_{nmji}^s)^{1-\zeta} \right)^{\frac{1-\sigma}{1-\zeta}} \right]^{\frac{1-\zeta}{1-\sigma}} (P_{nm}^s)^{\zeta-\kappa} (X_{nm}^s)^{\frac{\zeta-\kappa}{\kappa-1}} [P_{nm}^s]^{\frac{\zeta-\kappa}{1-\kappa}}$$

$$\left( \sum_{j=1}^N \sum_{i=1}^N M_{ji}^s \pi_{nmj}^{s,\text{firm}} S_{nji}^{s,\text{firm}} [t_{nj}^s F_{nmji}^s]^{\frac{\zeta-\kappa}{1-\kappa}} \right).$$

1112 Moving the terms containing  $P_{nm}^s$  to the left hand side, we get Equation (Appendix B.23). ■

1113 **Proposition Appendix B.3.** *The MNE-bilateral expenditure share that MNEs from country  $m$*   
 1114 *operating in country  $n$  spent on intermediate goods bought from MNEs from country  $i$  operating*  
 1115 *in country  $j$  equals the following:*

$$\pi_{nmji}^s = \frac{M_{ji}^s \pi_{nmj}^{s,\text{firm}} S_{nji}^{s,\text{firm}} [t_{nj}^s F_{nmji}^s]^{\frac{\zeta-\kappa}{1-\kappa}}}{\sum_{j=1}^N \sum_{i=1}^N M_{ji}^s \pi_{nmj}^{s,\text{firm}} S_{nji}^{s,\text{firm}} [t_{nj}^s F_{nmji}^s]^{\frac{\zeta-\kappa}{1-\kappa}}}. \quad (\text{Appendix B.24})$$

1116 Similar to Equation (11), the sourcing share,  $\pi_{nmj}^{s,\text{firm}}$ , and the output share,  $S_{nji}^{s,\text{firm}}$ , both con-  
 1117 tribute to the expenditure share. The difference between Equation (Appendix B.24) and Equation  
 1118 (11) arises from extensive margin adjustments. An increase in the measure of firms from  $i$  in  $j$   
 1119 leads to greater expenditure share on those MNEs.  $[t_{nj}^s F_{nmji}^s]^{\frac{\zeta-\kappa}{1-\kappa}}$  shows that the tariff and fixed  
 1120 cost reduce entry, which decreases the sales from selling MNEs to buying MNEs. The denominator



1121 is a normalization such that  $\sum_{i=1}^N \sum_{j=1}^N \pi_{nmji}^s = 1$ .

1122 *Proof of Proposition Appendix B.3.* Plug Equation (Appendix B.23) into Equation (Appendix B.20),  
 1123 we get Equation (Appendix B.24). ■

1124 With these results, we can define the equilibrium of this model:

1125 **Definition Appendix B.1.** *In this model of heterogeneous MNEs' sourcing and selling problems,*  
 1126 *an equilibrium is defined with wages, MNE-specific composite goods prices, expenditures on MNE-*  
 1127 *specific composite goods,  $\{w_n^s, P_{nm}^s, X_{nm}^s\}$ , such that the free entry condition and market clearing*  
 1128 *conditions hold.*

1129 *To ensure an interior equilibrium, I assume decreasing returns to entry. Specifically, creating*  
 1130 *an additional firm requires labor units proportional to the existing measure of the same type of*  
 1131 *firms in the economy. The free entry condition requires that the fixed entry cost equals the net*  
 1132 *profit, which equals the variable profit minus the fixed marketing cost:*

$$w_j^s f_{ji}^{s,e} (M_{ji}^s)^2 = \frac{\kappa - 1}{\kappa(\zeta - 1)} \sum_{n=1}^N \sum_{m=1}^N \frac{X_{nm}^s}{t_{nj}^s} \pi_{nmji}^s. \quad (\text{Appendix B.25})$$

1133 *Country-sector level labor supply is the same as the baseline model:*

$$L_n^s = \xi_n^s \left[ \frac{w_n^s}{P_n} \right]^\psi$$

1134 *The labor market clearing condition is the following:*

$$w_j^s L_j^s = \frac{\kappa - 1}{\kappa} \gamma_j^s \sum_{n=1}^N \sum_{m=1}^N \frac{X_{nm}^s \pi_{nmj}^s}{t_{nj}^s} + \sum_{i=1}^N w_j^s f_{ji}^{s,e} (M_{ji}^s)^2. \quad (\text{Appendix B.26})$$

1135 *The MNE-specific composite goods market clearing condition is the following:*

$$X_{ji}^s = I_j s_j^s s_{ji}^s + \frac{\kappa - 1}{\kappa} \sum_{s'=1}^S \gamma_j^{s's} \sum_{m=1}^N \sum_{n=1}^N \frac{X_{nm}^{s'}}{t_{nj}^{s'}} \pi_{nmji}^{s'} + \sum_{q=1}^N \sum_{p=1}^N M_{jiqp}^s P_{ji}^s F_{jiqp}^s, \quad (\text{Appendix B.27})$$

1136 in which the fixed marketing cost follows Equation (Appendix B.19) and the country level income,  
 1137  $I_n$ , equals the following:

$$\begin{aligned}
I_n &= \sum_{s=1}^S (\xi_n^s)^{\frac{1}{\psi}} w_n^s L_n^s + R_n + D_n + T_n, \\
T_n &= \sum_{s=1}^S \left[ 1 - (\xi_n^s)^{\frac{1}{\psi}} \right] w_n^s L_n^s, \\
R_n &= \sum_{s=1}^S \sum_{j=1}^N \sum_{m=1}^N X_{nm}^s \pi_{nmj}^s \frac{\tau_{nj}^s}{t_{nj}^s},
\end{aligned}$$

and  $D_n$  denotes the trade deficit of country  $n$ .

### Appendix B.8.2. Model Calibration

Given the model requirement that  $\zeta > \kappa$ , and my baseline estimate of  $\zeta = 2.71$ , I set  $\kappa = 2.5$ . This value is close to the 3 chosen by Hsieh and Klenow (2009). Other parameter values remain consistent with the baseline specification.

To calibrate the model, from now on, assume that the fixed marketing cost for MNEs from country  $i$  operating in country  $j$  to sell to MNEs from country  $m$  operating in country  $n$  is separable into three components: the *fixed trade cost* from host country  $j$  to host country  $n$ , the *fixed selling cost* faced by country  $i$  headquartered MNEs to sell to country  $n$ , and the *fixed sourcing cost* faced by country  $m$  headquartered MNEs to source from country  $j$ :

$$F_{nmji}^s = F_{nj}^{s,k} F_{ni}^{s,H} F_{mj}^{s,h} \quad (\text{Appendix B.28})$$

**Proposition Appendix B.4.** *The frictions identified in the baseline model should be interpreted as aggregate, economy-wide frictions. They are a combination of firm-level frictions and extensive margin frictions that affect firm entry and exit. In particular,*

$$(A_{ji}^s)^{\zeta-1} = (A_{ji}^{s,\text{firm}})^{\zeta-1} M_{ji}^s, \quad (\text{Appendix B.29})$$

$$(k_{nj}^s)^{1-\sigma} = (k_{nj}^{s,\text{firm}})^{1-\sigma} (P_{nj}^{s,p,\text{firm}})^{\zeta-\sigma} [t_{nj}^s]^{\frac{\zeta-\kappa}{1-\kappa}} [F_{nj}^{s,k}]^{\frac{\zeta-\kappa}{1-\kappa}}, \quad (\text{Appendix B.30})$$

$$H_{ni}^s = H_{ni}^{s,\text{firm}} [F_{ni}^{s,H}]^{\frac{\zeta-\kappa}{1-\kappa}}, \quad (\text{Appendix B.31})$$

$$h_{mj}^s = h_{mj}^{s,\text{firm}} [F_{mj}^{s,h}]^{\frac{\zeta-\kappa}{1-\kappa}}. \quad (\text{Appendix B.32})$$

Equation (Appendix B.29) shows that the MNE productivity identified with the baseline model

is a combination of firm level productivity and the measure of firms, where the measure of firms adds to aggregate productivity because of love-of-variety preference.

Equation (Appendix B.30) shows that the trade cost identified with the baseline model combines firm-level trade cost on the intensive margin as well as tariffs and fixed trade cost that reduce firm entry into exporting on the extensive margin, and price indices.

Equation (Appendix B.31) shows that the selling efficiency identified with the baseline model combines firm-level selling efficiency and such efficiency loss due to fixed costs for MNEs to access markets that are not their headquarters.

Equation (Appendix B.32) shows that the sourcing efficiency identified with the baseline model combines firm-level sourcing efficiency and such efficiency loss due to fixed costs for MNEs to source inputs from markets that are not their headquarters.

*Proof of Proposition Appendix B.4.* The MNE-bilateral expenditure share,  $\pi_{nmji}^s$ , defined with Equation (Appendix B.24), can be decomposed into the product of economy-wide sourcing share and output share:

$$\pi_{nmji}^s = \bar{\pi}_{nmj}^s \bar{S}_{nji}^s,$$

in which the economy wide output share,

$$\bar{S}_{nji}^s = \frac{H_{ni}^{s,\text{firm}} \left( \frac{\Theta_{ji}^s}{A_{ji}^{s,\text{firm}}} \right)^{1-\zeta} M_{ji}^s [F_{ni}^{s,H}]^{\frac{\zeta-\kappa}{1-\kappa}}}{\sum_{i=1}^N H_{ni}^{s,\text{firm}} \left( \frac{\Theta_{ji}^s}{A_{ji}^{s,\text{firm}}} \right)^{1-\zeta} M_{ji}^s [F_{ni}^{s,H}]^{\frac{\zeta-\kappa}{1-\kappa}}}, \quad (\text{Appendix B.33})$$

and the economy-wide sourcing share,

$$\bar{\pi}_{nmj}^s = \frac{(\bar{P}_{nj}^{s,p})^{1-\sigma} (k_{nj}^{s,\text{firm}} t_{nj}^s)^{1-\sigma} h_{mj}^s \left( P_{nj}^{s,p,\text{firm}} \right)^{\zeta-\sigma} [t_{nj}^s F_{nj}^{s,k}]^{\frac{\zeta-\kappa}{1-\kappa}} [F_{mj}^{s,h}]^{\frac{\zeta-\kappa}{1-\kappa}}}{\sum_{j=1}^N (\bar{P}_{nj}^{s,p})^{1-\sigma} (k_{nj}^{s,\text{firm}} t_{nj}^s)^{1-\sigma} h_{mj}^s \left( P_{nj}^{s,p,\text{firm}} \right)^{\zeta-\sigma} [t_{nj}^s F_{nj}^{s,k}]^{\frac{\zeta-\kappa}{1-\kappa}} [F_{mj}^{s,h}]^{\frac{\zeta-\kappa}{1-\kappa}}}. \quad (\text{Appendix B.34})$$

In Equation (Appendix B.34),  $\bar{P}_{nj}^{s,p}$  is the aggregate producer price index for country  $j$ 's sales to country  $n$ :

$$(\bar{P}_{nj}^{s,p})^{1-\zeta} = \sum_{i=1}^N H_{ni}^{s,\text{firm}} \left( \frac{\Theta_{ji}^s}{A_{ji}^{s,\text{firm}}} \right)^{1-\zeta} M_{ji}^s [F_{ni}^{s,H}]^{\frac{\zeta-\kappa}{1-\kappa}}.$$

1173  $A_{ji}^s$  and  $H_{ni}^s$  identified with the baseline model includes all shocks that vary on  $j-i$  and  $n-i$  level  
 1174 in the economy-wide output share (Equation Appendix B.33), respectively. Combining terms, we  
 1175 get Equations (Appendix B.29) and (Appendix B.31).

1176  $k_{nj}^s$  and  $h_{mj}^s$  identified with the baseline model includes all frictions that vary on  $n-j$  and  
 1177  $m-j$  level in the economy-wide sourcing share (Equation Appendix B.34), respectively. Combining  
 1178 terms, we get Equations (Appendix B.30) and (Appendix B.32). ■

1179 From now on, assume that the fixed marketing costs are proportional to the firm-level variable  
 1180 costs along the same dimension. Specifically,

$$\left[F_{ni}^{s,H}\right]^{\frac{\kappa}{1-\kappa}} \propto H_{ni}^{s,\text{firm}}, \left[F_{mj}^{s,h}\right]^{\frac{\kappa}{1-\kappa}} \propto h_{mj}^{s,\text{firm}}, \left[t_{nj}^s F_{nj}^{s,k}\right]^{\frac{\kappa}{1-\kappa}} \propto (k_{nj}^{s,\text{firm}})^{1-\sigma}.$$

1181 **Corollary Appendix B.1.** *Under these assumptions, we can solve firm-level variable costs on*  
 1182 *the intensive margin and fixed costs on the extensive margin with the economy-wide costs that we*  
 1183 *identified.*<sup>67</sup>

$$\left[F_{ni}^{s,H}\right]^{\frac{\zeta-\kappa}{1-\kappa}} \propto [H_{ni}^s]^{\frac{\zeta-\kappa}{\zeta}}, H_{ni}^{s,\text{firm}} \propto [H_{ni}^s]^{\frac{\kappa}{\zeta}}$$

$$\left[F_{mj}^{s,h}\right]^{\frac{\zeta-\kappa}{1-\kappa}} \propto [h_{mj}^s]^{\frac{\zeta-\kappa}{\zeta}}, h_{mj}^{s,\text{firm}} \propto [h_{mj}^s]^{\frac{\kappa}{\zeta}}$$

$$\left[t_{nj}^s F_{nj}^{s,k}\right]^{\frac{\zeta-\kappa}{1-\kappa}} = \left[\frac{(k_{nj}^s)^{1-\sigma}}{(P_{nj}^{s,p})^{\zeta-\sigma}}\right]^{\frac{\zeta-\kappa}{\zeta}}, (k_{nj}^{s,\text{firm}})^{1-\sigma} = \left[\frac{(k_{nj}^s)^{1-\sigma}}{(P_{nj}^{s,p})^{\zeta-\sigma}}\right]^{\frac{\kappa}{\zeta}}$$

1186 **Lemma Appendix B.4.** *Firm-level sourcing and output shares,  $\pi_{nmj}^s$  and  $S_{nji}^s$ , can be derived*  
 1187 *based on the known economy-wide sourcing and output shares and the identified frictions.*

1188 *Proof of Lemma Appendix B.4.* Take the ratio between economy-wide output shares, Equation  
 1189 (Appendix B.33), and firm-level output shares, Equation (Appendix B.21), we can write the firm-  
 1190 level output share as follows:

$$S_{nji}^{s,\text{firm}} = \bar{S}_{nji}^s \frac{\frac{1}{M_{ji}^s [F_{ni}^{s,H}]^{\frac{\zeta-\kappa}{1-\kappa}}}}{\sum_{i=1}^N \bar{S}_{nji}^s \frac{1}{M_{ji}^s [F_{ni}^{s,H}]^{\frac{\zeta-\kappa}{1-\kappa}}}}.$$

---

<sup>67</sup>We acquire the producer price index as follows:  $P_{nj}^{s,p} \propto \left(\frac{\pi_{nnj}^s}{h_{nj}^s}\right)^{\frac{1}{1-\sigma}} \frac{1}{k_{nj}^s t_{nj}^s}$ .

1191 This equation shows that as we know the economy-wide output share,  $\bar{S}_{nji}^s$ , the measure of firms,  
 1192  $M_{ji}^s$  (from Equation Appendix B.25), and the fixed selling cost,  $F_{ni}^{s,H}$ , we can get the firm-level  
 1193 output share,  $S_{nji}^{s,\text{firm}}$ .

1194 To get the firm-level sourcing share,  $\pi_{nmj}^{s,\text{firm}}$ , note that:

$$\pi_{nmj}^{s,\text{firm}} \propto \frac{\pi_{nmji}^s}{M_{ji}^s S_{nji}^{s,\text{firm}} \left[ t_{nj}^s F_{nj}^{s,k} F_{ni}^{s,H} F_{mj}^{s,h} \right]^{\frac{\zeta-\kappa}{1-\kappa}}}.$$

1195 We compute the right hand side, then normalize such that  $\sum_{j=1}^N \pi_{nmj}^{s,\text{firm}} = 1$ . ■

1196 With the calibrated shocks and market shares, we can define the model in the counterfactual  
 1197 equilibrium:

1198 **Definition Appendix B.2.** *An equilibrium in changes is defined with changes in wages, changes*  
 1199 *in MNE-specific composite goods prices, counterfactual expenditures on MNE-specific composite*  
 1200 *goods,  $\{\hat{w}_n^s, \hat{P}_{nm}^s, X_{nm}^{s'}\}$ , such that the free entry condition and market clearing conditions hold in*  
 1201 *the counterfactual equilibrium.*

1202 *The free entry condition in the counterfactual equilibrium is the following:*

$$f_{ji}^{s,e} (M_{ji}^s)^2 w_j^s \hat{f}_{ji}^{s,e} (\hat{M}_{ji}^s)^2 \hat{w}_j^s = \frac{\kappa-1}{\kappa(\zeta-1)} \sum_{n=1}^N \sum_{m=1}^N \frac{X_{nm}^{s'}}{t_{nj}^{s'}} \pi_{nmji}^{s'}. \quad (\text{Appendix B.35})$$

1203 *On the right hand side,  $\pi_{nmji}^{s'}$  denotes the MNE-bilateral expenditure shares in the counterfactual*  
 1204 *equilibrium:  $\pi_{nmji}^{s'} = \pi_{nmji}^s \hat{\pi}_{nmji}^s$ , in which  $\hat{\pi}_{nmji}^s$  equals the following:*

$$\hat{\pi}_{nmji}^s = \frac{\hat{M}_{ji}^s \hat{\pi}_{nmj}^{s,\text{firm}} \hat{S}_{nji}^{s,\text{firm}} \left[ \hat{t}_{nj}^s \hat{F}_{nj}^{s,k} \hat{F}_{ni}^{s,H} \hat{F}_{mj}^{s,h} \right]^{\frac{\zeta-\kappa}{1-\kappa}}}{\sum_{j=1}^N \sum_{i=1}^N \pi_{nmji}^s \hat{M}_{ji}^s \hat{\pi}_{nmj}^{s,\text{firm}} \hat{S}_{nji}^{s,\text{firm}} \left[ \hat{t}_{nj}^s \hat{F}_{nj}^{s,k} \hat{F}_{ni}^{s,H} \hat{F}_{mj}^{s,h} \right]^{\frac{\zeta-\kappa}{1-\kappa}}}. \quad (\text{Appendix B.36})$$

1205 In this equation,  $\hat{\pi}_{nmj}^{s,\text{firm}}$  and  $\hat{S}_{nji}^{s,\text{firm}}$  denote the changes in firm-level sourcing and output shares:

$$\hat{S}_{nji}^{s,\text{firm}} = \frac{\hat{H}_{ni}^{s,\text{firm}} \left( \frac{\hat{\Theta}_{ji}^s}{\hat{A}_{ji}^{s,\text{firm}}} \right)^{1-\zeta}}{\sum_{i=1}^N S_{nji}^{s,\text{firm}} \hat{H}_{ni}^{s,\text{firm}} \left( \frac{\hat{\Theta}_{ji}^s}{\hat{A}_{ji}^{s,\text{firm}}} \right)^{1-\zeta}}, \quad (\text{Appendix B.37})$$

$$\hat{\pi}_{nmj}^{s,\text{firm}} = \frac{\hat{h}_{mj}^{s,\text{firm}} (\hat{P}_{nj}^{s,p,\text{firm}} \hat{k}_{nj}^{s,\text{firm}} \hat{t}_{nj}^s)^{1-\sigma}}{(\hat{P}_{nm}^{s,\text{firm}})^{1-\sigma}}, \quad (\text{Appendix B.38})$$

1207 where  $\hat{P}_{nj}^{s,p,\text{firm}}$  denotes the change in firm-level producer price index for firms in country  $j$  selling  
 1208 to country  $n$  and equals the following:

$$\left(\hat{P}_{nj}^{s,p,\text{firm}}\right)^{1-\zeta} = \sum_{i=1}^N S_{nji}^{s,\text{firm}} \hat{H}_{ni}^{s,\text{firm}} \left(\frac{\hat{\Theta}_{ji}^s}{\hat{A}_{ji}^{s,\text{firm}}}\right)^{1-\zeta},$$

1209 and  $\hat{P}_{nm}^{s,\text{firm}}$  denotes the change in firm-level MNE-specific composite goods price:

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

1210 *The labor market clearing condition in the counterfactual equilibrium is the following:*

$$w_j^s L_j^s \hat{w}_j^s \hat{L}_j^s = \frac{\kappa-1}{\kappa} \gamma_j^s \sum_{n=1}^N \sum_{m=1}^N \frac{X_{nm}^{s'} \bar{\pi}_{nmj}^{s'}}{t_{nj}^{s'}} + \sum_{i=1}^N f_{ji}^{s,e} (M_{ji}^s)^2 w_j^s \hat{f}_{ji}^{s,e} (\hat{M}_{ji}^s)^2 \hat{w}_j^s, \quad (\text{Appendix B.39})$$

1211 *in which changes in country-sector level labor supply equal the following:*

$$\hat{L}_n^s = \hat{\xi}_n^s \left[ \frac{\hat{w}_n^s}{\hat{P}_n} \right]^\psi.$$

1212 *The MNE-specific composite goods market clearing condition in the counterfactual equilibrium*  
 1213 *is the following:*

$$X_{ji}^{s'} = I_j' s_j^s s_{ji}^s \hat{s}_j^s \hat{s}_{ji}^s + \frac{\kappa-1}{\kappa} \sum_{u=1}^S \gamma_j^{us} \sum_{m=1}^N \sum_{n=1}^N \frac{X_{nm}^{u'} \pi_{nmji}^u \hat{\pi}_{nmji}^u}{t_{nj}^{u'}} + \sum_{q=1}^N \sum_{p=1}^N M_{jiqp}^{s'} P_{ji}^{s'} F_{jiqp}^{s'}, \quad (\text{Appendix B.40})$$

1214 *in which the fixed marketing cost equals the following:*

$$\sum_{j=1}^N \sum_{i=1}^N M_{nmji}^{s'} P_{nm}^{s'} F_{nmji}^{s'} = \frac{\zeta - \kappa}{(\zeta - 1)\kappa} \sum_{j=1}^N \sum_{i=1}^N \frac{1}{t_{nj}^{s'}} X_{nm}^{s'} \pi_{nmji}^s \hat{\pi}_{nmji}^s.$$

1215 *In the counterfactual equilibrium, the country level income,  $I_n'$ , equals the following:*

$$\begin{aligned} I_n' &= \sum_{s=1}^S (\xi_n^{s'})^{\frac{1}{\psi}} w_n^{s'} L_n^{s'} + R_n' + D_n' + T_n', \\ T_n' &= \sum_{s=1}^S \left[ 1 - (\xi_n^{s'})^{\frac{1}{\psi}} \right] w_n^{s'} L_n^{s'}, \\ R_n' &= \sum_{s=1}^S \sum_{j=1}^N \sum_{m=1}^N X_{nm}^{s'} \pi_{nmj}^{s'} \frac{\tau_{nj}^{s'}}{t_{nj}^{s'}}, \end{aligned}$$

1216 *and  $D_n'$  denotes the trade deficit of country  $n$  in the counterfactual equilibrium. The change in*  
 1217 *sectoral final expenditure share on MNE-specific composite goods equals the following:*

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

1218 and the change in sectoral final expenditure share equals the following:

$$\hat{s}_n^s = \frac{\hat{a}_n^s (\hat{P}_n^s)^{1-\lambda}}{(\hat{P}_n^s)^{1-\lambda}}.$$

1219 These shares in counterfactual equilibrium equal the following:  $s_n^{s'} = s_n^s \hat{s}_n^s$  and  $s_{nm}^{s'} = s_{nm}^s \hat{s}_{nm}^s$ .

1220 Furthermore, the change in MNE-specific composite goods price equals the following:

$$(\hat{P}_{nm}^s)^{1-\zeta-\frac{\zeta-\kappa}{1-\kappa}} = \left[ \sum_{j=1}^N \pi_{nmj}^{s,\text{firm}} (\hat{k}_{nj}^{s,\text{firm}})^{1-\sigma} (\hat{t}_{nj}^s)^{1-\sigma} \hat{h}_{mj}^{s,\text{firm}} \left( \sum_{i=1}^N S_{nji}^{s,\text{firm}} \left( \frac{\hat{\Theta}_{ji}^s}{\hat{A}_{ji}^{s,\text{firm}}} \right)^{1-\zeta} \hat{H}_{ni}^{s,\text{firm}} \right)^{\frac{1-\sigma}{1-\zeta}} \right]^{\frac{1-\zeta}{1-\sigma}} (\hat{X}_{nm}^s)^{\frac{\zeta-\kappa}{\kappa-1}} \\ \left( \sum_{j=1}^N \sum_{i=1}^N \pi_{nmji}^s \hat{M}_{ji}^s \hat{\pi}_{nmj}^{s,\text{firm}} \hat{S}_{nji}^{s,\text{firm}} \left[ \hat{t}_{nj}^s \hat{F}_{nj}^{s,k} \hat{F}_{ni}^{s,H} \hat{F}_{mj}^{s,h} \right]^{\frac{\zeta-\kappa}{1-\kappa}} \right).$$

1221 The change in sectoral final goods price equals:  $(\hat{P}_n^s)^{1-\delta} = \sum_{m=1}^N s_{nm}^s \hat{\alpha}_{nm}^s (\hat{P}_{nm}^s)^{1-\delta}$ , and the change

1222 in country-level final goods price equals:  $(\hat{P}_n^s)^{1-\lambda} = \sum_{s=1}^S s_n^s \hat{\alpha}_n^s (\hat{P}_n^s)^{1-\lambda}$ .

### 1223 Appendix B.8.3. Supply and Demand Shocks in the Model with MNE Entry and Exit

1224 Table Appendix B.1 classifies the model's shocks into supply versus demand. Supply shocks  
 1225 include: firm-level MNE relative productivity ( $\frac{\hat{A}_{ji}^{s,\text{firm}}}{\hat{A}_{jj}^{s,\text{firm}}}$ ); MNE entry cost relative to domestic firms  
 1226 ( $\frac{\hat{f}_{ji}^{s,e}}{\hat{f}_{jj}^{s,e}}$ ) (these are MNE-specific); firm-level domestic productivity ( $\hat{A}_{jj}^{s,\text{firm}}$ ); domestic firm entry cost  
 1227 ( $\hat{f}_{jj}^{s,e}$ ); and labor supply ( $\hat{\xi}_n^s$ ) shocks (these affect MNEs proportionally to domestic firms). Demand  
 1228 shocks, mirroring the baseline model, include MNE final demand ( $\hat{\alpha}_{nm}^s$ ) and sectoral final demand  
 1229 ( $\hat{\alpha}_n^s$ ) shocks.

1230 Compared to Table 1, the model with MNE entry and exit into production and trade does  
 1231 not change the baseline model's classification of a shock into productivity, demand, or MNE-  
 1232 specific. Thus, it likely does not qualitatively affect the main results. Instead, it decomposes  
 1233 baseline-identified aggregate shocks into extensive and intensive margins.

Table Appendix B.1: **Classifying Shocks as Supply or Demand in the Model with MNE Entry and Exit**

	MNE-Specific Shocks	Supply and Demand Shocks in Trade-only Model	Other Shocks
Supply Shocks	Firm-Level MNE Relative Productivity Shock ( $\hat{A}_{jj}^{s,firm}$ )	Firm-Level Domestic Productivity Shock ( $\hat{A}_{jj}^{s,firm}$ )	
	MNE Entry Cost Relative to Domestic Firms ( $\hat{F}_{jj}^{s,e}$ )	Domestic Firm Entry Cost ( $\hat{f}_{jj}^{s,e}$ ) Labor Supply Shock ( $\hat{\epsilon}_n^s$ )	
Demand Shocks	MNE Final Demand Shock ( $\hat{\alpha}_{nm}^s$ )	Sectoral Final Demand Shock ( $\hat{\alpha}_n^s$ )	Trade Balance Shock ( $TD_n^s$ )
Other Shocks	Firm-Level MNE Sourcing Shock ( $\hat{h}_{mj}^{s,firm}$ )		Firm-Level Trade Cost Shock ( $k_{nj}^{s,firm}$ )
	Fixed MNE Sourcing Cost ( $\hat{F}_{mj}^{s,h}$ )		Fixed Trade Cost ( $F_{nj}^{s,k}$ )
	Firm-Level MNE Selling Shock ( $\hat{H}_{ni}^{s,firm}$ )		Tariff Shock ( $\hat{t}_{nj}^s$ )
	Fixed MNE Selling Cost ( $\hat{F}_{ni}^{s,H}$ )		

*Notes:* This table displays the shocks studied in the MNE model with entry and exit and classifies them as either supply or demand shocks.

## Appendix C. Model Shock Calibration and Elasticity Estimation

### Appendix C.1. Calibration of Other Model Frictions

*MNE Relative Productivity.* Productivity of MNEs from country  $i$  operating in  $j$  relative to domestic firms in  $j$  can be computed with the ratio of its input price relative to its output price:

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

The denominator, according to Section 4.1, equals the following:

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

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

$$\frac{\Theta_{ji}^s}{\Theta_{jj}^s} = \prod_{s'=1}^S \left( \frac{P_{ji}^{s'}}{P_{jj}^{s'}} \right)^{\gamma_i^{ss'}},$$

where the relative price of composite goods of foreign affiliates relative to local producers is the following, based on Section 4.1:

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



1242 Hence, MNE relative productivity,  $\frac{A_{ji}^s}{A_{jj}^s}$ , can be calibrated using  $GO_{ji}^s$ ,  $T_{pj}^s$ ,  $S_{pjj}^s$ ,  $H_{pi}^s$ ,  $\pi_{jjk}^s$ ,  $h_{ik}^s$ , and  
 1243 trade and MNE elasticities ( $\sigma$  and  $\zeta$ ).

1244 *Non-tariff Trade Cost.* I calibrate the non-tariff trade cost by manipulating the sourcing shares  
 1245 of domestic firms, noting that:

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

1246 Furthermore, using the definition for MNE output share, I get the following expression for the  
 1247 producer price index:

$$P_{jn}^{s,p} = \frac{(H_{ni}^s)^{\frac{1}{1-\zeta}} \frac{\Theta_{ji}^s}{A_{ji}^s}}{(S_{nji}^s)^{\frac{1}{1-\zeta}}}.$$

1248 Substituting the second equation into the first, then applying a guess-and-verify method, yields  
 1249 the following calibration equation for  $k_{nj}^s$ :

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

1250 *Domestic Productivity Shocks.* I calibrate domestic productivity shocks by solving a system of  
 1251 equations that links these shock with prices. The process begins with the change in domestic firm  
 1252 sourcing shares:

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

1253 in which the change in the producer price index equals:

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

1254 Setting  $n = j$  and combining these two equations, I get:

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

1255 Furthermore, Equations (Appendix B.3), (Appendix B.4), and (Appendix B.5) show that changes  
 1256 in prices can be expressed as a function of changes in global shocks and wages. As a consequence,  
 1257 I get  $2 \times N \times S$  equations for  $2 \times N \times S$  unknowns:  $\{\hat{A}_{jj}^s\}$  and  $\{\hat{P}_{jj}^s\}$ . With this system of  
 1258 equations, I am able to solve  $\hat{A}_{jj}^s$  and  $\hat{P}_{jj}^s$  iteratively.

1259 *Final Demand for Sectors and MNEs.* The calibrations of final demand shocks for sectors and  
 1260 MNEs are straightforward and can be achieved by inverting their respective demand functions,  
 1261 Equations (Appendix B.6) and (Appendix B.7):

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

1262 and

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

1263 *Labor Supply.* I invert the labor supply function to obtain the labor supply shock:

$$\hat{\xi}_j^s = \frac{\hat{L}_j^s}{\left[\frac{\hat{w}_j^s}{\hat{P}_j^s}\right]^\psi}.$$

1264 *Appendix C.2. GDP Change Decomposition by Shock Type*

1265 **Proposition Appendix C.1.** The change in a country's GDP can be decomposed into contri-  
 1266 bution by domestic productivity shocks, MNE relative productivity shocks, and changes in labor  
 1267 supply according to the following formula:

$$\log(\widehat{GDP}_j) = \sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji}^s}{\sum_{s=1}^S w_j^s L_j^s} \log(\hat{A}_{jj}^s) + \sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji}^s}{\sum_{s=1}^S w_j^s L_j^s} \log\left(\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}\right) + \sum_{s=1}^S \frac{w_j^s L_j^s}{\sum_{s=1}^S w_j^s L_j^s} \log(\hat{L}_j^s)$$

(Appendix C.1)

1268 *Proof of Proposition Appendix C.1.* Note that GDP at time  $t+\Delta$  measured with time  $t$  price equals:  
 1269  $GDP_{j,t+\Delta} = \sum_{s=1}^S \sum_{i=1}^N P_{ji,t}^{s,y} y_{ji,t+\Delta}^s - \sum_{s=1}^S \sum_{i=1}^N \sum_{s'=1}^S P_{ji,t}^{s'} M_{ji,t+\Delta}^{ss'}$ . GDP, as valued added, equals  
 1270 to output subtracting input. Divide it with GDP at time  $t$ :

$$\begin{aligned}\frac{GDP_{j,t+\Delta}}{GDP_{j,t}} &= \sum_{s=1}^S \sum_{i=1}^N \frac{P_{ji,t}^{s,y} y_{ji,t}^s}{GDP_{j,t}} \frac{y_{ji,t+\Delta}^s}{y_{ji,t}^s} - \sum_{s=1}^S \sum_{i=1}^N \sum_{s'=1}^S \frac{P_{ji,t}^{s'} M_{ji,t}^{ss'}}{GDP_{j,t}} \frac{M_{ji,t+\Delta}^{ss'}}{M_{ji,t}^{ss'}} \\ &= \sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji,t}^s}{GDP_{j,t}} \frac{y_{ji,t+\Delta}^s}{y_{ji,t}^s} - \sum_{s=1}^S \sum_{i=1}^N \sum_{s'=1}^S \frac{P_{ji,t}^{s'} M_{ji,t}^{ss'}}{GDP_{j,t}} \frac{M_{ji,t+\Delta}^{ss'}}{M_{ji,t}^{ss'}},\end{aligned}$$

1271 where  $GO_{ji,t}^s = P_{ji,t}^{s,y} y_{ji,t}^s$  denotes the output of MNE from  $i$  operating in  $j$ , sector  $s$ .  $P_{ji,t}^{s'} M_{ji,t}^{ss'}$   
1272 denotes the sector  $s'$  input used by the MNE.

1273 In the limit with  $\Delta \rightarrow 0$ , and plug in the production function:

$$\begin{aligned}\log(\widehat{GDP}_j) &= \sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji}^s}{GDP_j^s} \log(\hat{y}_{ji}^s) - \sum_{s=1}^S \sum_{i=1}^N \sum_{s'=1}^S \frac{P_{ji}^{s'} M_{ji}^{ss'}}{GDP_j^s} \log(\hat{M}_{ji}^{ss'}) \\ &= \sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji}^s}{GDP_j^s} \left( \log(\hat{A}_{ji}^s) + \gamma_j^s \log(\hat{L}_{ji}^s) + \sum_{s'=1}^S \gamma_j^{ss'} \log(\hat{M}_{ji}^{ss'}) \right) \\ &\quad - \sum_{s=1}^S \sum_{i=1}^N \sum_{s'=1}^S \frac{P_{ji}^{s'} M_{ji}^{ss'}}{GDP_j^s} \log(\hat{M}_{ji}^{ss'})\end{aligned}$$

1274 Note that:  $P_{ji}^{s'} M_{ji}^{ss'} = GO_{ji}^s \gamma_j^{ss'}$ . As a result,

$$\begin{aligned}\log(\widehat{GDP}_j) &= \sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji}^s}{GDP_j^s} (d \log(A_{ji}^s) + \gamma_j^s d \log(L_{ji}^s)) \\ &= \sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji}^s}{GDP_j^s} d \log(A_{ji}^s) + \frac{w_j^s L_{ji}^s}{GDP_j^s} d \log(L_{ji}^s) \\ &= \sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji}^s}{\sum_{s=1}^S w_j^s L_j^s} \log(\hat{A}_{jj}^s) + \sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji}^s}{\sum_{s=1}^S w_j^s L_j^s} \log\left(\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}\right) + \sum_{s=1}^S \frac{w_j^s L_j^s}{\sum_{s=1}^S w_j^s L_j^s} \log(\hat{L}_j^s).\end{aligned}$$

(Appendix C.2)

1275 The last equation aggregates labor supply changes to the sector level and shows that a country's  
1276 GDP change results from three components: (1) domestic productivity shocks,  $\sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji}^s}{\sum_{s=1}^S w_j^s L_j^s} \log(\hat{A}_{jj}^s)$ ;  
1277 (2) MNE relative productivity shocks,  $\sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji}^s}{\sum_{s=1}^S w_j^s L_j^s} \log\left(\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}\right)$ ; and (3) factor supply changes,  
1278  $\sum_{s=1}^S \frac{w_j^s L_j^s}{\sum_{s=1}^S w_j^s L_j^s} \log(\hat{L}_j^s)$ . ■

1279 A variance decomposition approach computes each component's contribution to GDP change.  
1280 For instance, the contribution of domestic productivity shocks is measured by the ratio of its  
1281 covariance with GDP to the variance of GDP. These covariance and variance can be calculated  
1282 across countries for a given year, or across all countries and years:

$$\frac{\text{Cov} \left( \sum_{s=1}^S \sum_{i=1}^N \frac{GO_{ji}^s}{\sum_{s=1}^S w_j^s L_j^s} \log \left( \hat{A}_{jj}^s \right), \log \left( \widehat{GDP}_j \right) \right)}{\text{Var} \left( \log \left( \widehat{GDP}_j \right) \right)}. \quad (\text{Appendix C.3})$$

1283 Table Appendix C.1 shows that across all countries and years, domestic productivity shocks  
1284 accounted for 51% of GDP changes, MNE relative productivity shocks for 42%, and factor supply  
1285 for 7%. During the Great Recession, domestic productivity shocks accounted for 46% of GDP  
1286 changes, MNE relative productivity shocks for 39%, and factor supply for 14% across countries.

Table Appendix C.1: **Cross-Country GDP Change Decomposition: Great Recession (2008-2009) and All Sample Years (2006-2016)**

Years	Domestic Productivity Shock (%)	MNE Relative Productivity Shock (%)	Factor Supply (%)
2008-2009	46.37 [44.71, 48.02]	39.42 [37.53, 41.31]	14.21 [13.75, 14.67]
All Years	50.89 [49.33, 52.45]	41.62 [39.71, 43.53]	7.49 [7.13, 7.85]

*Notes:* This table decomposes GDP change across countries for (1) 2008-2009 and (2) all sample years (2006-2016) into contributions by (1) domestic productivity shock, (2) MNE relative productivity shock, and (3) factor supply. The decomposition follows Equations (Appendix C.2) and (Appendix C.3). Numbers in hard brackets represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

### 1287 Appendix C.3. MNE Shocks During the Great Recession

1288 To examine how country characteristics influenced shock performance during the Great Reces-  
1289 sion, I regress the calibrated shocks from that period on gravity variables. Specifically, I consider  
1290 the following regression:

$$y_{ji}^s = \beta_1 \mathbb{1}(i = j) + \beta_2 \log(\text{Dist}_{ji}) + \beta_3 \mathbb{1}(\text{Legal}_{ji}) + \beta_4 \mathbb{1}(\text{Contiguity}_{ji}) + \beta_5 \mathbb{1}(\text{Common Lang}_{ji}) \\ + \beta_6 \log(\text{Trade}_{ji,2007}) + \beta_7 \log(\text{MP}_{ji,2007}) + \beta_8 \mathbb{1}(\text{Deep Trade Agree}_{ji,2007}) + C_{ji,2007}^s + FE_j^s + FE_i^s + \epsilon_{ji}^s, \quad (\text{Appendix C.4})$$

1291 where  $y_{ji}^s \in \left\{ \log \left( \frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s} \right), \log \left( \hat{h}_{ji}^s \right), \log \left( \hat{H}_{ji}^s \right), \log \left( \hat{a}_{ji}^s \right), \log \left( \hat{k}_{ji}^s \right) \right\}$  represents shocks to MNE  
1292 relative productivity, MNE sourcing and selling efficiencies, MNE final demand, and trade cost  
1293 during the Great Recession (2008-2009 log changes).<sup>68</sup>

<sup>68</sup>The pre-period control,  $C_{ji,2007}^s \in \left\{ \log \left( \frac{A_{ji}^s}{A_{jj}^s} \right)_{2007}, \log(h_{ji}^s)_{2007}, \log(H_{ji}^s)_{2007}, \log(a_{ji}^s)_{2007}, \log(k_{ji}^s)_{2007} \right\}$ , is the level of these variables in 2007.

1294 *MNE Productivity Decreased.* Column 1 of Table Appendix C.2 shows that average MNE produc-  
 1295 tivity decreased during the Great Recession, contributing to the global MP collapse. Pre-Recession  
 1296 trade and MP linkages, along with deep trade agreements between headquarters and host coun-  
 1297 tries, mitigated this decline.

1298 *MNEs Became More Vertical.* Columns 2 and 3 of Table Appendix C.2 show decreased MNE  
 1299 sourcing and selling efficiencies with non-headquarters countries, which led to greater MNE ver-  
 1300 ticalization during the Great Recession. This explains the increased MNE trade intensity relative  
 1301 to domestic firms during the Great Recession: MNEs gained a comparative advantage at sourcing  
 1302 and selling with their headquarters, while domestic firms increased local sourcing and selling.

1303 Furthermore, Column 4 shows that MNE final demand shocks decreased with increasing dis-  
 1304 tance between headquarters and host countries. Column 5 shows international trade costs in-  
 1305 creased during the Great Recession and with distance between exporting and importing countries.

1306 Tables Appendix C.2 through Appendix C.7 present robustness tests for these results. Each  
 1307 table extends a corresponding column from Table Appendix C.2 by systematically adding and  
 1308 removing controls and confirm the robustness of these key takeaways.

#### 1309 *Appendix C.4. Trade and MNE Elasticities*

1310 I develop a novel method for jointly estimating these elasticities, using variations in MP shares  
 1311 and tariffs. These estimations leverage trade and MP data spanning 2005-2016 from the OECD  
 1312 AAMNE database.

1313 The method start with the sourcing share of country  $n$  domestic firms on  $j$ ,  $\pi_{nnj,t}^s = \frac{h_{nj,t}^s (P_{nj,t}^{s,p} k_{nj,t}^s t_{nj,t}^s)^{1-\sigma}}{(P_{nn,t}^s)^{1-\sigma}}$   
 1314 and  $j$  domestic firms' output share in trade from  $j$  to  $n$ ,  $S_{njj,t}^s = \frac{H_{nj,t}^s \left( \frac{\Theta_{jj,t}^s}{A_{jj,t}^s} \right)^{1-\zeta}}{(P_{jn,t}^{s,p})^{1-\zeta}}$ .<sup>69</sup> Manipulating  
 1315 the second share to get the producer price index,  $P_{nj,t}^{s,p} = \frac{\Theta_{jj,t}^s}{A_{jj,t}^s} \left( \frac{S_{njj,t}^s}{H_{nj,t}^s} \right)^{\frac{1}{\zeta-1}}$  and plug it into the first  
 1316 share and take log, I get the estimation equation:

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<sup>69</sup>I added a year  $t$  subscript to highlight that the estimation take advantage of trade and MP data for all years available in OECD AAMNE.

$$\log \left( \frac{\pi_{nnj,t}^s}{h_{nj,t}^s} \right) = \frac{1-\sigma}{1-\zeta} \log \left( \frac{H_{nj,t}^s}{S_{njj,t}^s} \right) + (1-\sigma) \log(t_{nj,t}^s) + \gamma \mathbb{1}(\text{trade agreement})_{nj,t} + FE_{n,t}^s + FE_{j,t}^s + FE_{nj}^s + \epsilon_{nj,t}^s. \quad (\text{Appendix C.5})$$

Equation (Appendix C.5) uses tariff variation ( $t_{nj,t}^s$ ) to estimate the trade elasticity ( $\sigma$ ), and variation of domestic firm share in trade flow ( $S_{njj,t}^s$ ) to estimate the MNE elasticity ( $\zeta$ ). Multilateral resistance terms,  $FE_{n,t}^s$  and  $FE_{j,t}^s$ , capture variations in destination prices and origin productivity and input costs, respectively. The country-bilateral fixed effect,  $FE_{nj}^s$ , captures long-run average trade cost components (e.g., distance) and yields a short-run elasticity estimation (Boehm et al., 2023) desirable for studying the Great Recession. Besides tariffs, I also include time-varying trade agreements that influence trade costs.

*Instruments.* Following Boehm et al. (2023), I instrument the applied tariff ( $t_{nj,t}^s$ ) with  $t_{nj,t}^{s,IV} = \mathbb{1}\{n \text{ applies MFN on } j\} \times t_{n,t}^{s,MFN}$ , which captures whether country  $n$  applies MFN tariff on  $j$  and its magnitude. MFN tariff concessions are typically driven by WTO negotiations, making them less affected to country-bilateral trade flows and plausibly exogenous.<sup>70</sup> Applied tariffs are affected by MFN tariff changes if the MFN tariff applies, but are unaffected if country  $n$  offers preferential tariffs to country  $j$ ; the second situation serves as the control group.

I instrument  $\log \left( \frac{H_{nj,t}^s}{S_{njj,t}^s} \right)$  with tariffs applied in the opposite direction of trade flow-by country  $j$  on country  $n$ -in upstream and downstream sectors. Due to vertical linkages for country  $n$ 's MNEs in country  $j$  with their headquarters  $n$ , these tariffs affect these MNEs' performance more severely than  $j$ 's domestic firms, hence create variations in  $S_{njj,t}^s$  ( $j$ 's domestic firm's share in trade flow from  $j$  to  $n$ ). For instance, as  $n$ 's MNE in  $j$  relies on inputs from  $n$  (forward-vertical linkage),  $j$ 's tariff on  $n$  in upstream sectors severely raises their input cost and decreased their market share. Similarly,  $n$ 's MNE in  $j$  relies on markets from  $n$  (backward-vertical linkages),  $j$ 's tariff on  $n$  in downstream sectors severely decreases their sales. I construct the following two instruments:

---

<sup>70</sup>Boehm et al. (2023) restricts their sample to non-major economy exporters, as their trade flow is less likely to affect MFN tariff changes in major importers. However, since all countries in the OECD AAMNE database are major economies, I do not impose this restriction.

$$\text{Up IV}_{nj,t}^s = \frac{\sum_{s' \neq s} a_{j,t_0}^{ss',\text{tot}} t_{jn,t}^{s',IV}}{\sum_{s' \neq s} a_{j,t_0}^{ss',\text{tot}}}, \text{Down IV}_{nj,t}^s = \frac{\sum_{s' \neq s} b_{j,t_0}^{s's,\text{tot}} t_{jn,t}^{s',IV}}{\sum_{s' \neq s} b_{j,t_0}^{s's,\text{tot}}}.$$

1338  $a_{j,t_0}^{ss',\text{tot}}$  represents the total expenditure share by sector  $s$  on sector  $s'$ , including both direct and  
 1339 indirect linkages (Acemoglu et al., 2016).  $b_{j,t_0}^{s's,\text{tot}}$  denotes the total sales share of sector  $s'$  for  
 1340 sector  $s$  output, similarly accounting for both direct and indirect linkages. I evaluate these shares  
 1341 using 2005 data (the initial year,  $t_0$ ), mitigating potential effect from trade and MP changes in  
 1342 subsequent years on these shares.<sup>71</sup>

1343 *Estimation Results.* My preferred specification in Column 1 of Table Appendix C.8 yields esti-  
 1344 mated values of  $\sigma = 3.1$  and  $\zeta = 2.7$ . These short-run estimates are significantly below those  
 1345 reported by Ramondo and Rodríguez-Clare (2013) and Arkolakis et al. (2018).<sup>72</sup> This short-run  
 1346 trade elasticity is slightly higher than Boehm et al. (2023)'s estimate of  $\sigma = 1.76$ , yet it remains  
 1347 comparable to De Souza et al. (2024).<sup>73</sup>

1348 For robustness tests, Columns 2-4 of Table Appendix C.8 present estimations under various  
 1349 fixed effect combinations. Columns 1-4 of Table Appendix C.9 treat the applied tariff ( $t_{nj,t}^s$ ) as  
 1350 exogenous, constructing instruments for  $\log\left(\frac{H_{nj,t}^s}{S_{njj,t}^s}\right)$  using it. All these specifications yield qualita-  
 1351 tively similar results. Column 5 of Table Appendix C.9 shows that without an IV for  $\log\left(\frac{H_{nj,t}^s}{S_{njj,t}^s}\right)$ ,  
 1352 the estimated  $\zeta$  becomes unreasonable. Table Appendix C.10 presents sectoral estimates: trade  
 1353 and MNE elasticities lower for the non-manufacturing sector compared to manufacturing sectors.

#### 1354 *Appendix C.5. Construct Upstream and Downstream Shocks to MNE Share in Trade*

1355 I show how I compute the upstream and downstream shocks, used as IVs for domestic firms'  
 1356 trade shares. Following Acemoglu et al. (2016), I define country  $j$ 's direct input share matrix  $A_j$ ,

---

<sup>71</sup>Section Appendix C.5 details the construction of these upstream and downstream shocks to domestic firm trade shares, using input-output information from the OECD AAMNE.

<sup>72</sup>They typically find a trade elasticity of about 9 and an elasticity of substitution across headquarters of 4, given their long-run approach.

<sup>73</sup>De Souza et al. (2024) estimates the short-run trade elasticity with anti-dumping tariff variation and an event study approach.

1357 where the  $s - s'$  element,  $a_j^{ss'}$ , is:

$$a_j^{ss'} = \frac{\text{Sales}_j^{s \leftarrow s'}}{\text{Sales}_j^s}.$$

1358  $a_j^{ss'}$  represents the cross-industry sales from sector  $s'$  to sector  $s$ , divided by sector  $s$ 's total sales  
1359 for country  $j$ . The total input coefficient matrix,  $A_j^{\text{tot}}$ , is the Leontief inverse of  $A_j$ :

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

1360 of which the element  $a_j^{ss',\text{tot}}$  measures the total (direct + indirect) expenditure share sector  $s$   
1361 spends on sector  $s'$  in country  $j$ . The upstream shock for  $\log\left(\frac{H_{nj,t}^s}{S_{njj,t}^s}\right)$  (representing country  $j$ 's  
1362 domestic firm's share in trade from  $j$  to  $n$ ) in year  $t$  is calculated as follows:

$$\text{Up IV}_{nj,t}^s = \frac{\sum_{s' \neq s} a_{j,t_0}^{ss',\text{tot}} t_{jn,t}^{s',IV}}{\sum_{s' \neq s} a_{j,t_0}^{ss',\text{tot}}}.$$

1363 Here, the total expenditure share is computed using the OECD AAMNE database and evaluated  
1364 at the initial year (2005).  $t_{jn,t}^{s',IV}$  denotes the applied MFN tariff country  $j$  imposes on  $n$ .

1365 For the downstream shock, I define country  $j$ 's direct output share matrix  $B_j$ , where the  $s' - s$   
1366 element,  $b_j^{s's}$ , is:

$$b_j^{s's} = \frac{\text{Sales}_j^{s' \leftarrow s}}{\text{Sales}_j^s}.$$

1367  $b_j^{s's}$  represents the ratio of sales from sector  $s$  to  $s'$ , divided by sector  $s$ 's total sales for country  $j$ .  
1368 The total output coefficient matrix,  $B_j^{\text{tot}}$ , is the Leontief inverse of  $B_j$ :

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

1369 of which the element  $b_j^{s's,\text{tot}}$  measures the total (direct + indirect) output share sector  $s$  sells to



1370 sector  $s'$  in country  $j$ . The downstream shock is calculated as follows:

$$\text{Down IV}_{nj,t}^s = \frac{\sum_{s' \neq s} b_{j,t_0}^{s', \text{tot}} t_{jn,t}^{s', IV}}{\sum_{s' \neq s} b_{j,t_0}^{s', \text{tot}}}.$$

1371 Here, the total output share is computed using the OECD AAMNE database and evaluated at  
1372 the initial year (2005).

### 1373 *Appendix C.6. Headquarters' Share in MNE Productivity*

1374 To demonstrate that productivity shocks propagate through MNEs, I estimate headquarters  
1375 share in MNE productivity as follows:

$$\log \left( \frac{\hat{A}_{ji,t}^s}{\hat{A}_{jj,t}^s} \right) = \phi \log \left( \frac{\hat{A}_{ii,t}^s}{\hat{A}_{jj,t}^s} \right) + FE_{j,t} + FE_t^s + \epsilon_{ji,t}^s. \quad (\text{Appendix C.6})$$

1376 This equation treats MNE productivity shocks as a log-linear combination of headquarters' do-  
1377 mestic productivity shocks, host country's domestic productivity shocks, and a bilateral term.<sup>74</sup>  
1378 The identifying assumption is that if headquarters domestic productivity growth ( $\hat{A}_{ii,t}^s$ ) exceeds  
1379 host country domestic productivity growth ( $\hat{A}_{jj,t}^s$ ), then the headquarters' MNEs should experi-  
1380 ence greater productivity growth than domestic firms in the host country.<sup>75</sup> I leverage variations  
1381 across headquarters within the same host country.

1382 Column 1 of Table Appendix C.11 shows that headquarters domestic productivity shock ac-  
1383 counts for 23% of MNE productivity. This estimate is robust to different fixed effect combinations  
1384 (Columns 2-4). Table Appendix C.11 regresses MNE productivity shock ( $\log \left( \hat{A}_{ji,t}^s \right)$ ) on head-  
1385 quarters domestic productivity shock ( $\log \left( \hat{A}_{ii,t}^s \right)$ ) and host country's domestic productivity shock  
1386 ( $\log \left( \hat{A}_{jj,t}^s \right)$ ). In this specification, headquarters accounted for 15% to 20% of MNE produc-  
1387 tivity. Tables Appendix C.13 and Appendix C.14 present these estimates for different sectors:  
1388 headquarters accounted for a greater share of MNE productivity in durable manufacturing and  
1389 non-manufacturing sectors but a smaller share for non-durable manufacturing sector.

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<sup>74</sup>Specifically,  $\log \left( \hat{A}_{ji,t}^s \right) = \phi \log \left( \hat{A}_{ii,t}^s \right) + (1 - \phi) \log \left( \hat{A}_{jj,t}^s \right) + \log \left( \hat{\gamma}_{ji,t}^s \right)$ . Similar assumption was imposed by Cravino and Levchenko (2017), Alviarez et al. (2020), and Bilir and Morales (2020).

<sup>75</sup>Furthermore, this difference in headquarters and host country domestic productivity growth is uncorrelated with other factors affecting the MNE's productivity.

1391 I estimate the elasticity of substitution across MNE-specific composite goods with the following  
1392 regression, representing the log change of Equation (Appendix B.7):

$$\log(\hat{s}_{nm,t}^s) = \tilde{\delta} \log(\hat{P}_{nm,t}^s) + FE_{n,t}^s + \epsilon_{nm,t}^s, \forall m \neq n, \quad (\text{Appendix C.7})$$

1393 where  $\tilde{\delta} = 1 - \delta$ . Since I control host country-sector-time fixed effect, I take advantage of  
1394 cross-headquarters variation in price to identify this elasticity.

1395 I instrument  $\log(\hat{P}_{nm}^s)$  with the domestic productivity shock in the foreign headquarters mul-  
1396 tiplied by the MNE's sales share in its host country. The identifying assumption is that the  
1397 domestic productivity in the foreign headquarters is uncorrelated with the preference for MNEs  
1398 in the host country:

$$IV_{nm}^{s,MNE} = \frac{GO_{nm}^s}{\sum_{m \neq n} GO_{nm}^s} \log(\hat{A}_{mm}^s), \forall m \neq n. \quad (\text{Appendix C.8})$$

1399 Column 1 of Table Appendix C.15 estimates an MNE final demand elasticity of 2.73. Columns 2  
1400 and 3 show this estimate's robustness across different fixed effect combinations. Column 4 shows  
1401 that omitting the IV biases the estimate towards zero. This occurs because higher prices might  
1402 be driven by increased demand, which mitigates the negative impact of price on demand.

1403 I estimate the sectoral final demand elasticity with the log of Equation (Appendix B.6):

$$\log(s_{n,t}^s) = \tilde{\lambda} \log(P_{n,t}^s) + FE_{n,t}^s + \epsilon_{n,t}^s. \quad (\text{Appendix C.9})$$

1404 where  $\tilde{\lambda} = 1 - \lambda$ . Since I control country-time fixed effect, I use cross-sector variation in price to  
1405 identify this elasticity.

1406 I instrument  $\log(P_{n,t}^s)$  using domestic productivity shocks from all foreign headquarters, weighted  
1407 by their sales shares in the host country's total MNE sales. The identifying assumption is that  
1408 the domestic productivity shocks in foreign headquarters are uncorrelated with the sectoral final  
1409 demand shocks in the host country:

$$Instrument_n^{s,Demand} = \sum_{m \neq n} \frac{GO_{nm}^s}{\sum_{m \neq n} GO_{nm}^s} \log \left( \hat{A}_{mm}^s \right). \quad (\text{Appendix C.10})$$

Column 1 of Table Appendix C.16 estimates a final demand elasticity of 1.81. Column 2 confirms the estimate's robustness by further controlling sector fixed effect. Columns 3 and 4 highlight the importance of controlling country-time fixed effect and applying the IV, respectively, as not including them leads to unreasonable estimates.

#### Appendix C.8. Estimate Labor Supply Elasticity

I estimate the labor supply elasticity with the log of Equation (Appendix B.8). With country-sector fixed effect, I use wage variation over time to identify the labor supply elasticity.

$$\log(L_n^s) = \psi \log \left( \frac{\hat{w}_n^s}{\hat{P}_n} \right) + FE_n^s + FE_t + \epsilon_{n,t}^s. \quad (\text{Appendix C.11})$$

To instrument the change in real wage,  $\log \left( \frac{\hat{w}_n^s}{\hat{P}_n} \right)$ , I use the same instrument as the one for sectoral final demand elasticity. The identifying assumption is that the domestic productivity shocks in foreign headquarters are uncorrelated with labor supply shocks in the host country:

$$Instrument_n^{s,Labor} = \sum_{m \neq n} \frac{GO_{nm}^s}{\sum_{m \neq n} GO_{nm}^s} \log \left( \hat{A}_{mm}^s \right). \quad (\text{Appendix C.12})$$

Column 1 of Table Appendix C.17 shows a labor supply elasticity of 0.6, aligning with macro labor supply elasticities estimated in the literature, including De Souza and Li (2022) and Eckert (2019). Columns 2-5 experiment with alternative fixed effect combinations. Column 6, which omits the IV, leads to an unreasonable estimate.

Table Appendix C.2: **Model Shock Performance During the Great Recession**

	(1)	(2)	(3)	(4)	(5)
	$\log\left(\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}\right)$	$\log\left(\hat{h}_{ji}^s\right)$	$\log\left(\hat{H}_{ji}^s\right)$	$\log\left(\hat{a}_{ji}^s\right)$	$\log\left(\hat{k}_{ji}^s\right)$
$\mathbb{1}(i = j)$	0.1183*** (0.0450)	0.1316*** (0.0204)	0.1700*** (0.0170)	-0.0069 (0.0238)	-0.1431*** (0.0194)
$\log(\text{Dist}_{ji})$	0.0161 (0.0111)	-0.0191*** (0.0051)	-0.0047 (0.0040)	-0.0105* (0.0059)	0.0148*** (0.0048)
$\mathbb{1}(\text{Legal}_{ji})$	0.0105 (0.0098)	0.0216*** (0.0045)	0.0044 (0.0035)	0.0090* (0.0052)	0.0068 (0.0042)
$\mathbb{1}(\text{Contiguity}_{ji})$	0.0964*** (0.0247)	0.0645*** (0.0112)	0.0187** (0.0089)	-0.0204 (0.0131)	0.0320*** (0.0106)
$\mathbb{1}(\text{Common Lang}_{ji})$	-0.0003 (0.0183)	0.0257*** (0.0083)	0.0172*** (0.0066)	-0.0413*** (0.0097)	0.0140* (0.0079)
$\log(\text{Trade}_{ji,2007})$	0.0258*** (0.0061)	0.0404*** (0.0029)	-0.0013 (0.0022)	0.0176*** (0.0033)	-0.0572*** (0.0038)
$\log(\text{MP}_{ji,2007})$	0.1400*** (0.0053)	0.0031*** (0.0010)	0.0038*** (0.0008)	0.0005 (0.0012)	0.0004 (0.0010)
$\mathbb{1}(\text{Deep Trade Agree}_{ji,2007})$	0.0487* (0.0274)	0.0078 (0.0125)	0.0389*** (0.0099)	0.0236 (0.0145)	-0.0375*** (0.0118)
Pre-period Controls	✓	✓	✓	✓	✓
$j \times s$ FE	✓	✓	✓	✓	✓
$i \times s$ FE	✓	✓	✓	✓	✓
Observations	10800	10800	10800	10800	10800

*Notes:* This table presents regressions of various shocks on gravity variables, based on Equation (Appendix C.4). The sample is a cross-section of shocks from the Great Recession (2008-2009 log changes). The pre-period control refers to the level of the variable of interest in 2007. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix C.3: MNE Relative Productivity Shock During the Great Recession

	(1)	(2)	(3)	(4)	(5)
	$\log \left( \frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s} \right)$				
$\mathbb{1}(i = j)$	0.1328*** (0.0389)	0.0102 (0.0415)	0.1460*** (0.0375)	0.0825** (0.0403)	0.1473*** (0.0437)
$\log(\text{Dist}_{ji})$	-0.0462*** (0.0066)	0.0002 (0.0087)	-0.0199*** (0.0065)	0.0034 (0.0084)	-0.0406*** (0.0102)
$\mathbb{1}(\text{Legal}_{ji})$	0.0139 (0.0100)	0.0101 (0.0100)	0.0095 (0.0097)	0.0076 (0.0097)	0.0152 (0.0102)
$\mathbb{1}(\text{Contiguity}_{ji})$	0.0803*** (0.0255)	0.0664*** (0.0255)	0.1031*** (0.0247)	0.0954*** (0.0247)	0.0806*** (0.0255)
$\mathbb{1}(\text{Common Lang}_{ji})$	0.0074 (0.0187)	-0.0093 (0.0188)	0.0117 (0.0181)	0.0030 (0.0182)	0.0059 (0.0188)
$\log(\text{Trade}_{ji,2007})$		0.0512*** (0.0062)		0.0264*** (0.0061)	
$\log(\text{MP}_{ji,2007})$			0.1430*** (0.0052)	0.1395*** (0.0053)	
$\mathbb{1}(\text{Deep Trade Agree}_{ji,2007})$					0.0207 (0.0283)
$\log \left( \frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s} \right)_{2007}$	-0.0703*** (0.0039)	-0.0792*** (0.0040)	-0.2999*** (0.0092)	-0.2989*** (0.0091)	-0.0702*** (0.0039)
$j \times s$ FE	✓	✓	✓	✓	✓
$i \times s$ FE	✓	✓	✓	✓	✓
Observations	10800	10800	10800	10800	10800

*Notes:* This table presents regressions of the MNE relative productivity shock,  $\log \left( \frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s} \right)$ , on gravity variables, based on Equation (Appendix C.4). The sample is a cross-section of shocks from the Great Recession (2008-2009 log changes). \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix C.4: MNE Sourcing Shock During the Great Recession

	(1)	(2)	(3)	(4)	(5)
	$\log(\hat{h}_{ji}^s)$				
$\mathbb{1}(i = j)$	0.2293*** (0.0172)	0.1274*** (0.0183)	0.2133*** (0.0173)	0.1259*** (0.0183)	0.2367*** (0.0194)
$\log(\text{Dist}_{ji})$	-0.0557*** (0.0032)	-0.0214*** (0.0039)	-0.0507*** (0.0033)	-0.0211*** (0.0039)	-0.0529*** (0.0046)
$\mathbb{1}(\text{Legal}_{ji})$	0.0250*** (0.0044)	0.0217*** (0.0044)	0.0232*** (0.0044)	0.0211*** (0.0044)	0.0256*** (0.0045)
$\mathbb{1}(\text{Contiguity}_{ji})$	0.0839*** (0.0113)	0.0666*** (0.0112)	0.0769*** (0.0113)	0.0644*** (0.0112)	0.0841*** (0.0113)
$\mathbb{1}(\text{Common Lang}_{ji})$	0.0400*** (0.0083)	0.0267*** (0.0083)	0.0373*** (0.0083)	0.0263*** (0.0083)	0.0393*** (0.0084)
$\log(\text{Trade}_{ji,2007})$		0.0428*** (0.0028)		0.0404*** (0.0029)	
$\log(\text{MP}_{ji,2007})$			0.0068*** (0.0010)	0.0030*** (0.0010)	
$\mathbb{1}(\text{Deep Trade Agree}_{ji,2007})$					0.0103 (0.0126)
$\log(h_{ji}^s)_{2007}$	-0.2466*** (0.0077)	-0.2871*** (0.0081)	-0.2552*** (0.0078)	-0.2887*** (0.0081)	-0.2468*** (0.0077)
$j \times s$ FE	✓	✓	✓	✓	✓
$i \times s$ FE	✓	✓	✓	✓	✓
Observations	10800	10800	10800	10800	10800

*Notes:* This table presents regressions of the MNE relative productivity shock,  $\log(\hat{h}_{ji}^s)$ , on gravity variables, based on Equation (Appendix C.4). The sample is a cross-section of shocks from the Great Recession (2008-2009 log changes). \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix C.5: MNE Selling Shock During the Great Recession

	(1)	(2)	(3)	(4)	(5)
	$\log(\hat{H}_{ji}^s)$				
$\mathbb{1}(i = j)$	0.1467*** (0.0142)	0.1409*** (0.0153)	0.1382*** (0.0143)	0.1401*** (0.0153)	0.1737*** (0.0160)
$\log(\text{Dist}_{ji})$	-0.0175*** (0.0022)	-0.0154*** (0.0030)	-0.0142*** (0.0023)	-0.0149*** (0.0030)	-0.0078** (0.0035)
$\mathbb{1}(\text{Legal}_{ji})$	0.0030 (0.0035)	0.0028 (0.0035)	0.0020 (0.0035)	0.0020 (0.0035)	0.0052 (0.0035)
$\mathbb{1}(\text{Contiguity}_{ji})$	0.0210** (0.0089)	0.0201** (0.0089)	0.0176** (0.0089)	0.0178** (0.0089)	0.0218** (0.0089)
$\mathbb{1}(\text{Common Lang}_{ji})$	0.0212*** (0.0065)	0.0203*** (0.0066)	0.0195*** (0.0065)	0.0198*** (0.0066)	0.0186*** (0.0066)
$\log(\text{Trade}_{ji,2007})$		0.0022 (0.0021)		-0.0008 (0.0022)	
$\log(\text{MP}_{ji,2007})$			0.0035*** (0.0008)	0.0036*** (0.0008)	
$\mathbb{1}(\text{Deep Trade Agree}_{ji,2007})$					0.0361*** (0.0099)
$\log(H_{ji}^s)_{2007}$	-0.2549*** (0.0075)	-0.2550*** (0.0075)	-0.2566*** (0.0075)	-0.2566*** (0.0075)	-0.2570*** (0.0076)
$j \times s$ FE	✓	✓	✓	✓	✓
$i \times s$ FE	✓	✓	✓	✓	✓
Observations	10800	10800	10800	10800	10800

*Notes:* This table presents regressions of the MNE relative productivity shock,  $\log(\hat{H}_{ji}^s)$ , on gravity variables, based on Equation (Appendix C.4). The sample is a cross-section of shocks from the Great Recession (2008-2009 log changes). \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix C.6: MNE Final Demand Shock During the Great Recession

	(1)	(2)	(3)	(4)	(5)
	$\log(\hat{a}_{ji}^s)$				
$\mathbb{1}(i = j)$	0.0253 (0.0196)	-0.0239 (0.0213)	0.0185 (0.0199)	-0.0241 (0.0213)	0.0442** (0.0222)
$\log(\text{Dist}_{ji})$	-0.0348*** (0.0033)	-0.0167*** (0.0045)	-0.0324*** (0.0034)	-0.0167*** (0.0045)	-0.0277*** (0.0051)
$\mathbb{1}(\text{Legal}_{ji})$	0.0096* (0.0051)	0.0077 (0.0051)	0.0088* (0.0051)	0.0076 (0.0051)	0.0112** (0.0052)
$\mathbb{1}(\text{Contiguity}_{ji})$	-0.0133 (0.0130)	-0.0205 (0.0131)	-0.0157 (0.0131)	-0.0208 (0.0131)	-0.0128 (0.0130)
$\mathbb{1}(\text{Common Lang}_{ji})$	-0.0327*** (0.0096)	-0.0396*** (0.0096)	-0.0338*** (0.0096)	-0.0397*** (0.0096)	-0.0346*** (0.0096)
$\log(\text{Trade}_{ji,2007})$		0.0182*** (0.0031)		0.0179*** (0.0032)	
$\log(\text{MP}_{ji,2007})$			0.0024** (0.0011)	0.0004 (0.0012)	
$\mathbb{1}(\text{Deep Trade Agree}_{ji,2007})$					0.0265* (0.0145)
$\log(a_{ji}^s)_{2007}$	-0.2381*** (0.0097)	-0.2380*** (0.0097)	-0.2354*** (0.0098)	-0.2375*** (0.0098)	-0.2382*** (0.0097)
$j \times s$ FE	✓	✓	✓	✓	✓
$i \times s$ FE	✓	✓	✓	✓	✓
Observations	10800	10800	10800	10800	10800

*Notes:* This table presents regressions of the MNE relative productivity shock,  $\log(\hat{a}_{ji}^s)$ , on gravity variables, based on Equation (Appendix C.4). The sample is a cross-section of shocks from the Great Recession (2008-2009 log changes). \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

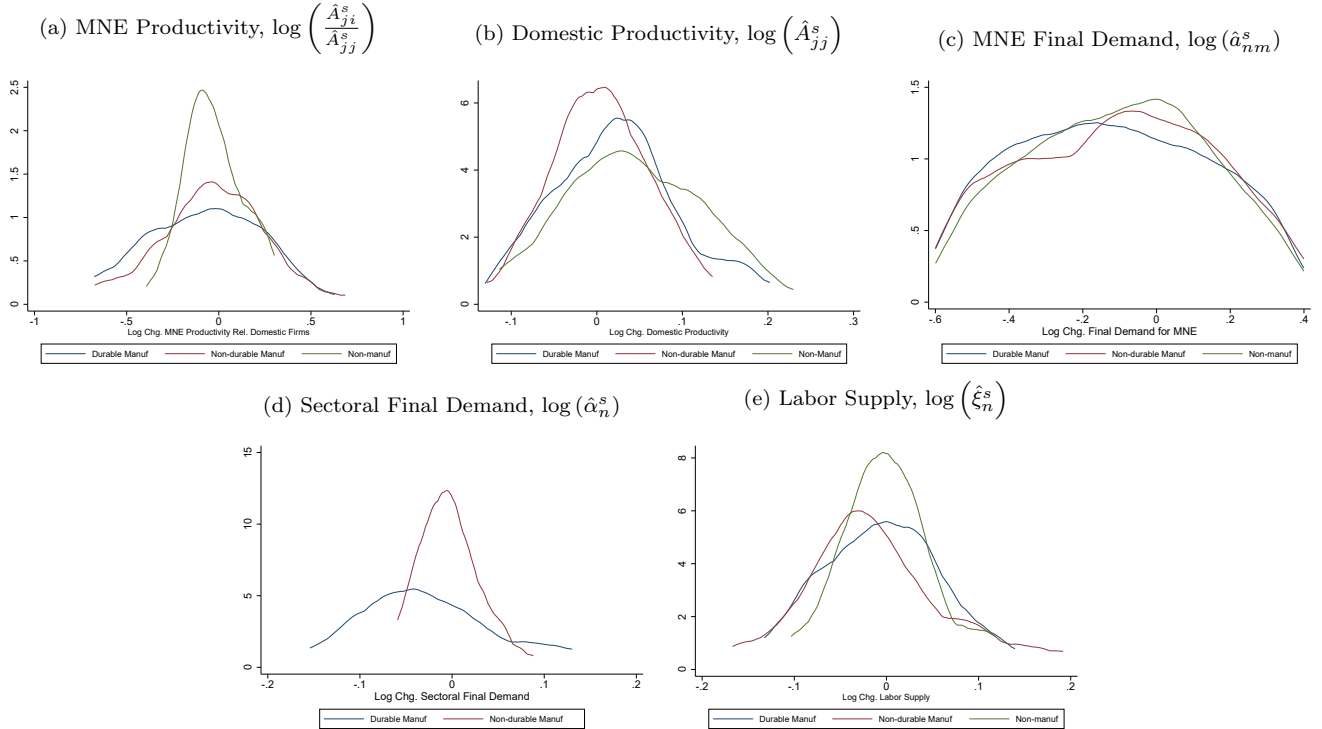


Table Appendix C.7: **Trade Cost Shock During the Great Recession**

	(1)	(2)	(3)	(4)	(5)
	$\log(\hat{k}_{ji}^s)$				
$\mathbb{1}(i = j)$	-0.1867*** (0.0169)	-0.1154*** (0.0173)	-0.1781*** (0.0170)	-0.1157*** (0.0173)	-0.2162*** (0.0190)
$\log(\text{Dist}_{ji})$	0.0489*** (0.0033)	0.0245*** (0.0036)	0.0460*** (0.0034)	0.0246*** (0.0036)	0.0383*** (0.0046)
$\mathbb{1}(\text{Legal}_{ji})$	0.0060 (0.0042)	0.0092** (0.0042)	0.0071* (0.0042)	0.0090** (0.0042)	0.0035 (0.0043)
$\mathbb{1}(\text{Contiguity}_{ji})$	0.0170 (0.0107)	0.0330*** (0.0106)	0.0210* (0.0107)	0.0327*** (0.0107)	0.0162 (0.0107)
$\mathbb{1}(\text{Common Lang}_{ji})$	0.0016 (0.0079)	0.0115 (0.0078)	0.0033 (0.0079)	0.0114 (0.0078)	0.0044 (0.0080)
$\log(\text{Trade}_{ji,2007})$		-0.0569*** (0.0036)		-0.0576*** (0.0038)	
$\log(\text{MP}_{ji,2007})$			-0.0041*** (0.0009)	0.0006 (0.0010)	
$\mathbb{1}(\text{Deep Trade Agree}_{ji,2007})$					-0.0405*** (0.0119)
$\log(k_{ji}^s)_{2007}$	-0.1741*** (0.0048)	-0.2506*** (0.0068)	-0.1766*** (0.0048)	-0.2512*** (0.0068)	-0.1747*** (0.0048)
$j \times s$ FE	✓	✓	✓	✓	✓
$i \times s$ FE	✓	✓	✓	✓	✓
Observations	10800	10800	10800	10800	10800

*Notes:* This table presents regressions of the MNE relative productivity shock,  $\log(\hat{k}_{ji}^s)$ , on gravity variables, based on Equation (Appendix C.4). The sample is a cross-section of shocks from the Great Recession (2008-2009 log changes). \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Figure Appendix C.1: **Sectoral Shock Distributions (2008-2009)**



**Description:** This figure displays the distributions of key model shocks across countries or country pairs by sector, measured as log changes from 2008 to 2009 under baseline calibration where  $\sigma$  and  $\delta$  take their mean values. These include MNE relative productivity shocks,  $\log\left(\frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s}\right)$ , domestic productivity shocks,  $\log\left(\hat{A}_{jj}^s\right)$ , MNE final demand shocks,  $\log\left(\hat{a}_{nm}^s\right)$ , sectoral final demand shocks,  $\log\left(\hat{a}_n^s\right)$ , and labor supply shocks,  $\log\left(\hat{\xi}_n^s\right)$ . Sectoral final demand shocks are only plotted for the durable and non-durable manufacturing sectors, having normalized non-manufacturing shocks to zero. To enhance presentation, distributions are winsorized at top and bottom 1%.

Table Appendix C.8: **Estimated MNE and Trade Elasticities: Baseline**

	(1)	(2)	(3)	(4)
	$\log\left(\frac{\pi_{nnj,t}^s}{h_{nj,t}^s}\right)$			
$\log\left(\frac{H_{nj,t}^s}{S_{njj,t}^s}\right)$	1.2324** (0.4895)	2.2954*** (0.6675)	2.1960*** (0.3202)	3.7023*** (0.4345)
$\log(t_{nj,t}^s)$	-2.1015*** (0.3100)	-0.9432 (0.6263)	-1.7176*** (0.3274)	-1.7219*** (0.4716)
$n \times j \times s$ FE	✓	✓		
$n \times j$ FE			✓	
$n \times s \times t$ FE	✓		✓	✓
$j \times s \times t$ FE	✓		✓	✓
$n \times t$ FE		✓		
$j \times t$ FE		✓		
Trade Agreement Control	✓	✓	✓	✓
Instrument	Three	Three	Three	Three
Mean Dep. VAR	-6.0583	-6.0583	-6.0583	-6.0583
Mean $\log\left(\frac{H_{nj,t}^s}{S_{njj,t}^s}\right)$	0.2557	0.2557	0.2557	0.2557
Mean $\log(t_{nj,t}^s)$	0.0166	0.0166	0.0166	0.0166
F-Stat	11.9	10.4	16.2	31.1
$\sigma$	3.1015	1.9432	2.7176	2.7219
Std. Err ( $\sigma$ )	(0.3100)	(0.6263)	(0.3274)	(0.4716)
$\zeta$	2.7052	1.4109	1.7822	1.4651
Std. Err ( $\zeta$ )	(0.7225)	(0.2979)	(0.1877)	(0.1386)
Observations	127440	127440	127440	127440

Notes: Column 1 presents the estimation of Equation Appendix C.5 where three instruments are used:  $t_{nj,t}^{s,IV} = \mathbb{I}\{\text{n applies MFN on j}\} \times t_{n,t}^{s,MFN}$ ,  $\text{Up IV}_{nj,t}^s = \frac{\sum_{s' \neq s} a_{j,t_0}^{ss',\text{tot}} t_{jn,t}^{s',IV}}{\sum_{s' \neq s} a_{j,t_0}^{ss',\text{tot}}}$ , and  $\text{Down IV}_{nj,t}^s = \frac{\sum_{s' \neq s} b_{j,t_0}^{s's,\text{tot}} t_{jn,t}^{s',IV}}{\sum_{s' \neq s} b_{j,t_0}^{s's,\text{tot}}}$ .  $\sigma$  and  $\zeta$  and their standard errors are computed with the Delta Method. Column 2-4 present estimations under alternative fixed effect combinations. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix C.9: **Estimated MNE and Trade Elasticities: Robustness Test**

	(1)	(2)	(3)	(4)	(5)
	$\log \left( \frac{\pi_{nnj,t}^s}{h_{nj,t}^s} \right)$				
$\log \left( \frac{H_{nj,t}^s}{S_{njj,t}^s} \right)$	2.7150*** (0.7055)	3.0955*** (0.8300)	1.5262*** (0.3830)	2.4179*** (0.7389)	-0.0097 (0.0096)
$\log (t_{nj,t}^s)$	-2.6918*** (0.3304)	-2.1431*** (0.3344)	-2.2187*** (0.2063)	-2.4329*** (0.2719)	-2.0327*** (0.1554)
$n \times j \times s$ FE	✓	✓			✓
$n \times j$ FE			✓		
$n \times s \times t$ FE	✓		✓	✓	
$j \times s \times t$ FE	✓		✓	✓	
$n \times t$ FE		✓			
$j \times t$ FE		✓			
Trade Agreement Control	✓	✓	✓	✓	
Instrument	Two	Two	Two	Two	NA
Mean Dep. VAR	-6.0583	-6.0583	-6.0583	-6.0583	-6.0583
Mean $\log \left( \frac{H_{nj,t}^s}{S_{njj,t}^s} \right)$	0.2557	0.2557	0.2557	0.2557	0.2557
Mean $\log (t_{nj,t}^s)$	0.0166	0.0166	0.0166	0.0166	0.0166
F-Stat	7.4	7.4	7.2	12.6	
$\sigma$	3.6918	3.1431	3.2187	3.4329	3.0327
Std. Err ( $\sigma$ )	(0.3304)	(0.3344)	(0.2063)	(0.2719)	(0.1554)
$\zeta$	1.9915	1.6923	2.4537	2.0062	-207.5118
Std. Err ( $\zeta$ )	(0.2849)	(0.2148)	(0.3890)	(0.3274)	(205.2997)
Observations	127440	127440	127440	127440	127440

*Notes:* Column 1 presents the estimation of Equation Appendix C.5 where applied tariffs are treated as exogenous and two instruments are used for  $\log \left( \frac{H_{nj,t}^s}{S_{njj,t}^s} \right)$ : Up  $IV_{nj,t}^s = \frac{\sum_{s' \neq s} a_{j,t_0}^{ss'} t_{jn,t}^{s'}}{\sum_{s' \neq s} a_{j,t_0}^{ss',tot}}$  and Down  $IV_{nj,t}^s = \frac{\sum_{s' \neq s} b_{j,t_0}^{s',tot} t_{jn,t}^{s'}}{\sum_{s' \neq s} b_{j,t_0}^{s',tot}}$ .  $\sigma$  and  $\zeta$  and their standard errors are computed with the Delta Method. Column 2-4 present estimations under alternative fixed effect combinations. Column 5 presents the estimation without any IV. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix C.10: **Estimated MNE and Trade Elasticities: Different Sectors**

	(1)	(2)	(3)	(4)	(5)	(6)
	$\log \left( \frac{\pi_{nnj,t}^s}{h_{nj,t}^s} \right)$					
	Durable	Non-durable	Non-manufacturing	Durable	Non-durable	Non-manufacturing
$\log \left( \frac{H_{nj,t}^s}{S_{njj,t}^s} \right)$	2.2994 (1.5453)	1.1169 (1.5896)	1.7361** (0.7550)	7.9670*** (1.5335)	0.9238 (1.9214)	1.9913*** (0.5666)
$\log (t_{nj,t}^s)$	-5.0279*** (0.9593)	-0.8575** (0.4370)	-1.6141** (0.6609)	-2.7485* (1.6267)	-4.6221*** (0.7293)	-1.6810** (0.8476)
$n \times j$ FE	✓	✓	✓			
$n \times t$ FE	✓	✓	✓	✓	✓	✓
$j \times t$ FE	✓	✓	✓	✓	✓	✓
Trade Agreement Control	✓	✓	✓	✓		
Instrument	Three	Three	Three	Three	Three	Three
Mean Dep. VAR	-5.3859	-5.6966	-7.0923	-5.3859	-5.6966	-7.0923
Mean $\log \left( \frac{H_{nj,t}^s}{S_{njj,t}^s} \right)$	0.3336	0.2506	0.1830	0.3336	0.2506	0.1830
Mean $\log (t_{nj,t}^s)$	0.0144	0.0193	0.0162	0.0144	0.0193	0.0162
F-Stat	30.7	2.7	5.0	47.6	39.8	12.7
$\sigma$	6.0279	1.8575	2.6141	3.7485	5.6221	2.6810
Std. Err ( $\sigma$ )	(0.9593)	(0.4370)	(0.6609)	(1.6267)	(0.7293)	(0.8476)
$\zeta$	3.1867	1.7678	1.9297	1.3450	6.0034	1.8442
Std. Err ( $\zeta$ )	(1.5276)	(1.1607)	(0.5553)	(0.2147)	(10.4367)	(0.4888)
Observations	42480	42480	42480	42480	42480	42480

Notes: Columns 1-3 present the estimations of Equation Appendix C.5 for different sectors. Three instruments are used:  $t_{nj,t}^{s,IV} = \mathbb{I}\{\text{n applies MFN on j}\} \times t_{n,t}^{s,MFN}$ ,  $\text{Up IV}_{nj,t}^s = \frac{\sum_{s' \neq s} a_{j,t_0}^{s',\text{tot}} t_{jn,t}^{s',IV}}{\sum_{s' \neq s} a_{j,t_0}^{s',\text{tot}}}$ , and  $\text{Down IV}_{nj,t}^s = \frac{\sum_{s' \neq s} b_{j,t_0}^{s',\text{tot}} t_{jn,t}^{s',IV}}{\sum_{s' \neq s} b_{j,t_0}^{s',\text{tot}}}$ .  $\sigma$  and  $\zeta$  and their standard errors are computed with the Delta Method. Column 3-6 present these estimations under alternative fixed effect combinations. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix C.11: **Estimate Headquarters' Share in MNE Productivity: Baseline**

	(1)	(2)	(3)	(4)
	$\log \left( \frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s} \right)$			
$\log \left( \frac{\hat{A}_{ii,t}^s}{\hat{A}_{jj,t}^s} \right)$	0.2349*** (0.0159)	0.2531*** (0.0200)	0.2532*** (0.0199)	0.3892*** (0.0145)
$j \times t$ FE	✓	✓	✓	
$i \times t$ FE		✓	✓	
$s \times t$ FE	✓		✓	
$n \times s$ FE			✓	
Mean Dep. VAR	0.0150	0.0150	0.0150	0.0150
Mean Indep. VAR	0.0000	0.0000	0.0000	0.0000
Observations	118800	118800	118800	118800

Notes: Column 1 presents the estimation of Equation (Appendix C.6). Columns 2-4 present estimations under alternative fixed effect combinations. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix C.12: **Estimate Headquarters' Share in MNE Productivity: Robustness Test**

	(1)	(2)	(3)	(4)
	$\log \left( \frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s} \right)$			
$\log \left( \hat{A}_{ii,t}^s \right)$	0.1485*** (0.0182)	0.1342*** (0.0266)	0.0985*** (0.0264)	0.2056*** (0.0192)
$\log \left( \hat{A}_{jj,t}^s \right)$	0.5875*** (0.0269)	0.6231*** (0.0266)	0.5775*** (0.0271)	0.4312*** (0.0192)
$j \times t$ FE	✓	✓	✓	
$i \times t$ FE		✓	✓	
$s \times t$ FE	✓		✓	
$n \times s$ FE			✓	
Mean Dep. VAR	0.0162	0.0162	0.0162	0.0162
Mean $\log \left( \hat{A}_{ii,t}^s \right)$	0.0012	0.0012	0.0012	0.0012
Mean $\log \left( \hat{A}_{jj,t}^s \right)$	0.0012	0.0012	0.0012	0.0012
Observations	118800	118800	118800	118800

Notes: Column 1 estimates the following equation:  $\log \left( \hat{A}_{ji,t}^s \right) = \phi_1 \log \left( \hat{A}_{ii,t}^s \right) + \phi_2 \log \left( \hat{A}_{jj,t}^s \right) + FE_{j,t} + FE_t^s + \epsilon_{ji,t}^s$ . Columns 2-4 present estimations under alternative fixed effect combinations. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix C.13: **Estimate Headquarters' Share in MNE Productivity: Different Sectors**

	(1)	(2)	(3)
	$\log \left( \frac{\hat{A}_{ji}^s}{\hat{A}_{jj}^s} \right)$		
	Durable	Non-durable	Non-manufacturing
$\log \left( \frac{\hat{A}_{ii,t}^s}{\hat{A}_{jj,t}^s} \right)$	0.2060*** (0.0269)	0.0466* (0.0277)	0.2579*** (0.0492)
$j \times t$ FE	✓	✓	✓
Mean Dep. VAR	0.0135	0.0200	0.0114
Mean Indep. VAR	0.0000	0.0000	0.0000
Observations	39600	39600	39600

Notes: Columns 1-3 presents the estimation of Equation (Appendix C.6) for different sectors. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix C.14: **Estimate Headquarters' Share in MNE Productivity: Different Sectors, Robustness Test**

	(1)	(2)	(3)
	$\log(\hat{A}_{ji}^s)$		
	Durable	Non-durable	Non-manufacturing
$\log(\hat{A}_{ii,t}^s)$	0.2517*** (0.0290)	0.0305 (0.0306)	0.4382*** (0.0561)
$\log(\hat{A}_{jj,t}^s)$	0.4852*** (0.0290)	0.3173*** (0.0306)	0.6954*** (0.0561)
$j$ FE	✓	✓	✓
$i$ FE	✓	✓	✓
Mean Dep. VAR	0.0157	0.0168	0.0162
Mean $\log(\hat{A}_{ii,t}^s)$	0.0012	0.0012	0.0012
Mean $\log(\hat{A}_{ii,t}^s)$	0.0012	0.0012	0.0012
Observations	39600	39600	39600

Notes: Column 1-3 estimate the following equation for different sectors:  $\log(\hat{A}_{ji,t}^s) = \phi_1 \log(\hat{A}_{ii,t}^s) + \phi_2 \log(\hat{A}_{jj,t}^s) + FE_{j,t} + FE_t^s + \epsilon_{ji,t}^s$ . \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix C.15: **Estimated Final Demand Elasticity for MNEs**

	(1)	(2)	(3)	(4)
	$\log(\hat{s}_{nm,t}^s)$			
$\log(\hat{P}_{nm}^s)$	-1.7259** (0.7041)	-2.1205*** (0.7860)	-0.8084*** (0.2170)	-0.0205*** (0.0067)
$n \times s \times t$ FE	✓			✓
$n \times t$ FE		✓	✓	
$s \times t$ FE		✓	✓	
$m \times t$ FE			✓	
Instrument	MNE productivity	MNE productivity	MNE productivity	NA
Mean Dep. VAR	0.0098	0.0098	0.0098	0.0098
Mean Indep. VAR	0.0349	0.0349	0.0349	0.0349
First Stage F	16.3	15.2	146.7	
Observations	116820	116820	116820	116820

Notes: This table presents the estimate of final demand elasticity for MNEs. Column 1 shows the baseline specification, Equation (Appendix C.7). Columns 2 and 3 show the estimates under alternative fixed effect combinations. Column 4 shows the estimate without the IV. The IV is constructed based on Equation (Appendix C.8). \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix C.16: **Estimated Sectoral Final Demand Elasticity**

	(1)	(2)	(3)	(4)
	$\log(s_{n,t}^s)$			
$\log(P_{n,t}^s)$	-0.8076** (0.3425)	-0.8978* (0.5094)	-0.3427 (0.2334)	-0.0137 (0.0443)
$n \times t$ FE	✓	✓		✓
$s$ FE		✓		
Instrument	MNE productivity	MNE productivity	MNE productivity	NA
Mean Dep. VAR	-0.0012	-0.0012	-0.0012	-0.0012
Mean Indep. VAR	0.0263	0.0263	0.0263	0.0263
First Stage F	28.0	13.5	2.2	
Observations	1980	1980	1980	1980

*Notes:* This table presents the estimate of final demand elasticity for MNEs. Column 1 shows the baseline specification, Equation (Appendix C.9). Column 2 further controls sector fixed effect. Column 3 does not control country-time fixed effect. Column 4 shows the estimate without the IV. The IV is constructed based on Equation (Appendix C.10). \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

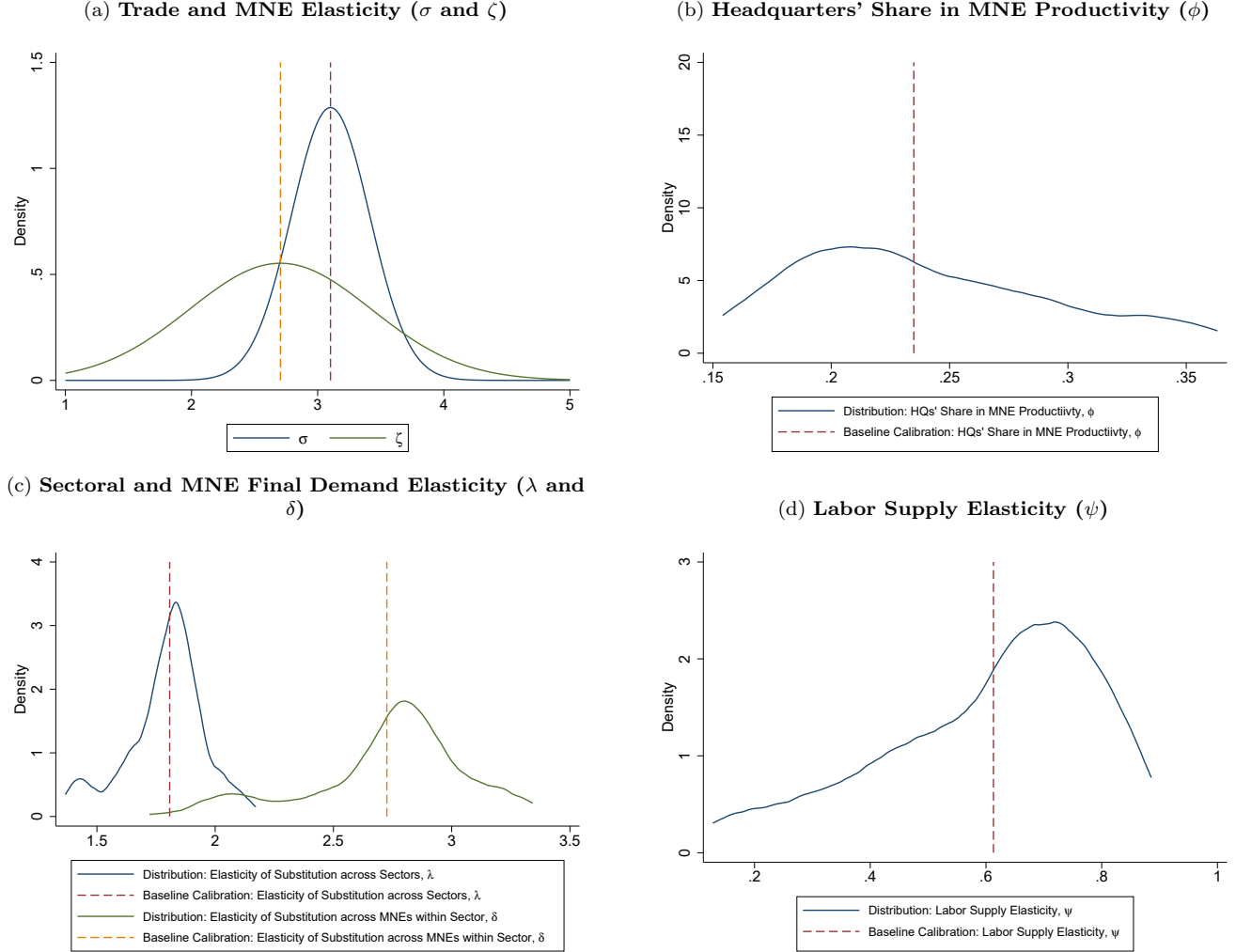
Table Appendix C.17: **Estimated Labor Supply Elasticity**

	(1)	(2)	(3)	(4)	(5)	(6)
$\log\left(\frac{\hat{w}_n^s}{P_n}\right)$	0.6129* (0.3204)	0.3824* (0.1955)	0.3032 (0.2449)	0.5674* (0.3036)	0.4132* (0.2164)	-0.0523*** (0.0183)
$n$ FE				✓		
$s$ FE				✓		
$t$ FE	✓			✓		✓
$n \times s$ FE	✓	✓	✓			✓
$s \times t$ FE			✓			
Instrument	MNE productivity	MNE productivity	MNE productivity	MNE productivity	MNE productivity	
Mean Dep. VAR	-0.0063	-0.0063	-0.0063	-0.0063	-0.0063	-0.0063
Mean Indep. VAR	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
First Stage F	7.2	14.1	6.7	7.5	13.5	NA
Observations	1008	1008	1008	1008	1008	1008

*Notes:* This table presents the estimate of labor supply elasticity. Column 1 shows the baseline specification, Equation (Appendix C.11). Column 2-4 experiment with alternative fixed effect combinations. Column 5 does not control any fixed effect. Column 6 shows the estimate without the IV. The IV is constructed based on Equation (Appendix C.12). \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .



Figure Appendix C.2: Estimated Elasticity Distributions



*Notes:* This figure shows the distributions of model parameters: trade and MNE elasticity ( $\sigma$  and  $\zeta$ ), headquarters' share in MNE productivity ( $\phi$ ), sectoral and MNE final demand elasticity ( $\lambda$  and  $\delta$ ), as well as labor supply elasticity ( $\psi$ ). Figure Appendix C.2a presents the asymptotic normal distributions for  $\sigma$  and  $\zeta$ , with their estimated means and standard errors reported in Column 1 of Table Appendix C.8. Since other parameter estimations depend on  $\sigma$  and  $\zeta$ , I draw 300 independent values for  $\sigma$  and  $\zeta$  from their distributions in Figure Appendix C.2a. For each draw, I re-estimate the remaining parameters and then plot their distributions. Dashed vertical lines indicate each parameter's baseline estimated value when  $\sigma$  and  $\zeta$  are at their respective mean. To enhance presentation, simulated distributions are winsorized at top and bottom 5%.

1426 *Calibrated MNE Sourcing and Selling Frictions and MNE Productivity All Follow Gravity.* Tables  
 1427 Appendix C.18 and Appendix C.19 show that the calibrated MNE sourcing and selling efficiencies  
 1428 and their productivity all follow gravity: MNEs are more efficient at sourcing and selling with  
 1429 their headquarters and countries proximate with their headquarters (consistent with Fact 5). Fur-  
 1430 thermore, MP incurs a productivity loss which increases with the distance between headquarters  
 1431 and host countries (Antràs and Yeaple, 2014).

1432 Specifically, I consider the following regression:

$$y_{ji,t}^s = \beta_1 \mathbb{1}(i = j) + \beta_2 \log(\text{Dist}_{ji}) + \beta_3 \mathbb{1}(\text{Legal}_{ji}) + \beta_4 \mathbb{1}(\text{Contiguity}_{ji}) + \beta_5 \mathbb{1}(\text{Common Lang}_{ji}) \\ + \beta_6 \mathbb{1}(\text{Deep Trade Agree}_{ji,t}) + FE_i + FE_j + FE_t + \epsilon_{ji,t}^s,$$

1433 where  $y_{ji,t}^s \in \left\{ \log(h_{ji,t}^s), \log(H_{ji,t}^s), \log\left(\frac{A_{ji,t}^s}{A_{jj,t}^s}\right) \right\}$  denotes MNE sourcing and selling efficiencies  
 1434 and their productivity relative to domestic firms. The sample pools all country-pairs and years  
 1435 (2005-2016), either by individual sector or combining all sectors.

1436 *Model Matches Inter-MNE Trade.* The model's calibration does not use sales from foreign affiliates  
 1437 to foreign affiliates. Instead, these sales can be predicted by Equation (11): sales from foreign  
 1438 affiliate in country  $j$  to foreign affiliate in  $n$  equal  $n$ -located foreign affiliates' expenditure on  $j$ ,  
 1439 multiplied by foreign affiliates' share in trade flows from  $j$  to  $n$ . Figure Appendix C.3 demonstrates  
 1440 that predicted MNE-to-MNE trade closely matches the data.

1441 *Model Matches GDP Data.* Figure Appendix C.4 shows the calibrated model's ability to replicate  
 1442 GDP data, which was not used in the model's calibration. Figure Appendix C.4a shows the  
 1443 model matches year-over-year GDP growth across countries for all years. Figure Appendix C.4b  
 1444 shows the model matches year-over-year GDP growth across countries during the Great Recession.  
 1445 Figure Appendix C.4c further demonstrates the model predicts a world GDP loss of 1.7% during  
 1446 the Great Recession, which is close to the 1.4% observed in the data.

1447 *Model Replicates Contribution by MNEs to Trade Collapse in Data.* Table Appendix D.13 repli-  
 1448 cates the empirical regressions from Table Appendix A.4, studying MNEs' impact on the trade  
 1449 collapse using model-predicted MNE trade. Columns 1-4 of Table Appendix D.13 reproduce the

findings: overall trade declined during the Great Recession (Column 1); MNE trade declined more because MNE sales declined more and MNEs are more trade intensive, yet MNE trade intensity did not decline relative to domestic firms (Columns 2-3 for MNE importers/exporters respectively). Column 4 confirms robustness when pooling MNE importers and exporters.

In Columns 5-8, I replicate these empirical regressions using trade values predicted by the calibrated model as the dependent variable. They yield qualitatively similar coefficients to the empirical regressions.

*Model Matches Headquarters GDP-MNE Sales Correlation.* I show that the correlation between headquarters' GDP and its MNEs' gross output is similar in both data and the model, implying that headquarters shocks propagate to host countries via MNEs. I apply the following regressions on country-bilateral and sector-level MP data for all years (2005-2016):

$$\begin{aligned}\log(GO_{ji,t}^s) &= \beta_1 \log(GDP_{i,t}^s) + FE_i^s + FE_{j,t}^s + \epsilon_{ij,t}^s, \\ \log(GO_{ji,t}^s) &= \beta_1 \log(GDP_{i,t}^s) + \beta_2 \log(GDP_{j,t}^s) + FE_i^s + FE_j^s + FE_t^s + \epsilon_{ij,t}^s.\end{aligned}\tag{Appendix C.13}$$

The first regression controls for host country ( $j$ )-sector ( $s$ )-year ( $t$ ) fixed effects and uses variations in headquarters' GDP over time to identify its effect on MNE gross output. The second regression relaxes the  $j - s - t$  fixed effect and controls host country GDP directly.

Columns 1 and 2 show that headquarters country's GDP is strongly correlated with their MNEs' sales, and the correlation between headquarters' GDP and MNE sales is higher than the correlation between host country's GDP and MNE sales. In Columns 3 and 4, using model predicted MNE sales and GDP, I'm able to replicate quantitatively similar patterns.

Table Appendix C.18: **Gravity of MNE Sourcing and Selling Efficiencies**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$\log(h_{ji,t}^s)$				$\log(H_{ji,t}^s)$			
	Durable Manufacturing	Non-durable Manufacturing	Non-manufacturing	All	Durable Manufacturing	Non-durable Manufacturing	Non-manufacturing	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)
$\log(\text{Dist}_{ji})$	-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)
$1(\text{Legal}_{ji})$	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)
$1(\text{Contiguity}_{ji})$	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)
$1(\text{Common Lang}_{ji})$	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)
$1(\text{Deep Trade Agree}_{ji,t})$	-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)
$j$ FE	✓	✓	✓	✓	✓	✓	✓	✓
$i$ FE	✓	✓	✓	✓	✓	✓	✓	✓
$t$ FE	✓	✓	✓	✓	✓	✓	✓	✓
Observations	43,200	43,200	43,200	129,600	43,200	43,200	43,200	129,600

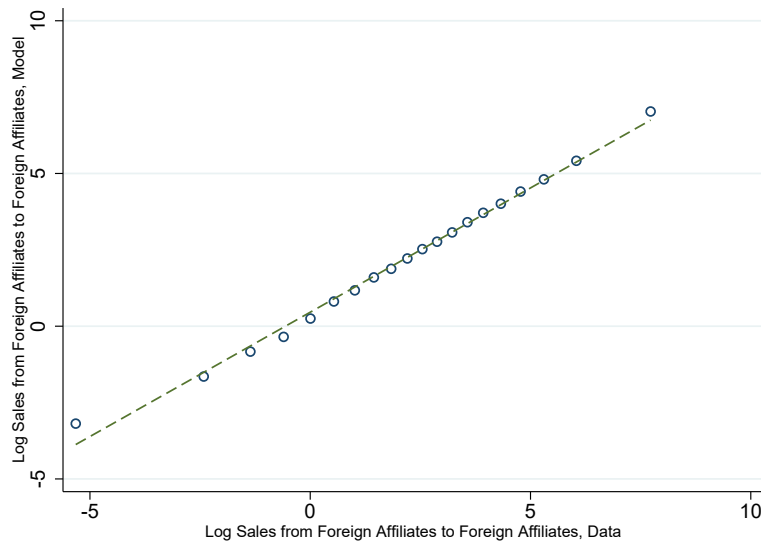
*Notes:* This table presents the correlations between the MNE sourcing and selling efficiencies ( $h_{ji,t}^s$  and  $H_{ji,t}^s$ ) and gravity variables: if the MNE is sourcing from and selling to their headquarters, the distance between the headquarters and sourcing origin/selling destination, as well as whether the headquarters share the same legal origin, common border, common language, and deep trade agreements with the trade partner. Robust standard errors in parentheses. The sample comprises all country-pairs and years (2005-2016). \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table Appendix C.19: **Gravity of MNE Relative Productivity**

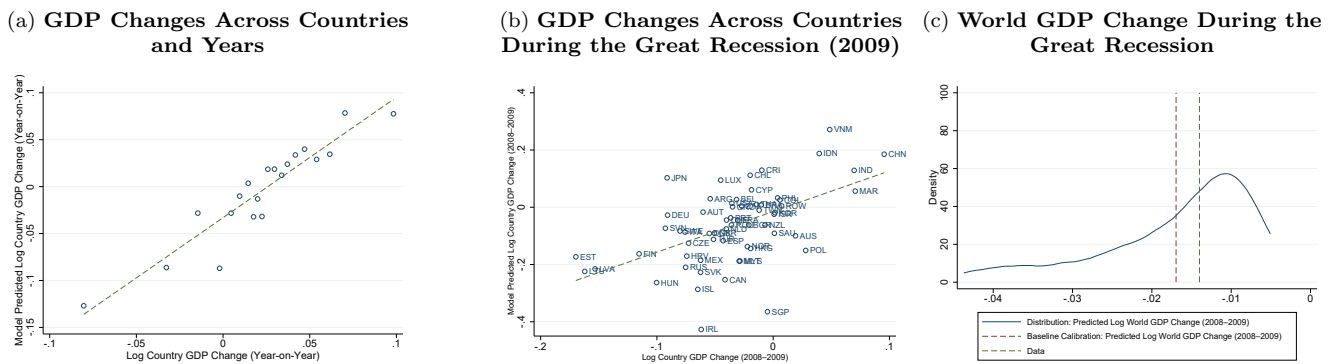
	(1)	(2)	(3)	(4)
	$\log(\frac{A_{ji,t}^s}{A_{jj,t}^s})$			
	Durable Manufacturing	Non-durable Manufacturing	Non-manufacturing	All
$1(i = j)$	3.860*** (0.0843)	17.38*** (0.324)	4.606*** (0.127)	8.617*** (0.145)
$\log(\text{Dist}_{ji})$	-0.917*** (0.0192)	-3.739*** (0.0737)	-2.134*** (0.0288)	-2.263*** (0.0330)
$1(\text{Legal}_{ji})$	0.228*** (0.0220)	1.500*** (0.0847)	0.556*** (0.0331)	0.761*** (0.0379)
$1(\text{Contiguity}_{ji})$	1.473*** (0.0546)	7.034*** (0.210)	2.224*** (0.0821)	3.577*** (0.0939)
$1(\text{Common Lang}_{ji})$	0.647*** (0.0413)	1.301*** (0.159)	0.739*** (0.0621)	0.896*** (0.0711)
$1(\text{Deep Trade Agree}_{ji,t})$	-0.326*** (0.0332)	-1.215*** (0.128)	-0.558*** (0.0500)	-0.700*** (0.0572)
$j$ FE	✓	✓	✓	✓
$i$ FE	✓	✓	✓	✓
$t$ FE	✓	✓	✓	✓
Observations	43,200	43,200	43,200	129,600

*Notes:* This table presents the correlations between the productivity of an MNE relative to domestic firms in the same host country ( $\frac{A_{ji,t}^s}{A_{jj,t}^s}$ ) 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 deep trade agreements with the host country. Robust standard errors in parentheses. The sample comprises all country-pairs and years (2005-2016). \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Figure Appendix C.3: Sales from MNEs to MNEs in Model and Data



*Notes:* This figure plots actual (x-axis) versus model-predicted (y-axis) inter-MNE sales between any country pair  $j$ - $n$  for all years (2005-2016). To avoid clutter, I present the binscatter plots with 20 equally sized bins.

Figure Appendix C.4: **GDP in Model and Data**

*Notes:* These figures demonstrate the model's ability to replicate GDP data. Figure Appendix C.4a plots model-predicted (y-axis) versus data (x-axis) year-over-year GDP changes across countries. To avoid clutter, I present binscatter plots with 20 equally sized bins. Figure Appendix C.4b plots 2009 country-level GDP growth with model-predicted on the vertical axis and actual on the horizontal. Figure Appendix C.4c presents model-implied world GDP growth (red), actual world GDP growth (green), and the distribution of model-implied world GDP growth. This distribution arises from 300 independent draws of  $\sigma$  and  $\zeta$ , for each of which I recalibrate the model and compute world GDP statistics.

Table Appendix C.20: **Impact of MNEs on Trade Collapse: Data and Model**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$\log(T_{nmji,t}^s)$				$\log(T_{nmji,t}^s)$			
$\mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\}$	-0.1680*** (0.0193)	-0.1625*** (0.0210)	-0.1709*** (0.0208)	-0.1632*** (0.0222)	-0.1455*** (0.0196)	-0.1381*** (0.0213)	-0.1521*** (0.0217)	-0.1437*** (0.0231)
$\mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{m = F\}$		0.0386 (0.0309)		0.0273 (0.0304)		0.0420 (0.0359)		0.0367 (0.0358)
$\mathbb{I}\{t = 2009\} \times \mathbb{I}\{n \neq j\} \times \mathbb{I}\{i = F\}$			0.0732** (0.0338)	0.0613* (0.0336)			0.0796** (0.0362)	0.0733** (0.0369)
$\mathbb{I}\{t = 2009\} \times \mathbb{I}\{m = F\}$		-0.0952*** (0.0291)		-0.0836*** (0.0286)		-0.1121*** (0.0327)		-0.1069*** (0.0326)
$\mathbb{I}\{t = 2009\} \times \mathbb{I}\{i = F\}$			-0.0937*** (0.0321)	-0.0809** (0.0320)			-0.0866** (0.0343)	-0.0796** (0.0351)
$n \times m \times j \times i \times s$ FE	✓	✓	✓	✓	✓	✓	✓	✓
$t$ FE	✓	✓	✓	✓	✓	✓	✓	✓
Observations	125316	125316	125316	125316	125316	125316	125316	125316

Notes: Table reports the regression results of equation (Appendix A.2) and (Appendix A.3). The regression is weighted on sum of pre-period trade value ( $\sum_{t=2006}^{2008} T_{nmij,t}^s$ ). Robust standard errors clustered at the importer country-importer firm type-exporter country-exporter firm type-sector ( $nmjis$ ) level are displayed in parentheses. The sample is restricted to year 2007, 2008 and 2009. Columns 1-4 employ actual MNE trade flow values as the dependent variable, whereas Columns 5-8 use values predicted by the calibrated model. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix C.21: **Correlation Between MNE Sales and Headquarters GDP in Data and Model**

	$\log(GO_{ji,t}^s), \text{Data}$		$\log(GO_{ji,t}^s), \text{Model}$	
	(1)	(2)	(3)	(4)
$\log(GDP_{i,t}^s)$	0.2997*** (0.0781)	0.2997*** (0.0777)	0.2050*** (0.0519)	0.2050*** (0.0517)
$\log(GDP_{j,t}^s)$		0.2599*** (0.0777)		0.1806*** (0.0517)
$i \times s$ FE	✓	✓	✓	✓
$j \times s$ FE		✓		✓
$s \times t$ FE		✓		✓
$j \times s \times t$ FE	✓		✓	
Observations	127440	127440	127440	127440

Notes: This table presents estimated coefficients from Equation (Appendix C.13), which regresses MNE sales on headquarters' and host country's GDP. The sample comprises all country-bilateral, sector-level MP data spanning 2005-2016. Columns 1-2 employ actual MNE sales and GDP data, while Columns 3-4 use MNE sales and GDP implied by the calibrated model.

## 1469 Appendix D. Quantitative Analysis

### 1470 *Appendix D.1. Impact of Sector Characteristics on Key Model Shocks (Final Demand, Domestic* 1471 *Productivity, MNE Relative Productivity)*

1472 To related calibrated model shocks to actual economic indicators and inform policy, I employ  
1473 a variance decomposition approach similar to Levchenko et al. (2010) and Levchenko et al. (2011).  
1474 Specifically, I regress sectoral final demand shocks, domestic productivity shocks, and MNE relative  
1475 productivity shocks on a broad set of sectoral characteristics. I then compute each characteristic's  
1476 predictive power for these shocks.

1477 Using the NBER-CES Manufacturing Industry Database, which covers 355 NAICS 6-digit  
1478 sectors for the US, I compute the filtered final demand shock for each sector. This computation  
1479 follows the calibration method used in the model, detailed in Section Appendix C.1:

$$\hat{\alpha}_{US}^s = \frac{\hat{s}_{US}^s}{\hat{s}_{US}^{\text{Benchmark}}} \frac{\left(\hat{P}_{US}^{\text{Benchmark}}\right)^{1-\lambda}}{\left(\hat{P}_{US}^s\right)^{1-\lambda}}.$$

1480 Here,  $\hat{s}_{US}^s$  denotes the change in sector  $s$ 's share in US final expenditure (computed using NBER-  
1481 CES and US BEA Input-Output Table data), and  $\hat{P}_{US}^s$  denotes the change in sectoral price (from  
1482 NBER-CES). I set  $\lambda = 1.81$ . I take NAICS 6-digit sector 339999 as the benchmark sector.

1483 I measure sectoral domestic productivity shock ( $\log(\hat{A}_{US,US}^s)$ ) as the change in value added  
1484 per worker deflated by the change in sector price. To measure the shock to MNE productivity  
1485 relative to domestic firms ( $\log\left(\frac{\hat{A}_{US,MNE}^s}{\hat{A}_{US,US}^s}\right)$ ), I use the difference in the change of value added per  
1486 worker between foreign affiliates operating in the US (from US BEA statistics) and overall US  
1487 value added per worker.<sup>76</sup> I compute these shocks in terms of changes from 2008 to 2009. As  
1488 regressors, I employ a comprehensive set of sector characteristics from the literature, including  
1489 measures of sectoral financial constraints as well as production and trade characteristics.<sup>77</sup>

1490 I consider the following regression of sectoral shock  $y^s \in \left\{ \log(\hat{\alpha}_{US,US}^s), \log(\hat{A}_{US,US}^s), \log\left(\frac{\hat{A}_{US,MNE}^s}{\hat{A}_{US,US}^s}\right) \right\}$   
1491 on sectoral characteristics across sectors, where  $X^{s,r}$  denotes the  $r$ th characteristics for sector  $s$ :

<sup>76</sup>See Section Appendix A.1 for a detailed account of how I collected and combined these datasets.

<sup>77</sup>They include sectoral asset tangibility, capital intensity, contract intensity, external finance dependence, intermediate input intensity, inventory ratio, skill intensity, trade credit intensity, and sector upstreamness.

$$y^s = \sum_r \beta^r X^{s,r} + \epsilon^s. \quad (\text{Appendix D.1})$$

Column 1 of Table Appendix D.1 shows a negative correlation between the filtered demand shock and both capital and skill intensity. This is consistent with Levchenko et al. (2010) and other trade collapse studies finding the greatest demand decline in durable manufacturing. Sectors with higher contract intensity experienced less demand decline, consistent with Rauch (1999) and Nunn (2007) showing relationship-specific trade's resilience. Columns 2-11 show that regressing the filtered demand shock on sectoral characteristics individually leads to coefficients consistent with the joint regression.

Table Appendix D.2 shows that sectors intensive in inventories, trade, and upstreamness experienced greater decrease in domestic productivity shocks. This suggests that sectors with larger inventory holdings, often indicative of financial constraint (Manova et al., 2015), incurred larger productivity decreases during the Great Recession. Furthermore, due to trade and supply chain disruptions, trade-intensive sectors and those dependent on other sectors for sales also suffered greater productivity loss.

Table Appendix D.3 shows that MNEs held a comparative advantage over domestic firms in sectors characterized by higher trade intensity and more intensive trade credit requirements. These findings are consistent with cross-country evidence from Section Appendix C.3 and works like Alfaro and Chen (2012). Furthermore, upstream sectors experienced a greater decline in MNE productivity relative to domestic firms.

*Variance Decomposition.* The contribution of each sector characteristics  $r$  to each shock  $s$  can be computed with a variance decomposition approach, as follows:

$$\frac{\text{Cov}_s \left( \sum_r \hat{\beta}^r X^{s,r}, \hat{\beta}^r X^{s,r} \right)}{\text{Var}_s \left( \sum_r \hat{\beta}^r X^{s,r} \right)}. \quad (\text{Appendix D.2})$$

For each shock, I obtain the estimated coefficient for sector characteristic  $r$ ,  $\hat{\beta}^r$ , from Column 1 of its corresponding regression table. I then calculate each sector characteristic's contribution using a covariance-to-variance ratio. Specifically, I take the covariance between the overall predicted shock (accounting for all sector characteristics) and the predicted change attributed to that specific



1516 characteristic, divided by the variance of the overall predicted shock. All covariance and variance  
1517 terms are computed across sectors. The contribution of all characteristics add up to one.

1518 Table 3 shows the key industry characteristics for each shock type: For final demand shocks:  
1519 *Capital intensity*, *skill intensity*, and *contract intensity*. For domestic productivity shocks: *Inven-*  
1520 *tory intensity*, *trade intensity*, and *sector upstreamness*. For MNE relative productivity shocks:  
1521 *Trade intensity*, *sector upstreamness*, and *trade credit intensity*.

1522 I investigate the impact of policies targeting firms in sectors adversely affected by demand, do-  
1523 mestic productivity, or MNE relative productivity shocks. Specifically, *demand policies* mitigate  
1524 firm performance differences related to variations in capital, skill, and contract intensity. These  
1525 policies mitigate 74.1% of actual demand shocks, 2.5% of domestic productivity shocks, and 17.1%  
1526 of MNE relative productivity shocks. *Supply policies* address firm performance differences stem-  
1527 ming from variations in inventories, trade intensity, and upstreamness. They mitigate 92.6% of  
1528 domestic productivity shocks, 9.5% of demand shocks, and 62.7% of MNE relative productivity  
1529 shocks. *MNE policies* target firm performance differences linked to variations in trade intensity,  
1530 trade-credit intensity, and upstreamness. They reduce MNE relative productivity shocks by 79.8%,  
1531 demand shocks by 11.3%, and domestic productivity shocks by 50.3%.

Table Appendix D.1: Impact of Sector Characteristics on Sectoral Final Demand Shocks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	$\log(\hat{\alpha}_{US}^s)$										
Asset Tang.	-0.028 (0.119)	-0.448*** (0.088)									
Capital Intensity	-0.044*** (0.013)		-0.092*** (0.011)								
Contract Intens.	0.196*** (0.046)			0.299*** (0.041)							
External Fin. Depen.	-0.018 (0.024)				0.006 (0.027)						
Interm. Intens.	-0.194*** (0.070)					-0.287*** (0.077)					
Inventory Ratio	0.235 (0.300)						1.134*** (0.257)				
Skill Intensity	-0.110*** (0.024)							-0.094*** (0.026)			
Trade Credit Intens.	1.073*** (0.365)								1.062** (0.431)		
Trade Intens.	0.008** (0.004)									0.014*** (0.004)	
Upstreamness	-0.000 (0.011)										-0.051*** (0.012)
R-squared	0.299	0.067	0.156	0.127	0.000	0.037	0.051	0.035	0.017	0.027	0.045
Observations	352	364	364	364	364	364	364	364	364	352	364

*Notes:* This table presents the coefficient of regression (Appendix D.1) where I regress sector final demand shock  $\log(\hat{\alpha}_{US}^s)$  on sector characteristics jointly and individually. The sample is cross-NAICS 6-digit sector data from the NBER-CES database matched with sector characteristics from various sources. The shock refers to change from 2008 to 2009. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix D.2: Impact of Sector Characteristics on Domestic Productivity Shocks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	$\log(\hat{A}_{US,US}^s)$										
Asset Tang.	-0.230 (0.148)	0.065 (0.091)									
Capital Intensity	0.018 (0.016)		0.003 (0.012)								
Contract Intens.	-0.001 (0.057)			0.007 (0.044)							
External Fin. Depen.	0.002 (0.029)				0.011 (0.027)						
Interm. Intens.	-0.178** (0.088)					-0.088 (0.079)					
Inventory Ratio	-1.516*** (0.373)						-0.953*** (0.261)				
Skill Intensity	-0.025 (0.029)							-0.024 (0.027)			
Trade Credit Intens.	-0.196 (0.455)								-0.774* (0.436)		
Trade Intens.	-0.011** (0.005)									-0.011** (0.005)	
Upstreamness	-0.057*** (0.014)										-0.044*** (0.012)
R-squared	0.126	0.001	0.000	0.000	0.000	0.003	0.036	0.002	0.009	0.015	0.033
Observations	352	364	364	364	364	364	364	364	364	352	364

*Notes:* This table presents the coefficient of regression (Appendix D.1) where I regress domestic productivity shock  $\log(\hat{A}_{US,US}^s)$  on sector characteristics jointly and individually. The sample is cross-NAICS 6-digit sector data from the NBER-CES database matched with sector characteristics from various sources. The shock refers to change from 2008 to 2009. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table Appendix D.3: **Impact of Sector Characteristics on MNE Performance Relative to Domestic Firms**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	$\log \left( \frac{\hat{A}_{US,MNE}^s}{\hat{A}_{US,US}^s} \right)$										
Asset Tang.	0.908 (0.553)	-0.230 (0.350)									
Capital Intensity	-0.120** (0.059)		-0.152*** (0.046)								
Contract Intens.	0.108 (0.214)			0.467*** (0.167)							
External Fin. Depen.	0.213* (0.111)				0.185* (0.103)						
Interm. Intens.	-0.067 (0.328)					-0.097 (0.305)					
Inventory Ratio	-1.016 (1.403)						0.583 (1.027)				
Skill Intensity	0.125 (0.109)							0.037 (0.102)			
Trade Credit Intens.	5.955*** (1.705)								4.852*** (1.662)		
Trade Intens.	0.089*** (0.018)									0.092*** (0.018)	
Upstreamness	-0.182*** (0.053)										-0.208*** (0.047)
R-squared	0.175	0.001	0.030	0.022	0.009	0.000	0.001	0.000	0.024	0.070	0.052
Observations	343	355	355	355	355	355	355	355	355	343	355

*Notes:* This table presents the coefficient of regression (Appendix D.1) where I regress sector MNE relative productivity shock  $\log \left( \frac{\hat{A}_{US,MNE}^s}{\hat{A}_{US,US}^s} \right)$  on sector characteristics jointly and individually. The sample is cross-NAICS 6-digit sector data from NBER-CES and US BEA Multinational Activities Database matched with sector characteristics from various sources. The shock refers to change from 2008 to 2009. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

1532 *Appendix D.2. How Trade-Only Model Underestimated the Impact of Productivity Shocks on Trade*  
1533 *Collapse*

1534 With a decomposition similar to Proposition 1, the change in world trade to GDP ratio in an  
1535 economy with both domestic firms and MNEs during the Great Recession equals the following:

$$\begin{aligned}
& \frac{T_{D,2009} + T_{F,2009}}{GDP_{D,2009} + GDP_{F,2009}} - \frac{T_{D,2008} + T_{F,2008}}{GDP_{D,2008} + GDP_{F,2008}} \\
= & \underbrace{\frac{T_{D,2009}}{GDP_{D,2009}} - \frac{T_{D,2008}}{GDP_{D,2008}}}_{\text{Trade Collapse in Trade Only Model}} \\
& + \underbrace{\frac{GDP_{F,2008}}{GDP_{D,2008} + GDP_{F,2008}} + \frac{GDP_{F,2009}}{GDP_{D,2009} + GDP_{F,2009}}}_{\text{MNE Share in World GDP}} \underbrace{\left( \left( \frac{T_{F,2009}}{GDP_{F,2009}} - \frac{T_{F,2008}}{GDP_{F,2008}} \right) - \left( \frac{T_{D,2009}}{GDP_{D,2009}} - \frac{T_{D,2008}}{GDP_{D,2008}} \right) \right)}_{\text{MNE Trade Resilience Relative to Domestic Firms}} \\
& + \underbrace{\left( \frac{T_{F,2008}}{GDP_{F,2008}} + \frac{T_{F,2009}}{GDP_{F,2009}} - \frac{T_{D,2008}}{GDP_{D,2008}} + \frac{T_{D,2009}}{GDP_{D,2009}} \right)}_{\text{MNE High Trade Intensity}} \underbrace{\left( \frac{GDP_{F,2009}}{GDP_{D,2009} + GDP_{F,2009}} - \frac{GDP_{F,2008}}{GDP_{D,2008} + GDP_{F,2008}} \right)}_{\text{MP Collapse}}
\end{aligned}$$

(Appendix D.3)

1536 On the right-hand side of Equation (Appendix D.3), the first term measures the trade collapse  
1537 in the trade-only model or a model with only horizontal MNEs, who have same trade intensity  
1538 as domestic firms. The second term represents the product of MNE share in world GDP and the  
1539 difference in trade-to-GDP ratio changes between MNEs and domestic firms. The third term is  
1540 the product of the higher MNE trade intensity and the MP collapse.

1541 Because MNEs were disproportionately affected by productivity shocks and have high trade  
1542 intensity, the third term contributed negatively to productivity shocks' overall impact on the trade  
1543 collapse. Furthermore, these productivity shocks did not significantly affect MNE trade resilience  
1544 relative to domestic firms. Since trade-only models or those with only horizontal MNEs ignore  
1545 the second and third terms, they underestimate productivity shocks' contribution to the trade  
1546 collapse.

Table Appendix D.4: **Impact of Demand and Supply Shocks on Trade and GDP in Baseline MNE Model, Trade Only Model, and Model without MNE Sourcing and Selling Efficiencies**

	Global Trade Relative to GDP				Global GDP			
	Demand Shocks		Supply Shocks		Demand Shocks		Supply Shocks	
	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)
Baseline MNE Model	-5.18	43.68	-8.05	67.88	-0.07	4.54	-1.88	130.34
	[-5.21, -5.15]	[43.43, 43.94]	[-8.11, -7.99]	[67.35, 68.42]	[-0.06, -0.07]	[4.35, 4.73]	[-1.87, -1.90]	[129.22, 131.47]
Trade Only Model	-3.95	33.31	-0.90	7.62	-0.08	5.47	-1.38	95.82
	[-3.98, -3.92]	[33.06, 33.55]	[-0.92, -0.89]	[7.49, 7.74]	[-0.08, -0.08]	[5.30, 5.64]	[-1.38, -1.39]	[95.66, 95.98]
Without Sourcing and Selling Efficiencies	-3.89	32.80	-2.44	20.59	-0.09	6.47	-1.35	93.44
	[-3.91, -3.87]	[32.61, 32.99]	[-2.45, -2.43]	[20.47, 20.71]	[-0.09, -0.10]	[6.23, 6.71]	[-1.35, -1.35]	[93.13, 93.74]

*Notes:* This table presents the impact of demand and supply shocks on global trade relative to GDP and on global GDP in the baseline MNE model, the trade only model, and the model without MNE sourcing and selling efficiencies. The “Percent” variable indicates the percentage change in trade relative to GDP and in GDP, compared to 2008 levels. The “Share” variable denotes the proportion of the decrease in trade/GDP among total losses during the Great Recession. Numbers in hard brackets represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

Table Appendix D.5: **Impact of Demand and Supply Shocks on Trade and GDP in Extended MNE Models**

	Global Trade Relative to GDP				Global GDP			
	Demand Shocks		Supply Shocks		Demand Shocks		Supply Shocks	
	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)
CES Production ( $\rho = 0.67$ )	-5.35	45.16	-8.64	72.84	-0.05	3.30	-1.90	131.40
	[-5.39, -5.32]	[44.89, 45.43]	[-8.70, -8.57]	[72.26, 73.42]	[-0.05, -0.05]	[3.14, 3.46]	[-1.88, -1.92]	[130.22, 132.59]
CES Production ( $\rho = 0.1$ )	-5.52	46.53	-9.15	77.19	-0.05	3.37	-1.93	133.84
	[-5.56, -5.48]	[46.19, 46.86]	[-9.21, -9.09]	[76.69, 77.70]	[-0.05, -0.05]	[3.21, 3.54]	[-1.92, -1.95]	[132.56, 135.12]
International Capital Flow	-5.38	45.35	-5.40	45.56	-0.05	3.29	-1.84	127.10
	[-5.40, -5.36]	[45.18, 45.53]	[-5.44, -5.36]	[45.24, 45.89]	[-0.05, -0.05]	[3.13, 3.45]	[-1.82, -1.85]	[126.12, 128.08]
Entry and Exit	-5.71	48.15	-10.78	90.95	-0.03	2.02	-1.89	130.56
	[-5.84, -5.58]	[47.04, 49.25]	[-11.26, -10.31]	[86.94, 94.98]	[-0.03, -0.03]	[1.78, 2.25]	[-1.87, -1.90]	[129.66, 131.46]

*Notes:* This table presents the impact of demand and supply shocks on global trade relative to GDP and on global GDP in different extensions of the MNE model: (a) CES production functions with  $\rho = 0.67$ , (b) CES production functions with  $\rho = 0.1$ , (c) international capital flows and risk sharing, and (d) firm entry and exit. The “Percent” variable indicates the percentage change in trade relative to GDP and in GDP, compared to 2008 levels. The “Share” variable denotes the proportion of the decrease in trade/GDP among total losses during the Great Recession. Numbers in hard brackets represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

Table Appendix D.6: **Impact of Removing Demand or Supply Shocks on Trade and GDP in Baseline MNE Model, Trade Only Model, and Model without MNE Sourcing and Selling Efficiencies**

	Global Trade Relative to GDP				Global GDP			
	No Demand Shocks		No Supply Shocks		No Demand Shocks		No Supply Shocks	
	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)
Baseline MNE Model	2.16 [2.11, 2.21]	18.22 [17.80, 18.63]	7.24 [7.02, 7.46]	61.07 [59.25, 62.90]	0.07 [0.06, 0.07]	4.56 [4.36, 4.76]	1.89 [1.87, 1.91]	130.82 [129.28, 132.37]
Trade Only Model	3.82 [3.79, 3.85]	32.22 [31.95, 32.49]	1.00 [0.98, 1.01]	8.39 [8.26, 8.53]	0.08 [0.08, 0.08]	5.65 [5.46, 5.83]	1.39 [1.39, 1.40]	96.39 [96.24, 96.55]
Without Sourcing and Selling Efficiencies	2.11 [2.08, 2.13]	17.78 [17.57, 17.99]	0.89 [0.88, 0.90]	7.49 [7.39, 7.60]	0.10 [0.09, 0.10]	6.68 [6.41, 6.96]	1.35 [1.35, 1.36]	93.61 [93.36, 93.86]

*Notes:* This table presents the impact of removing demand or supply shocks on global trade relative to GDP and on global GDP in the baseline MNE model, the trade only model, and the model without MNE sourcing and selling efficiencies. The “Percent” variable indicates the percentage increase in trade relative to GDP and in GDP, compared to 2009 levels. The “Share” variable denotes the proportion of the increase in trade/GDP that recovers the losses during the Great Recession. Numbers in hard brackets represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

Table Appendix D.7: **Impact of Removing Demand or Supply Shocks on Trade and GDP in Extended MNE Models**

	Global Trade Relative to GDP				Global GDP			
	No Demand Shocks		No Supply Shocks		No Demand Shocks		No Supply Shocks	
	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)
CES Production ( $\rho = 0.67$ )	2.32 [2.27, 2.38]	19.58 [19.12, 20.04]	6.81 [6.68, 6.95]	57.46 [56.33, 58.58]	0.04 [0.04, 0.05]	3.11 [2.95, 3.28]	1.93 [1.91, 1.96]	133.82 [132.18, 135.47]
CES Production ( $\rho = 0.1$ )	3.40 [3.32, 3.48]	28.71 [28.04, 29.38]	6.17 [6.12, 6.23]	52.06 [51.60, 52.52]	-0.01 [-0.01, -0.01]	-0.53 [-0.72, -0.35]	1.91 [1.89, 1.93]	132.12 [130.54, 133.70]
International Capital Flow	3.95 [3.90, 3.99]	33.29 [32.92, 33.65]	7.05 [6.81, 7.30]	59.48 [57.42, 61.53]	0.10 [0.09, 0.10]	6.67 [6.36, 6.97]	1.89 [1.87, 1.92]	130.99 [129.40, 132.58]
Entry and Exit	6.22 [5.56, 6.87]	52.44 [46.87, 57.97]	13.28 [13.07, 13.49]	112.01 [110.25, 113.76]	0.04 [0.03, 0.04]	2.71 [2.42, 2.99]	1.94 [1.94, 1.95]	134.44 [133.93, 134.96]

*Notes:* This table presents the impact of demand and supply shocks on global trade relative to GDP and on global GDP in different extensions of the MNE model: (a) CES production functions with  $\rho = 0.67$ , (b) CES production functions with  $\rho = 0.1$ , (c) international capital flows and risk sharing, and (d) firm entry and exit. The “Percent” variable indicates the percentage increase in trade relative to GDP and in GDP, compared to 2009 levels. The “Share” variable denotes the proportion of the increase in trade/GDP that recovers the losses during the Great Recession. Numbers in hard brackets represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

Table Appendix D.8: **Impact of Different Shocks on Global Trade, MP, and GDP in Baseline MNE Model**

	Global Trade Relative to GDP		Global MP Relative to GDP		Global GDP	
	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)
Demand Shock	-5.18 [-5.21, -5.15]	43.68 [43.43, 43.94]	-3.75 [-3.78, -3.73]	41.20 [40.97, 41.43]	-0.07 [-0.06, -0.07]	4.54 [4.35, 4.73]
Domestic Productivity Shock	-5.11 [-5.20, -5.03]	43.10 [42.39, 43.82]	-6.64 [-6.77, -6.50]	72.84 [71.37, 74.31]	-1.02 [-0.98, -1.06]	70.39 [67.74, 73.04]
Labor Supply Shock	-2.33 [-2.35, -2.31]	19.64 [19.47, 19.80]	-0.87 [-0.92, -0.82]	9.57 [9.01, 10.13]	0.32 [0.34, 0.31]	-22.43 [-23.74, -21.13]
MNE Productivity Shock	-6.08 [-6.16, -5.99]	51.25 [50.56, 51.94]	-6.93 [-7.02, -6.85]	37.29 [36.84, 37.75]	-0.96 [-0.93, -0.99]	66.54 [64.45, 68.62]

*Notes:* This table presents the impact of different shocks on global trade relative to GDP, global MP relative to GDP, and global GDP in the baseline MNE model. The “Percent” variable indicates the percentage change in trade relative to GDP and in GDP, compared to 2008 levels. The “Share” variable denotes the proportion of the decrease in trade/GDP among total losses during the Great Recession. Numbers in hard brackets represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .



Table Appendix D.9: **Impact of Domestic Productivity and MNE Relative Productivity Shocks on Global Trade, MP, and GDP in Extended MNE Models**

	Global Trade Relative to GDP		Global MP Relative to GDP		Global GDP	
	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)
<b>Domestic Productivity Shocks</b>						
CES Production ( $\rho = 0.67$ )	-5.46 [-5.51, -5.42]	46.09 [45.71, 46.48]	-16.28 [-16.37, -16.19]	87.59 [87.12, 88.07]	-1.02 [-0.98, -1.06]	70.59 [67.85, 73.33]
CES Production ( $\rho = 0.1$ )	-5.64 [-5.70, -5.58]	47.56 [47.07, 48.04]	-16.12 [-16.21, -16.04]	86.77 [86.30, 87.24]	-1.03 [-0.99, -1.07]	71.21 [68.37, 74.04]
International Capital Flow	-3.36 [-3.38, -3.34]	28.36 [28.20, 28.53]	-14.77 [-14.84, -14.71]	79.50 [79.14, 79.87]	-0.99 [-0.95, -1.02]	68.42 [65.93, 70.90]
Entry and Exit	-8.44 [-8.97, -7.92]	71.20 [66.77, 75.66]	-18.39 [-19.49, -17.29]	98.94 [93.06, 104.90]	-0.86 [-0.84, -0.87]	59.40 [58.43, 60.37]
Without Sourcing and Selling Efficiencies	-4.05 [-4.09, -4.02]	34.19 [33.87, 34.50]	-15.78 [-15.85, -15.71]	84.91 [84.52, 85.31]	-1.30 [-1.26, -1.35]	90.23 [86.99, 93.47]
<b>Productivity Shocks Affecting MNEs Relative to Domestic Firms</b>						
CES Production ( $\rho = 0.67$ )	-6.40 [-6.49, -6.31]	53.97 [53.18, 54.76]	-7.65 [-7.69, -7.61]	41.17 [40.94, 41.39]	-0.92 [-0.90, -0.95]	63.88 [62.05, 65.71]
CES Production ( $\rho = 0.1$ )	-6.77 [-6.87, -6.67]	57.11 [56.28, 57.94]	-8.63 [-8.65, -8.61]	46.43 [46.31, 46.56]	-0.88 [-0.86, -0.90]	60.93 [59.37, 62.48]
International Capital Flow	-5.50 [-5.53, -5.46]	46.37 [46.07, 46.68]	-6.84 [-6.92, -6.75]	36.80 [36.35, 37.25]	-0.97 [-0.94, -1.00]	67.35 [65.16, 69.54]
Entry and Exit	-4.89 [-5.02, -4.77]	41.28 [40.20, 42.36]	-14.94 [-17.48, -12.46]	80.40 [67.06, 94.07]	-1.03 [-1.01, -1.05]	71.39 [69.99, 72.78]
Without Sourcing and Selling Efficiencies	-1.53 [-1.55, -1.51]	12.89 [12.70, 13.08]	-13.03 [-13.08, -12.98]	70.12 [69.87, 70.36]	-0.33 [-0.32, -0.35]	23.16 [22.21, 24.11]

*Notes:* This table presents the impact of domestic productivity shocks and MNE relative productivity shocks on global trade relative to GDP, global MP relative to GDP, and global GDP in the baseline MNE model. The “Percent” variable indicates the percentage change in trade relative to GDP and in GDP, compared to 2008 levels. The “Share” variable denotes the proportion of the decrease in trade/GDP among total losses during the Great Recession. Numbers in hard brackets represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

Table Appendix D.10: **Impact of Demand and Supply Policies on Trade and GDP in Baseline MNE Model and Trade Only Model**

	Global Trade Relative to GDP				Global GDP			
	Baseline MNE Model		Trade Only Model		Baseline MNE Model		Trade Only Model	
	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)
Demand Policies	2.65 [2.56, 2.73]	22.31 [21.58, 23.05]	3.49 [3.46, 3.51]	29.40 [29.19, 29.62]	0.42 [0.41, 0.43]	29.33 [28.67, 30.00]	0.21 [0.21, 0.21]	14.49 [14.25, 14.73]
Supply Policies	6.29 [6.09, 6.49]	53.07 [51.36, 54.78]	2.53 [2.50, 2.56]	21.37 [21.12, 21.61]	1.75 [1.73, 1.77]	121.05 [119.80, 122.30]	0.90 [0.86, 0.95]	62.59 [59.73, 65.46]

*Notes:* This table presents the impact of demand and supply policies (as defined in Section 5.1) on global trade relative to GDP and on global GDP in the MNE model and the trade only model. The “Percent” variable indicates the percentage increase in trade relative to GDP and in GDP, compared to 2009 levels. The “Share” variable denotes the proportion of the increase in trade/GDP that recovers the losses during the Great Recession. Numbers in hard brackets represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

Table Appendix D.11: **Impact of Demand and Supply Policies on Trade and GDP in Extended MNE Models**

	Global Trade Relative to GDP				Global GDP			
	Demand Policies		Supply Policies		Demand Policies		Supply Policies	
	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)	Percent (%)	Share (%)
CES Production ( $\rho = 0.67$ )	2.74 [2.65, 2.82]	23.10 [22.38, 23.82]	5.70 [5.56, 5.84]	48.10 [46.93, 49.27]	0.40 [0.39, 0.41]	27.72 [27.00, 28.44]	1.74 [1.72, 1.75]	120.06 [118.80, 121.32]
CES Production ( $\rho = 0.1$ )	3.71 [3.61, 3.80]	31.28 [30.47, 32.09]	5.50 [5.43, 5.57]	46.40 [45.80, 47.00]	0.35 [0.34, 0.36]	24.22 [23.31, 25.13]	1.71 [1.69, 1.73]	118.40 [117.19, 119.60]
International Capital Flow	4.09 [4.02, 4.16]	34.46 [33.87, 35.06]	6.05 [5.83, 6.27]	51.02 [49.17, 52.87]	0.47 [0.46, 0.48]	32.48 [32.02, 32.94]	1.76 [1.74, 1.78]	121.63 [120.31, 122.95]
Entry and Exit	7.16 [6.46, 7.85]	60.40 [54.52, 66.23]	12.11 [11.92, 12.29]	102.12 [100.56, 103.68]	0.37 [0.36, 0.37]	25.42 [24.93, 25.91]	1.79 [1.78, 1.79]	123.61 [123.33, 123.88]
Without Sourcing and Selling Efficiencies	1.92 [1.90, 1.95]	16.22 [16.03, 16.41]	2.38 [2.37, 2.38]	20.04 [19.96, 20.11]	0.37 [0.37, 0.38]	25.94 [25.37, 26.52]	1.68 [1.67, 1.70]	116.50 [115.27, 117.73]

*Notes:* This table presents the impact of demand and supply policies (as defined in Section 5.1) on global trade relative to GDP and on global GDP in different extensions of the MNE model: (a) CES production functions with  $\rho = 0.67$ , (b) CES production functions with  $\rho = 0.1$ , (c) international capital flows and risk sharing, (d) firm entry and exit, and (e) without MNE sourcing and selling efficiencies. The “Percent” variable indicates the percentage increase in trade relative to GDP and in GDP, compared to 2009 levels. The “Share” variable denotes the proportion of the increase in trade/GDP that recovers the losses during the Great Recession. Numbers in hard brackets represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

Table Appendix D.12: **Impact of MNE Policies on Trade and GDP in Baseline MNE Model, Trade Only Model, and Model without MNE Sourcing and Selling Efficiencies**

	Global Trade Relative to GDP		Global GDP	
	Percent (%)	Share (%)	Percent (%)	Share (%)
Baseline MNE Model	5.23 [5.03, 5.43]	44.11 [42.46, 45.77]	1.29 [1.28, 1.29]	88.98 [88.85, 89.10]
Trade Only Model	1.68 [1.66, 1.70]	14.15 [13.99, 14.31]	0.48 [0.46, 0.51]	33.38 [31.77, 35.00]
Without Sourcing and Selling Efficiencies	1.33 [1.32, 1.34]	11.24 [11.17, 11.30]	1.08 [1.08, 1.09]	74.89 [74.58, 75.20]

*Notes:* This table presents the impact of MNE policies (as defined in Section 5.1) on global trade relative to GDP and on global GDP in the baseline MNE model, the trade only model, and the model without MNE sourcing and selling efficiencies. The “Percent” variable indicates the percentage increase in trade relative to GDP and in GDP, compared to 2009 levels. The “Share” variable denotes the proportion of the increase in trade/GDP that recovers the losses during the Great Recession. Numbers in hard brackets represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

Table Appendix D.13: **Impact of MNE Policies on Trade and GDP in Extended MNE Models**

	MNE Policies			
	Global Trade Relative to GDP		Global GDP	
	Percent (%)	Share (%)	Percent (%)	Share (%)
CES Production ( $\rho = 0.67$ )	4.69 [4.55, 4.83]	39.52 [38.34, 40.71]	1.27 [1.27, 1.27]	87.92 [87.85, 87.99]
CES Production ( $\rho = 0.1$ )	4.54 [4.46, 4.61]	38.25 [37.60, 38.91]	1.24 [1.24, 1.24]	85.51 [85.45, 85.56]
International Capital Flow	5.50 [5.30, 5.70]	46.41 [44.70, 48.11]	1.31 [1.31, 1.31]	90.63 [90.38, 90.89]
Entry and Exit	10.94 [10.50, 11.37]	92.24 [88.54, 95.91]	1.47 [1.46, 1.48]	101.57 [101.04, 102.10]

*Notes:* This table presents the impact of MNE policies (as defined in Section 5.1) on global trade relative to GDP and on global GDP in different extensions of the MNE model: (a) CES production functions with  $\rho = 0.67$ , (b) CES production functions with  $\rho = 0.1$ , (c) international capital flows and risk sharing, and (d) firm entry and exit. The “Percent” variable indicates the percentage increase in trade relative to GDP and in GDP, compared to 2009 levels. The “Share” variable denotes the proportion of the increase in trade/GDP that recovers the losses during the Great Recession. Numbers in hard brackets represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

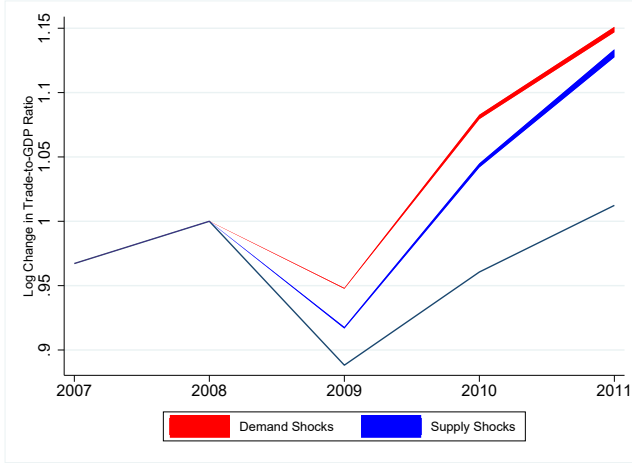
Table Appendix D.14: **Impact of MP-Propagated Top 10 Global HQ Domestic Productivity Shocks on GDP, MP, and Trade in Other Countries**

	GDP (%)	MP (%)	Trade (%)
Top 10 HQ Domestic Productivity Propagated through MP	29.07 [13.28, 44.85]	18.67 [15.07, 22.27]	5.41 [2.91, 7.90]
Top 10 HQ Domestic Productivity	0.15 [-0.06, 0.36]	-2.49 [-2.78, -2.19]	-0.99 [-4.02, 2.04]
Top 10 HQ Final Demand	0.18 [0.07, 0.29]	-0.44 [-0.73, -0.15]	-1.07 [-3.92, 1.77]

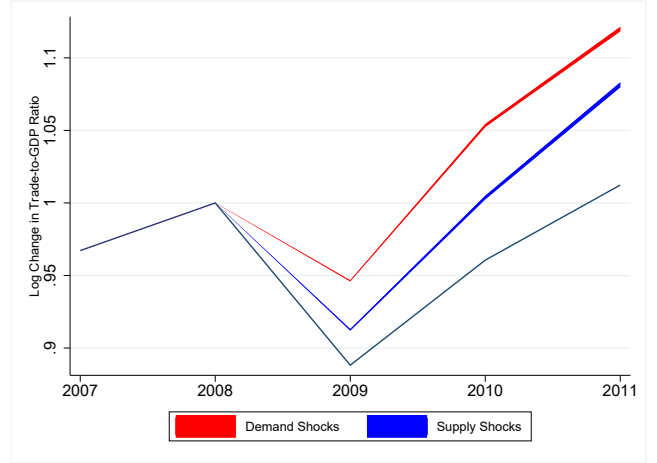
*Notes:* This table shows the impact of top 10 global MP headquarters’ shocks on cross-country variations in GDP change, MP-to-GDP ratio change, and trade-to-GDP ratio change during the Great Recession among other countries. These shocks include: (1) domestic productivity shocks propagating through MP; (2) domestic productivity shocks (direct); and (3) final demand shocks. Numbers represent the percentage of cross-country variation explained by each shock category. Numbers in hard brackets represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

Figure Appendix D.1: MP Model Concludes that Supply Shocks Contributed More to the Trade Collapse than Demand Shocks: Extended Models

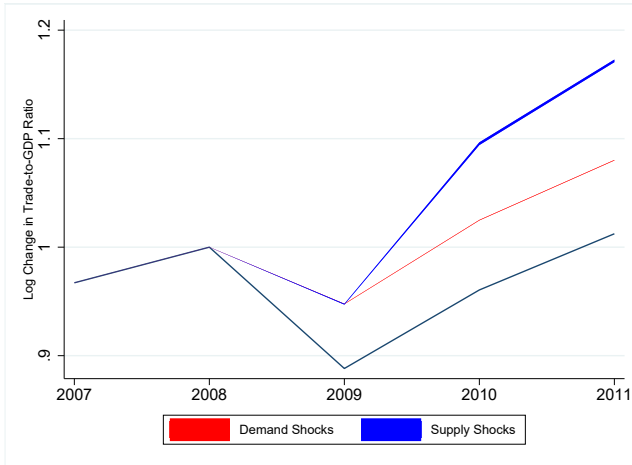
(a) CES Production Function,  $\rho = 0.67$



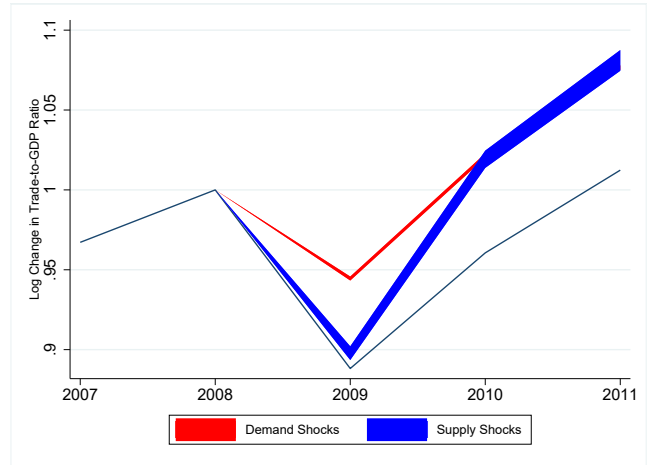
(b) CES Production Function,  $\rho = 0.1$



(c) International Capital Flows

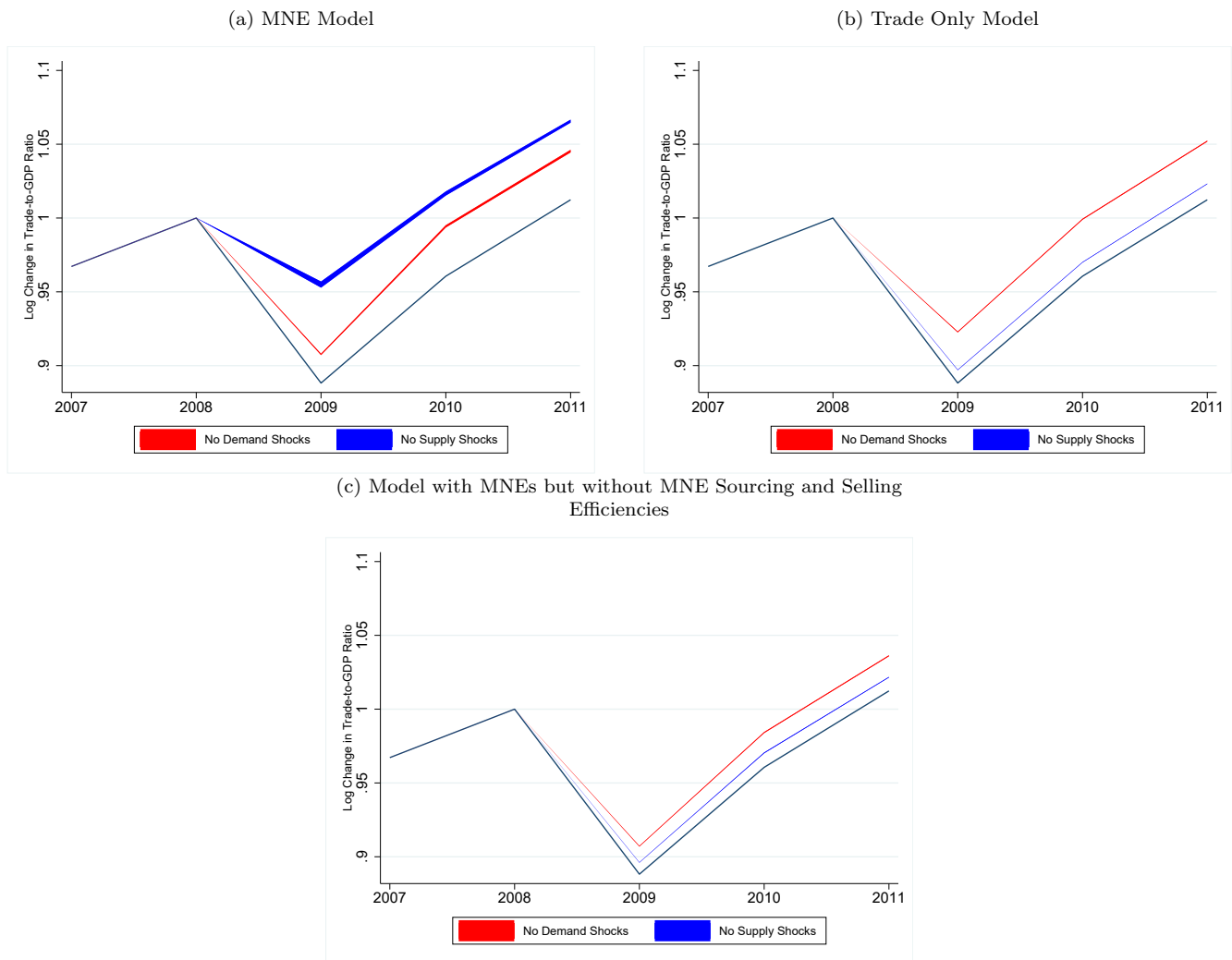


(d) Entry and Exit



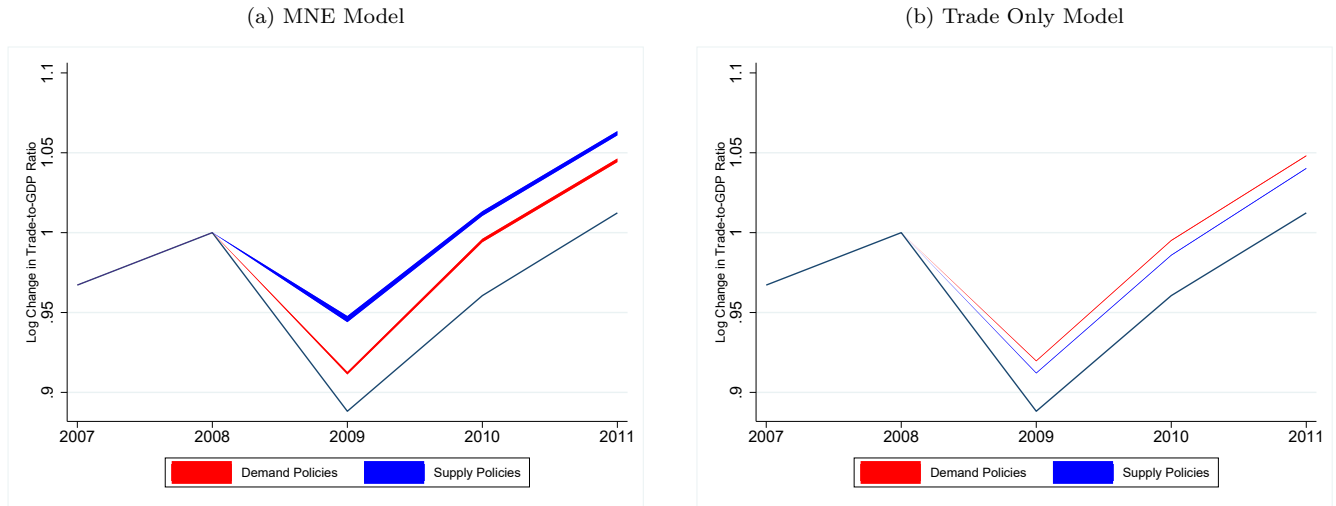
Notes: This figure shows demand and supply shock impacts on trade collapse across extended MP model specifications, including: (a) CES production functions with  $\rho = 0.67$ , (b) CES production functions with  $\rho = 0.1$ , (c) international capital flows and risk sharing, and (d) firm entry and exit. The area represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

Figure Appendix D.2: **MP Model Concludes that Removing Supply Shocks Lead to Greater Trade Recovery than Demand Shocks**



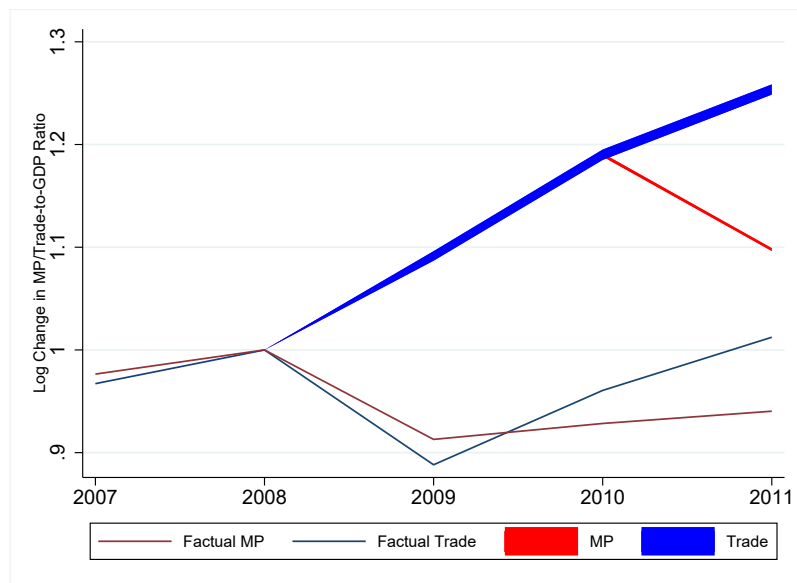
*Notes:* This figure shows the impact of removing demand or supply shocks on the trade collapse in different models: (a) the baseline model with MP, (b) the model with only trade but no MP, and (c) MP model without sourcing and selling efficiencies. The area represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

Figure Appendix D.3: **MP Model Concludes that Policies Targeting Supply Lead to Greater Trade Recovery than Demand Shocks**



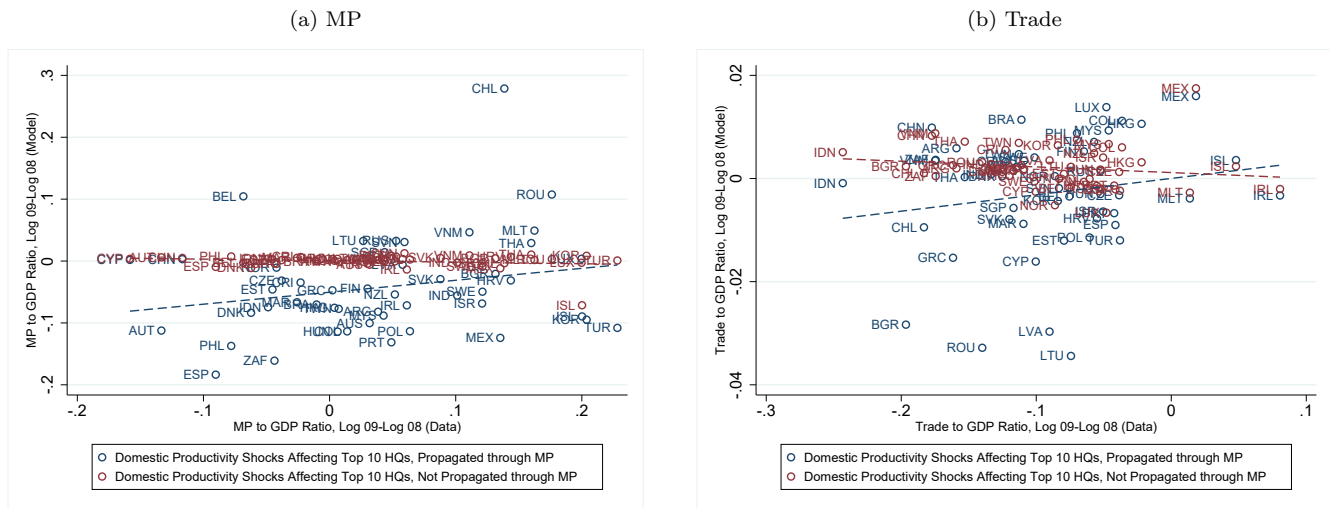
*Notes:* This figure shows the impact of supply and demand policies on the trade collapse in different models: (a) the baseline model with MP and (b) the model with only trade but no MP. The area represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

Figure Appendix D.4: **Impact of Shocks to MNE Sourcing and Selling Efficiencies on Trade and MP during the Great Recession**



*Notes:* This figure shows the impact of shocks to MNE sourcing and selling efficiencies on the trade and MP collapse. The area represent 95% confidence intervals, computed from 300 independent draws from the distributions of externally calibrated parameters:  $\sigma$  and  $\zeta$ .

Figure Appendix D.5: **Propagation through MP Linkages Amplified the Effect of Top Headquarters' Domestic Productivity Shocks on Other Countries' MP and Trade**



*Notes:* This figure shows the impact of top 10 headquarters' domestic productivity shocks on MP/trade-to-GDP ratio growth across other countries during the Great Recession under two scenarios: (1) propagation through both MP and trade; and (2) propagation solely through trade. Actual data is presented on the horizontal axis, while model-simulated outcomes for each scenario appear on the vertical axis. The dashed line is the fitted regression line. These results reflect the baseline calibration. Their confidence intervals are presented in Table Appendix D.14.