Multinational Production and Sectoral Productivity Differences *

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Abstract

This paper first assembles a unique industry-level dataset of bilateral foreign affiliate sales to document a new empirical regularity: multinational production is disproportionately allocated to industries where local producers are relatively less productive. Then, it shows analytically and quantitatively that multinational production raises country's average productivity, while significantly reducing the relative productivity differences across sectors within a country. To measure these channels, this paper incorporates sectoral heterogeneity into a Ricardian general equilibrium model of trade and multinational production. The model is estimated to measure the extent of technology transfers across countries and sectors as well as to quantify the welfare effects of multinational activity. The heterogeneity of foreign affiliate sales across sectors is quantitatively important in accounting for welfare gains from multinational activity. In particular, gains from multinational production are 15 percentage points higher compared with a counterfactual scenario in which relative productivity is homogeneous across sectors. Furthermore, as a consequence of the impact of multinational production on relative productivity differences, gains from trade are about half of what they would be without sectoral heterogeneity in multinational activity (10 percent rather than 19 percent).

Keywords: Multinational Production; Technology Transfer; Sectoral TFP; Welfare

JEL Classification Numbers: F11, F14, F23, O33.

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1 Introduction

Multinational production (MP) as a fraction of total output is highly heterogeneous across sectors within a country as well as across countries within a sector. For instance, while in United Kingdom multinationals account for less than 25 percent of total output in the Metals sector, more than 62 percent of total production in the Transportation and Equipment sector is produced by companies of foreign parents. Furthermore, the sectoral heterogeneity of MP also varies significantly across countries. In France, as opposed to the pattern described for United Kingdom, 45 percent of output in the Metals sector and 27 percent of output in the Transportation and Equipment sector are produced by foreign affiliates. In spite of the significant heterogeneity observed in multinational production (MP) at the sectoral level, most of existing literature uses aggregated MP data and unisectoral frameworks, neglecting therefore the potential role of relative productivity differences across sectors in explaining the observed allocation and welfare implications of multinational activity.

To examine the interaction between multinational production and productivity at the sectoral level, this paper assembles a novel dataset of bilateral foreign affiliate sales that, for the first time, incorporates the sectoral dimension into a multi-country framework. Using this unique dataset of MP sales for thirty-four countries, nine tradable sectors, and one non-tradable sector, this paper establishes a new empirical regularity: multinational production is disproportionately allocated to industries where local producers are relatively less productive. Building on this fact, this paper shows that productivity differences across sectors plays a crucial role in determining the sectoral allocation of multinational production, with less-productive sectors receiving the largest fraction of MP relative to output.

Multinational production, unlike trade, entails a direct transfer of technology across countries, which increases productivity in the host economy.[1] By incorporating a sectoral dimension into the analysis of multinational activity, this paper shows, both analytically and quantitatively, that MP raises country's average productivity while significantly reduces the relative differences in productivity across sectors. The welfare implications of the interaction between sectoral productivity and multinational production are significant. This paper shows that by omitting the heterogeneity of MP activity across sectors, and therefore its impact on sectoral productivity differences, existing uni-sectoral models of trade and MP systematically overstates the gains from trade and understate the gains from MP. Thus, distinguishing between the absolute and relative impact of MP on productivity is essential to improve our understanding, including the quantification, of the consequences of multinational production.

[1] Recent empirical literature has shown a positive and significant impact of foreign affiliate activity on host country aggregate productivity. By opening a subsidiary abroad—greenfield—or by acquiring an existing company in the target market, multinational production activity brings innovation in products and processes through adoption of new machinery and organizational practices, improving the overall level of technology in the host economy. See [e.g., Guadalupe et al., 2012, Alfaro and Chen, 2013, Chen and Moore, 2010, Arnold and Javorcik, 2009]. Also see [Harrison and Rodríguez-Clare, 2011] for recent overviews of the literature on the relationship between multinational production, productivity, and economic growth.

This paper addresses three questions. The first is whether the observed uneven allocation of MP across sectors is significantly related to differences in sectoral productivity. The second question is whether multinational activity affects the average productivity of each industry differently. Third, the paper evaluates analytically and quantitatively, the welfare implications of the interaction between MP and relative differences in sectoral productivity.

To this aim, this paper assembles a novel dataset that provides detailed information on production and employment of foreign affiliates in each host country, distinguishing the sector of operation and the source country where the parent firm is located. Using this data containing information of thirty-four countries, nine tradable sectors, and one non-tradable sector for the period 2002–2010, we established four stylized facts about MP activity at the sectoral level: (i) for each source-host country pair, the MP share on output is significantly heterogeneous across sectors; (ii) there are significant cross-country differences in the sectoral heterogeneity of multinational production; (iii) sectoral heterogeneity of MP shares remains even after aggregating foreign affiliate sales across all source countries for each host-sector pair; and (iv) MP as a share of output is higher in industries where local producers are relatively less productive.

To capture these stylized facts, analytically and quantitatively, we incorporate differing productivity levels across industries into a benchmark Ricardian general equilibrium model of trade and multinational production developed by [Ramondo and Rodríguez-Clare, 2013] (henceforth RRC). Additionally, the model of this paper features asymmetric MP and trade barriers; multiple factors of production (labor and capital); differences in factor and intermediate input intensities across sectors; a realistic input-output matrix between sectors; inter- and intra-sectoral trade; and a non-tradable sector. By combining these features into a unified framework, this paper offers the first set of productivity estimates at the sectoral level for local producers as well as for the entire economy. The total factor productivity at the sectoral level calculated directly from data does not distinguish between the productivity corresponding to local producers from the productivity corresponding to all producers in the economy, regardless of its ownership structure. Because the presence of multinational firms implies a transfer of technology into the host market, we proceeded to disentangle the productivity corresponding to local producers from the overall sectoral productivity. Breaking down the productivity by its ownership structure allows us to evaluate the extent to which sectoral differences in local producers' productivity determine the uneven allocation of foreign affiliate sales across sectors, and also allows us to measure the extent and sectoral heterogeneity of the technology transfer implied by multinational activity.

The analytical results and quantitative estimations reveal that the effect of multinational production on the state of technology is higher in those sectors in which local producers are relatively less productive. Four analytical predictions emerge from the model. The first two highlight the channels of interaction between sectoral productivity differences and MP patterns in any equilibrium. The other two are concerned with the general equilibrium responses of aggregate trade flows and welfare in a counterfactual scenario where the MP-to-output ratios are homogeneous across sectors. The four analytical predictions are: (1) relative sectoral differences in *local* producers' productivity determine the sectoral allocation of MP in the host economy; (2) sectors with a larger MP share will have higher productivity increases due to multinational activity; (3) any deviation from homogeneous MP shares across sectors—holding aggregate MP volumes relative to output constant—leads to larger gains from MP than what is implied by uni-sectoral models; (4) gains from trade are lower than they would be if MP were to affect productivity in all sectors homogeneously.

The assembled dataset is then used to quantitatively estimate the parameters of the model and also to test the model's analytical predictions. In particular, for each country-sector pair, we extract the productivity of local producers and show that, compared with all producers in the economy, local producers have a larger dispersion of relative productivity across sectors. This implies that the comparative advantage of all producers in the economy—both local and foreign firms—is weaker than the comparative advantage corresponding exclusively to local producers. These differences are explained by the larger presence of MP in sectors where local producers in the host economy are relatively less productive. As a result, the productivity enhancement due to MP is uneven and biased toward sectors in which local firms exhibit comparative disadvantage. These results are robust to potential selection effects, wherein the least productive firms exit because of the higher competition imposed by foreign firms; and they are also robust to the presence of knowledge spillovers through which local producers can benefit from the superior technology used by their foreign counterparts.[2]

Three counterfactual exercises are conducted to explore quantitatively the impact of MP on welfare, based on the estimated parameters. First, we show that the heterogeneity of foreign affiliate sales across sectors is quantitatively important in accounting for welfare gains associated with MP. In particular, these gains are 15 percentage points higher compared with a scenario of homogeneous multinational production. Second, we calculate the consequences for trade flows and welfare when we allow multinational activity to affect only the average productivity of the host economy, while keeping relative productivity differences intact. Results show that the gains from trade are nearly twice as large as in the benchmark estimation, where MP changes both absolute and relative productivity—19 percent compared with 10 percent. Consequently, recognizing that sectoral differences in MP allocation affect the relative differences in productivity across sectors in the host country is crucial for understanding the apparently modest gains from trade found in the literature. Finally, we evaluate the role of MP in the production of non-tradables and its potential effects on the competitiveness of tradable sectors. Results show that welfare increases by 4.6 percent, and the price index of tradables decreases by 1.6 percent, when we allow foreign affiliates to operate in the non-tradable sector.

This paper contributes to a voluminous body of research on economic growth and international

[2]Technology transfer and technology diffusion are used interchangeably. Note that these are different from knowledge spillovers, a term we reserve for the process by which domestic firms learn from foreign affiliates operating in the same market.

technology diffusion [e.g., Alvarez et al., 2011, Chaney, 2012, Rodríguez-Clare, 2007, Li, 2011]. In these models, international technology transfer is a mechanism that explains economic growth, but most of them leave unspecified the channels through which this type of diffusion takes place. An exception is [Li, 2011], who assesses the impact of trade on knowledge by using data on payments for international trade in royalties, license fees, and information-intensive services for a sample of thirty-one countries. This paper differs from previous research in that it uses multinational bilateral sales at the sectoral level to measure quantitatively the extent of technology transfer associated with MP. In particular, for this exercise a dataset is assembled for a sample of thirty-five countries and ten sectors for the period 2003–2007.

This paper is also closely related to previous efforts to quantify the impact of multinational production in a general equilibrium framework. [Ramondo and Rodríguez-Clare, 2013] develop a general equilibrium model of trade and multinational production under perfect competition to measure the gains from openness associated with the interaction of trade and MP, and it is the benchmark used as our reference. Using a similar framework, [Shikher, 2012] measures the extent of technology diffusion across countries. [Arkolakis et al., 2013] develop a quantitative multi-country general equilibrium model of monopolistic competition in which the location of innovation and production is endogenous and geographically separable. There are important differences between the present work and those papers, however. First, they use a uni-sectoral framework, and therefore by design they are silent with respect to how multinational production affects relative technology differences across sectors in the host economy. This gap is filled by estimating a multi-sector general equilibrium model of trade and multinational production, which offers a set of productivity estimates at the sectoral level for local producers exclusively as well as for the entire economy. A second difference in this paper is that it aims to provide more reliable estimates of local producers' productivity and allows for asymmetries in multinational production barriers at the industry level.[3]

An important way in which this paper contributes to the literature pertains to welfare gains from trade. [e.g., Caliendo and Parro, 2012, Costinot et al., 2012, Levchenko and Zhang, 2012, Hsieh and Ossa, 2011] incorporate sectoral heterogeneity, intermediate input usage, and sectoral linkages in order to understand the contributions of these components to the welfare increase associated with a reduction in trade barriers. To highlight the interaction between multinational activity and a country's comparative advantage, this paper extends the structure of these models by expanding the firm's set of choices to allow the possibility of serving a country through multinational production.

Finally, this paper joins in the debate on whether the primary motive for MP is (1) to satisfy final demand—*horizontal MP* [Ramondo et al., 2013, Bernard et al., 2009, 2011, Guadalupe et al.,

[3]Previous literature uses measures of effective labor and the fraction of workers in the R&D sector to estimate a country's productivity. This could potentially be a misleading indicator given that an important fraction of the private R&D in developed countries is conducted by foreign affiliates. Instead, this paper uses a gravity equation derived from a sectoral model of trade and multinational production to estimate jointly the technology parameters, as well as trade and MP barriers, for every country-sector pair in the sample.

2012, e.g.,], or (2) to take advantage of international differences in factor prices by producing intermediate inputs that will be used by the parent firm or by another affiliate in a third country in later stages of the production process—*vertical MP* [Antras and Helpman, 2004, Alfaro and Chen, 2013, e.g.,]. The existence of a negative and significant relationship between sectoral MP sales and total factor productivity is consistent with a horizontal view of MP activity where foreign affiliates compete with local producers to satisfy the host market.

The remainder of the paper is organized as follows. Section 2 discusses the pattern of multinational production at the sectoral level. Section 3 lays out the theoretical framework and derives analytical results on the impact of sectoral dispersion in MP on gains from trade and gains from multinational activity. Section 4 sets up the quantitative framework and estimates the parameters of the model. Section 5 presents the results and discusses the effect of MP on comparative advantage. Section 6 measures the welfare gains of multinational activity. Section 7 concludes.

2 Empirical Facts: Sectoral MP and Relative Productivity

This section uses a unique industry-level dataset of bilateral foreign affiliates sales to establish some key regularities about the patterns of multinationals at the sectoral level. First, it shows that MP as a fraction of total output is sizable but also significantly heterogeneous across sectors within a country. More importantly, it shows that, there are substantial cross-country differences in the heterogeneity of MP shares across sectors. This is, the share of MP on output is not only significantly different across sectors within a country, but the pattern of sectoral heterogeneity varies substantially across countries. Second, this section documents that relative differences in sectoral productivity are closely related to the observe allocation of MP across sectors. In particular it shows that (i) within a source-host country pair, the fraction of output produced by foreign firms in a given sector is inversely related to the relative differences in productivity between host and source country; and (ii) within a host country, sectors where the fraction of output produced by firms of foreign countries is relatively higher, on average, are also those with lower relative productivity.

2.1 Data Description

This paper assembles a dataset of foreign affiliate sales and employment which adds a sectoral dimension to the aggregate bilateral data used in previous work, as discussed in the introduction. In particular, it records the activity of foreign affiliates in each host country distinguishing the sector of operation and the source country where the parent firm is located.[4] This dataset enables

[4]In contrast to bilateral trade data, which is available for many countries at different levels of sectoral disaggregation, there is no systematic dataset of bilateral MP sales broken down by sectors.[5] An exception is [Fukui and Lakatos, 2012], which is also an attempt to introduce a sectoral dimension to bilateral data on foreign affiliate sales. The methodology used in constructing the dataset for the present paper differs substantially

the breakdown of domestic production and employment into their corresponding foreign and domestic components at the sectoral level. Each observation in the dataset is a source-host-sector triplet, averaged over the period 2002–2010; containing information for thirty-four countries, nine tradable sectors, and four non-tradable sectors.[6]

The main source of information is unpublished OECD data, drawn from the International Direct Investment Statistics and the Statistics on Measuring Globalisation. For European countries that do not belong to the OECD, information is drawn from the Foreign Affiliates Statistics provided by Eurostat.[7] Finally UNCTAD, and ORBIS datasets were used to improve the quality and coverage of the information to ensure that the aggregated values of multinational activity calculated from our three-dimensional dataset are consistent with more aggregated information, such as, (i) the total manufacturing sales of foreign affiliates in each source-host country pair and (ii) the sales of foreign affiliates from all source countries in each host country-sector pair.

The dataset includes information for majority-owned foreign affiliates, that is, those in which fifty percent or more of the control is exerted by a parent firms located in a foreign country.[8] After all quality controls have been applied, we get positive MP values for 5,139 source-host-sector relationships from a potential of about 11,220 triplet, in tradable and non-tradable sectors. Section B.2 in the Appendix provides detailed information about the construction and validation of the dataset used in this paper.

2.2 Relevance of Multinational Production

We adopt the foreign affiliate sales in each source-host-sector triplet as well as the sum of multinational sales across all foreign countries for each host country-sector pair, as measures of the relevance of multinational activity in the economy. To account for differences in the sector size across countries, we normalize MP sales by the total output of host market h in sector j. Let I^j_{hs} denote the sales of source country s in location h in sector j; and I^j_h denote the production in sector j in country h regardless producer's nationality. Then, the relative importance of the production carried by foreign affiliates from source country s operating in host country h and

from theirs in the primary sources of information used and the methods implemented.

[6]The nine tradable sectors are all manufactures: food and beverage; textiles; wood and paper; chemical products, mineral products; fabricated metals; machinery and equipment; transportation equipment; and furniture and recycling. The non-tradable sectors are electricity and construction; wholesale, retail trade, restaurants and hotels; transport, storage, and communication and other services. Agriculture; mining; and the finance, insurance and real estate sectors are in our sample but were excluded from the analysis. For proposes of the analysis the four non-tradable categories are consolidated in one aggregated non-tradable sector.

[7]See table A.1 in the Appendix for the list of countries in the sample.

[8]A country secures control over a corporation by owning more than half of the voting shares or otherwise controlling more than half of the shareholders' voting power.

sector j, is given by the bilateral MP share:[9]

$$MP\text{share}_h^j = \sum_{s \neq h} \frac{I_{hs}^j}{I_h^j} = \frac{\sum_{s \neq h} I_{hs}^j}{I_h^j}$$

Table 1 presents summary statistics on the share of MP for countries in the sample. All 34 countries serve simultaneously as source and host countries in tradables and non-tradable sectors. Out of 1,122 potential source-host country pairs, there are 789 and 903 pairs with positive bilateral MP relationships, for tradables and non-tradables respectively. With nine tradable sectors there are 4,236 source-host-sector triplet (out of 10,098), where a positive fraction of the output is produced by foreign owned firms. Moreover, the median host country in the sample receives foreign production from 23 source countries and keeps operations in 27 host markets. However, there is significant variation across countries. The United Kingdom, Germany, and the United States have affiliates in most foreign markets and they host operations for many source countries, whereas Japan, and New Zealand and Switzerland host MP operations from 17, 18 and 9 source countries respectively (see Table A.2 in the Appendix)

The presence of multinational production across countries is patently visible. The third column of the bottom panel of Table 1 shows that, for the median host country, affiliates of foreign parents account for 34 percent of production in tradables and 37 percent in non-tradables.[10] There is an important variation in the presence of MP across countries, though. To observe this, the second and fourth columns in Table A.2 show the share of MP over output for each country, as a host and as a source, respectively. For some economies, such as Austria, Canada, Poland, and the United Kingdom, the presence of multinational firms is significant, with more than 35 percent of the output carried out by foreign affiliates. In contrast, Japan is an important source of MP for the rest of the world, accounting for 13 percent of total Japanese production; but the relative importance of foreign multinational corporations in Japan is rather limited, where foreign affiliates' production reached less than 3 percent of country's total output.[11] cou

[9]Note that MP does not include the production of domestic multinationals. It considers only the output being produced by foreign affiliates of multinational parents based abroad.

[10]As revealed by the input-output tables, the non-tradable sector is an important component of the set of intermediate inputs used by all industries. On average, 40 percent of the intermediate inputs used by an industry are from the non-tradable sector, implying that the effect of multinational production on the technology of non-tradables could have a sizable impact on the structure of prices in all sectors of the economy. Section 6.4 provides an analysis of what would happen in a scenario where multinational production in the non-tradable sector is prohibitively costly.

[11]Notice that Japan is the second largest economy in our sample. Therefore is more likely that multinationals don't produce a substantial fraction of country's output. Nevertheless, the market share of foreign firms is 2 percent, which is 5 percentage points lower than for United States.

Table 1: Summary statistics

	All sample		Median country	
	Tradable	*Non-tradable*	*Tradable*	*Non-tradable*
$MP_{sh}^{j} > 0$				
Source countries	34	34	23	28
Host countries	34	34	27	28
Source-host pairs	789	903	–	–
Source-host-sector tuples	4,236	903	148†	–
Sectors	9	4	9	3
MP/output	0.24	0.17	0.34	0.37
Food, beverages	0.19		0.27	
Textiles	0.10		0.19	
Wood and paper products	0.12		0.25	
All chemical products	0.26		0.33	
Non-metallic mineral products	0.29		0.37	
Basic and fabricated metal products	0.16		0.26	
Machinery and equipment	0.20		0.31	
Transportation equipment	0.34		0.37	
Furniture, recycling	0.15		0.21	
Non-tradables		0.17		0.37

Note: The top panel of this table shows statistics of the number of source countries, host countries, source-host pairs and source-host-sector triplet; for the world—comprised of all 34 countries in the sample- (first and second column) and for the median country (third and fourth columns). The bottom panel show the share of MP on output in each sector for the pooled of host countries in the sample as well as for the median host country. MP represents the foreign affiliate sales from all source countries in a given host-sector pair. † Shows the number of source-sector pairs for the average host country in the sample.

2.3 Cross-Country Differences in the Sectoral Heterogeneity of Multinational Production

Foreign sales aggregated across source countries exhibit substantial heterogeneity among sectors within a country. Panel (a) in Figure 1 shows the relevance of MP, measured by total MP over output, for each country in the sample; while panel (b) depicts the sectoral composition of MP normalized by each sector's production, for six selected host countries and nine manufacturing sectors. One way to explore the extent of sectoral MP heterogeneity is by comparing the sectors for which the share of MP on sectoral output is the highest and sectors for which this value is the lowest. For example, in the United Kingdom, the share of output produced by foreign affiliates in the Transport Equipment sector is four times higher than in Textiles; while in Finland, the fraction of output in hands of foreign multinationals in 11 times higher in the Minerals than in Wood and Paper sector.

The level of heterogeneity of MP shares across sectors is, in fact, sizable. Nonetheless, it is possible that such heterogeneity is mostly being driven by sector specific characteristics that are common across countries, and therefore not related to specific country-sector fundamentals, such as sectoral productivity differences across countries. For this reason, we proceed to explore a second level of heterogeneity by assessing the extent at which there are significant cross country differences in the degree of heterogeneity of MP shares across sectors. Thus, not only we are interested in the differences in MP shares across sectors within a country, but also how this heterogeneity differs across countries.

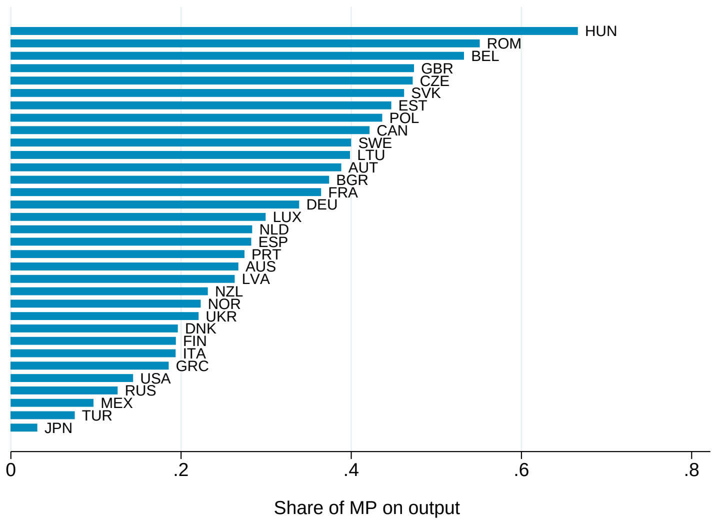
This goal can be attained by comparing the sectoral pattern of MP shares of each country to the one corresponding to the world economy, which will be used as our reference group.[12] To measure the extent of a country's sectoral MP share heterogeneity relative to the world, we then calculate the Krugman specialization index, which takes the value of zero if the pattern of MP shares across sectors in a given country resembles the structure of the world economy; and takes the maximum of $2(J-1)/J = 1.78$ if the heterogeneity of sectoral MP has no sectors in common with the world average. Figure A.3 in the Appendix shows the value of the Krugman index for all countries in the sample. Interestingly enough, United Kingdom figures among the five countries with the lowest Krugman Index, even when, as we observed, in panel (b) in Figure 1, it shows a substantial heterogeneity on MP shares across sectors. Conversely, despite of the relatively small differences observed in its sectoral MP shares, France shows a substantially higher Krugman index. This is explained by the fact that the sectoral heterogeneity in MP shares observed in United Kingdom although more pronounced, is more similar to the sectoral heterogeneity of the world economy compared to France.

Figure 2 shows for six selected economies and nine tradable sectors, the difference between the

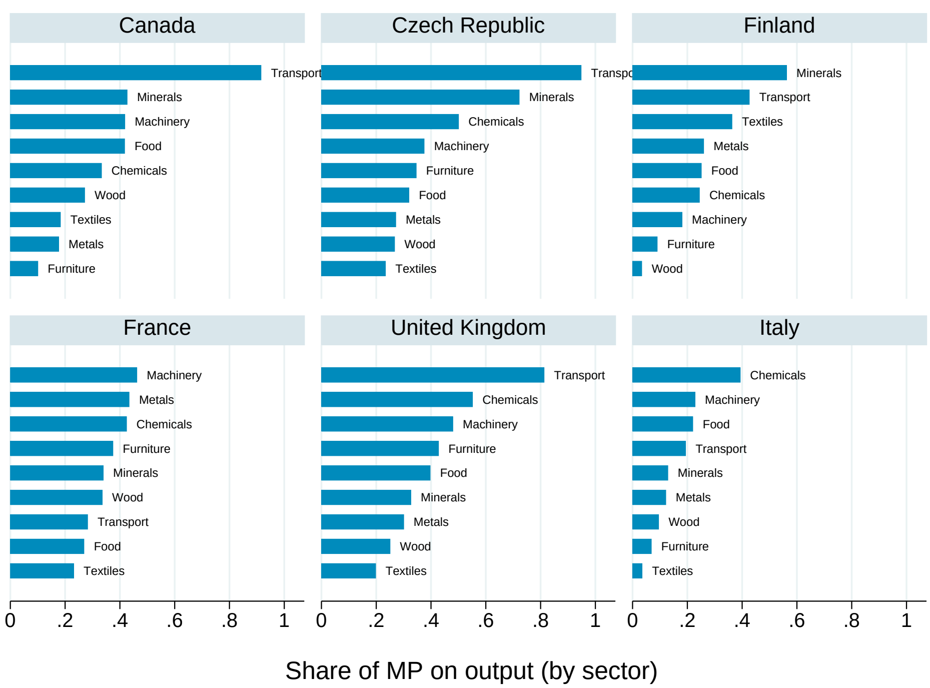
[12] The benchmark is sectoral differences in MP shares observed for the world, which is comprised of the 34 countries in our sample.

Figure 1: Relevance of multinational production (MP/output) and sectoral heterogeneity

(a) Share of MP on output



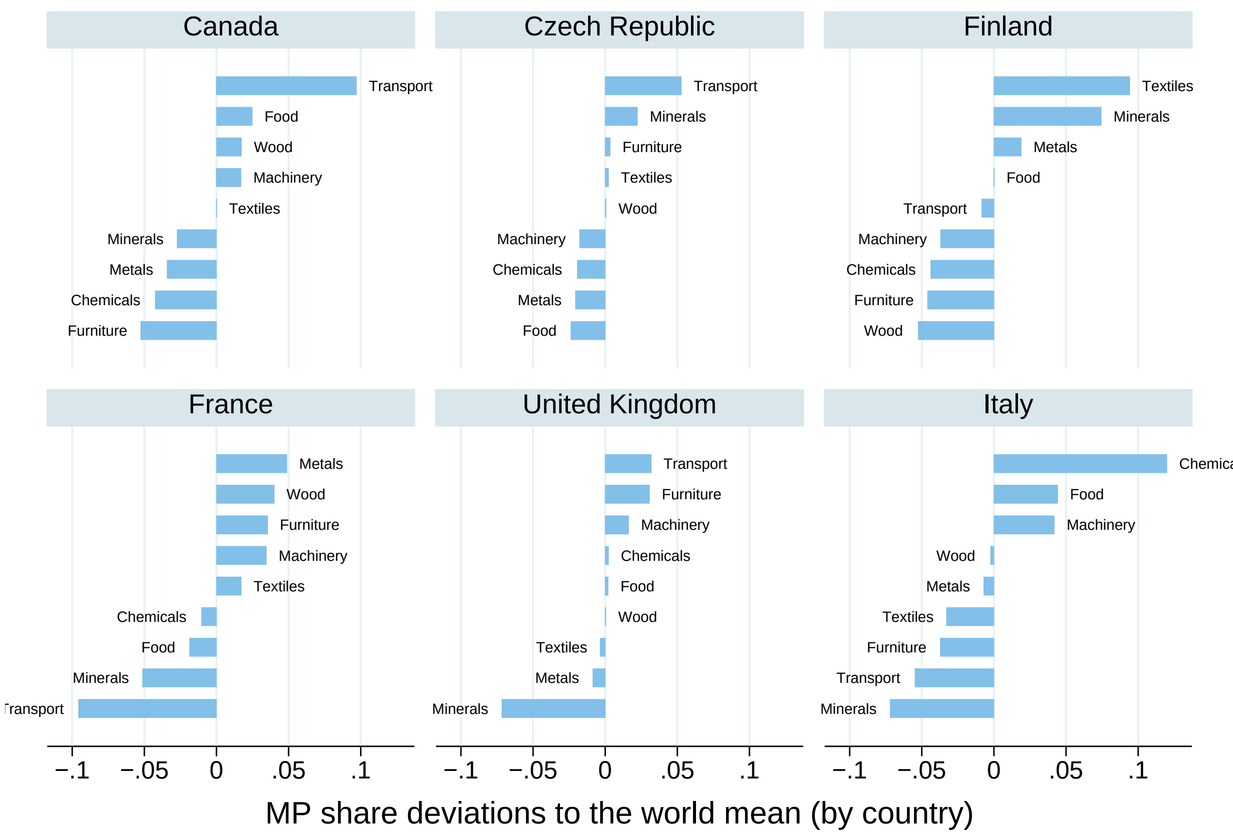
(b) Sectoral heterogeneity of Share of MP on output



Notes: Figure (a) shows the fraction of output produced by affiliates of foreign parents in each country ($MP/output$) for tradables sectors only. Figure (b) shows the fraction of output in sector j produce by affiliates of foreign parents $(MP/output)_j^h$ for a group selected countries and nine manufacturing sectors.

normalized share of MP on output in each country and its counterpart for the world economy.[13] Sector for which this measure takes positive (negative) values are those in which the country host proportionally more (less) foreign production relative to the world average. In Canada, foreign multinational firms in the Transport Equipment sector are relative more important as a fraction of output, compared to the world benchmark in that sector. Conversely the presence of foreign affiliates in the Chemicals sectors is lower than the world average. This situation is reverse for Italy, country for which the production of foreign affiliates in the Transport Equipment sector is relatively low compared with world average, but relatively high in Chemicals. This differences across countries within a sector are depicted in Figure A.4 in the Appendix, which shows for four selected sectors, which countries host foreign multinationals proportionally more and which ones receive much less relative to the rest of the world.

Figure 2: Cross-country differences in the heterogeneity of sectoral MP shares (selected countries)



Notes: This figure shows per sector and country, the difference between the normalized share of MP on output in country h and the world economy $\left(\frac{(MP/output)_h^j}{\sum_{j=1}^J (MP/output)_h^j} - \frac{(MP/output)_{world}^j}{\sum_{j=1}^J (MP/world)_h^j}\right)$. Positive values of this measure reveal those sector in which the economy host more foreign production than the world average, and negative values reveal the sectors in which the country host less multinational activity compared to country average. See 1 for a detail explanation of the construction of this index.

[13]The Krugman index of a country is calculated by the summing the absolute values of each bar across sectors

2.4 Sectoral MP and Relative Productivity: A Negative Relationship

The observed heterogeneity of MP among sectors does not follow a random pattern. Instead, this section documents that relative differences in sectoral productivity are negative correlated to the observe allocation of MP shares across sectors. In particular, it shows that (i) within a source-host country pair, the fraction of output produced by foreign firms in a given sector is inversely related to the differences in sectoral productivity between host and source country; and (ii) within a host country, the fraction of output produced by firms of foreign countries is relatively higher, on average, in sectors with lower relative productivity.

In our baseline regressions, we study the relationship between bilateral MP from source country s, in host country h and industry j, and sectoral productivity differences. We specify the relationship as:

$$ln\left(\frac{MP^j_{hs}}{output^j_h}\right) = ln\left(\frac{I^j_{hs}}{I^j_h}\right) = \alpha_s + \alpha_h + \alpha_j + \beta \times ln\left(\frac{TFP^j_h}{TFP^j_s}\right) + \delta X_{s,h} + \epsilon_{i,s,h}$$

where $MP^j_{hs}/output^j_h$ is the output produced by affiliates from source country s in host country h in sector j relative to total production of country h in sector j; $ln(TFP^j_h/TFP^j_s)$ measure the percentage productivity difference between host country h in sector j and source country s in the same sector; and $X_{s,h}$ includes a set of bilateral specific variables that proxy for trade cost and Hecksher-Ohlin forces. The effects of market size in providing incentives for sourcing and hosting multinational activity are absorbed in the source and host fixed effects α_h, α_s in our regressions. The main estimates are obtained by Poisson Pseudo Maximum Likelihood due to the fact that half of the source-host-sector triplets are zeros, which made OLS estimates to be biased.

Table 2 shows our baseline estimates using four different measures of relative productivity. Standard errors clustered by source-host pair are reported in parenthesis. The first, third and fifth columns report estimates using source country, host country and sector fixed effects, along with a set gravity bilateral variables such as: log of distance between source and host country, existence of common border, whether countries share common language, whether they had colonial ties and whether they are part of a regional trade agreement. Finally, all specifications control for Hecksher Ohlin forces, as captured by the interaction between host country h factor endowments $ln(K/L)_h$ and sector j factor intensities $ln(K/L)^j$. The specification in the second, forth and sixth columns replaces the source and host fixed effects by a $source{\times}host$ country fixed effect to further control for factors that are specific to the bilateral relationship and that are not captured by any of the bilateral gravity variables.

The relative productivity measures used in column (1) and (2) is the productivity estimates from a Ricardian trade model ([Costinot et al., 2012]); column (3) and (4) uses the new reveal comparative advantage index (RCA) from the CEPII database.[14] Finally, columns (5) and (6)

[14]The RCA index is available for Austria, Canada, Germany, Spain, France, U.K. Italy, Japan, Mexico, Nether-

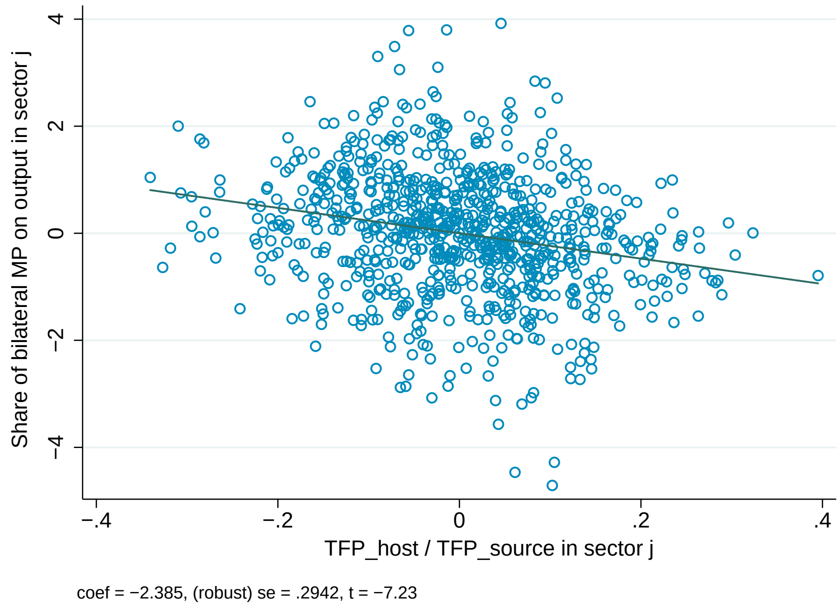
Table 2: Relationship Between Bilateral Sectoral MP and Relative Productivity

Dep. Variable $ln\left(MP^j_{hs}/output^j_h\right)$	Relative Productivity Measures: Model Base Productivity		RCA Index		GDDC productivity	
	(1)	(2)	(3)	(4)	(5)	(6)
$ln\left(TFP^j_h/TFP^j_s\right)$	–1.872***	–1.657***	–1.359***	–1.387***	–0.428**	–0.392**
	(0.3260)	(0.3304)	(0.4376)	(0.4464)	(0.2023)	(0.1709)
ln(Distance)	–0.5130***		–0.168		–0.161	
	(0.0926)		(0.1923)		(0.1572)	
Common Language	0.077		0.6093**		0.0692	
	(0.1996)		(0.297)		(0.2164)	
Colony	0.643***		0.2961		0.5254***	
	(0.1496)		(0.2768)		(0.1703)	
Border	0.188		0.225		0.666***	
	(0.1819)		(0.2094)		(0.2411)	
RTA	0.259		0.300		0.865***	
	(0.1832)		(0.3604)		(0.2495)	
Hecksher-Ohlin:						
$log(K/L)^j \times log(K/L)_h$	–0.2676	–0.258	–0.1529	–0.1612	–0.163	–0.168
	(0.2502)	(0.2518)	(0.1756)	(0.1767)	(0.1432)	(0.1449)
Controls						
Source-country FE	Yes	–	Yes	–	Yes	–
Host-country FE	Yes	–	Yes	–	Yes	–
Host-source FE	No	Yes	No	Yes	No	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	10,098	7,101	1,404	1,242	2,448	2,200
Adjusted R^2	0.29	0.42	0.59	0.69	0.34	0.47

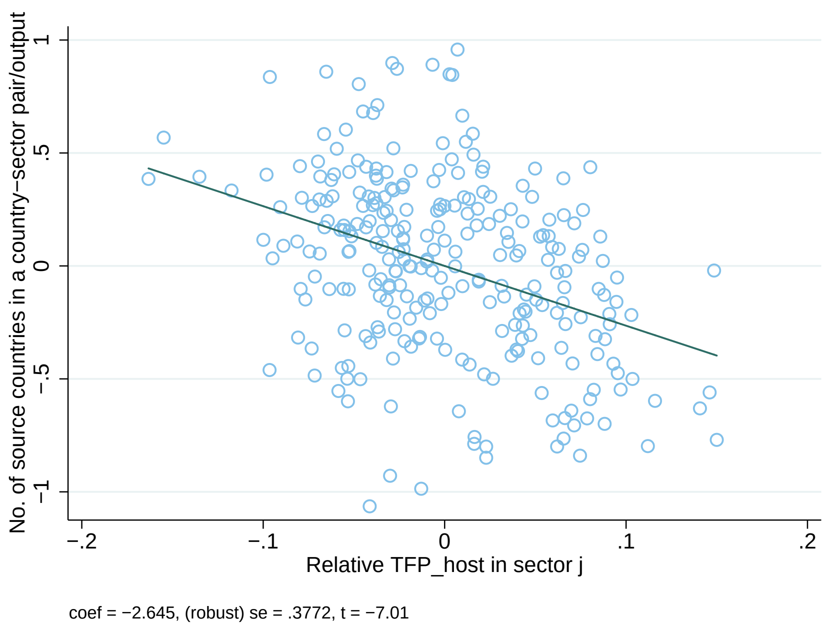
Notes: This table presents the results of the Poisson Pseudo Maximum Likelihood between the share of MP for each source-host-sector triplet ($MP\text{share}^j_{hs}$) and the ratio of productivities (TFP_h/TFP_s) for different specifications and productivity measures. Column (1), (3) and (5) report results with source, location and sector fixed effects, while columns (2), (4) and (6) report results with source-location and sector fixed effects. The relative productivity measure used in column (1) and (2) is the productivity estimates from a Ricardian trade model (Costinot, et al (2012); column (3) and (4) uses the new reveal comparative advantage index (RCA) at the CEPII database (available for Austria, Canada, Germany, Spain, France, U.K. Italy, Japan, Mexico, Netherlands, Russia, Turkey and U.S.). Finally, columns (5) and (6) use the multi-factor productivity provided by GGDC Productivity Level Database available for eighteen OECD economies. To correct for trade-driven selection, observed relative productivity indexes (RCA and GGDC) were multiplied by the relative openness between any two pairs of countries $\left(\pi^j_{ii}/\pi^j_{i'i'}\right)^{1/\theta}$, with $\theta = 4$. Robust standard errors, clustered by source-location pair are reported in parentheses. ***, ** and * denote significance at 1%, 5%, and 10% level.

Figure 3: Sectoral MP and relative productivity

(a) Bilateral sectoral MP and relative productivity differences



(b) No. of source countries in country-sector pair as a fraction of sectoral output and relative productivity



Notes: the top panel figure displays the partial correlation of $ln(MPshare_h^j)$ against the ratio of productivities $ln(TFP_h^j/TFP_s^j)$, after netting out source host country and sector effects. It also controls for gravity bilateral variables: log of distance between source and host country, the existence of common border, whether countries share common language, whether they had colonial ties and whether they are part of a regional trade agreement. Finally it controls for Hecksher Ohlin forces, as captured by the interaction between host country h factor endowments $ln(K/L)_h$ and sector j factor intensities $ln(K/L)^j$. MP share is measured as the output produce by affiliates from source country s in host country h in sector j relative to total production of country h in sector j. Productivity is measured by the new reveal comparative advantage index (RCA) from the CEPII dataset after correcting for openness. The figure in the bottom panel displays the partial correlation of the number of source countries producing in sector j and country h (normalized by the output of country h in sector j against relative productivity $ln(TFP_h^j)$ (all same controls applied).

use the relative multi-factor productivity provided by *GGDC* Productivity Level Database and available for eighteen OECD economies. To correct for trade-driven selection, observed productivity indexes (*RCA* and *GGDC*) were multiplied by a factor of relative openness between any two pair of countries.[15][16]

In all six baseline regressions, we obtain a negative coefficient on the relative difference of productivity between host and source countries, and it is statistically significant at the 5% level of higher. These findings suggest that differences in sectoral productivity between the host and source countries are negatively associated with the bilateral share of sectoral MP after controlling for the fixed attributes of a source country that makes it more or less suitable for investing abroad, the fixed attributes of the host country that make it more or less attractive to receive foreign investment and finally the specific characteristics of each sector. Under the specification with separate host and source fixed effect, we find that the geographic distance carries a negative sign in all of our regressions and that common language, colony ties, common border and regional trade agreement has a positive effect on bilateral MP at the sectoral level.[17] Panel (a) in Figure 3 shows the correlation between the share of bilateral MP on output in sector j and the relative differences in productivity between the source and host country, after netting out all the effects exert by the included covariates. The negative and significant relationship between relative productivity and the cross-sector variation of MP shares constitutes preliminary evidence supporting the predictions that emerge from the model presented in next section.

To check the robustness of the negative relationship found between MP and relative productivity, we perform a set of robustness checks, allowing for different specifications, estimation methods, levels of aggregation, and alternative measures of multinational activity and sectoral productivity. Tables A.3 shows the results obtained by ordinary least square where the zeros are ignored. As expected, the coefficient on relative productivity are larger in magnitude and significant at the 1% level for all specifications and productivity measures.[18] Tables A.4 shows the robustness of our result, when bilateral MP is normalized by the output produced by local firms only.[19] Fi-

lands, Russia, Turkey and U.S.

[15]Relative openness is measured by the ratio of domestic absorption of host and source country $\left(X^j_{ss}/X^j_{hh}\right)$, where X^j_{ss} is the local production used to satisfy the local demand, measured as the difference between output and exports in sector j. The factor correction requires this ration being to the power of the inverse of the trade elasticity, which has been set equal 4 in the baseline estimates.

[16]Note that, as we move to the right of the table, the number of source-host-sector observations changes. This is due to differences in the country coverage of different productivity measured used in the analysis.

[17]This results are opposite to the ones predicted by a canonical model of horizontal MP, where foreign production and trade are substitutes. The literature has rationalized the gravity of MP by allowing for trade in intermediate inputs from parents to their affiliates overseas and also assuming that services from headquarters are required as input in production by foreign affiliates.

[18]To avoid cases where few observations could influence the sign and significance of our results, for the potential presence of outliers or observation with significant leverage, each set of regression is performed excluding one of the countries at the time, and also excluding one of the sectors at the time. All regressions were also calculated by dropping those observations that were identified as highly leverage or highly influential, measure by the difference between the regression coefficient for a the relative technology calculated for all of the data and the regression coefficient calculated with the observation deleted. Observations for which this difference was above $2/sqrt(n)$ were deleted of the sample. In all cases, the sign and significance of the results remain unchanged.

[19]In the baseline regressions bilateral MP is normalized by the total production of sector j, which includes the

nally, we also test the negative relationship between MP and relative productivity at the sectoral level using an alternative aggregation of MP activity. For each host-sector pair, we aggregate the foreign production from all source countries in the sample and normalize it by the total output of country h in sector j (see Table A.5). The negative coefficient on the productivity of country h in sector j relative to a reference country[20] suggests that the share of multinational activity is higher in sectors in which local producers exhibit relative low productivity. Panel (a) and panel (b) in Figure A.5 in the Appendix depict the conditional correlation normalizing sectoral MP by total output and by production corresponding to local producers, respectively. Finally, we test the relationship between MP and relative productivity using a similar level of aggregation, but measuring the extent of MP activity by the number of source countries investing in a given host-sector pair instead of using aggregate foreign sales. Panel (b) in Figure 3 depicts the conditional correlation of MP and relative productivity when the number of source countries normalized by the size of the sector in the host country, is used as an alternative measure of multinational activity. Another potential concern is the extent to which the size of foreign affiliate sales in a given host country might be influenced by the tax strategies followed by the parent firm (Hines 2003). Results could be biased, for instance, in cases where the tax regime is host-sector–specific and therefore not controlled by the set of fixed effects included in our specifications. To alleviate this concern, we use the share of employment as an alternative measure of MP activity, since it is less subject to manipulation for tax reasons. The results are also robust to this definition of MP activity (regression table to be included in the appendix).

Although the mechanism highlighted in this paper is based on a horizontal perspective of multinational activity, both horizontal and vertical MP sales coexist in reality[21] Even when is not possible to disentangle horizontal from vertical MP, it is possible to make some inferences based on the commercial international transactions of multinationals.[22] A rough way to distinguish between vertical and foreign MP sales is by analyzing the destination markets of the foreign affiliates production. In particular, the share of foreign affiliate's output sold back to the source country, where the headquarters is located, is likely to be vertical MP sales.[23] It is even possible that sales

production by local suppliers as well as by foreign affiliates.

[20]the reference country used in this estimations is the productivity of U.S. in the nine tradable sectors. Results for all specifications are remarkable similar, if instead we normalize the productivity of a country sector pair relative to the world frontier.

[21]*Horizontal MP* refers to a forms of multinational activity in which the foreign production is used as an alternative to trade to serve foreign markets. By contrast under *vertical MP* firms don't seek to produce overseas to be closer their final consumers but instead to produce intermediate inputs at a lower cost.

[22]There are some necessary observations to be made in this regard. First, more than two-thirds of foreign affiliate sales occur in the host market (Ramondo et al. (2012)). Second most countries in our sample are middle- and high-income OECD and European countries, which makes the vertical hypothesis less appealing. Third, even when the observed MP sales are indeed a reflection of both horizontal and vertical multinational production, if the majority of MP sales were vertical, we would expect either none or a positive correlation between MP and sectoral productivity instead. This is, foreign affiliates that are vertically integrated will likely benefit from operating in sectors where local producers are relatively more productive; it would be the case if foreign firms can use specialized workers from the comparative advantage industry, which increases productivity and lowers the cost of production of intermediate inputs.

[23]Note that this is not always the case, given that an MP-horizontal firm could produce abroad and ship the final goods back home to satisfy final demand rather than selling to their parent or another related party firm. This

to a third country are not meant to satisfy final consumers—using the host economy as an export platform—but to continue a following stage of the production process within the firm. Therefore, subtracting foreign affiliate exports from total MP sales in a given country-sector pair gives us the part of MP sales that take place in the host market, which are likely driven by an horizontal motive. Unfortunately, while the dataset assembled in this paper has information on sales, employment, and number of affiliates per source-host-sector triplet, it does not have information on international trade transactions—exports and imports—by foreign affiliate firms. Nonetheless, to address concerns about the influence of vertical MP on the relationship between productivity and MP activity, we explore the correlation between MP sales and sectoral productivity using Bureau of Economic Analysis (BEA) data for U.S. multinationals operating abroad. The BEA dataset contains information about foreign affiliate sales, value added, imports, and exports, from which we can construct domestic sales of foreign U.S. affiliates abroad,[24] which allow us to explore the mechanism highlighted in this paper in a cleaner way. Figure A.6 (and Figure A.7) are consistent with our previous results: foreign affiliate sales as a share of output are relatively higher in sectors where the host economies have lower relative productivity.

3 Model

In order to illustrate the mechanism of the model analytically, this section presents a two-country, two-sector model of trade and multinational production. In Section 4, the model is generalized to make it quantitatively informative by including asymmetric MP barriers; multiple factors of production (labor and capital); differences in factor and intermediate input intensities across sectors; a realistic input-output matrix between sectors; inter- and intra-sectoral trade; and a non-tradable sector.

Allowing countries to interact through trade and MP in a multi-sectoral environment has important analytical and quantitative implications compared with the benchmark, a uni-sectoral MP-trade model developed by [Ramondo and Rodríguez-Clare, 2013]. Those implications can be summarized in the following four analytical predictions: (1) relative sectoral differences in *local* producers' productivity determine the sectoral allocation of MP in the host economy; (2) sectors with a larger MP share will have higher productivity increases due to multinational activity; (3) gains from trade are lower than they would be if MP were to affect productivity in all sectors homogeneously; and (4) any deviation from homogeneous MP shares across sectors—holding aggregate MP volumes relative to output constant—leads to larger gains from MP than what is implied by uni-sectoral models.

scenario can take place if the cost of the input bundle is low enough that the gains from reduction in input cost more than compensate for the transportation cost from the host market to the source country.

[24] Domestic sales are a conservative measure of the multinational production conducted by U.S. foreign affiliates with horizontal motives. This is, domestic sales of foreign affiliates likely underestimate horizontal MP, given that part of affiliate exports are meant to satisfy final demand in other markets, using the host country as an export platform.

3.1 A Simple Model: Environment

Consider an economy with two countries, and labor as the only factor of production. There are two sectors $j = \{a, b\}$, and each has an infinite number of varieties produced with constant returns to scale, indexed by ω. In every country and sector, each variety is produced by many firms engaging in perfect competition. Both sectors are subject to international trade and MP barriers.

Let s denote the source country of the technology, h the host country, and m the destination market. In order to serve any given market at the lowest possible price, a firm in sector j chooses between (1) producing at home s and exporting to the destination market m; (2) building up an affiliate at the destination market m to produce and sell locally (h=m); or (3) setting a foreign affiliate in a third country ($h \neq m$) used as an export platform, to ship goods to the final destination m.[25] A firm that chooses to produce at home to serve country m uses its technology to full extent, but faces a transportation cost of exporting (d^j_{ms}). A firm that chooses to produce at the destination market instead (h=m) completely avoids the transportation cost of exporting but suffers a loss in productivity when implementing its technology in a foreign country (g^j_{hs}). In addition, if the foreign affiliate uses a third country h to produce and export to country m, it also faces the transportation cost associated with exporting from h to m (d^j_{mh}).

Technology: Each source country s has a technology to produce each variety ω, at home and abroad. Let $z^j_{hs}(\omega)$ denote the number of units of the ωth variety in sector j that can be produced with one unit of labor by a firm from a source country s that is located in host country $h = \{1, 2\}$.

The technology of each country s in sector j ($\mathbf{z^j_s}$), is described by a vector in which each element represents the source country's productivity in each host country h (z^j_{hs}).

$$\mathbf{z^j_s}\left(\omega\right) \equiv \left\{z^j_{1s}\left(\omega\right), z^j_{2s}\left(\omega\right)\right\} \quad \forall i, j = \{1, 2\}. \tag{1}$$

Then, the productivity of a source country s in sector j ($\mathbf{z^j_s}$) is drawn independently across goods, countries, and sectors from a multivariate Frechet distribution.[26].

$$F^j_s(\mathbf{z}) = exp\left\{-T^j_s\left[(z^j_{1s})^{-\theta} + (z^j_{2s})^{-\theta}\right]\right\}. \tag{2}$$

Equation (2) states that productivities across locations are related in two ways. First, they are drawn from a distribution with the same location parameter, or mean productivity (T^j_s): a higher T^j_s leads to a larger productivity draw on average, at home and abroad. Note that regardless of

[25] Note that, without symmetry, an export platform can exist even in a two-country setting. A country may find it profitable to produce abroad to satisfy the home market if factor prices are low enough overseas. This pattern of production does not reflect vertical MP; in this case, the purpose of producing in a foreign country is to produce final goods rather than intermediate inputs.

[26] Note that whenever $z^j_{hs}\left(\omega\right) = 0$ for $s \neq i$ $\forall \omega \in \{0, 1\}$ and $\forall j = 1, 2$, then the model collapses to a multi-sector general equilibrium model of international trade without multinational production [e.g., Caliendo and Parro, 2012, Levchenko and Zhang, 2012]

the location of production, the mean productivity that matters is the productivity of the source country s. Second, the stochastic component of the productivity is governed by the dispersion parameter θ, which is assumed to be common across countries and sectors and reflects idiosyncratic differences in technology know-how across varieties in any given sector j. The larger is θ, the lower is the dispersion of productivities within a sector. Finally, albeit productivities across locations are drawn from a distribution with the same mean (T_s^j) and variance (θ), productivities are assumed to be independent across host countries.[27]

Therefore, productivity differences in this model are characterized by: (1) differences in relative productivity across industries $\left(T_s^1/T_s^2\right)$—or Ricardian comparative advantage at the industry level; and (2) intra-industry heterogeneity governed by θ. In this stochastic model, a higher T_1^a ($T_1^a > T_2^a$) captures the idea that country 1 is relatively better at producing z_{h1}^a goods in any host country h—including its own market. This does not imply, however, that country 1 should only produce varieties from sector a in any given location h, but instead that it should produce relatively more of these goods. Whatever the magnitude of T_1^a, country 2 may still have lower labor requirements for some varieties.

Production: In providing variety ω in sector j to any country m, country s's firms have two strategies available to them, from which they will choose the most cost-efficient one. These strategies are:

(1) *Exporting from home country*: A firm can use its technology to produce at home and export to market m, in which case the source of technology and the location of production are the same ($h = s$). The output of variety ω in sector j produced at home to serve market m is given by:

$$Q_{mhs}^j(\omega) = Q_{mss}^j(\omega) = L_s^j \left(\frac{z_{ss}^j(\omega)}{g_s^j} \right) = L_s^j z_{ss}^j(\omega), \tag{3}$$

where $z_{ss}^j(\omega)$ represents the productivity of a firm when it produces at home. There are no additional costs (or efficiency losses) for operating in its own market; therefore, $g_{ss} = 1$.

(2) *Multinational production*: A firm could set an affiliate in any other location $h \neq s$, and from there sell to market m:

$$Q_{mhs}^j(\omega) = L_h^j \left(\frac{z_{hs}^j(\omega)}{g_{hs}^j} \right). \tag{4}$$

The output level associated with MP depends on the factor endowments in the country where

[27] The assumption of independence across locations corresponds to a particular case of a more general specification in which the degree of correlation among the elements of vector $\mathbf{z_s^j}$ is governed by the parameter ρ in the equation below

$$F_s^j(\mathbf{z}) = exp\left\{ -T_s^j \left[(z_{1s}^j)^{-\theta/(1-\rho)} + (z_{2s}^j)^{-\theta/(1-\rho)} \right]^{1-\rho} \right\}.$$

The simplified assumption used in this paper ($\rho = 0$) gives us the tractability to rely on gravity equations to estimate the parameters of interest. It also allows us to compare our results with previous work that has focused on the estimation of the mean productivity parameters using trade data at the sectoral level.

production takes place (L_h^j); the penalty associated with implementing the home country's technology abroad ($g_{hs}^j > 1$); and the productivity of firms from country s producing at location h ($z_{hs}^j(\omega)$). The penalty parameter g_{hs}^j is a deterministic measure of the efficiency losses a country faces in producing in some location outside home, which is source-host-sector–specific and common across varieties. Therefore, a higher g_{hs}^j reflects lower productivity of affiliates from s in h, for all varieties in sector j.

Finally, output in each sector j is produced using a CES production function that aggregates a continuum of varieties $\omega \in [0,1]$ that do not overlap across sectors. Q_h^j is a CES aggregate and $Q_h^j(\omega)$ is the amount of variety ω used in production in sector j and country h. The elasticity of substitution across varieties ω is denoted by ε_j.

$$Q_h^j = \left(\int_0^1 Q_h^j(\omega)^{\frac{\varepsilon_j - 1}{\varepsilon_j}} d\omega \right)^{\frac{\varepsilon_j}{\varepsilon_j - 1}}. \tag{5}$$

Note that in a two-country environment, the host country and the destination country are the same ($h = m$).

Preferences: Preferences are Cobb-Douglas over the broad sectors of the economy.[28]

$$Y_m = \left(Y_m^a\right)^{\xi_m} \left(Y_m^b\right)^{1-\xi_m}, \tag{6}$$

where ξ_m denotes the Cobb-Douglas weight for sector a. The resources constraint faced by consumers in this two-country, two-sector model is given by:

$$P_m Y_m = p_m^a Y_m^a + p_m^b Y_m^b = w_m L_m, \tag{7}$$

where Y_m^j represents the expenditure of country m on sector j goods and p_m^j is the price of the sector j composite.

Trade and MP Costs: Trade frictions take the standard iceberg form. Formally, it is assumed that for each unit of variety ω shipped from country of production h to the target country m, only $1/d_{mh}^j$ arrives, with d_{mh}^j such that $d_{mh}^j = 1$ and $d_{mh}^j < d_{mk}^j d_{kh}^j$ for any country k, ruling out any third-country arbitrage opportunities.[29] More important, trade barriers are not symmetric $\left(d_{mh}^j \neq d_{hm}^j\right)$, and they can be decomposed into a symmetric component $\left(d_{mh}^j\right)$ and a specific (exporter-sector) component $\left(d_h^j\right)$. Barriers to investment are described in a similar manner. These are non-symmetric as well $\left(g_{hs}^j \neq g_{sh}^j\right)$, and they can also be decomposed into a symmetric component $\left(g_{hs}^j\right)$ and a specific (source-sector) component $\left(g_s^j\right)$. These modeling choices for trade and MP barriers will be discussed in detail in Section F.2 in the Appendix.

[28] In the N-sector, N-country model, the preferences are generalized to a CES specification, adding flexibility to the elasticity of substitution across sectors.

[29] The last property is binding only in an $N > 2$ model, such as the one presented in the next section.

Market Structure: The features of the model outlined above imply that producing one unit of variety ω in sector j in country h with technologies from country s requires $g^j_{hs}/z^j_{hs}(\omega)$ input bundles. Since labor is the only factor of production, the cost of an input bundle is given by:

$$c^j_h(\omega) = w^j_h. \tag{8}$$

Equation (8) is based on the assumption that every firm operating in country h uses the local input bundle regardless of its country of origin.[30] Under perfect competition and given the assumptions made for trade and investment barriers, the price at which country s can supply variety ω in sector j to country m, when producing in country h, is equal to:

$$p^j_{mhs}(\omega) = \left(\frac{c^j_h g^j_{hs}}{z^j_{hs}(\omega)}\right) d^j_{mh}. \tag{9}$$

Therefore, seller s will choose the location $h = \{1, 2\}$ that allows him to reach country m with the lowest possible price, $p^j_{ms}(q) = min\left\{p^j_{m1s}(\omega); p^j_{m2s}(\omega)\right\}$. Conditional on each provider being at the cheapest possible location, consumers in market m will choose to buy from the source technology country $s = \{1, 2\}$ that offers the lowest price $p^j_m(\omega) = min\left\{p^j_{m1}(\omega); p^j_{m2}(\omega)\right\}$.

Hence, the probability that country m imports good ω in sector j from country h, using technologies from country s, is given by:

$$\pi^j_{mhs} = \underbrace{\left(\frac{T^j_s {\Delta^j_{ms}}^{-\theta_j}}{T^j_1 {\Delta^j_{m1}}^{-\theta_j} + T^j_2 {\Delta^j_{m2}}^{-\theta_j}}\right)}_{\text{Term 1}} \underbrace{\left(\frac{{\delta^j_{mhs}}^{-\theta_j}}{{\delta^j_{m1s}}^{-\theta_j} + {\delta^j_{m2s}}^{-\theta_j}}\right)}_{\text{Term 2}}, \tag{10}$$

where $\Delta^j_{ms} = \left[\left(\delta^j_{m1s}\right)^{-\theta_j} + \left(\delta^j_{m2s}\right)^{-\theta_j}\right]^{-\frac{1}{\theta_j}}$ and $\delta^j_{mhs} = d^j_{mh} c^j_h g^j_{hs}$. Notice that $\pi^j_{mhs}(\omega)$ is the sectoral counterpart of the object $\pi_{mhs}(\omega)$ in RRC, and it represents the share of goods in sector j that country m buys from firms located in country h whose source is country s. The right-hand side of equation (10) can be easily interpreted as the product of two independent events: Term 1 on the left describes the event whereby a producer in sector j from country s is the lowest-price supplier of ω in country m independently of the location of production. Term 2 on the right describes the event whereby country h is the host country that offers the lowest cost of production in sector j for source country s selling to market m. Therefore, π^j_{mhs} collapses to the following equation:

[30] This assumption implies that foreign affiliates do not require input bundles from the source country s to produce variety ω in the host country h. The assumption is made only for simplicity, to better highlight the channel proposed in this paper.

$$\pi_{mhs}^{j} = \left[\frac{T_s^j {\delta_{mhs}^{j}}^{-\theta_j}}{T_1^j {\Delta_{m1}^{j}}^{-\theta_j} + T_2^j {\Delta_{m2}^{j}}^{-\theta_j}} \right], \tag{11}$$

The actual price paid by consumers in country m to buy goods in sector j is given by:

$$p_m^j = \Gamma_j \left(T_1^j {\Delta_{m1}^{j}}^{-\theta_j} + T_2^j {\Delta_{m2}^{j}}^{-\theta_j} \right)^{-\frac{1}{\theta_j}}, \tag{12}$$

where $\Gamma_j = \left[\Gamma \left(\frac{\theta_j + 1 - \varepsilon_j}{\theta_j} \right) \right]^{\frac{1}{1-\varepsilon_j}}$ and Γ is the Gamma function.

Trade and MP Shares: The share of goods that country m imports from country h $\left(\pi_{mh}^j\right)$, can be calculated by aggregating π_{mhs}^j across all source countries. Therefore, the probability that country m will buy a sector j variety from country h is calculated by summing up the probabilities of importing goods produced in country h using technologies from every source country s, including itself:

$$\pi_{mh}^j = \pi_{mh1}^j + \pi_{mh2}^j$$

By substituting (11) in the above equation, we get:

$$\pi_{mh}^j = \frac{\widetilde{T_h^j} \left(c_h^j d_{mh}^j \right)^{-\theta}}{\widetilde{T_1^j} \left(c_1^j d_{m1}^j \right)^{-\theta} + \widetilde{T_2^j} \left(c_2^j d_{m2}^j \right)^{-\theta}}, \tag{13}$$

where $\widetilde{T_h^j}$ is the *effective technology* and is given by:

$$\widetilde{T_h^j} = T_1^j {g_{h1}^j}^{-\theta} + T_2^j {g_{h2}^j}^{-\theta}. \tag{14}$$

The above equation states that in the presence of multinational production, the set of available technologies for each country is enlarged. Each country-sector pair has an effective productivity that equals its local productivity in that sector plus the productivity of the foreign affiliates producing in the country, discounted by the investment barriers g_{hs}^j. How much a country could benefit from foreign technologies depends on the barriers to MP represented by g_{hs}^j, which limit the host economy's capacity to absorb the productivity of foreign affiliates from country s, so as to enhance their overall productivity. Note that technology $\widetilde{T_h^j}$ is not available to all—local and foreign— producers in country h. Instead, each firm producing in host country h uses technology from its own source country T_s^j and $\widetilde{T_h^j}$. The model does not internalize the potential knowledge spillovers that may take place from foreign to local producers. The productivity in the host country is enlarged as a result of the coexistence of local and foreign producers with different levels of technology, and not because local producers become more productive by learning from their foreign counterparts.

The value of foreign output in sector j, produced in country h using country s's technologies to serve country m, is then given by $\pi^j_{mhs} p^j_m Q^j_m$, where $p^j_m Q^j_m$ is the total expenditure on sector j goods by consumers in country m.[31] Total output of foreign affiliates from country s located in country h can be calculated by summing foreign affiliate sales over all destination markets (m). Thus, total MP in sector j by affiliates from country s located in country h is given by:

$$I^j_{hs} = \pi^j_{1hs} X^j_1 + \pi^j_{2hs} X^j_2 \qquad \forall j = \{1, 2\},$$

where $X_m = p^j_m Q^j_m$. Substituting (12) in the former expression, we get:

$$I^j_{hs} = \frac{T^j_s \left(g^j_{hs} c^j_h \right)^{-\theta}}{\left(p^j_h \right)^{-\theta}} \Xi^j_h, \tag{15}$$

where $\Xi^j_h = \sum_{m=1}^{2} \left(d^j_{mh} p^j_h / p^j_m \right)^{-\theta} X^j_m = I_h \left(\frac{X_h}{X_{hh}} \right)$[32] Therefore, the share of goods produced in country h with s technologies—or MP share—is given by:

$$y^j_{hs} = \frac{I^j_{hs}}{\sum_i I^j_{hs}} = \frac{I^j_{hs}}{I^j_h} = \frac{T^j_s \left(g^j_{hs} \right)^{-\theta}}{\widetilde{T}^j_h}. \tag{16}$$

3.2 Welfare: Analytical Predictions

Welfare in country h is given by the indirect utility function and corresponds to real income:

$$W_h = \prod_{j=a,b} \frac{w_s}{\left(p^j_s \right)^{\xi_j}}, \tag{17}$$

[31] Note that for a given host and source country pair (h, s) π^j_{mhs} is not mutually exclusive across destination countries (m), given that some foreign affiliates could serve more markets than others

[32] Normalizing the bilateral trade shares by the share of country s's expenditure devoted to locally produced goods $\left(\hat{x}^j_{hh} = \frac{X^j_{hh}}{X^j_h} \right)$ yields:

$$\frac{\hat{x}^j_{mh}}{\hat{x}^j_{hh}} = \left(d^j_{mh} \frac{p^j_h}{p^j_m} \right)^{-\theta}$$

$$X^j_{mh} = \hat{x}^j_{hh} \left(d^j_{mh} p^j_h / p^j_m \right)^{-\theta} X^j_m$$

Summing over m:

$$I^j_h = \sum_m X^j_{mh} = \hat{x}^j_{hh} \sum_m \left(d^j_{mh} p^j_h / p^j_m \right)^{-\theta} X^j_m$$

$$I^j_h = \hat{x}^j_{hh} \Xi_h$$

The optimal sectoral factor allocations must satisfy $I^j_h = \frac{w_h L^j_h}{\alpha_j \beta_j}$; therefore, Ξ^j_h can be rewritten as a function of observables only: $\Xi^j_h = \frac{1}{\hat{x}^j_{hh}} \frac{w_h L^j_h}{\alpha_j \beta_j} = I_h \left(\frac{X_h}{X_{hh}} \right)$.

where p_h^j is the price in country h of goods in sector j (see equation (12)). An expression for w_h/p_h^j as a function of local producers' technology $\left(T_h^j\right)$, along with the expenditure share on domestically produced goods (π_{hh}^j) and the share of goods produced domestically by local producers (y_{hh}^j), can be derived using equation (15) when $h = s$:

$$\frac{w_h}{p_h^j} = \left(T_s^j\right)^{\frac{1}{\theta}} \left(y_{hh}^j\right)^{-\frac{1}{\theta}} \left(\pi_{hh}^j\right)^{-\frac{1}{\theta}}, \tag{18}$$

where $y_{hh}^j = \frac{I_{hh}^j}{I_h^j}$ and $\pi_{hh}^j = \frac{X_{hh}^j}{X_h^j}$.

Taking the product of (18) for both sectors and weighting by ξ_j, we derive an expression for real wages in country h:

$$W_h = \prod_{j=a,b} \left[\left(T_h^j\right)^{\frac{1}{\theta}} \left(y_{hh}^j\right)^{-\frac{1}{\theta}} \left(\pi_{hh}^j\right)^{-\frac{1}{\theta}}\right]^{\xi_j}. \tag{19}$$

Following [Levchenko and Zhang, 2013], in deriving analytical predictions for welfare, it is further assumed that the expenditure shares in the two sectors are equal ($\xi_j = 1/2$). Therefore, welfare is expressed by:

$$W_h = \frac{w_h}{\left(p_h^a p_h^b\right)^{\frac{1}{2}}} = \left(T_h^a T_h^b\right)^{\frac{1}{2\theta}} \left(\pi_{hh}^a \pi_{hh}^b\right)^{-\frac{1}{2\theta}} \left(y_{hh}^a y_{hh}^b\right)^{-\frac{1}{2\theta}}. \tag{20}$$

In addition, it is assumed that the average productivity in both countries is the same, and that they differ only in their comparative advantage. Therefore, country 1 in sector a has the same productivity as country 2 in sector b, and country 2 in sector a has the same productivity as country 1 in sector b: $T_1^a = T_2^b$ and $T_1^b = T_2^a$. Without loss of generality, let us assume that country 2 has comparative advantage in sector a ($T_2^a > T_1^b$), and also that trade and investment barriers are symmetric along country pairs as well as across sectors:

$$d_{12}^j = d_{21}^j = d \quad \forall j = \{a, b\}$$

$$g_{12}^j = g_{21}^j = g \quad \forall j = \{a, b\}$$

The assumption with regard to productivities, utility function, and symmetry in trade barriers and investment barriers, together with the normalization of the labor endowments, ensures that in general equilibrium wages are equal in the two countries ($w_1 = w_2 = 1$), which have been normalized to one.

3.2.1 Analytical Prediction 1: MP sales are disproportionately higher in comparative disadvantage sectors.

Proposition 1. *In a two-country, two-sector world economy, the lower the technology of country 1 in sector a (country 1's comparative disadvantage sector) relative to sector b, the higher the probability that firms from country 2 will produce in sector a relative to sector b in country 1.*

Proof. See Appendix (D.1).

When T_1^a increases, the comparative disadvantage of country 1 in sector a is weaker, reducing the proportion of MP in sector 1 carried out by country 2 firms. When T_2^a increases, the comparative disadvantage of country 1 in sector a is more pronounced, increasing the proportion of multinational production in sector 1 carried out by country 2 firms.[33] This analytical prediction finds empirical support in the negative and significant relationship between productivity and MP shares at the sectoral level.

3.2.2 Analytical Prediction 2: The higher the heterogeneity of MP across sectors, the higher the gains from MP.

Analogous to trade, the gains from MP are the proportional change in country h's real wage as one moves from a counterfactual equilibrium with trade but no MP (investment barriers are prohibitively costly) to the actual equilibrium with positive MP and trade flows. Using equation (18) and comparing the results both with and without MP, we get an expression for the welfare gains:

$$GMP_h = \frac{W^s_{g>0}}{W^s_{g\to\infty}} = \left[\frac{\sum\limits_{j=a,b}\left(1+\frac{T_1^{\neq j}}{T_1^j}d^{-\theta}\right)}{\sum\limits_{j=a,b}(1+(dg^j)^{-\theta})+\frac{T_1^{\neq j}}{T_1^j}({g^j}^{-\theta}+d^{-\theta})}\right]^{-\frac{1}{2\theta}}, \tag{21}$$

$$GMP_h = W^h_{g>0}/W^h_{g\to\infty} = \left(y^a_{hh}y^b_{hh}\right)^{-\frac{1}{2\theta}}\left(\frac{\pi^a_{hh}\pi^b_{hh}}{\bar{\pi}^a_{hh}\bar{\pi}^b_{hh}}\right)^{-\frac{1}{2\theta}}, \tag{22}$$

where $\bar{\pi}^j_{hh}$ is the domestic demand share in the counterfactual equilibrium with no MP, and where the MP shares are given by:

$$\left(y^a_{hh}y^b_{hh}\right)^{-\frac{1}{2\theta}} = \left(\frac{T^a_h}{\widetilde{T}^a_h}\frac{T^b_h}{\widetilde{T}^b_h}\right)^{-\frac{1}{2\theta}}.$$

[33] A similar argument can be constructed for the following case: when T_2^b increases, the comparative disadvantage of country 2 in sector a is weaker, reducing the proportion of MP in sector a carried out by country 2 firms in that sector.

Proposition 2. *The higher the heterogeneity of MP across sectors, the higher the gains from MP. When the share of domestically produced goods is the same across sectors* ($y_{hh}^a = y_{hh}^b$)*, the gains from MP attain a minimum. Therefore, uni-sectoral trade-MP models understate the actual gains from MP as long as* $y_{hh}^a \neq y_{hh}^b$.

Proof. See Appendix (D.3).

Note that gains from trade depend on the heterogeneity of the effective productivity parameters—*effective or Ricardian comparative advantage*—and not on the heterogeneity of the fundamental productivity parameters—*fundamental comparative advantage*—while the gains from MP depend on the heterogeneity of fundamental productivities across sectors. The latter is reflected in differences in MP shares across sectors, as countries will have less MP as a share of total production in their fundamental comparative advantage sectors, and more MP in their fundamental disadvantage sectors. Figure 4 depicts the actual gains from MP in the two-sector analytical model as well as the gains from MP implied by uni-sectoral models of trade and MP (denoted by the horizontal dashed line).

In Section 4, actual data on manufacturing production and MP sales are used for a sample of ten sectors and thirty-five countries to assess the magnitude of the disparities between the gains from MP implied by both uni-sector and multi-sector models of trade and MP.

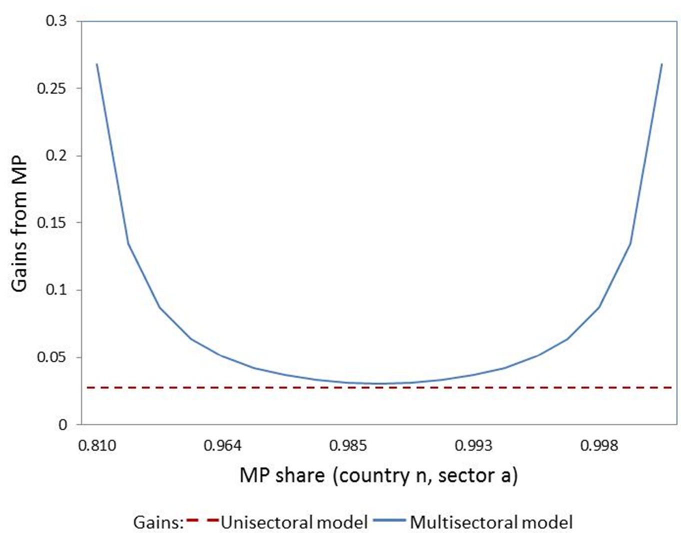


Figure 4: Sectoral Heterogeneity and Gains from MP

3.2.3 Analytical Prediction 3: Gains from trade are lower the more heterogeneous the technology upgrade across sectors.

Formally, gains from trade are the proportional change in real wages in country h as we move from a counterfactual equilibrium, with MP but not trade; to the actual equilibrium, with both MP and trade.

From equation (20), the gains from trade are expressed as:

$$W^h_{d>0}/W^h_{d\to\infty} = GT_h = \left(\pi^a_{hh}\pi^b_{hh}\right)^{-\frac{1}{2\theta}}. \tag{23}$$

As can be observed in equation (23), gains from trade are a function of trade shares and the dispersion parameter θ, similar to the result obtained in a multi-sector trade-only model.[34] Nevertheless, the focus of this paper is to understand to what extent the gains from trade are affected by the reduction in effective productivity differences induced by multinational production.

Given the fact that labor is the only factor of production and wages are equal to one,[35] equation (13) collapses to:

$$\pi^j_{mh} = \frac{\widetilde{T^j_h}/T^j_h}{(1+(dg^j)^{-\theta}) + \frac{T^{\neq j}_h}{T^j_h}({g^j}^{-\theta} + d^{-\theta})}. \tag{24}$$

Substituting (24) in (23), the expression for gains from trade (GT) is:

$$GT = \left[\frac{\left(\widetilde{T^a_h}/T^a_h\right)\left(\widetilde{T^b_h}/T^b_h\right)}{\left((1+(dg^a)^{-\theta}) + \frac{T^b_h}{T^a_h}({g^a}^{-\theta} + d^{-\theta})\right)\left((1+(dg^b)^{-\theta}) + \frac{T^a_h}{T^b_h}({g^b}^{-\theta} + d^{-\theta})\right)}\right]^{-1/2\theta}. \tag{25}$$

Proposition 3. *The more heterogeneous the technology upgrade across sectors toward comparative disadvantage sectors, the lower the dispersion of effective technologies and the lower the gains from trade.*

Proof. See Appendix (D.2).

The result stated in Proposition 2 is illustrated in Figure 2, which shows the percentage difference between the gains from trade implied by a proportional technology transfer across sectors $\left(\widetilde{T^a_1}/T^a_1 = \widetilde{T^b_1}/T^b_1\right)$ and the actual gains from trade, as a function of the dispersion in T^j_h across sectors, measured by the standard deviation between T^a_h and T^b_h. Greater relative sectoral

[34] The focus of this paper is on measuring gains from trade based on primitives rather than on observables. For a complete review of the literature on this topic, see [Costas et al., 2012] and [Levchenko and Zhang, 2013]

[35] Investment barriers are now $g^a_{12} = g^b_{21}$ and $g^a_{21} = g^b_{12}$. Given the rest of the assumptions, wages are still the same across countries.

productivity differences lead to larger disparities between the gains in the actual equilibrium and the gains in the counterfactual scenario.

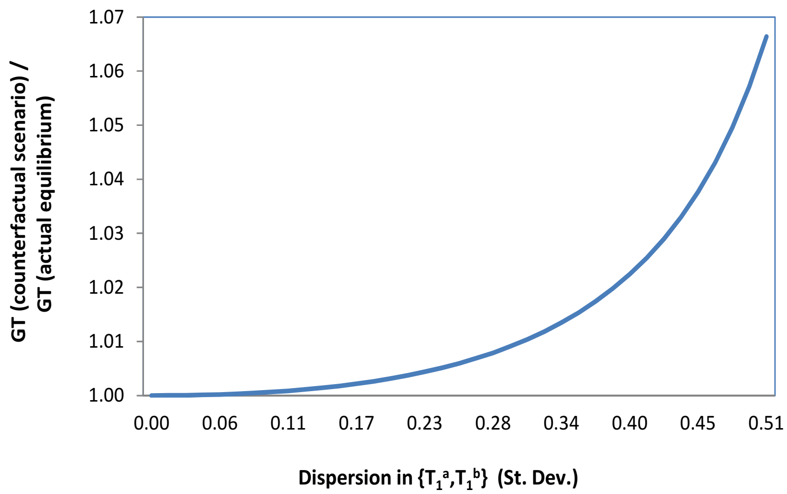


Figure 5: MP Technology Transfer and Gains from Trade

Ricardian comparative advantage at the industry level plays an important role in the magnitude and sectoral distribution of technology transfer that takes place when firms decide to produce overseas. Results indicate that the stronger the reduction in comparative advantage due to MP, the lower the estimated gains from trade. Also, the stronger the comparative advantage of local producers in the host country, the bigger the effect of MP on the observed differences in relative technology across sectors.

4 Quantitative Framework

In order to take the model to the data, in this section we quantitative estimate a multi-country multi-sector version of the model, with labor and capital as factors of production, intermediate inputs, and inter-linkages across sectors. This environment incorporates N countries and $J+1$ sectors; the first J sectors are tradables and the $J+1$ sector is a non-tradable. Both capital K_h and labor L_h are mobile across sectors and immobile across countries; and w_h and r_h represent the wage rate and the rental return of capital, respectively.

Finally, with $N>2$, firms have the option to locate a foreign affiliate directly in the destination market to serve it locally or in a third country, used as an export platform, to ship goods to the final destination. In addition to g^j_{hs}, a firm that uses a third country h to produce and export to country m also faces the transportation cost d^j_{mh} associated with exporting from h to m. Note that in order to serve any foreign market with a variety from sector $J+1$, the only option is to locate a plant in the target market. Therefore, for all non-tradable varieties, the host economy and the destination market are necessarily the same ($h = m$).

The main equations of the model are extended below in order to incorporate multiple countries, multiple tradable sectors, a non-tradable sector, capital, intermediate inputs usage, and linkages across sectors.

Preferences: Utility of the representative consumer in country m is linear in the composite final good Y_m, and is given by:

$$Y_m = \left(\sum_{j=1}^{J} \omega_j^{\frac{1}{\eta}} \left(Y_m^j\right)^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}\xi_m} \left(Y_m^{J+1}\right)^{1-\xi_m}, \tag{26}$$

where ξ_m denotes the Cobb-Douglas weight for the tradable sector composite good and Y_m^{J+1} is the non-tradable sector composite good. The elasticity of substitution between the tradable sectors is denoted by η, and ω_j is the test parameter for tradable sector j. Note that the consumer's utility is CES on tradable sectors, allowing η to be different from one (in the previous section, with Cobb-Douglas preferences, η=1). Moreover, in the quantitative exercise, ξ_m will vary across countries, to capture the positive relationship between income and the non-tradable consumption shares observed in the data.

Production: Production of variety ω in sector j, by firms from country s producing in country h in order to sell to market m, is given by:

$$Q^j_{mhs}(\omega) = \left[\left(L_h^j\right)^{\alpha_j} \left(K_h^j\right)^{1-\alpha_j} \right]^{\beta_j} \left[\prod_{k=1}^{J+1} \left(Q_s^k\right)^{\gamma_{kj}} \right]^{1-\beta_j} \left(\frac{z^j_{hs}(\omega)}{g^j_{hs}} \right),$$

where value-added-based labor intensity is given by α_j, while the share of value added in total output is given by β_j—both of which vary by sector. The weight of intermediate inputs from sector k used by sector$j$ is denoted by γ_{kj}. Therefore, the unit cost c^j_h is given by:

$$c_h^j = \left[\left(w_h^j\right)^{\alpha_j} \left(r_h^j\right)^{1-\alpha_j} \right]^{\beta_j} \left[\prod_{k=1}^{J+1} \left(p_h^k\right)^{\gamma_{kj}} \right]^{1-\beta_j}. \tag{27}$$

Technology: Any firm gets a productivity draw $z^j_{hs}(\omega)$ in each of the N possible host countries

h, as described by the vector below:

$$\mathbf{z_s^j}(\omega) \equiv \left\{ z_{hs}^j(\omega) \right\}_{h=1}^{N} \quad \forall s = 1, ...N,$$

where $\mathbf{z_s^j}(\omega)$ is drawn independently across goods, countries, and sectors from a multivariate Frechet distribution:

$$F_s^j(\mathbf{z}) = exp\left[-T_s^j \left(\sum_s \left(z_{hs}^j \right)^{-\theta_j} \right) \right]. \tag{28}$$

Productivities $z_{hs}^j(\omega)$ are assumed to be independent across host countries.

Market Structure: The probability that country m will import good ω in sector j from country h, using technologies from country s, is given by:

$$\pi_{mhs}^j = \frac{T_s^j \left(\Delta_{ms}^j \right)^{-\theta_j}}{\sum_k T_k^j \left(\Delta_{mk}^j \right)^{-\theta_j}} \cdot \frac{\left(\delta_{mhs}^j \right)^{-\theta_j}}{\sum_m \left(\delta_{mhs}^j \right)^{-\theta_j}}. \tag{29}$$

The actual price of any variety in sector j in country m is given by:

$$p_m^j = \Gamma_j \left(\widetilde{\Delta_m^j} \right)^{-\frac{1}{\theta_j}} = \Gamma_j \left(\sum_s T_s^j \left(\Delta_{ms}^j \right)^{-\theta_j} \right)^{-\frac{1}{\theta_j}}. \tag{30}$$

Closing the Model: Given the set of prices $\left\{ w_h, r_h, P_h, \left\{ p_h^j \right\}_{j=1}^{J+1} \right\}_{h=1}^{N}$, we first describe how production is allocated across countries and sectors. Let Q_h^j denote the total sectoral demand in country h and sector j. Q_h^j is used for both final consumption $\left(p_h^j Y_h^j \right)$ and intermediate inputs in domestic production of all sectors. How much all sectors k in country h require from sector j depends on the world demand of country h's sector j goods, $\sum_{k=1}^{J+1} (1-\beta_k)\gamma_{j,k} \left(\sum_{m=1}^{N} \sum_{h=1}^{N} \pi_{mhs}^k p_m^k Q_m^k \right)$. Therefore, the goods market clearing condition is given by:

$$p_h^j Q_h^j = p_h^j Y_h^j + \sum_{k=1}^{J+1} (1-\beta_k)\gamma_{j,k} \left(\sum_{m=1}^{N} \sum_{s=1}^{N} \pi_{mhs}^k p_m^k Q_m^k \right) \quad \forall j = \{1, ..., J+1\},$$

where $\sum_{m=1}^{N} \sum_{s=1}^{N} \pi_{mhs}^{J+1} = 0$ whenever $m \neq h$. Also note that in this specification the requirements of every tradable sector k for inputs from sector j depend on $\pi_{mh}^k = \sum_{s=1}^{N} \pi_{mhs}^k$, which is the probability that country m will import from country h regardless of the origin of the technology used in production. Also, the requirements of the non-tradable sector $J+1$ from any other sector j depend on $\pi_{hh}^{J+1} = \sum_{s=1}^{N} \pi_{hhs}^{J+1}$, where π_{hhs}^{J+1} is the probability that country h will produce in non-tradable sectors using the technologies from country s's foreign affiliates.

The goods market clearing condition stated above takes into account that the majority of world trade is in intermediate inputs, and the fact that a good is traded several times before being consumed, as well as the existence of two-way input linkages between the tradable and non-tradable sectors.

Solving for the consumer's problem, the final demand of sector j in country h is given by:

$$Y_h^j = \xi_h \frac{w_h L_h + r_h K_h}{p_h^j} \frac{\omega_j \left(p_h^j\right)^{1-\eta}}{\sum_{k=1}^J \omega_k \left(p_h^k\right)^{1-\eta}} \qquad \forall j = \{1, ..., J\},$$

and

$$Y_h^{J+1} = (1-\xi_h) \frac{w_h L_h + r_h K_h}{p_h^{J+1}} \qquad j = J+1.$$

Trade: In each tradable sector j, some varieties ω are imported from abroad and some varieties ω are exported to the rest of the world. Country k's exports and imports in sector j are given by:

$$EX_k^j = \sum_{m \neq k}^N \sum_{s=1}^N \pi_{mks}^j p_m^j Q_m^j \quad IM_k^j = \sum_{h \neq k}^N \sum_{s=1}^N \pi_{khs}^j p_k^j Q_k^j,$$

and total exports and total imports are given by:

$$EX_k = \sum_{j=1}^J EX_k^j \qquad IM_k = \sum_{j=1}^J IM_k^j.$$

The trade balance condition will equalize $IM_k = EX_k$.

Multinational Production: The value of MP in tradable sector j from country s in country h to serve country m is $\pi_{mhs}^j p_m^j Q_m^j$, where $p_m^j Q_m^j$ is the total expenditure on goods on tradable sector j by country m. Thus, total MP in tradable sector j by country s in country h is:

$$I_{hs}^j = \sum_m \pi_{mhs}^j p_m^j Q_m^j \qquad \forall j = 1, ..., J, \tag{31}$$

$$I_{hs}^{J+1} = \pi_{hhs}^{J+1} p_h^{J+1} Q_h^{J+1} \qquad j = J+1. \tag{32}$$

Total inward MP in country h from the rest of the world in sector j can be obtained by summing (31) and (32) over all source-of-technology countries s.

$$I_h^j = \sum_s I_{hs}^j \quad \forall j = 1, ..., J+1.$$

In the same way, outward MP in tradable sector j by country s in country h is given by:

$$O_{hs}^{j} = \sum_{m} \pi_{mhs}^{j} p_{m}^{j} Q_{m}^{j} \quad \forall j = 1, ..., J, \tag{33}$$

$$O_{hs}^{J+1} = \pi_{hhs}^{J+1} p_{h}^{J+1} Q_{h}^{J+1} \quad \text{J} = J+1. \tag{34}$$

Similarly, total outward MP from country s to the rest of the world in sector j can be obtained by summing (33) and (34) over all location-of-production countries h:

$$O_{s}^{j} = \sum_{h} O_{hs}^{J+1} \quad \forall j = 1, ..., J+1.$$

Factor Allocations: The factor allocations are now calculated across sectors. The total production revenue in tradable sector j in country h is given by $\sum_{m=1}^{N} \sum_{i=1}^{N} \pi_{nsi}^{j} p_{n}^{j} Q_{n}^{j}$. The optimal sectoral factor allocations in country h and tradable sector j must thus satisfy:

$$\sum_{m=1}^{N} \sum_{s=1}^{N} \pi_{mhs}^{j} p_{m}^{j} Q_{m}^{j} = \frac{w_h L_h^j}{\alpha_j \beta_j} = \frac{r_h K_h^j}{(1-\alpha_j)\, \beta_j}. \tag{35}$$

For the non-tradable sector $J+1$, the optimal factor allocations in country m are given by:

$$\sum_{s=1}^{N} \pi_{hhs}^{J+1} p_{h}^{J+1} Q_{h}^{J+1} = \frac{w_h L_h^{J+1}}{\alpha_{J+1} \beta_{J+1}} = \frac{r_h K_h^{J+1}}{(1-\alpha_{J+1})\, \beta_{J+1}}. \tag{36}$$

4.1 Estimating the Model's Parameters: $\widetilde{T}_h^j$, T_h^j, g_{hs}^j, and d_{mh}^j

In this section, we estimate the sector-level technology parameters for local producers (T_h^j) in thirty-five countries, nine tradable sectors, and one non-tradable sector, in two steps. First, the effective technology parameter ($\widetilde{T}_h^j$) is estimated by fitting the structural trade gravity equation implied by the model, using trade and production data.[36] In this step, we also estimate the bilateral trade cost at the sectoral level. Then, we proceed to estimate the corresponding MP barriers at the sectoral level by fitting the structural MP gravity equation implied by the model

[36]The gravity equations are derived from the model under the assumption that productivity draws are uncorrelated across host countries. Ramondo and Rodriguez-Clare (2011) use aggregated multinational production data to calibrate h and d assuming two alternative values for ρ, $\rho = 0$ and $\rho = 0.5$. The goodness of the model measured by how it matches the patterns of the data is extremely similar in both cases. The only variable where $\rho = 0$ performs better is in accounting for foreign affiliate exports. As pointed out by [Ramondo and Rodríguez-Clare, 2013] and more recently by [Tintelnot, 2012], this is a consequence of the limitations of a model of MP that excludes the fixed cost of operating an affiliate overseas. However, this simplified assumption buys us the tractability of using the gravity equation for trade and MP, which is directly comparable to previous work that has focused on the estimation of the mean productivity parameters using trade data at the sectoral level.

using foreign affiliate sales data and production data for local firms.[37] Finally, using the effective technology parameters and the MP barriers, we calculate the effective technology parameters for every country-sector pair, solving the following system of equations:

$$\widetilde{T}_h^j = \sum_s T_s^j {g_{hs}^j}^{-\theta} \quad \forall j = 1 : J+1$$

The effective productivity estimates that emerge from the gravity equation reflect the average productivity of all producers in a given sector of the economy. Controlling for factor and intermediate input prices, as well as for trade barriers, a country that produces a larger share of its domestic demand exhibits a high effective productivity. A relatively high effective productivity could be a reflection of highly productive local producers, but it could also be a reflection of the access to superior technologies available to foreign affiliates operating in the host market. Intuitively, a country that produces a larger share of its output using domestic technologies has a higher relative fundamental productivity. Conversely, if the share of foreign affiliate production is high, the country has a relatively low state of technology in that sector. Therefore, the mean of the absolute difference between T_h^j and its effective counterpart $\tilde{T}_h^j$ in each sector is a measure of the absolute transfer of technology generated by MP, while the difference in the dispersion of effective and fundamental technology across sectors is a measure of the effect of MP on comparative advantage.

4.1.1 Multinational Production and Trade Gravity Equations

The capacity to relate the model to observables in the data relies on the properties derived from the seminal work of Eaton and Kortum (2002). In particular, the average spending in country m on goods produced in country h by affiliates from country s is equal over all exporters and sources of technology, implying that the share of goods country m buys from country h using country s technologies is also the share of its expenditure on these goods.

$$\pi_{mhs}^j = \frac{X_{mhs}^j}{X_m^j}. \tag{37}$$

By summing π_{mhs}^j across all source countries s,[38] we obtain county h's trade shares, reflecting the probability that country m will import sector j goods produced in country h, regardless of the source of the technology used in production (π_{mhs}^j):

$$\pi_{mh}^j = \sum_s \pi_{mhs}^j = \sum_s \frac{X_{mhs}^j}{X_m^j} = \frac{X_{mh}^j}{X_m^j}. \tag{38}$$

[37]For every country h and sector j, the production of local producers $\left(I_{hh}^j\right)$ is calculated by subtracting the production of foreign affiliates from total production.

[38]Note that π_{mhs}^j is independent across source countries, because a given source country s would not set operations in two different host countries h in order to serve a given market m.

Substitute the derived expression for π^j_{mhs} (see equation (29)) in equation (38):

$$\frac{X^j_{mh}}{X^j_m} = \sum_s \left[\frac{T^j_s \left(g^j_{hs}\right)^{-\theta_j} \left(c^j_h d^j_{mh}\right)^{-\theta_j}}{\sum_s T^j_s \sum_k \left(g^j_{ks}\right)^{-\theta_j} \left(c^j_k d^j_{mk}\right)^{-\theta_j}} \right]$$

$$\frac{X^j_{mh}}{X^j_m} = \frac{\widetilde{T^j_h} \left(c^j_h d^j_{mh}\right)^{-\theta_j}}{\sum_k \widetilde{T^j_k} \left(c^j_k d^j_{mk}\right)^{-\theta}}, \tag{39}$$

where $\widetilde{T^j_h} = \sum_s T^j_s \left(g^j_{hs}\right)^{-\theta_j}$. This implies that the effective technology $(\widetilde{T^j_h})$ employed by a country to produce and compete in the international market is a combination of the average productivity of the local producers in sector j and the average productivity of the foreign affiliates operating in the domestic market. But the local economy has a limited capacity to absorb foreign technologies, reflected by the cost of producing in a foreign market (g^j_{hs}).

To get the specification that will be taken to the data, equation (39) is divided by country m's normalized import share:

$$\frac{X^j_{mh}/X^j_m}{X^j_{mm}/X^j_m} = \frac{\widetilde{T^j_h} \left(c^j_h d^j_{mh}\right)^{-\theta}}{\widetilde{T^j_m} \left(c^j_m\right)^{-\theta}}. \tag{40}$$

Taking logs to both sides of the equation, we get the trade gravity equation:

$$\ln\left(\frac{X^j_{mh}}{X^j_{mm}}\right) = \ln\left(\widetilde{T^j_h} \left(c^j_h\right)^{-\theta}\right) - \ln\left(\widetilde{T^j_m} \left(c^j_m\right)^{-\theta}\right) - \theta \ln\left(d^j_{mh}\right). \tag{41}$$

Next, we derive a gravity equation for bilateral MP to identify MP barriers (g^j_{hs}) and the state of technology of local producers (T^j_h) for every country h and sector j in the sample.

The volume of foreign affiliate sales from source country s in host country h depends on two things: (1) the size of the markets foreign affiliates can access from the host country, including the host market itself; and (2) the probability that foreign affiliates from country s, by locating in market h, offer the lowest possible price to consumers in market m (π_{mhs}). Therefore, the sales of foreign affiliates from country s located in country h in sector j are given by:

$$I^j_{hs} = \sum_m \pi_{mhs} X^j_m$$

$$I^j_{hs} = \frac{T^j_s \left(g^j_{hs} c^j_h\right)^{-\theta}}{\sum_s \sum_k T^j_s \left(g^j_{ks}\right)^{-\theta} \left(c^j_k d^j_{hk}\right)^{-\theta}} \sum_m \frac{{d^j_{mh}}^{-\theta} \times \left(p^j_h\right)^{-\theta}}{\left(p^j_m\right)^{-\theta}} \cdot X^j_m,$$

$$I_{hs}^{j} = \frac{T_s^j \left(g_{hs}^j c_h^j\right)^{-\theta}}{\left(p_h^j\right)^{-\theta}} \Xi_h^j \tag{42}$$

where $\Xi_h^j = \sum_m \left(\frac{d_{mh}^j p_h^j}{p_m^j}\right)^{-\theta} X_m^j = \frac{X_h^{j\,2}}{X_{hh}^j}$,

$$\frac{I_{hs}^j}{\Xi_h^j} = \frac{I_{hs}^j}{X_h^j}\frac{X_{hh}^j}{X_h^j} = \frac{T_s^j \left(g_{hs}^j c_h^j\right)^{-\theta}}{\left(p_h^j\right)^{-\theta}}. \tag{43}$$

In this equation, the term I_{hs}^j/X_h^j represents the output share of country s's foreign affiliates in the total output of country h in sector j; while X_{hh}^j/X_h^j corresponds to the share of spending in country h on goods produced in country h, regardless of the source of the technology used in production.

Dividing I_{hs}^j/Ξ_h^j by its counterpart in the host country (I_{hh}^j/Ξ_h^j), we get:

$$\frac{I_{hs}^j/\Xi_h^j}{I_{hh}^j/\Xi_h^j} = \frac{T_s^j \left(g_{hs}^j\right)^{-\theta}}{T_h^j}. \tag{44}$$

This expression is analogous to the one for bilateral trade flows presented in equation (40). The only difference is that the unit cost of country h's input bundle cancels out of the gravity equation. Using technology from country s to produce in country h entails hiring factors of production and buying intermediate input in the host country h. Taking logs at both sides of equation (44), we get our preferred normalization for estimation:

$$\ln\left(\frac{I_{hs}^j}{I_{hh}^j}\right) = \ln\left(T_s^j\right) - \ln\left(T_h^j\right) - \theta \ln\left(g_{hs}^j\right). \tag{45}$$

Equation (45) implies that countries with a higher state of technology in sector j should have larger market shares, both abroad and domestically. Therefore, a relatively larger share of their domestic production should be in the hands of local producers and they should also have a greater presence in foreign markets in sector j relative to other countries. Conversely, less productive countries should have higher shares of production in the hands of foreign producers and smaller market shares abroad.

Bilateral Barriers to Multinational Production and Trade: g^j_{hs} and d^j_{mh}

To estimate MP and trade bilateral cost at a sectoral level, we assume a relationship between d^j_{mh} and g^j_{hs}, and observable data. In particular, the log of iceberg trade cost $\ln(d^j_{mh})$ and the log of iceberg MP cost $\ln(g^j_{hs})$ are modeled as a linear function of distance, and whether countries share a common border, common language, regional trade agreements, and common currency:

$$\ln\left(d^j_{mh}\right) = d^j_k + b^j_{mh} + lan^j_{mh} + CU^j_{mh} + RTA^j_{mh} + ex^j_h + \nu^j_{mh}, \tag{46}$$

$$\ln\left(g^j_{hs}\right) = d^j_k + b^j_{hs} + lan^j_{hs} + CU^j_{hs} + RTA^j_{hs} + source^j_s + \mu^j_{hs}, \tag{47}$$

where d_k represents an indicator variable of the distance between countries m and h lying in the kth distance interval. Intervals are measured in miles: $[0, 350]$, $[350, 750]$, $[750, 1500]$, $[1500, 3000]$, $[3000, 6000]$ and $[6000, max]$. The variable b^j indicates whether two countries share a common border; lan^j, whether they have a common language; CU^j, whether they belong to a currency union; and RTA^j, whether they are part of a regional trade agreement. Finally, ν^j_{mh} and μ^j_{hs} denote the error terms of the trade and MP gravity equations, respectively. They reflect the trade and MP cost coming from all other factors and are assumed to be orthogonal to the regressors for estimation proposes. These features of trade cost are similar to those of [Eaton and Kortum, 2002], and are extended to the specification of MP cost. Additionally, based on empirical evidence showing that the elasticity of trade volumes to trade barriers varies significantly across sectors [Do and Levchenko, 2007], we allow each of these bilateral variables to have a different effect on trade (d^j_{mh}) and MP cost (g^j_{hs}) across sectors.

The asymmetric specification of the trade barriers in equation (46) follows Waugh (2010), who includes an exporter effect $\left(ex^j_h\right)$. This represents the extra cost to country h of exporting a good to country m in sector j. In order to account for bilateral trade volumes and relative price data, Waugh argues that trade cost must be systematically asymmetric, with less developed countries facing a higher cost of exporting relative to more developed countries.[39]

Following a similar argument, our specification for MP barriers includes a source effect $\left(source^j_s\right)$, which represents the extra cost to country s of producing a good in country h in sector j. More specifically, less developed countries face systematically higher cost to produce overseas.[40] The inclusion of a source effect produces estimates that are consistent with the observed patterns of prices and income data. Three empirical observations are highlighted. First, the majority of the output is produced by local producers—home bias—and it is positively correlated with the

[39] In the data, tradable prices are unresponsive to a country's income level. Including an importer effect in the trade cost specification will predict that less developed countries face higher prices relative to more developed countries, a prediction that is inconsistent with the data. Therefore, the assumption that less developed countries face higher costs of importing, compared with more developed countries, is not appealing.

[40] There appears to be no precedent in the estimation of asymmetric barriers for MP at either the aggregate or the sectoral level. Previous efforts assume an aggregate and symmetric specification, where the cost that country s faces to produce in country h is equal to the cost country h faces to produce in country s. See [e.g., Ramondo and Rodríguez-Clare, 2013, Arkolakis et al., 2013, **?**]

country's income level. Second, there is a systematic correlation between bilateral MP shares and relative level of development: the larger the difference in relative income, the larger the disparity in bilateral MP share between two countries. Finally, tradable and non-tradable prices are positively correlated with income per worker. Section F.2 in the Appendix presents evidence to support the chosen specification in equation (47).

4.1.2 Estimated State of Technology: T_h^j and $\widetilde{T}_h^j$

In order to recover the effective technology parameters $\widetilde{T}_h^j$ and trade cost d_{mh}^j implied by the pattern of trade at the sectoral level, we estimate trade gravity equation (41), from which $-ln\left(\widetilde{T}_m^j(c_m^j)^{-\theta}\right)$ is recovered as an imported fixed effect.

$$\ln\left(\frac{X_{mh}^j}{X_{mm}^j}\right) = \underbrace{\ln\left(\widetilde{T_h^j}\left(c_h^j\right)^{-\theta}\right)}_{\text{exporter fixed effect}} \underbrace{- \ln\left(\widetilde{T_m^j}\left(c_m^j\right)^{-\theta}\right)}_{\text{importer fixed effect}}$$

$$\underbrace{-\theta d_k^j - \theta b_{mh}^j - \theta lan_{mh}^j - \theta CU_{mh}^j - \theta RTA_{mh}^j - \theta ex_h^j}_{\text{bilateral observables}} \underbrace{-\theta \nu_{mh}^j}_{\text{error term}} . \tag{48}$$

Isolating $\widetilde{T}_m^j$ from the estimated importer fixed effect entails a two-step procedure, as proposed by [Shikher, 2012].[41] First, we compute the cost of an input bundle in host country h and sector j (c_h^j), which is a function of wages w_h, return of capital r_h, and intermediate input prices p_h^j (see equation (27)). There are data available for w_h and r_h, but intermediate input prices at the sectoral level are not observable. Therefore, tradable prices in each sector-country pair $\left(p_h^j\right)$, are obtained using both the estimated importer fixed effect and data on share of expenditure on domestic goods $\left(X_{hh}^j/X_h^j\right)$. Finally, c_h^j is constructed to disentangle $\widetilde{T}_m^j$ from the importer fixed effect. The bilateral trade cost d_{mh}^j is computed based on the estimated coefficients:

$$\widehat{d}_{mh}^j = \exp\{\widehat{d}_k^j + \widehat{b}_{mh}^j + \widehat{lan}_{mh}^j + \widehat{CU}_{mh}^j + \widehat{RTA}_{mh}^j + \widehat{ex}_h^j + \widehat{\mu}_{mh}^j\}.$$

[41] See section F.1 in the Appendix for details.

To estimate the bilateral sector-level MP cost $\left(g_{sh}^{j}\right)$, we fitted the following gravity equation:

$$\ln\left(\frac{I_{hs}^{j}}{I_{hh}^{j}}\right) = \underbrace{\ln\left(T_{s}^{j}\right)}_{\text{source fixed effect}} - \underbrace{\ln\left(T_{h}^{j}\right)}_{\text{host fixed effect}} \tag{49}$$

$$\underbrace{-\theta d_{k}^{j} - \theta b_{hs}^{j} - \theta lan_{hs}^{j} - \theta CU_{hs}^{j} - \theta RTA_{hs}^{j} - \theta source_{s}^{j}}_{\text{bilateral observables}} \underbrace{-\theta\mu_{hs}^{j}}_{\text{error term}},$$

where g_{hs}^{j} is computed based on the estimated coefficients:

$$\widehat{g}_{hs}^{j} = \exp\{\widehat{d}_{k}^{j} + \widehat{b}_{hs}^{j} + \widehat{lan}_{hs}^{j} + \widehat{CU}_{hs}^{j} + \widehat{RTA}_{hs}^{j} + \widehat{source}_{s}^{j} + \widehat{\mu}_{hs}^{j}\}.$$

Note that the exporter $\widehat{ex}_{h}^{j}$ and the source $\widehat{source}_{s}^{j}$, components of the trade and MP cost, respectively, are calculated using the exporter (source) and importer (host) fixed effect estimated from the corresponding trade (MP) gravity equations. In particular:

$$\widehat{ex}_{h}^{j} = -1/\theta\,[\text{importer fixed effect+exporter fixed effect}]\,,$$

$$\widehat{source}_{s}^{j} = -1/\theta\,[\text{source fixed effect+host fixed effect}]\,.$$

Finally, using $\widehat{g}_{hs}^{j}$ and $\widetilde{T}_{s}^{j}$ for every country pair and sector j, we solve for the system of equations (50) in order to recover the technology parameters of local producers (T_{s}^{j}):

$$\widetilde{T}_{h}^{j} = \sum_{i}(g_{hs}^{j})^{-\theta}T_{s}^{j} \quad \forall h, s = 1, ...J+1, \tag{50}$$

$$\begin{bmatrix} \widetilde{T}_{1}^{j} \\ \widetilde{T}_{2}^{j} \\ .. \\ .. \\ \widetilde{T}_{N}^{j} \end{bmatrix} = \begin{bmatrix} g_{11}^{j} & g_{12}^{j} & .. & .. & g_{1N}^{j} \\ g_{21}^{j} & g_{22}^{j} & .. & .. & g_{2N}^{j} \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ g_{N1}^{j} & g_{N2}^{j} & .. & .. & g_{NN}^{j} \end{bmatrix} \times \begin{bmatrix} T_{1}^{j} \\ T_{2}^{j} \\ .. \\ .. \\ T_{N}^{j} \end{bmatrix}.$$

The estimates derived from this procedure constitute the baseline for the analysis that follows. Note that the estimates of trade costs include the residual from the trade gravity regression ($\widehat{\mu}_{mh}^{j}$). This, together with the estimated fixed effects, ensures that the model exactly fits the observed bilateral trade for every sector. This is not the case for MP sales, however. Although the residual from the MP gravity equation is also included in the MP cost calculation, in our baseline estimation we solve for the fundamental technology parameters $\left(T_{h}^{j}\right)$ using the system of equations in (50) rather than relying on the source and location fixed effects estimated in the MP gravity equation (49).

To ensure robustness, we estimate the productivity of local producers (T_{h}^{j}) with the MP gravity equation, by exponentiating the host fixed effect. Then, the effective technology parameters ($\widetilde{T}_h^j$) are computed, solving for each equation in (50) independently for each country. In this case, we match bilateral MP exactly—given the estimated MP cost and the fixed effect from the MP gravity—but we do not match bilateral trade flows. The estimated technology parameters under both methods are highly correlated (0.78) and in fact the second approach yields a more pronounced difference in the pattern of comparative advantage between local and foreign producers. We choose to estimate the overall productivity from the trade gravity equation in order to obtain estimates consistent with the ones obtained in trade-only models where there is no separation between the overall and local productivity.

Note that the stochastic approach developed by Eaton and Kortum (2002) implies that every country should buy a non-zero amount of goods from every country-sector pair, and also should host operations for all source countries in each sector. In fact, the MP bilateral matrix in each sector has many recorded zeros, even at a high level of aggregation. This has consequences in the estimation of the gravity equations above as well as in the computation of the equilibrium. The gravity equations are estimated using Pseudo Poisson Maximum Likelihood (PPML), suggested by Santos Silva and Tenreyro (2006), to alleviate any bias from log-linearizing (equations 45 and 41) in the presence of heteroskedasticity and the omission of zero trade flows. Results are not much different when compared with the ones obtained by ordinary least squares (OLS), although as expected the OLS overestimates the elasticity of trade and MP flows to distance and other resistance variables. Regarding the computation, when computing the equilibrium, we set trade and MP cost to be arbitrarily large for the instances in which X_{mh}^j and I_{hs}^j are zero.

5 Multinational Production and Sectoral Productivity Differences

This section describes the basic patterns in how estimated sector-level technology varies across local and foreign producers for all of the countries in the sample. In particular, we measure the effect of MP activity on the strength of comparative advantage. Using bilateral multinational gross output and international trade data at the sectoral level, two measures of production technology are estimated. The first corresponds to the technology of *local* producers (i.e., excluding foreign affiliates) (T_s^j), while the second corresponds to the state of technology of *all* producers in the economy ($\widetilde{T}_s^j$). Two sets of results are presented for the countries' relative technology: with respect to the United States and with respect to the global frontier. The global frontier in each sector is calculated by taking the geometric mean of the two highest values of $\widetilde{T}_s^j$.

The baseline analysis uses the dispersion of productivities within each sector ($\theta = 4.2$), which is the preferred value of Simonovska and Waugh (2010). As a robustness check, results are presented for two alternative values for the dispersion parameter: (1) the preferred estimation of Eaton and

Kortum (2002), θ=8.28; and (2) a sectoral θ_j estimated by Caliendo and Parro (2012).[42]

5.1 Local and Overall Productivity Patterns

Table 3 presents descriptive statistics of relative technologies both for local producers and for all producers. The first column reports the percentage change in the mean absolute distance to the frontier across all tradable sectors between local producers' productivity $(T_n^j)^{\frac{1}{\theta}}$ and all producers' productivity $(\widetilde{T}_n^j)^{\frac{1}{\theta}}$, a measure of the change in absolute advantage due to MP $\left[\left(\widetilde{T}_n^j/T_n^j\right)^{\frac{1}{\theta}}-1\right]$. The second column reports the percentage change in the coefficient of variation across tradable sectors between local producers' productivity $(T_n^j)^{\frac{1}{\theta}}$ and all producers' productivity $(\widetilde{T}_n^j)^{\frac{1}{\theta}}$. The latter can be interpreted as a measure of the change in comparative advantage implied by foreigner affiliate activity. In particular, the coefficient of variation across sectors is computed for $(\widetilde{T}_n^j)^{\frac{1}{\theta}}$ and $(T_n^j)^{\frac{1}{\theta}}$ and the percentage change between them $\left[\frac{CV(\widetilde{T}_n^j)^{\frac{1}{\theta}}}{CV(T_n^j)^{\frac{1}{\theta}}}-1\right]$ is recorded. Larger negative changes imply greater reduction in productivity dispersion across sectors and thus greater reduction in comparative advantage attributable to the effect of MP. Conversely, positive values imply that a country's comparative advantage has become stronger—productivity dispersion increases—as a consequence of MP.

Table 3: Change in Absolute and Comparative Advantage

	Variable	Mean
Group 1 (10 countries)	ΔCV	-0.19
	ΔT	0.09
Group 2 (25 countries)	ΔCV	-0.29
	ΔT	0.17
All sample (35 countries)	ΔCV	-0.25
	ΔT	0.14

For different values of θ the results are remarkably similar. The correlation between the T_i^j's estimated under $\theta = 8.28$ and the ones estimated under the baseline ($\theta = 4.2$) is above 0.90. Also, the average change in comparative advantage due to MP is similar for both values of θ, -0.24 and -0.25, respectively. Moreover, there is a strong positive correlation in the change in absolute advantage (0.50) and comparative advantage (0.48) under alternative values of θ.

The left panel in Table 4 ranks countries based on the average technology upgrade allowed by MP. In particular, Czech Republic, Poland, Lithuania, Hungary, and Austria are the countries where absolute advantage has been affected most by the activity of foreign affiliates in their local markets, while Israel, Greece, Belgium, Australia, and New Zealand have seen the smallest increase in their mean productivity. In the right panel in Table 4, countries are ranked according

[42]See Table B.11 in Tables and Figures for the values of θ_j by sector under this specification.

Table 4: Average and Relative Change in Productivity due to MP

Average Change		Relative Change	
Top 10: Largest Change Countries		Top 10: Largest Change Countries	
Czech Rep.	0.41	Poland	-0.53
Poland	0.35	Czech Rep	-0.52
Lithuania	0.30	Spain	-0.52
Hungary	0.29	Portugal	-0.52
Austria	0.24	Canada	-0.51
Netherlands	0.22	Austria	-0.48
Slovakia	0.22	Italy	-0.47
Portugal	0.22	Turkey	-0.43
Sweden	0.20	Russia	-0.42
Canada	0.17	Sweden	-0.41
Turkey	0.14	Slovenia	-0.39
Bottom 10: Smallest Change Countries		Bottom 10: Smallest Change Countries	
Finland	0.09	Japan	-0.14
France	0.07	Belgium	-0.08
Switzerland	0.06	Denmark	-0.07
Denmark	0.04	Greece	-0.06
Norway	0.04	United Kingdom	-0.06
New Zealand	0.04	Norway	-0.04
Australia	0.03	Latvia	0.05
Belgium	0.02	Germany	0.08
Greece	0.01	France	0.14
Israel	0.01	Bulgaria	0.14

Notes: This table reports the ten largest (top panel) and ten smallest (bottom panel) countries affected by MP, measured by the percentage change in the mean absolute distance to the United States in $T_{all}^{\frac{1}{\theta}} - T_{mp}^{\frac{1}{\theta}}$ across all tradable sectors.

to the change in productivity dispersion between $(T_h^j)^{\frac{1}{\theta}}$ and $(\widetilde{T}_h^j)^{\frac{1}{\theta}}$. As can be seen, Austria, Poland, Czech Republic, Portugal, and Spain stand as the countries with the largest reduction in comparative advantage, while Bulgaria, France, Germany, and Latvia show the largest increase in relative difference in productivity across sectors. Finally, Norway, Greece, and the United Kingdom register the lowest reduction in relative technology difference across sectors.

Ranked by technology level, the top panel of Table A.7 in the Tables and Figures shows the change in average and relative productivity for the ten most advanced countries, and the bottom panel groups the rest of the countries in the sample. For the set of countries with the highest effective technology, the mean productivity increases by 19 percent, while the differences in productivity across sectors are reduced by 9 percent due to multinational activity. The less advanced countries experience an even higher increase in mean productivity (17 percent) as well as a larger reduction in the heterogeneity of productivity across sectors (29 percent).[43] The difference in means across both groups is statistically significant, showing that, even when both groups are clearly affected by MP, the impact on absolute and comparative advantage is relatively larger in less advanced countries.[44]

5.2 The Effect of MP on Sectoral Productivity Differences

The results presented in the previous section suggest that MP is unevenly affecting the average sectoral technology. In particular, the technology boost generated by multinational firms operating in the host market is disproportionately larger in comparative disadvantage sectors. As mentioned in Section 2.4, this is in part a consequence of a larger foreign affiliate output share in low-productivity sectors.

Table **??** in Tables and Figures shows the correlation between the estimated average productivity of local producers (T_i^j) and the sectoral MP in country h. For most countries in the sample, the correlation is negative and statistically significant at the 10 percent level.[45] When all of the countries and sectors are pooled, after controlling for country- and sector-specific characteristics, the overall correlation is negative and significant at the one percent level (-0.304). Figure 6 shows the result of this conditional correlation along with a fitted regression line.[46]

To shed further light on whether sectors in which local producers show greater disadvantage are the ones that receive the biggest boost from MP, making the comparative advantage of the entire economy look weaker, consider the following regression:

[43]If instead of the entire sample, we compare the top ten and the bottom ten countries, the already highlighted differences become even more pronounced for the change in absolute advantage (0.22 for the bottom ten countries), while the change in the coefficient of variation stays virtually the same.

[44]These results are in line with the findings of Levchenko and Zhang (2011). Exploiting the temporal dimension, they found that over time countries increased their level of technology and also experienced a reduction in the dispersion of relative productivity across sectors.

[45]Similar results are obtained if instead MP is normalized by absorption, calculated as output minus exports.

[46]This correlation is similar to the one in Figure 2.4 presented in Section 2.4, but it replaces the calculated total factor productivity (TFP) with the state of technology estimated relying on the structure of the model

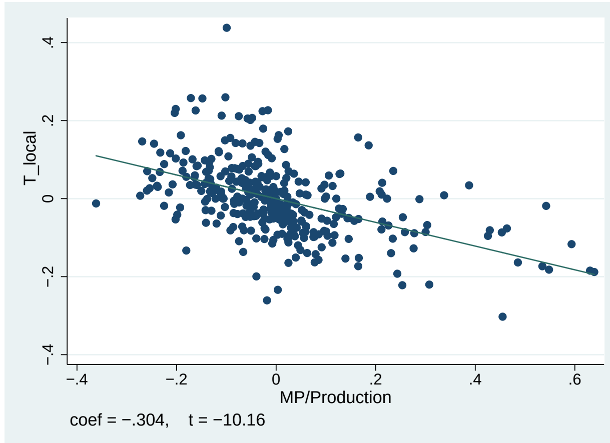


Figure 6: Multinational Production and Technology

$$log\left(\frac{\widetilde{T}_h^j}{T_h^j}\right)^{1/\theta_j} = \beta\cdot log\left(T_h^j\right)^{1/\theta_j} + \gamma_h + \gamma_j + \nu_{hj} \tag{51}$$

On the left-hand side of the equation is the technological upgrade in country h in sector j, $\left(\widetilde{T}_h^j/T_h^j\right)^{1/\theta_j}$, generated by multinational activity. On the right-hand side, the regressor of interest is the mean technology of local producers (T_h^j). The specification includes country and sector fixed effects.[47] The country effect captures the average change in productivity due to MP across all sectors in each country—the absolute advantage effect. The β coefficient picks up the impact of local producers' productivity on the relative difference between overall productivity and local producers' productivity. In particular, a negative β implies that relative to the country-specific average, the least productive sectors get the largest boost in technology from MP; see Table 5 and Figure 7 below. The results are robust to alternative estimations of average productivity and values of θ are illustrated in the Appendix A.

The results presented in this section stand as evidence of the role of MP in changing the pattern of comparative advantage in a country by affecting disproportionately more those sectors in which local producers exhibit relative disadvantage. In this context, sectoral trade models that ignore MP greatly understate the relative technology differences across sectors among local producers.

To capture the reduction in comparative advantage generated by multinational activity, we compute the change in average trade shares $\left(X_{nn}^j/X_n^j\right)$ when the coefficient of variation of local producers' technology is one percent larger than the coefficient of variation of all producers in the economy, while keeping constant the average productivity—or absolute advantage. In the next section, a counterfactual scenario is constructed to illustrate the trade implications of the actual reduction in comparative advantage due to MP.

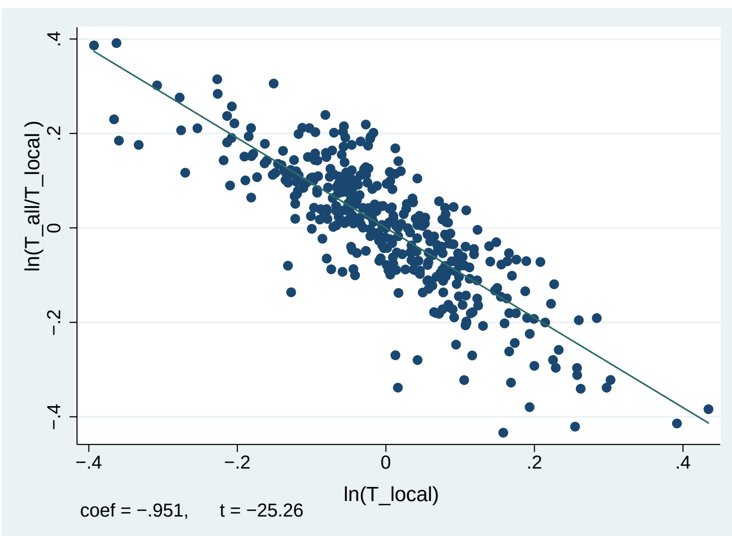
[47] All of the standard errors are clustered by country, to account for unspecified heteroskedasticity at the country level. All the results are robust, however, to clustering at the sectoral level.

Table 5: Pooled Regression Results

Dep.Variable: $ln\left(\widetilde{T}_h^j\right)^{1/\theta} - ln\left(T_h^j\right)^{1/\theta}$	
$ln\left(T_h^j\right)^{1/\theta}$	-0.951***
	(0.038)
Observations	315
R^2	0.850
Sector FE	yes
Coutry FE	yes

Notes: Standard errors clustered at the country level in parentheses. Significance is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$. This table reports the results of regressing the technology upgrade due to MP in host country h in sector j $\left(\widetilde{T}_h^j/T_h^j\right)^{1/\theta_j}$ on the productivity of local producers, $\left(T_h^j\right)^{1/\theta_j}$.

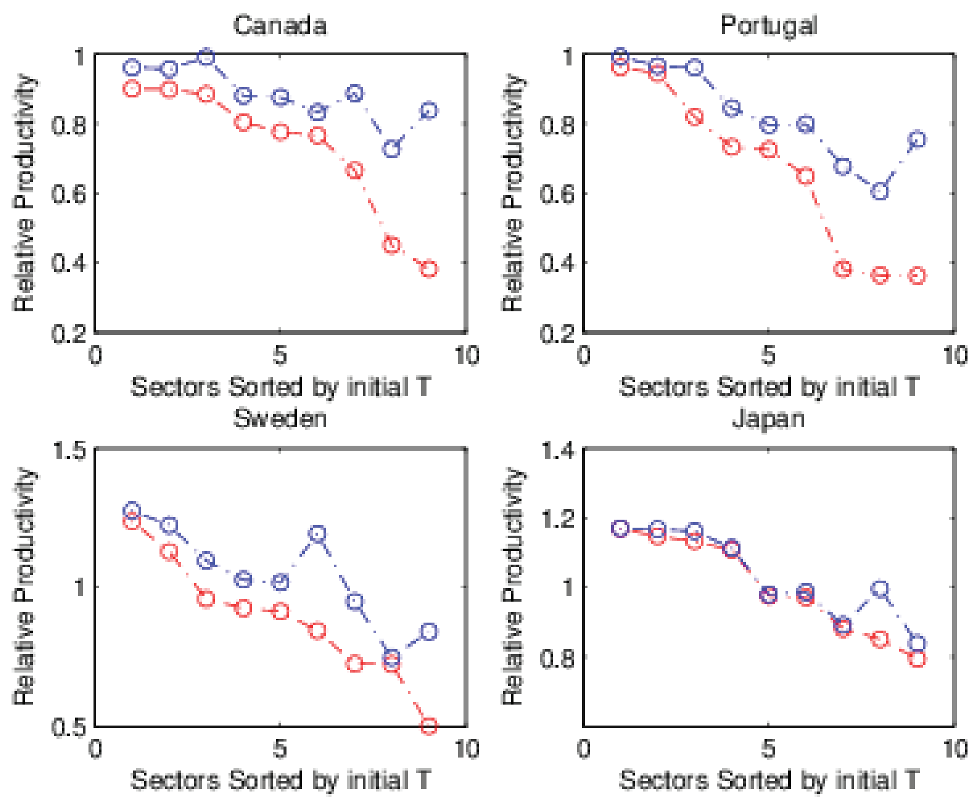
Figure 7: Impact of Multinational Production in Technological Change



Notes: This figure shows the conditional correlation of the technology upgrade due to MP in host country h in sector j $\left(\widetilde{T}_h^j/T_h^j\right)^{1/\theta_j}$ (vertical axis) and the productivity of local producers, $\left(T_h^j\right)^{1/\theta_j}$ (horizontal axis) after controlling for sector and country fixed effects.

The basic patterns of the data are illustrated with some examples for individual countries. Figure (8) present scatterplots of tradable sector productivity both for local producers and for the overall economy. On the x-axis, sectors are placed in order of their distance from the global productivity frontier, such that the local producers' comparative advantage sectors are furthest to the left. The two countries in the top panel, Canada and Portugal, show a pronounced weakening of comparative advantage according to our estimates. Japan does not exhibit much weakening of comparative advantage: while there is an average productivity increase, there is no systematic relationship in terms of distance to frontier between local producers and all producers in the economy.

Figure 8: Relative Productivities



Notes: This figure displays the tradable-sector productivities in selected countries, expressed as the ratio to the U.S productivity for the overall economy (red circles) and for local producers exclusively (blue circles). The x-axis labels sectors in descending order of the ratio to the frontier of local producers productivity (so that the sectors where local producers are relative more productive are on the left).

6 Welfare Analysis

This section computes the welfare impact of MP taking into account the affects of multinational production on comparative advantage. After solving the model using the preferred estimates of parameters for technology, MP barriers, and trade barriers (following the algorithm set forth in Section E in the Appendix), we now proceed to evaluate the fit of the model as well as its implications for welfare.

6.1 Model Fit

The goodness of the model can be evaluated by how closely it matches the patterns of trade and MP data along several dimensions. Table A.9 in Tables and Figures reports statistics from the data and the calibrated model. It reports the mean, the median, and the correlation between the model and the data for wages, return of capital, and manufactured imports as a share of GDP, as well as inward and outward MP as a share of total output. Figures A.8, A.9, A.10, and A.11 present the comparison between the model and the data for each of this variables.

First, the ability of the model to replicate the income differences across countries is tested by comparing the wages and return of capital in every country h relative to the United States. This is a non-trivial test for the model, for two reasons: (1) because trade and MP interact in every tradable sector, and (2) because the model includes a non-tradable sector, where multinationals have a significant presence. The median relative wages of the model (0.79) are very close to those reported in the data (0.71), although they are slightly higher in the model. The association between relative wages in the model and wages observed in the data is very high (0.92).

Second, even though the fundamental technology parameters and the MP barriers were not estimated to match the bilateral MP shares, the statistics presented for the model and the data are similar. Even when the model overestimates the share of total output produced by foreign affiliates, it is not by much—the median of the aggregate MP-to-output ratio is 0.30 in the model and 0.26 in the data, while the correlation equals 0.76. This is somewhat similar to the outcomes observed by comparing the production of a country's affiliates overseas with total production within the country's frontiers. Note that in the data the mean of the outward-MP-to-output ratio (0.21) is considerably higher than the median (0.09), which tells us that the distribution of outward MP to output is skewed to the left. The model replicates this pattern, as shown by a high correlation with the data (0.8).

Finally, we assess how well the model captures the trade patterns observed in the data. Looking at the ratio of total imports to GDP, we can see that the mean of the model and the mean of the data are very close and they have a high degree of correlation.

Next we use the model to construct a number of counterfactuals that allow us to understand the mechanism underlying the relationship between MP and comparative advantage.

6.2 Counterfactual 1: Gains from MP in a Multisectoral Model

As mentioned previously, gains from MP are defined by the proportional change in country h's real income per capita as we move from a counterfactual equilibrium with trade but no MP to the actual equilibrium. In a competitive model, total income equals the total returns to factors of production. Therefore welfare—or real income per-capita—is expressed by:

$$\frac{w_h + r_h k_h}{P_h}$$

The gains form MP are computed then by solving the baseline model, calculating the welfare, and comparing this welfare to a counterfactual scenario in which all countries are assumed to be open to trade but close to foreign producers. In order to assess the effect of heterogeneity in MP shares across sectors, Table 4 compares the gains from MP in a multi-sectoral model with the gains from MP in a uni-sectoral model. The latter by definition assumes that MP shares are the same across all sectors of the economy.

As can be observed in the table, the mean gains from MP are 15 percentage points higher in a multi-sector framework compared with a uni-sector framework. The real income increase following an opening to multinational activity is 27 percent compared to the 12 percent obtained in an scenario where MP shares are homogeneous across sectors. Either measured by the median or by the mean, the heterogeneity of foreign affiliate sales across sectors almost double the gains in welfare associated to MP activity. This exercise shows that uni-sector models significantly understate the gains from multinational activity. Similar to the effect in gains from trade due to sectoral heterogeneity [Levchenko and Zhang, 2013], deviations from equal MP shares across sectors due to comparative advantage, significantly increases the gains from MP.

Table 6: Gains from MP in a Multi-sectoral Model

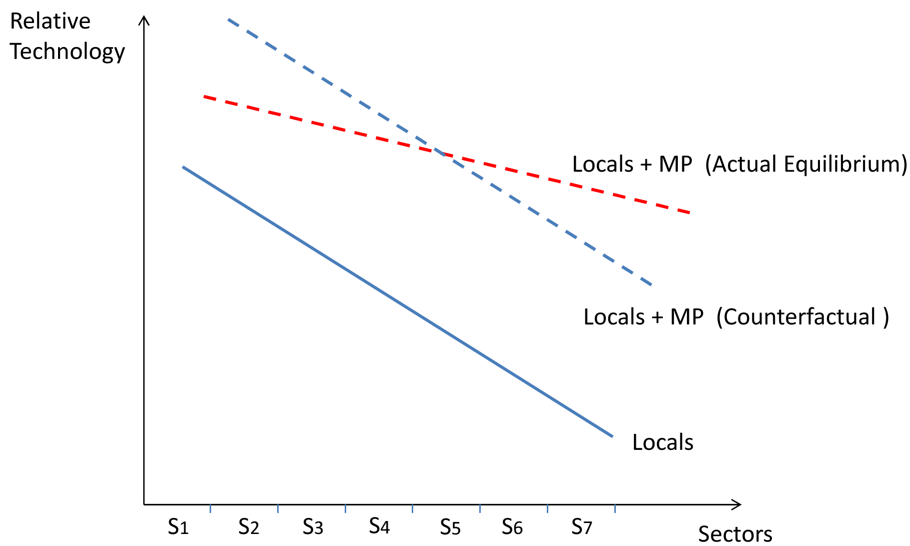
	Mean	Median	Std.Dev	Min	Max
	MP Gains (Multisector) (%)				
Counterfactual Vs Baseline	27.01	15.59	0.29	9.58	93.48
	MP Gains (Uni-sector) (%)				
Counterfactual Vs Baseline	12.03	8.42	0.17	0.02	79.35

6.3 Counterfactual 2: Proportional Technology Transfer

In order to assess the effect of MP on comparative advantage, this section presents a counterfactual scenario where MP changes only the average productivity of the economy, while keeping constant the country's comparative advantage. To achieve this outcome, we calculate the geometric average across sectors of the productivity of local producers $\left(T_h^j\right)$ and all producers in the economy $\left(\widetilde{T}_h^j\right)$. The ratio of the two tells us the average productivity increase due to multinational activity. The counterfactual effective productivity is calculated by increasing T_h^j by the increase factor $\frac{\left(\prod_{j=1}^J \widetilde{T}_h^j\right)^{1/J}}{\left(\prod_{j=1}^J T_h^j\right)^{1/J}}$ in every tradable sector j. Figure (9) illustrates this exercise.

$$\left(\widetilde{T}_h^j\right)_{\text{count}} = T_h^j \times \frac{\left(\prod_{j=1}^J \widetilde{T}_h^j\right)^{1/J}}{\left(\prod_{j=1}^J T_h^j\right)^{1/J}} \ \forall j = 1..J$$

Figure 9: Counterfactual 2: Proportional Technology Transfer



Notes: This figure displays the tradable-sector productivities, expressed as the ratio to the global frontier productivity for the overall economy (dash lines) and for local producers exclusively (solid blue line). The x-axis labels sectors in descending order of the ratio to the frontier of local producers productivity (so that the sectors where local producers are relative more productive are on the left). The dash red line represents the productivity for the overall economy in the actual equilibrium. The dash blue line represents the overall economy productivity in the counterfactual scenario in which MP affects all sectors proportionally. The average productivity is the same in the actual equilibrium and in the counterfactual scenario (blue dash line and red dash line)

Table 7 compares the gains from trade in the actual equilibrium with the counterfactual scenario. The magnitudes are substantial. The mean gains from trade in the counterfactual scenario are almost double the actual gains from trade, going from 10.39 percent to 19.05 percent for the

Table 7: Proportional Technology Transfer

	Mean	Median	Std Dev	Min	Max
			Gains from Trade (%)		
Actual Gains	10.39	9.28	0.05	1.19	24.53
Counterfactual	19.05	17.42	0.08	9.18	33.81
			Welfare Change (%)		
Baseline Vs Counterfactual	-3.55	-5.36	0.04	-13.34	1.13
			Trade Openness (%)		
Baseline Vs Counterfactual	13.32	10.21			

average country in our sample, with a minimum gain of 9.18 percent and a maximum of 33.8 percent. Next, comparing the change in real wage between the baseline and the counterfactual scenario, we find that the sole effect of MP on comparative advantage is expressed in a reduction in real wage of 3.55 percent. Trade openness, measured by the ratio of a country's trade (exports plus imports) to its GDP, is almost 13.3 percent higher in the counterfactual, where MP does not affect the country's comparative advantage.

If instead we impose a proportional increase in the productivity of local producers in all sectors such that it matches the observed aggregate trade shares, rather than the observed aggregate productivity, we get similar results.

6.4 Counterfactual 3: Multinational Production and Non-Tradables

Multinational production is the only option available for producers in the non-tradable sector to serve a foreign market. Therefore, it is not surprising that about 60 percent of MP activity is in non-tradables. Moreover, non-tradables account for a significant portion of the intermediate inputs used in the majority of tradable sectors. Thus, access to cheaper non-tradable goods due to MP activity can increase the competitiveness of tradable sectors, thereby improving the welfare of the economy.

Table 5 shows the change in welfare going from a counterfactual scenario, where the barriers to investment in the non-tradable sector are arbitrarily large, to the actual equilibrium. The results in the table show that real wages increase by 4.7 percent, while the reduction in the tradable price index is 1.9 percent.

Table 8: Multinational Production and Non-Tradables

	Mean	Median	Std.Dev	Min	Max
			Welfare Change (%)		
Counterfactual Vs Baseline	6.53	4.69	0.05	1.54	12.33
			Tradable Price Index (%)		
Counterfactual Vs Baseline	1.62	1.87	0.04	0.63	2.13

7 Conclusion

This paper shows that by omitting the sectoral heterogeneity of MP sales and therefore its impact on comparative advantage, existing models of trade and MP in uni-sectoral frameworks systematically overstate the gains from trade and understate the gains from MP. A unique industry-level dataset of bilateral foreign affiliate sales for thirty-five countries documents a new empirical regularity: multinational production is disproportionately allocated to industries where local producers exhibit comparative disadvantage.

To quantify this phenomenon, the role of differing productivity levels across industries is incorporated into a Ricardian general equilibrium model of trade and multinational production. This paper offers the first set of productivity estimates at the sectoral level for local producers as well as for the entire economy. Compared with previous uni-sectoral models, this paper offers more reliable estimates of fundamental technology, since previous literature does not effectively isolate the technology corresponding to local producers at the sectoral level.

There are three main contributions stemming from this work. First, it shows that comparative advantage plays a crucial role in determining the allocation of multinational production across sectors: foreign affiliate activity is higher on average in sectors where the host economy has comparative disadvantage. The analytical results and quantitative estimations reveal that the effect of multinational production on the state of technology is higher in those sectors in which local producers are relatively less productive, implying that multinational production weakens a country's comparative advantage. Second, it shows that gains from trade are about half of what they would be in the absence of sectoral heterogeneity in multinational activity. In particular, in a counterfactual scenario in which multinational production affects only the average productivity level of the host economy while keeping its comparative advantage unchanged, estimated gains from trade would be twice as large (19.04 percent compared with 10.4 percent). Multinational production not only closes the absolute technology gap across countries, it also reduces the relative technology differences across sectors within a country. Third, it shows that heterogeneity of foreign affiliate sales across sectors is quantitatively important in accounting for welfare gains associated with MP activity.

The results of this study highlight the importance of incorporating a sectoral dimension in the analysis of MP activity. It distinguishes between the absolute and comparative advantage effects of MP, which is essential to improve our understanding of the welfare implications and the mechanism through which an economy responds to multinational production.

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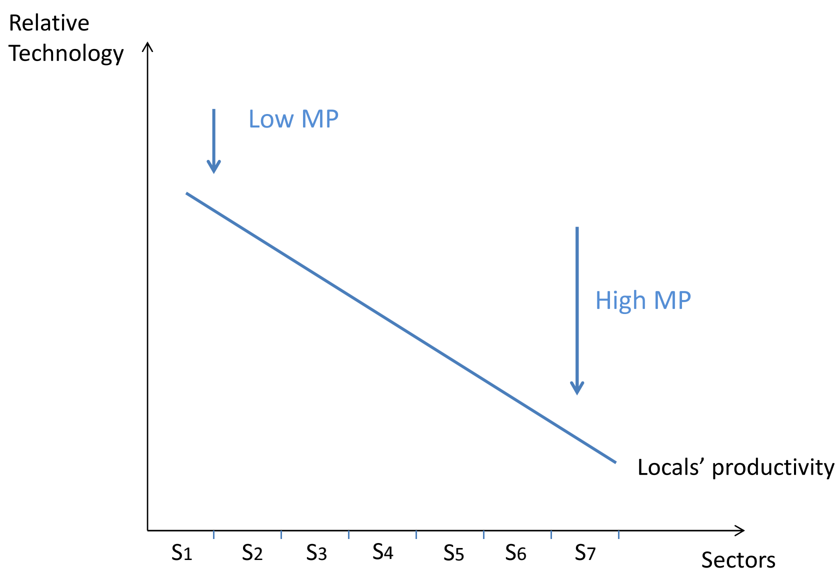
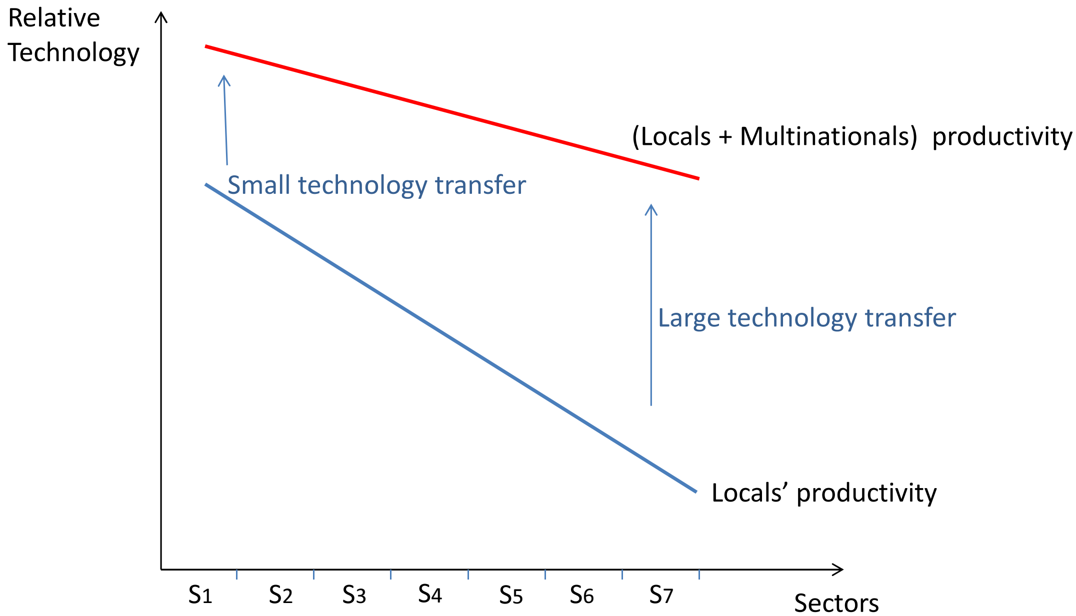
Appendix A: Figures and Tables

Figure A.1: Effect of Comparative Advantage on MP Allocation



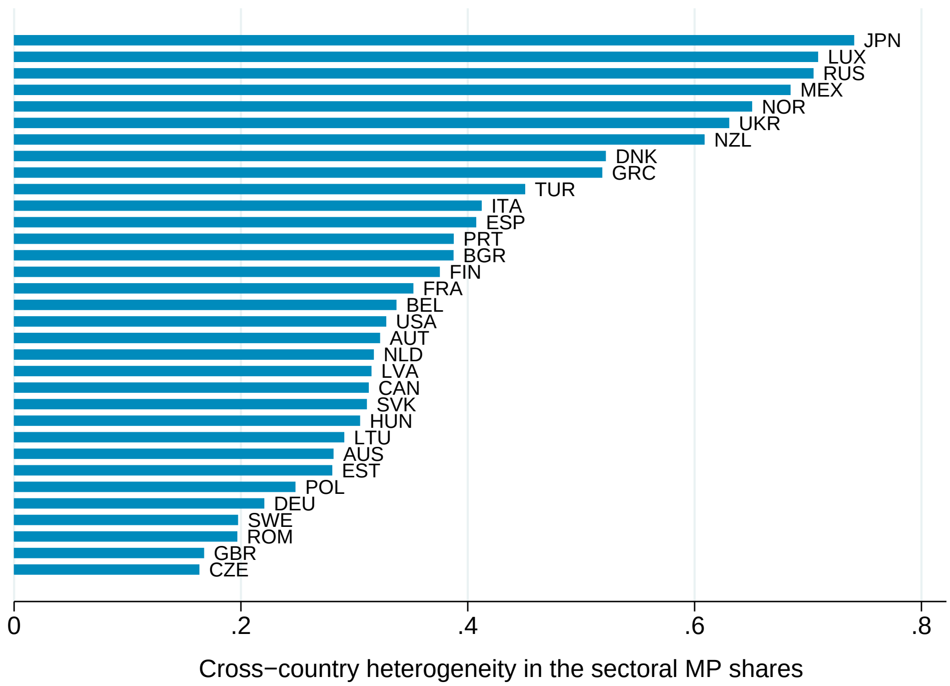
Notes: This figure displays the tradable-sector productivities of local producers, expressed as the ratio to the global frontier productivity for a representative economy. The x-axis labels sectors in descending order of the ratio to the frontier (so that the sectors where local producers are relative more productive are on the left). The Figure shows that the share of MP on the host country's output is higher in sectors where the relative productivity of local producers is low.

Figure A.2: Effect of MP on Comparative Advantage



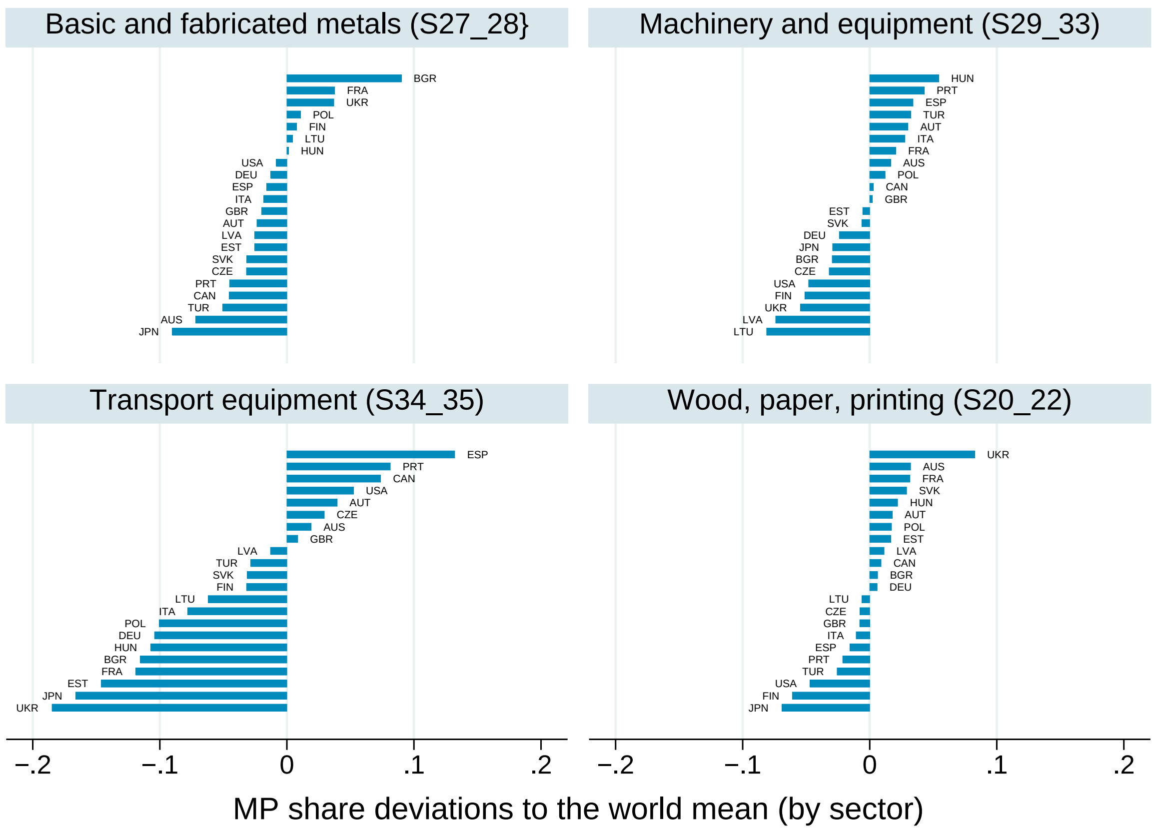
Notes: This figure displays the tradable-sector productivities, expressed as the ratio to the global frontier productivity for the overall economy (red) and for local producers exclusively (blue). The x-axis labels sectors in descending order of the ratio to the frontier of local producers productivity (so that the sectors where local producers are relative more productive are on the left). The Figure shows that the red line is above the blue line for all tradable sector and that the red line is steeper than the blue line; indicating that MP increases the productivity in all sectors but it affects more the productivity of those sectors where local producers are relatively less productive.

Figure A.3: Index of cross-country differences in the heterogeneity MP shares across sectors



Notes: This figures shows the sectoral specialization of $(MP/output)_h^j$ measured by the Krugman index. This index measures the cross-country differences in the degree of sectoral heterogeneity of $(MP/output)$ across sectors, in relation to a reference group (the world economy comprised by all countries in the sample). The Krugman specialization index takes value zero if country i has a share of MP on output across sectors that is identical to the one of the world average; and takes a maximum of 2(No of sectors-1)/No of sectors (1.78, with nine tradable sectors) if the heterogeneity of sectoral MP in country i has no sectors in common with the world economy. Therefore, the Krugman index of c does not measure the heterogeneity of MP shares within a country, but rather the cross-country differences in the heterogeneity MP shares across sectors.

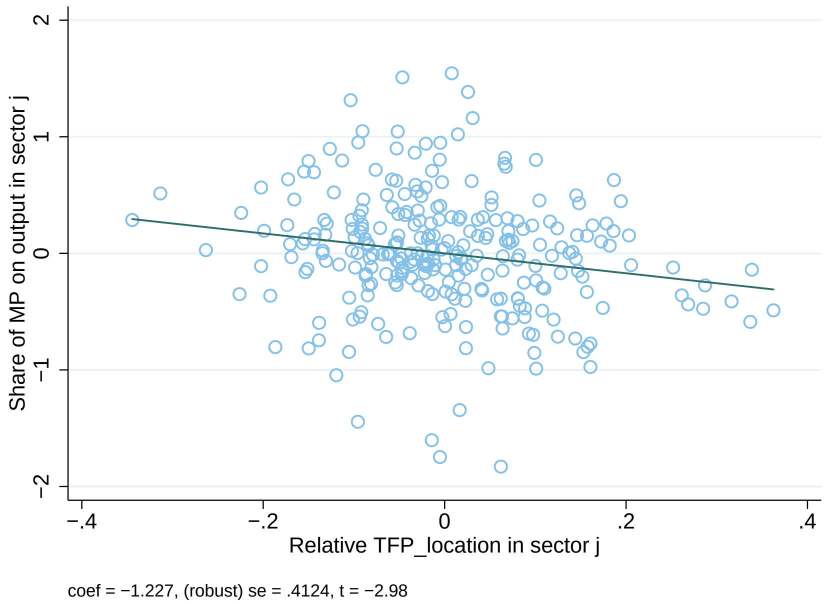
Figure A.4: Cross-country differences in the heterogeneity of sectoral MP shares (selected sectors)



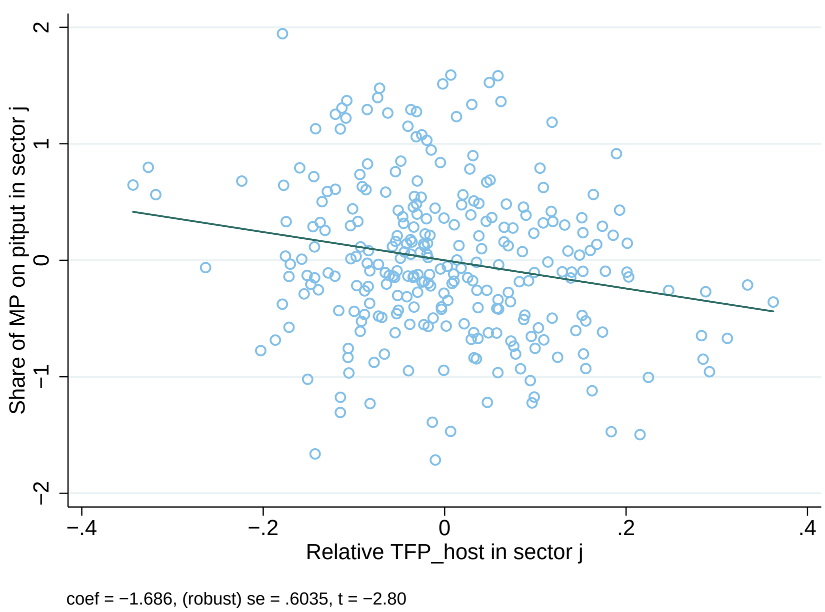
Notes: This figure shows per country, the difference between the share of MP on output in country i and the world economy $((MP/output)_h^j - (MP/output)_{world}^j)$ in selected sectors. Positive values of this measure reveal which countries host relative more multinational activity compared to the the world average; while negative values reveal which countries host relative less multinational activity compared to the the world average. See **??** for a detail explanation of the construction of this index.

Figure A.5: Sectoral MP and relative productivity

(a) Share of MP on output and relative productivity



(b) Share of MP on output (produced by local firms) and relative productivity



Notes: These figures displays the partial correlation of the ($MP\text{share}_h^j$) against relative productivity $ln(TFP_h^j/TFP_s^j)$, after netting out source country, host country and sector effects. It also controls for Heckscher Ohlin forces, as captured by the interaction between host country h factor endowments $log(K/L)_h$ and sector j factor intensities $log(K/L)^j$. MP share is measured as the output produce by all foreign affiliates, regardless of the source country, in host country h in sector j, relative to total production of country h in sector j (top panel) and relative to the output in country h sector j produced by local firms (i.e. excluding foreign affiliates) (bottom panel). Relative productivity is measured by the estimates from a Ricardian trade model (Costinot, et al 2012).

Figure A.6: Relationship Between U.S. MP shares and Comparative Advantage

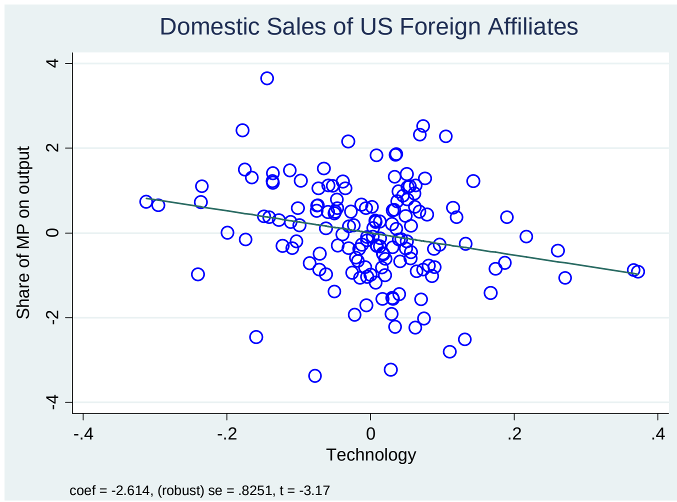
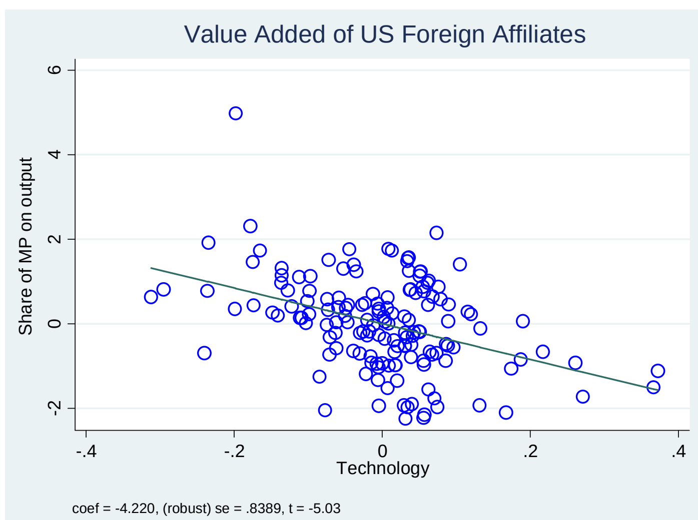


Figure A.7: Relationship Between U.S. MP shares and Comparative Advantage: Value Added



Notes: This figure depicts the partial correlation between the share of MP of U.S foreign affiliates in each host country-sector pair and the productivity of the host economy in each sector after netting out the country and sector fixed effects.. It considers only the sales of U.S affiliates in the country of operation (host country); that is, excluding all their exports to third countries. The y-axis represent the vale of MP/output in each host country-sector pair, and the x-axis represent the productivity of each host country-sector pair. The source of the data is the Bureau of Economic Analysis (BEA)

Table A.1: List of countries in the sample

Australia	Austria	Belgium
Canada	Czech Republic	Denmark
Estonia	Finland	France
Germany	Greece	Hungary
Italy	Japan	Latvia
Luxembourg	Mexico	Lithuania
New Zealand	Netherlands	Poland
Portugal	Norway	Romania
Russian Federation	Slovakia	Slovenia
Spain	Sweden	Switzerland
Turkey	United Kingdom	Ukraine
United States		

Table A.2: Multinational Production by Country

Country	Number of Source Countries	MP/output (Inward)	Number of Location Countries	MP/output (Outward)
Australia	20	0.31	31	0.16
Austria	31	0.36	32	0.33
Belgium	27	0.53	32	0.22
Bulgaria	33	0.35	18	0.05
Canada	9	0.35	32	0.18
Czech Rep.	33	0.20	25	0.05
Denmark	26	0.20	31	0.30
Estonia	30	0.50	20	0.15
Finland	29	0.22	31	0.42
France	33	0.27	33	0.32
Germany	33	0.30	33	0.27
Greece	23	0.14	23	0.05
Hungary	33	0.79	19	0.06
Italy	33	0.16	32	0.08
Japan	17	0.02	33	0.13
Lithuania	29	0.57	19	0.12
Latvia	30	0.70	20	0.05
Luxembourg	25	0.48	31	2.64
Mexico	20	0.13	27	0.04
Netherlands	30	0.31	33	0.82
New Zealand	18	0.24	28	0.17
Norway	27	0.31	30	0.19
Poland	33	0.44	28	0.03
Portugal	29	0.28	27	0.08
Romania	33	0.56	16	0.01
Russia	33	0.16	27	0.08
Slovakia	33	0.57	17	0.05
Spain	31	0.24	31	0.11
Sweden	28	0.32	32	0.45
Switzerland	9	0.06	33	0.85
Turkey	25	0.07	26	0.02
Ukraine	33	0.31	16	0.13
United Kingdom	33	0.47	33	0.33
United States	23	0.08	33	0.10

Note: Inward MP refers to foreign affiliate sales from all source countries in a given host-sector pair. Outward MP refers to the sales of foreign affiliates in all host countries for each source-sector pair. The first column represents the number of source countries operating in each country. Similarly, the third column represents the number of host countries in which each country has operations. The table contains statistics for tradable and non-tradable sectors and thirty-four reporting countries.

Table A.3: Relationship Between Bilateral Sectoral MP and Relative Productivity

Dep. Variable $ln\left(MP_{hs}^{j}/output_{h}^{j}\right)$	Relative Productivity Measures: Model Base Productivity (1)	(2)	RCA Index (3)	(4)	GDDC productivity (5)	(6)
$ln\left(TFP_{h}^{j}/TFP_{s}^{j}\right)$	–3.150***	–2.679***	–2.162***	–2.385***	–1.008***	–1.132***
	(0.2063)	(0.2269)	(0.3114)	(0.2942)	(0.1347)	(0.1437)
ln(Distance)	–0.600***		–0.190		–0.434***	
	(0.0674)		(0.1569)		(0.1061)	
Common Language	0.159		0.806***		0.212	
	(0.1588)		(0.2175)		(0.1853)	
Colony	0.388***		0.153		0.499***	
	(0.1518)		(0.2150)		(0.1856)	
Border	0.382***		0.407**		0.568***	
	(0.1433)		(0.1965)		(0.2032)	
RTA	–0.170		0.105		0.340	
	(0.1397)		(0.4435)		(0.2530)	
Heckshер-Ohlin:						
$log(K/L)^{j} \times log(K/L)_{h}$	0.179	0.310	–0.096	–0.061	0.184	0.304
	(0.2846)	(0.3365)	(0.3536)	(0.3340)	(0.3611)	(0.4103)
Controls						
Source-country FE	Yes	–	Yes	–	Yes	–
Host-country FE	Yes	–	Yes	–	Yes	–
Host-source FE	No	Yes	No	Yes	No	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	4,011	3,848	872	855	1,519	1,509
Adjusted R^2	0.49	0.68	0.62	0.73	0.54	0.69

Notes: This table presents the results of the Least Square Regression between the share of MP for each source-host-sector triplet ($MP\text{share}_{hs}^{j}$) and the ratio of productivities (TFP_h/TFP_s) for different specifications and productivity measures. Column (1), (3) and (5) report results with source, location and sector fixed effects, while columns (2), (4) and (6) report results with source-location and sector fixed effects. The relative productivity measure used in column (1) and (2) is the productivity estimates from a Ricardian trade model (Costinot, et al (2012); column (3) and (4) uses the new reveal comparative advantage index (RCA) at the CEPII database (available for Austria, Canada, Germany, Spain, France, U.K. Italy, Japan, Mexico, Netherlands, Russia, Turkey and U.S.). Finally, columns (5) and (6) use the relative multi-factor productivity provided by GGDC Productivity Level Database and available for eighteen OECD economies. To correct for trade-driven selection, RCA and GGDC observed relative productivity index were multiplied by a factor of relative openness between any two pair of countries $\left(\pi_{ii}^{j}/\pi_{i'i'}^{j}\right)^{1/\theta}$, with $\theta = 4$. Robust standard errors, clustered by source-location pair are reported in parentheses. ***, ** and * denote significance at 1%, 5%, and 10% level.

Table A.4: Relationship Between Bilateral Sectoral MP and Relative Productivity

Dep. Variable $ln\left(MP^j_{hs}/Inn^j_h\right)$	Relative Productivity Measures: Model Base Productivity (1)	(2)	RCA Index (3)	(4)	GDDC productivity (5)	(6)
$ln\left(TFP^j_h/TFP^j_s\right)$	–3.363***	–2.927***	–2.382***	–2.599***	–0.975***	–0.970***
	(0.2172)	(0.2552)	(0.3114)	(0.3275)	(0.1547)	(0.1775)
ln(Distance)	–0.585***		–0.189		–0.471***	
	(0.0669)		(0.1562)		(0.1079)	
Common Language	0.2027		0.814***		0.180	
	(0.1599)		(0.2001)		(0.1905)	
Colony	0.3629**		0.228		0.519***	
	(0.1599)		(0.2238)		(0.1869)	
Border	0.438***		0.407**		0.516***	
	(0.1445)		(0.1929)		(0.2078)	
RTA	–0.156		0.208		0.284	
	(0.1405)		(0.4532)		(0.2539)	
Heckscher-Ohlin:						
$log(K/L)^j \times log(K/L)_h$	0.167	0.345	–0.056	0.023	0.227	0.285
	(0.2846)	(0.3392)	(0.3536)	(0.3540)	(0.3603)	(0.3895)
Controls						
Source-country FE	Yes	–	Yes	–	Yes	–
Host-country FE	Yes	–	Yes	–	Yes	–
Host-source FE	No	Yes	No	Yes	No	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	4,019	3,843	874	859	1,513	1,488
Adjusted R^2	0.51	0.68	0.63	0.72	0.55	0.69

Notes: Inn^j_h represents the output in host country h and sector j produced by local producers only (i.e. excluding foreign affiliates). This table presents the results of the Least Square Regression between the share of MP for each source-host-sector triplet ($MP\text{share}^j_{hs}$) and the ratio of productivities (TFP_h/TFP_s) for different specifications and productivity measures. Column (1), (3) and (5) report results with source, location and sector fixed effects, while columns (2), (4) and (6) report results with source-location and sector fixed effects. The relative productivity measure used in column (1) and (2) is the productivity estimates from a Ricardian trade model (Costinot, et al (2012); column (3) and (4) uses the new reveal comparative advantage index (RCA) at the CEPII database (available for Austria, Canada, Germany, Spain, France, U.K. Italy, Japan, Mexico, Netherlands, Russia, Turkey and U.S.). Finally, columns (5) and (6) use the relative multi-factor productivity provided by GGDC Productivity Level Database and available for eighteen OECD economies. To correct for trade-driven selection, RCA and GGDC observed relative productivity index were multiplied by a factor of relative openness between any two pair of countries $\left(\pi^j_{ii}/\pi^j_{i'i'}\right)^{1/\theta}$, with $\theta = 4$. Robust standard errors, clustered by source-location pair are reported in parentheses. ***, ** and * denote significance at 1%, 5%, and 10% level.

Table A.5: Relationship Between Sectoral MP and Relative Productivity

	Relative Productivity Measures					
	Model Base Productivity		RCA Index		GDDC productivity	
	(1)	(2)	(3)	(4)	(5)	(6)
$ln\left(TFP_h^j\right)$	–2.645***	–3.318***	–1.805***	–2.331***	–1.027**	–0.834**
	(0.3771)	(0.4936)	(0.3419)	(0.4168)	(0.2218)	(0.3136)
Hecksher-Ohlin:						
$log(K/L)^j \times log(K/L)_h$	–0.0716	–0.0748	–0.056	–0.0404	0.5105	0.447
	(0.2391)	(0.2049)	(0.3536)	(0.2039)	(0.0956)	(0.1147)
Controls						
Source-country FE	Yes	Yes	Yes	Yes	Yes	Yes
Host-country FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	273	279	107	107	127	129
Adjusted R^2	0.95	0.93	0.94	0.91	0.96	0.94

Dep var: $ln\left(\text{No. of sources}_h^j / output_h^j\right)$, columns: (1), (3) and (5)

Dep var: $ln\left(\text{No. of sources}_h^j / Inn_h^j\right)$, columns: (2), (4) and (6)

Notes: Inn_h^j represents the output in host country h and sector j produced by local producers only (i.e. excluding foreign affiliates). This table presents the results of the Least Square Regression between the share of MP for each host-sector pair ($MP\text{share}_h^j$) and the host country relative productivity (TFP_h) for different specifications and productivity measures. Column (1), (3) and (5) report results with source, location and sector fixed effects, while columns (2), (4) and (6) report results with source-location and sector fixed effects. The relative productivity measure used in column (1) and (2) is the productivity estimates from a Ricardian trade model (Costinot, et al (2012); column (3) and (4) uses the new reveal comparative advantage index (RCA) at the CEPII database (available for Austria, Canada, Germany, Spain, France, U.K. Italy, Japan, Mexico, Netherlands, Russia, Turkey and U.S.). Finally, columns (5) and (6) use the relative multi-factor productivity provided by GGDC Productivity Level Database and available for eighteen OECD economies. To correct for trade-driven selection, RCA and GGDC observed relative productivity index were multiplied by a factor of relative openness between any two pair of countries $\left(\pi_{ii}^j/\pi_{i'i'}^j\right)^{1/\theta}$, with $\theta = 4$. Robust standard errors, clustered by source-location pair are reported in parentheses. ***, ** and * denote significance at 1%, 5%, and 10% level.

Table A.6: Relationship Between Sectoral MP and Relative Productivity

	Relative Productivity Measures					
	Model Base Productivity		RCA Index		GDDC productivity	
	(1)	(2)	(3)	(4)	(5)	(6)
$ln\left(TFP_h^j\right)$	–1.227***	–1.686***	–1.567***	–2.076***	–0.405**	–0.673**
	(0.4124)	(0.6035)	(0.4736)	(0.5771)	(0.1963)	(0.3218)
Hecksher-Ohlin:						
$log(K/L)^j \times log(K/L)_h$	–0.404**	–0.1724*	–0.056	–0.0931	–0.1745	–0.1354
	(0.2049)	(0.1861)	(0.3536)	(0.2969)	(0.1751)	(0.1918)
Controls						
Source-country FE	Yes	Yes	Yes	Yes	Yes	Yes
Host-country FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	281	280	104	107	156	156
Adjusted R^2	0.74	0.70	0.82	0.82	0.78	0.77

Dep var: $ln\left(\text{MP}_h^j/output_h^j\right)$, columns: (1), (3) and (5)

Dep var: $ln\left(\text{MP}_h^j/Inn_h^j\right)$, columns: (2), (4) and (6)

Notes: Inn_h^j represents the output in host country h and sector j produced by local producers only (i.e. excluding foreign affiliates). This table presents the results of the Least Square Regression between the share of MP for each host-sector pair ($MP\text{share}_h^j$) and the host country relative productivity (TFP_h) for different specifications and productivity measures. Column (1), (3) and (5) report results with source, location and sector fixed effects, while columns (2), (4) and (6) report results with source-location and sector fixed effects. The relative productivity measure used in column (1) and (2) is the productivity estimates from a Ricardian trade model (Costinot, et al (2012); column (3) and (4) uses the new reveal comparative advantage index (RCA) at the CEPII database (available for Austria, Canada, Germany, Spain, France, U.K. Italy, Japan, Mexico, Netherlands, Russia, Turkey and U.S.). Finally, columns (5) and (6) use the relative multi-factor productivity provided by GGDC Productivity Level Database and available for eighteen OECD economies. To correct for trade-driven selection, RCA and GGDC observed relative productivity index were multiplied by a factor of relative openness between any two pair of countries $\left(\pi_{ii}^j/\pi_{i'i'}^j\right)^{1/\theta}$, with $\theta = 4$. Robust standard errors, clustered by source-location pair are reported in parentheses. ***, ** and * denote significance at 1%, 5%, and 10% level.

Table A.7: Productivity T_n^j and $\widetilde{T}_n^j$

Country	Average Change	Relative Change
Australia	0.03	-0.22
Austria	0.24	-0.48
Belgium	0.02	-0.08
Bulgaria	0.14	0.14
Canada	0.17	-0.51
Czech Rep.	0.41	-0.52
Denmark	0.04	-0.07
Estonia	0.19	-0.28
Finland	0.09	-0.22
France	0.07	0.14
Germany	0.11	0.08
Greece	0.01	-0.06
Hungary	0.29	-0.37
Ireland	0.07	-0.27
Israel	0.01	-0.09
Italy	0.14	-0.47
Japan	0.03	-0.14
Latvia	0.10	0.05
Lithuania	0.30	-0.16
Mexico	0.15	-0.34
Netherlands	0.22	-0.29
New Zealand	0.04	-0.26
Norway	0.04	-0.04
Poland	0.35	-0.53
Portugal	0.22	-0.52
Romania	0.19	-0.27
Russia	0.20	-0.42
Slovakia	0.22	-0.29
Slovenia	0.09	-0.39
Spain	0.13	-0.52
Sweden	0.20	-0.41
Switzerland	0.06	-0.32
Turkey	0.14	-0.43
United Kingdom	0.07	-0.06
Average	0.15	-0.26

Note: The first column reports the percentage change in the mean absolute distance to the frontier across all tradable sectors between local producers' productivity $(T_n^j)^{\frac{1}{\theta}}$ and all producers' productivity $(\widetilde{T}_n^j)^{\frac{1}{\theta}}$. The second column reports the percentage change in the coefficient of variation across tradable sectors in the distance to the frontier between local producers' productivity $(T_n^j)^{\frac{1}{\theta}}$ and all producer's productivity $(\widetilde{T}_n^j)^{\frac{1}{\theta}}$. In the baseline, $\theta = 4.0$.

Table A.8: Comparison beteween $\widetilde{T}_{trade}$ and $\widetilde{T}_{mp}$

	Panel A: Sector by Sector Rank Correlations		
Sector Code	Sector Name	Correlation	Countries
S15-16	Food and Beverages	0.72	35
S17-19	Textiles apparel	0.61	35
S20-22	Wood, paper and printing	0.84	35
S23-25	Chemical products	0.91	35
S26	Non-Metallic Mineral Products	0.65	35
S27-28	Basic and Fabricated Metal Products	0.56	35
S29-33	Computing, Machinery, Communication Equipment	0.81	35
S34-35	Transport Equipment	0.62	35
S36-37	Furniture and Other Manufacturing	0.64	35

Panel B: Fixed Effects Regressions

	(1)	(2)	(3)
Dep. Var: $\log(\widetilde{T}^{j}_{trade})$			
$\log(\widetilde{T}^{j}_{mp})$	0.961***	0 .9980***	0.3236***
	(0.0871)	(0.0364)	(0.0760)
Obsevations	315	315	315
R-squared	0.5284	0.4474	0.8657
Partial ρ	0.638	0.642	0.319
Sector FE	no	yes	yes
Country FE	yes	no	yes

Notes: This table reports the results of comparing the overall productivity estimates using the main procedure adopted in the paper$\widetilde{T}^{j}_{trade}$ (i.e. using the gravity equation) with the overall productivity estimates using the MP gravity equation $\widetilde{T}^{j}_{mp}$ (i.e.to estimate the locals producers productivity T^{j}_{h} and the MP barriers h^{j}_{hs} in order to calculate the overall productivity. Panel A reports the Spearman rank correlations of the two alternative overlal productivity measures by sector. Panel B reports the results of a fixed effect regression of $\widetilde{T}^{j}_{trade}$ on $\widetilde{T}^{j}_{mp}$. In Panel B robust standard errors reported in parentheses. Significance is denoted: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$. Partial ρ is the partial correlation between the right-hand side and the left hand side variables, after netting out the fixed effects included in the column.

Table A.9: The Fit of the Baseline Model with the Data

		Model	Data
Wages			
	Mean	0.761	0.650
	Median	0.790	0.710
	corr(model,data)	0.920	
Imports/GDP			
	Mean	0.364	0.359
	Median	0.342	0.291
	corr(model,data)	0.829	
Inward MP/Production			
	Mean	0.338	0.269
	Median	0.302	0.258
	corr(model,data)	0.758	
Outward MP/Production			
	Mean	0.310	0.205
	Median	0.070	0 .091
	corr(model,data)	0.804	

Note: This table reports the mean and median of wages relative to the United States, return to capital relative to the United States, and imports as a share of GDP, both in the model and in the data. In the data, Imports/GDP are the manufacturing imports as a share of GDP in the 2000s, sourced from the World Bank's World Development Indicators. Wages, production and inward and outward multinational production in the data are calculated as described in Section B.12.

Figure A.8: Wages Relative to United States

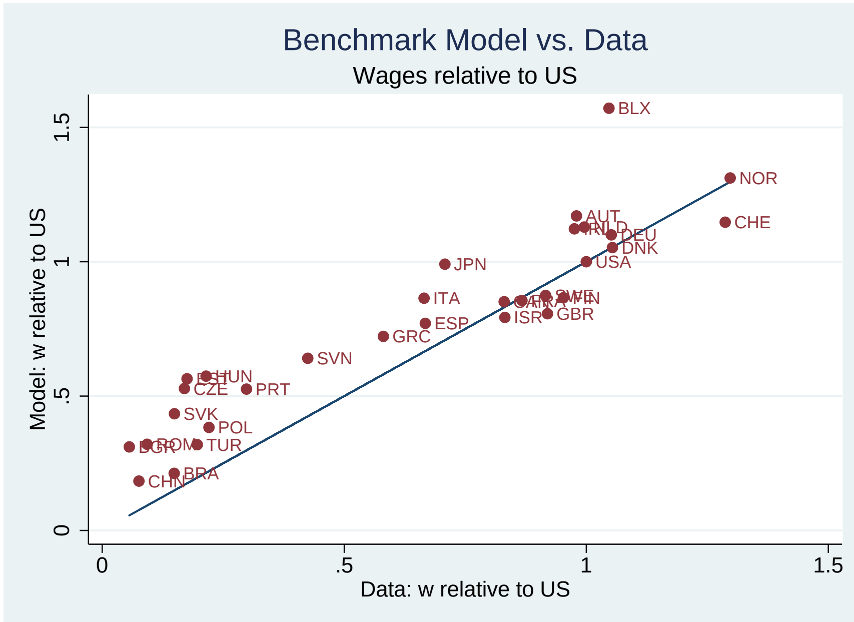
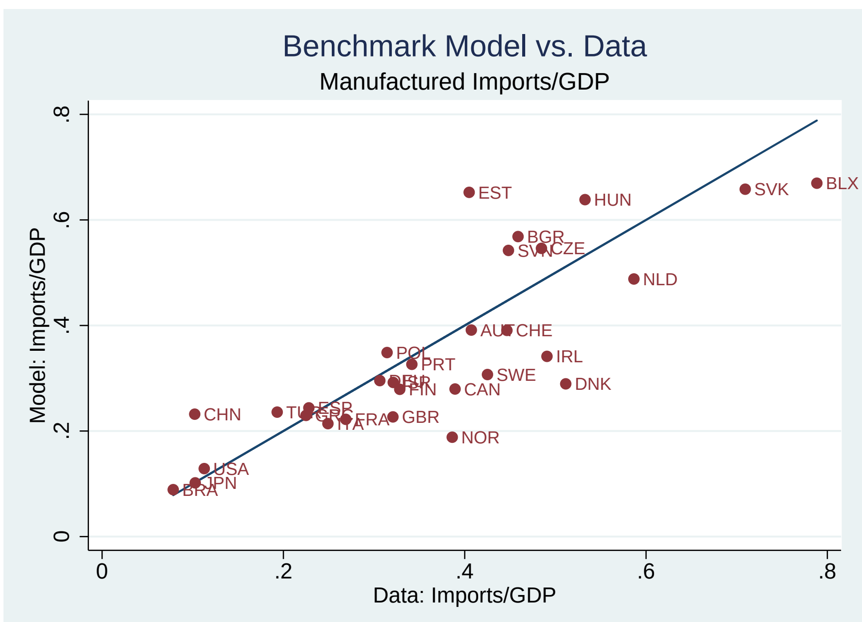


Figure A.9: Imports/GDP



Note: The Figure in the top represents the scatter-plot of wages in the data (x-axis) against the model's counterpart (y-axis). The bottom panel represents the scatter-plot of Imports/GDP in the data (x-axis) against the model's counterpart (y-axis). In the data, Imports/GDP are the average manufacturing imports as a share of GDP over the period 2003-2007, sourced from the World Bank's World Development Indicators. Wages, in the data are calculated as described in Section B.12 using UNIDO data. The solid line is the 45-degree line.

Figure A.10: Inward MP/Production

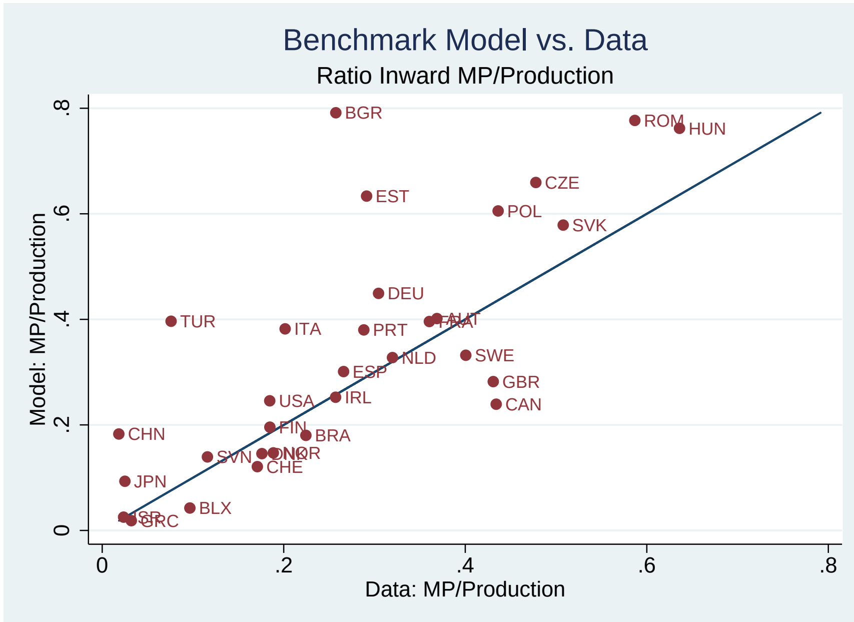
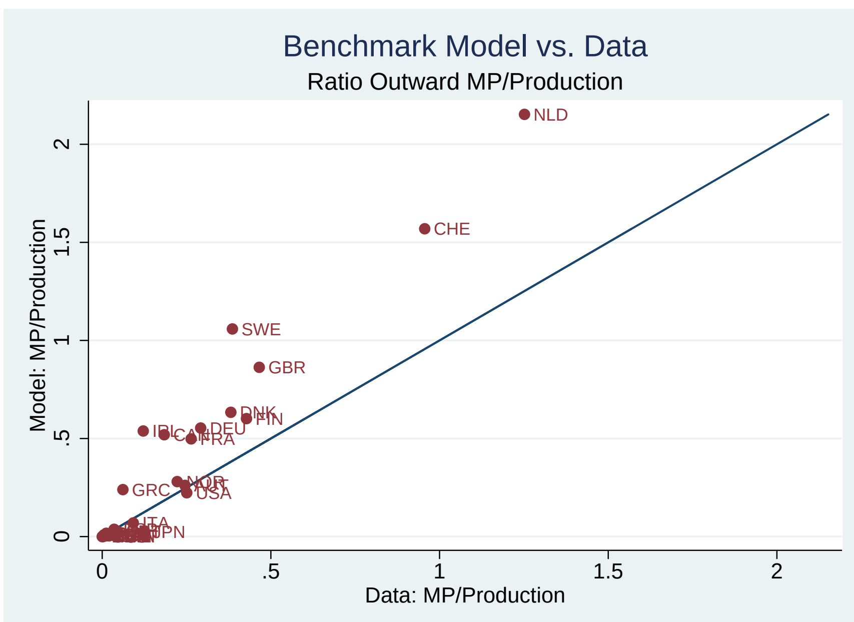


Figure A.11: Outward MP/Production



Note: The Figure in the top represents the scatter-plot of Inward MP in the data (x-axis) against the model's counterpart (y-axis). The bottom panel represents the scatter-plot of Outward/GDP in the data (x-axis) against the model's counterpart (y-axis). In the data, Inward MP are calculated by summing the foreign affiliate production of all possible sources for each host country-sector pair, and then is normalized by the total output of the hots country in each sector. The solid line is the 45-degree line.

Appendix B: Data Description

B.1 Multinational Production Data

Multinational production data at the bilateral sectoral level was sources mainly from unpublished OECD data, in particular, International Direct Investment Statistics and the Statistics on Measuring Globalisation. This datasets contain information concerning the economic activities of multinational firms (such as production, employment, number of affiliates, etc.) for thirty reporting countries belonging to the OECD, and the fifty-five partner countries that are host or source of their MP operations. Nominal data is reported in the currency of the reporting country, which is converted to U.S. dollars using the average annual exchange rate provided by the OECD. This data, contains information of foreign affiliate activity established in the reported country—or inward MP—and the activity of affiliates whose parent company is based on the reporter country but that operate in foreign markets—or outward MP.

Only consider bilateral MP higher than one million dollars

Orbis dataset where each subsidiary s linked to its ultimate owner, which is an establishment that is not the subsidiary of any other organization. We classify as multinationals all ultimate owners of at least one foreign subsidiary that has more than has positive employment and more than one $USD 100,000.

We construct a data set of firm-level observations from the comprehensive dataset ORBIS, which covers around 100 million listed and private companies around the world for which it compiles information of recording balance sheet, profit and lose account items. The dataset in created by Bureau van Dijk and based in the mandatory information from field and publicly available accounts. The ORBIS unit of observation is an individual company, which may be a subsidiary of a larger group. One of the most relevant features of ORBIS is its ownership information. ORBIS provides detailed information on the shareholders and subsidiaries of the company, on shareholders' type (ie. individual or corporate) and country of residency. We classify firms as multinationals if they are owned by a corporate shareholder (with more 50 percent of their capital) either resident abroad or owning subsidiaries in at least one other foreign country. This document provides a detail explanation of how we construct a sample of firms suitable for the analysis of multinational corporations. It also presents a set of descriptive statistics that uncovers the key characteristics of the sample of firms for the period 2004-2012. The document is organized as follows: first we explain the process of downloading data in which we present the selection criteria used to select the firms and the variables of interest. Second we go through the cleaning process. Third we offered a set of statistics relative to the sample of countries, the consolidation code, financial variables, ownership statistics, value added statistics.

The industry classification used is ISIC Revision 3. A total of seventy sectors and sub-sectors are covered in the original data for agriculture, mining, manufacturing, and services. We could potentially get a higher level of sectoral disaggregation, but because of disclosure and confidentiality issues, many observations are available only at a more aggregate level.[48] Therefore, to maximize the accuracy and coverage of the data, we aggregate it to nine tradable and four non-tradable sectors. In order to build a dataset based on primary information for the largest possible set of countries, we aggregate the information at roughly the 1-digit ISIC level, as shown in Table B.10.

For those countries that do not belong to the OECD, or for which complete information was not available in the OECD data, we draw information from the Foreign Affiliate Statistics database provided by Eurostat. This dataset, reports information for 41 source and 22 host countries at the source-host-sector triplet. A total of 117 sectors and sub-sectors are covered in the original dataset. Eurostat uses NACE Revision 2, for which we develop a concordance to merge it with the ISIC classification used by the OECD database.

In order to ensure that a zero was not mistaken for a missing value in the data, we rely on two additional measures of multinational activity recorded in the dataset (employment and the number of foreign affiliates in a given source-host-sector triplet) as well as information on revenues reported by ORBIS and BEA. Whenever possible, inward flows were chosen, given that it is more likely that multinational sales are better reported by the host country than by the sending country. Moreover, the host country also reports the ultimate sector of investment, which can be different from the parent firm's sector in the source country.

Given the different data sources used in its construction, it is important to assess the quality of the dataset. Because of disclosure and confidentiality issues, the accuracy of reported foreign affiliate sales increases with the aggregation level. This means that we have better information about the total manufacturing sales of Italian multinationals in France, but less accurate information about how much of those sales occur in the chemical and textile sectors. Therefore, we rely on two-dimensional data to assess the quality of this three-dimensional dataset. The first one of the two-dimensional datasets contains information on bilateral MP sales for total manufacturing in a given source-host pair, while the second one aggregates MP sales across all source countries for any given host-sector pair and also across all host countries for any given source-sector pair. Information for total manufacturing is used to assess how well the sectoral disaggregation accounts for total manufacturing flows. These two datasets constitute a benchmark for the aggregate flows, which can be used to check the validity of more disaggregated information coming from other sources. Total manufacturing foreign affiliate sales are calculated by summing them across the nine manufacturing sectors and then comparing them with the total manufacturing sales of foreign affiliates reported directly by OECD, Eurostat, and UNCTAD.

The final database comprises thirty-five countries, nine tradable sectors, and one aggregated non-tradable sector. Each observation is averaged over the period 2003–2007. After all of the quality controls have been applied to of this dataset, we get positive MP values for 2,987 source-

[48] For some sector-country pairs, only a few affiliates are operating and therefore the full disclosure of this information could reveal confidential data about a particular firm.

host-sector relationships, from a potential of about 11,900.

Table B.10: Sectors

ISIC Code	Name
S15-16	Food, beverages, and tobacco
S17-19	Textiles, wearing apparel, leather, footwear
S20-22	Wood and paper products, publishing, printing
S23-25	All chemical products
S26	Non-metallic mineral products
S27-28	Basic and fabricated metal products
S29-33	Total machinery and equipment; medical and precision instruments
S34-35	Transportation equipment
S36-37	Furniture, recycling, and manufacturing n.e.c.
S40-45	Electricity, gas and water supply, construction
S50-55	Trade, repair, hotels and restaurants
S60-64	Transportation, storage and communications
S65-74	Finance, insurance, real estate, business activities

B.2 Trade and Production Data

Production data: gross manufacturing production data at the sectoral level is from the 2012 UNIDO Industrial Statistics Database, which reports output, value added, employment, and wage bills at a 2-digit ISIC Revision 3 level of disaggregation. The data were further aggregated in order to match the classification used in the assembled MP database. Production data at the 2-digit ISIC level was extensively checked for quality. In cases where a country-year-sector observation had missing values, or were production was lower than exports, those values were imputed based on information from previous years as well as information on export patters. The production dataset is also used to calibrate important parameters of the model, such as the share of value added in production (β_j) and the share of labor on total value added (α_j), which are calculated by taking the median of each parameter across countries for each tradable sector. Note, however, that the UNIDO database does not contain information on the non-tradable sector. Therefore, to calculate α_{J+1} and β_{J+1}, we use the 2002 Benchmark Detailed Make and Use Tables for the United States. Table B.11 lists the sectors along with the key parameters values for each sector: α_j, β_j, and the taste parameter ω. More important, we use the production data to compute the share of output produced by local producers in country h and sector j. This is calculated by subtracting from the output the total production of foreign affiliates, in every country-sector pair.

Trade Shares: Bilateral trade data was drawn from Comtrade (4-digit SITC Revision 2), and aggregated up to the 2-digit ISIC level, using a concordance that we develop. Then we aggregate further to the sectoral aggregation shown in Table B.11 to merge the trade data with production

Table B.11: Model Parameters

ISIC code	Sector Name	α	β	ω	θ
S15-16	Food, beverages, and tobacco	0.351	0.256	0.209	2.84
S17-19	Textiles, wearing apparel, leather, footwear	0.515	0.308	0.103	5.59
S20-22	Wood and paper products, publishing, printing	0.401	0.339	0.025	9.50
S23-25	All chemical products	0.303	0.241	0.114	8.28
S26	Non-metallic mineral products	0.343	0.371	0.071	3.38
S27-28	Basic and fabricated metal products	0.396	0.273	0.014	6.58
S29-33	Total machinery and equipment; medical and precision	0.424	0.276	0.187	10.6
S34-35	Transportation equipment	0.467	0.252	0.175	1.84
S36-37	Furniture, recycling, and manufacturing n.e.c.	0.483	0.253	0.065	5.00
S-NT	Non-Tradables	0.54	0.64		

Note: This table reports the median of the labor share in value added (α_j), the share of value added in total production (β_j), and the taste parameter for tradable sector j. The values of the dispersion parameter θ correspond to estimates of Caliendo and Parro (2011).

and MP datasets. Note that imports were use for trade values, which were discounted by a factor of 1.2 because transportation cost is included in the value. To calculate the trade shares $\left(X^j_{mh}/X^j_m\right)$ at a sectoral level, we first compute a country's exports in a given sector, by aggregating bilateral exports across all partners countries. We then divide the value of country m's imports from country h by the demand of the importer for sector j goods $\left(X^j_m\right)$; which is gross production minus exports, plus imports in sector j, yielding bilateral trade shares. Also note that imports and exports are calculated using only the countries in the sample.

Bilateral gravity variables: the distance measures used to estimate trade cost, as well as data on common border and common language, are taken from the Centre d'Etudes Prospectives et d'Informations Internationals (CEPII). Information on trade agreements comes from the RTA database maintained by the WTO.

Factor prices: For each country in the sample wages are calculated by dividing the wage bill aggregated across all manufacturing sectors by total employment in manufacturing; wages are then normalized by the U.S. wage. For the few countries for which information on wage bill or employment was not available, the income percapita reported by the Penn World Tables (PWT) was used.

To calculate the return of capital, we rely on the market clearing condition of the model ($r_h/w_h = ((1-\alpha)\,L_h)\,/\,(\alpha K_h)$), along with the data on labor and capital.[49] Total labor force in each country (L_n) and capital stock are obtained from the PWT. Total labor force is calculated as the ratio of real GDP (calculated as the product of real GDP per capita and total population) and real GDP per worker. Total capital is calculated using the perpetual inventory method ($K_{h,t} = (1-\delta)\,K_{h,t-1} + I_{h,t}$), where I_h is the total investment in country h in period t; the de-

[49]Where α is the aggregate share of labor in GDP, which is set to 2/3.

preciation rate δ is assumed to be 6 percent. The initial value of K is equal to $I_{h,0}/(\gamma+\delta)$, where γ is the average growth rate of investment in the first ten years for which data are available.

Intermediate input coefficients: The intermediate input coefficients (γ_{kj}) are obtained from the Direct Requirements Table in the 2002 Benchmark Detailed Make and Use Tables for the United States, which uses the NAICS classification. Specifically, this data report the intermediate input in each row (k) required to produce one dollar of final output in each column (j). Then, we use a concordance to the ISIC Revision 3 classification to build a direct requirement table at the 2-digit ISIC level, and then further aggregate to the ten-sector level classification used in this paper. For a given column j, we can aggregate the rows k using the concordance. In order to further aggregate the columns to the ten-sector level, we compute the weighted average across columns, with the weights given by the relative importance of each sector.

Table B.12: Intermediate Input Coefficients (γ_{kj})

ISIC	S15-16	S17-19	S20-22	S23-25	S26	S27-28	S29-33	S34-35	S36-37	S-NT
S15-16	0.42698	0.01428	0.00325	0.00299	0.00178	0.00000	0.00000	0.00000	0.00000	0.02200
S17-19	0.00139	0.43133	0.02012	0.00487	0.00492	0.00000	0.00409	0.01526	0.04584	0.00376
S20-22	0.09119	0.01537	0.42683	0.02177	0.05206	0.01314	0.01432	0.01046	0.13538	0.03858
S23-25	0.07866	0.19233	0.09395	0.50759	0.08068	0.04675	0.07382	0.05587	0.13819	0.05982
S26	0.01923	0.00285	0.00719	0.01080	0.26005	0.01002	0.01082	0.01109	0.00709	0.01215
S27-28	0.05982	0.01364	0.02972	0.02629	0.05872	0.47551	0.16597	0.15129	0.15656	0.01885
S29-33	0.01617	0.01586	0.03696	0.02881	0.03558	0.06016	0.30742	0.09851	0.03202	0.03468
S34-35	0.00352	0.00095	0.00379	0.00219	0.00443	0.00356	0.01111	0.36735	0.00212	0.01440
S36-37	0.00013	0.00824	0.00244	0.00157	0.00274	0.00136	0.00604	0.00415	0.08574	0.00772
S-NT	0.29500	0.30511	0.37570	0.39307	0.49900	0.38946	0.40636	0.28600	0.39700	0.78800

Note: This table reports the value of the intermediate input in row k required to produce one dollar of final output in column j (γ_{kj}).

Prices of tradables and non-tradables: The price of non-tradables relative to the United States $\left(p_n^{J+1}/p_{usa}^{J+1}\right)$ and the price of non-tradables relative to tradables in each country $\left(p_h^{J+1}/p_h^{T}\right)$ are calculated using data from the International Comparison of Prices program (ICP).[50]

In order to estimate the productivity of each country-sector pair in levels rather than relative to the United States, we need to estimate U.S. productivity in every sector. To do this, we calculate the TFP in each tradable sector using the NBER-CES Manufacturing Industry Database, which reports total output, input usage in production, employment, and capital stock along with sectoral deflators for each. The data are available at the 6-digit NAICS classification and they are converted into the ISIC 2-digit classification using a concordance we have created. Finally, the share of expenditures of traded goods (ξ_h) in each country is sourced from Levchenko and Zhang (2012).

[50]The sectors grouped as tradables are: food and non-alcoholic beverages, alcoholic beverages and tobacco, clothing and footwear, furnishings, household equipment, and household maintenance. As non-tradables we group housing; water, electricity, gas, and other fuels; health; transport; communication; recreation and culture; education; restaurants and hotels.

Appendix C: Estimated Parameters

1. Preferences

a) σ, where $\frac{1}{1-\sigma}$ is the inter-temporal elasticity of substitution

b) η, elasticity of substitution between the tradable sectors

c) ξ_n, Cobb Douglas weight for the tradable sector composite good in country n

d) ω_j, weights of each tradable sector in final consumption

2. Technology

a) ϵ_j, elasticity of substitution in production across goods in sector j

b) α_j, value added based on labor intensity

c) β_j, valued added based on labor intensity

d) γ_{kj}, output industry$j$ requirement from input industry k.

e) θ_j, dispersion of productivity draws in sector j

f) T_n^j, state of technology in country n and sector j

3. Multinational production and Trade barriers

a) d_{ns}^j, iceberg trade cost of exporting from country s to country n in sector j

b) h_{si}^j, iceberg MP cost of produce in country s using technologies from country i in sector j

4. Labor and capital endowment

a) L_n, stock of labor in each country

b) K_n, stock of capital in each country

Appendix D: Proof of Propositions

D.1 Proof of Proposition 1

Proposition 1: *In a two-country, two-sector world economy, the lower the technology of country 1 in sector a (country 1's comparative disadvantage sector) relative to sector b, the higher the probability that firms from country 2 will produce in sector a relative to sector b in country 1.*

Proof. Define the ratio of probabilities that country 2 will produce in country 1 as:

$$\frac{\pi_{112}^a}{\pi_{112}^b} = \frac{T_2^a}{T_2^b}\left[\frac{T_2^b\left(g^{-\theta}+d^{-\theta}\right)^{-\frac{1}{\theta}}+T_1^b\left[1+(gd)^{-\theta}\right]^{-\frac{1}{\theta}}}{T_2^a\left(g^{-\theta}+d^{-\theta}\right)^{-\frac{1}{\theta}}+T_1^a\left[1+(gd)^{-\theta}\right]^{-\frac{1}{\theta}}}\right]$$

Dividing and multiplying by T_1^a:

$$\frac{\pi_{112}^a}{\pi_{112}^b} = \frac{T_2^a}{T_2^b}\left[\frac{\frac{T_2^b}{T_1^a}\left(g^{-\theta}+d^{-\theta}\right)^{-\frac{1}{\theta}}+\frac{T_1^b}{T_1^a}\left[1+(gd)^{-\theta}\right]^{-\frac{1}{\theta}}}{\frac{T_1^a}{T_1^b}\left(g^{-\theta}+d^{-\theta}\right)^{-\frac{1}{\theta}}+\left[1+(gd)^{-\theta}\right]^{-\frac{1}{\theta}}}\right]$$

For any set of parameter values T_2^a, T_2^b, and T_1^a consistent with the assumption made, a higher T_1^b increases the comparative disadvantage of country 1 in sector a, increasing the relative probability of hosting multinational production in that sector. In other words, the stronger the comparative advantage of country 1 in sector b, the higher the probability that goods in sector a in country 1 will be produced using the technology of foreign affiliates from country 2. Formally, this means that:

$$\partial\left(\frac{\pi_{112}^a}{\pi_{112}^b}\right)/\partial T_1^a < 0$$

$$\partial\left(\frac{\pi_{112}^a}{\pi_{112}^b}\right)/\partial T_2^a > 0$$

$$\partial\left(\frac{\pi_{112}^a}{\pi_{112}^b}\right)/\partial T_1^a = \frac{T_2^b}{T_2^b}\left[T_2^b\left(g^{-\theta}+d^{-\theta}\right)^{-\frac{1}{\theta}}+T_1^b\left[1+(gd)^{-\theta}\right]\right]\left(-\frac{1}{\left(T_1^b\right)^2\left[1+(gd)^{-\theta}\right]}\right) < 0$$

$$\partial\left(\frac{\pi_{112}^a}{\pi_{112}^b}\right)/\partial T_2^a = \frac{\left[T_2^b\left(g^{-\theta}+d^{-\theta}\right)^{-\frac{1}{\theta}}+T_1^b\left[1+(gd)^{-\theta}\right]\right]}{T_2^b}\left(\frac{T_1^a\left[1+(gd)^{-\theta}\right]}{\left(T_2^a\left(g^{-\theta}+d^{-\theta}\right)^{-\frac{1}{\theta}}+T_1^a\left[1+(gd)^{-\theta}\right]\right)^2}\right) > 0$$

□

D.2 Proof of Proposition 2

Proposition 2: *The more heterogeneous the technology upgrade across sectors toward comparative disadvantage sectors, the lower the dispersion of effective technologies and the lower the gains from trade.*

Proof. Without loss of generality, let us define two welfare scenarios for country 1 (and the same for country 2): First, one in which sectoral productivity increases disproportionately toward comparatively disadvantaged sectors; and a second one in which productivity increases homogeneously in both sectors due to MP.

Scenario 1: To construct the first scenario, we apply a common MP barrier across all sectors ($g^a = g^b = g$). A common g in both sectors causes an uneven technology upgrade across sectors. Using this assumption together with equation (14), we can rewrite the expression of technology upgrade in sector j as follows:

$$\frac{\widetilde{T_1^j}}{T_1^j} = \frac{T_1^j + g^{-\theta} T_2^j}{T_1^j} = 1 + g^{-\theta} \frac{T_2^j}{T_1^j}$$

Replacing this expression in equation (25) and using the mirror image assumption ($T_2^a = T_1^b$ and $T_2^b = T_1^a$) yields:

$$GT_{(S1)} = \left[\frac{\left(1 + g^{-\theta} \frac{T_1^b}{T_1^a}\right) \left(1 + g^{-\theta} \frac{T_1^a}{T_1^b}\right)}{\left((1 + (dg)^{-\theta}) + \frac{T_1^b}{T_1^a}(g^{-\theta} + d^{-\theta})\right) \left((1 + (dg)^{-\theta}) + \frac{T_1^a}{T_1^b}(g^{-\theta} + d^{-\theta})\right)} \right]^{-1/2\theta}$$

Scenario 2: To make this scenario comparable to scenario 1, we solve for the set of g^a and g^b such that (1) the productivity upgrade across sectors is the same $\left(\frac{\widetilde{T_h^a}}{T_h^a} = \frac{\widetilde{T_h^b}}{T_h^b}\right)$; and (2) the average effective productivity in country 1 $\left(\frac{\widetilde{T_1^a} + \widetilde{T_1^b}}{2}\right)$ is the same when MP barriers are the same across sectors ($g^a = g^b = g$), as in scenario 1, and also when they are not ($g^a \neq g^b$), as in this scenario.

The first condition implies that:

$$\left(\frac{g^a}{g^b}\right)^{-\theta} = \left(\frac{T_1^a}{T_1^b}\right)^2$$

The second condition implies that:

$$g^{-\theta} \left(T_1^b + T_1^a\right) = g_a^{-\theta} T_1^b + g_b^{-\theta} T_1^a$$

Substituting $g_a^{-\theta} = g_b^{-\theta} \left(\frac{T_1^a}{T_1^b}\right)^2$ from the first equations into the second equation we get expressions for g_a and g_b:

$$g_a^{-\theta} = g^{-\theta}\left(\frac{T_1^a}{T_1^b}\right)$$

and

$$g_b^{-\theta} = g^{-\theta}\left(\frac{T_1^b}{T_1^a}\right)$$

Replacing the expressions for $g_a^{-\theta}$ and $g_b^{-\theta}$ in equation (25), we get the gains from trade in Scenario 2:

$$GT_{(S2)} = \left[\frac{\left(1+g^{-\theta}\right)^2}{\left(1+\left(dg\frac{T_1^a}{T_1^b}\right)^{-\theta}+\frac{T_1^b}{T_1^a}\left(\left(g\frac{T_1^a}{T_1^b}\right)^{-\theta}+d^{-\theta}\right)\right)\left(1+\left(dg\frac{T_1^b}{T_1^a}\right)^{-\theta}+\frac{T_1^a}{T_1^b}\left(\left(g\frac{T_1^b}{T_1^a}\right)^{-\theta}+d^{-\theta}\right)\right)}\right]^{-1/2\theta}$$

The gains from trade are higher in the counterfactual scenario compared with the actual equilibrium ($GT_{(S2)} > GT_{(S1)}$) if:

$$\frac{\left(1+g^{-\theta}\frac{T_1^b}{T_1^a}\right)\left(1+g^{-\theta}\frac{T_1^a}{T_1^b}\right)}{\left(1+g^{-\theta}\right)^2} > \frac{\left[\left(1+(dg)^{-\theta}\right)+\frac{T_1^b}{T_1^a}\left(g^{-\theta}+d^{-\theta}\right)\right]\left[\left(1+(dg)^{-\theta}\right)+\frac{T_1^a}{T_1^b}\left(g^{-\theta}+d^{-\theta}\right)\right]}{\left[1+\left(dg\frac{T_1^a}{T_1^b}\right)^{-\theta}+\frac{T_1^b}{T_1^a}\left(\left(g\frac{T_1^a}{T_1^b}\right)^{-\theta}+d^{-\theta}\right)\right]\left[1+\left(dg\frac{T_1^b}{T_1^a}\right)^{-\theta}+\frac{T_1^a}{T_1^b}\left(\left(g\frac{T_1^b}{T_1^a}\right)^{-\theta}+d^{-\theta}\right)\right]}$$

or:

$$\frac{\left(1+g^{-\theta}\frac{T_1^b}{T_1^a}\right)\left(1+g^{-\theta}\frac{T_1^a}{T_1^b}\right)}{\left(1+g^{-\theta}\right)^2}\frac{\left[1+\left(dg\frac{T_1^a}{T_1^b}\right)^{-\theta}+\frac{T_1^b}{T_1^a}\left(\left(g\frac{T_1^a}{T_1^b}\right)^{-\theta}+d^{-\theta}\right)\right]}{\left[\left(1+(dg)^{-\theta}\right)+\frac{T_1^b}{T_1^a}\left(g^{-\theta}+d^{-\theta}\right)\right]}\frac{\left[1+\left(dg\frac{T_1^b}{T_1^a}\right)^{-\theta}+\frac{T_1^a}{T_1^b}\left(\left(g\frac{T_1^b}{T_1^a}\right)^{-\theta}+d^{-\theta}\right)\right]}{\left[\left(1+(dg)^{-\theta}\right)+\frac{T_1^a}{T_1^b}\left(g^{-\theta}+d^{-\theta}\right)\right]} > 1$$

The above is true if the following three conditions are satisfied simultaneously:

$$\frac{\left(1+g^{-\theta}\frac{T_1^b}{T_1^a}\right)\left(1+g^{-\theta}\frac{T_1^a}{T_1^b}\right)}{\left(1+g^{-\theta}\right)^2} >= 1$$

$$\frac{\left[1+\left(dg\frac{T_1^a}{T_1^b}\right)^{-\theta}+\frac{T_1^b}{T_1^a}\left(\left(g\frac{T_1^a}{T_1^b}\right)^{-\theta}+d^{-\theta}\right)\right]}{\left[\left(1+(dg)^{-\theta}\right)+\frac{T_1^b}{T_1^a}\left(g^{-\theta}+d^{-\theta}\right)\right]} >= 1$$

$$\frac{\left[1+\left(dg\frac{T_1^b}{T_1^a}\right)^{-\theta}+\frac{T_1^a}{T_1^b}\left(\left(g\frac{T_1^b}{T_1^a}\right)^{-\theta}+d^{-\theta}\right)\right]}{\left[\left(1+(dg)^{-\theta}\right)+\frac{T_1^a}{T_1^b}\left(g^{-\theta}+d^{-\theta}\right)\right]} >= 1$$

It can be shown that the first condition is true as long as:

$$\frac{T_1^a}{T_1^b} + \frac{T_1^b}{T_1^a} = \left(X + \frac{1}{X}\right) >= 2$$

where $X = \frac{T_1^a}{T_1^b}$. This is true for any ratio of productivities $\frac{T_1^a}{T_1^b}$. Note that $\left(X + \frac{1}{X}\right)$ reaches its minimum, which equals 2, when $X = 1$. The second and third conditions are always satisfied given that it is always true that $X^{-\theta} > 0$ and $\left(X^{-1}\right)^{-\theta} > 0$. Therefore, $GT_{(S2)} > GT_{(S1)}$.

□

D.3 Proof of Proposition 3

Proposition 3: *The higher the heterogeneity of MP across sectors, the higher the gains from MP. When the share of domestically produced goods is the same across sectors ($y_{hh}^a = y_{hh}^b$), the gains from MP attain a minimum. Therefore, uni-sectoral trade-MP models understate the actual gains from MP as long as $y_{hh}^a \neq y_{hh}^b$*

Proof. The gains from MP are given by:

$$GMP_h = \left[\frac{\left(1 + \frac{T_1^a}{T_1^b} d^{-\theta}\right) + \left(1 + \frac{T_1^b}{T_1^a} d^{-\theta}\right)}{\left(1 + (dg)^{-\theta}\right) + \frac{T_1^a}{T_1^b}\left(g^{-\theta} + d^{-\theta}\right) + \left(1 + (dg)^{-\theta}\right) + \frac{T_1^b}{T_1^a}\left(g^{-\theta} + d^{-\theta}\right)}\right]^{-\frac{1}{2\theta}}$$

The first-order condition of this expression is equal to zero when $T_h^a = T_h^b$. At this point, GMP_h attains a minimum given that the second-order condition is higher than zero, as shown below.

$$\begin{aligned}\frac{\partial GMP_h}{\partial T_1^a/T_1^b} = &-\frac{1}{2\theta}[Y]\left[\left(d^{-\theta}\left(1 - X^{-2}\right)\right)\left(2 + 2(dg)^{-\theta} + \left(d^{-\theta} + g^{-\theta}\right)\left(X^{-1} + X\right)\right)\right] \\ &+\frac{1}{2\theta}[Y]\left[\left(2 + d^{-\theta}\left(X^{-1} + X\right)\right)\left(\left(d^{-\theta} + g^{-\theta}\right)\left(1 - X^{-2}\right)\right)\right]\end{aligned} \quad (52)$$

where $Y = GMP_h^{-\frac{1}{2\theta}-1}$ and $X = T_1^a/T_1^b$. The above equation is equal to zero only when $T_1^a = T_1^b$. As shown below, the second derivative of GMP_h is positive; therefore, we reach a minimum when relative productivities are the same across sectors:

$$\frac{\partial^2 GMP_h}{\partial\left(T_1^a/T_1^b\right)^2} > 0$$

□

Appendix E: Equilibrium Solution

Given $\left\{L_h, K_h, \left\{T_h^j\right\}_{j=1}^{J}, \xi_n\right\}_{n=1}^{N}$, $\left\{\varepsilon, \alpha_j, \theta^j, \beta_j, \{\gamma_{k,j}\}, \left\{g_{hs}^j\right\}_{N\times N}, \left\{d_{hs}^j\right\}_{N\times N}\right\}_{j=1}^{J+1}$, and η, we compute the competitive equilibrium of the model as follows.

1. Guess $\{w_h, r_h\}_{n=1}^{N}$

a) Compute the prices from the following equations:

$$c_h^j = \left[(w_h)^{\alpha_j}(r_h)^{1-\alpha_j}\right]^{\beta_j}\left[\prod_{k=1}^{J+1}\left(p_h^k\right)^{\gamma_{kj}}\right]^{1-\beta_j}$$

$$\delta_{mhs}^j = c_h g_{hs} d_{mh}$$

$$\Delta_{ms}^j = \left[\sum_h \left(\delta_{mhs}^j\right)^{-\theta_j}\right]^{-\frac{1}{\theta_j}}$$

$$\widetilde{\Delta}_m^j = \sum_s T_s^j \left(\Delta_{ms}^j\right)^{-\theta_j}$$

$$\widetilde{\Delta}_m^{J+1} = \sum_s T_s^{J+1}\left(c_m^{J+1} g_{hs}^{J+1}\right)^{-\theta_j}$$

$$p_m^j = \Gamma_j \left(\widetilde{\Delta}_m^j\right)^{-\frac{1}{\theta_j}}$$

$$P_m = B_m \left(\sum_{j=1}^{J} \omega_j \left(p_m\right)^{1-\eta}\right)^{\frac{1}{1-\eta}\xi_m} \left(p_m^{J+1}\right)^{1-\xi_n}$$

b) Compute the final demand as follows: for any country n:

$$Y_m^j = \xi_n \frac{w_m L_m + r_m K_m}{p_m^j} \frac{\omega_j \left(p_m^j\right)^{1-\eta}}{\sum_{k=1}^{J} \omega_k \left(p_m^k\right)^{1-\eta}} \quad \forall j \in \{1, ..., J\}$$

$$Y_m^{J+1} = \left(1-\xi_m\right)\frac{w_m L_m + r_m K_m}{p_m^{J+1}}$$

c) Compute the probabilities π_{mhs}^j as follows:

$$\pi^j_{mhs} = \frac{T^j_s \left(h^j_{hs}\right)^{-\theta_j} \left(c^j_h d^j_{mh}\right)^{-\theta_j}}{\sum_h \sum_s T^j_s \left(g^j_{hs}\right)^{-\theta} \left(c^j_h d^j_{mh}\right)^{-\theta_j}}$$

d) Total Demand. In this section we are looking for the Q^k_h that satisfies the following equation:

$$p^j_h Q^j_h = p^j_h Y^j_h + \sum_{k=1}^{J} \left(1 - \beta_k\right) \gamma_{j,k} \left(\sum_{m=1}^{N} \sum_{s=1}^{N} \pi^k_{mhs} p^k_m Q^k_m \right) + \left(1 - \beta_{J+1}\right) \gamma_{j,J+1} \sum_{s=1}^{N} \pi^{J+1}_{hhs} p^{J+1}_h Q^{J+1}_h$$

e) Compute the factor allocations across sectors as follows: for any country n

$$\sum_{m=1}^{N} \sum_{s=1}^{N} \pi^j_{mhs} p^j_m Q^j_m = \frac{w_h L^j_h}{\alpha_j \beta_j} = \frac{r_h K^j_h}{\left(1 - \alpha_j\right) \beta_j}$$

$$\sum_{s=1}^{N} \pi^{J+1}_{hhs} p^{J+1}_m Q^{J+1}_m = \frac{w_h L^{J+1}_h}{\alpha_{J+1} \beta_{J+1}} = \frac{r_h K^{J+1}_h}{\left(1 - \alpha_{J+1}\right) \beta_{J+1}}$$

f) Update $\{w'_h, r'_h\}_{n=1}^{N}$ with the feasibility conditions for factors: for any n

$$\sum_{j=1}^{J+1} L^j_h = L_h, \ \sum_{j=1}^{J+1} K^j_h = K_h$$

2. Repeat the above procedures until $\{w'_h, r'_h\}_{n=1}^{N}$ is close enough to $\{w_h, r_h\}_{n=1}^{N}$.

Appendix F: Estimation

F.1 Effective technology: two-step procedure

The importer fixed effect recovered from the gravity equation is given by:

$$S_n^j = \frac{\widetilde{T}_n^j}{\widetilde{T}_{us}^j}\left(\frac{c_n^j}{c_{us}^j}\right)^{-\theta}$$

The share of spending on home-produced goods is given by:

$$\frac{X_{nn}^j}{X_n^j} = \widetilde{T}_n^j\left(\frac{c_n^j}{p_n^j}\right)^{-\theta}$$

Dividing it by US, we have:

$$\frac{X_{nn}^j/X_n^j}{X_{us,us}^j/X_{us}^j} = \frac{\widetilde{T}_n^j}{\widetilde{T}_{us}^j}\left(\frac{c_n^j}{c_{us}^j}\right)^{-\theta}\left(\frac{p_n^j}{p_{us}^j}\right)^{-\theta} = S_n^j\left(\frac{p_{us}^j}{p_n^j}\right)^{-\theta}$$

The ratio of price levels in sector j relative to US becomes

$$\frac{p_n^j}{p_{us}^j} = \left(\frac{X_{nn}^j/X_n^j}{X_{us,us}^j/X_{us}^j}\frac{1}{S_n^j}\right)^{\frac{1}{\theta}}$$

Then, cost of the input bundles relative to the U.S can be written as:

$$\frac{c_n^j}{c_{us}^j} = \left(\frac{w_n^j}{w_{us}^j}\right)^{\alpha_j\beta_j}\left(\frac{r_n^j}{r_{us}^j}\right)^{(1-\alpha_j)\beta_j}\left(\prod_{k=1}^{J+1}\left(\frac{p_n^k}{p_{us}^k}\right)^{\gamma_{k,j}}\right)^{1-\beta_j}$$

F.2 Bilateral Multinational Production Barriers: an origin fixed effect (TBC)

The specification for the investment barriers includes an origin effect $\left(origin_i^j\right)$.[51] In this section, we support the chosen specification in equation (4), where the inclusion of an origin effect allows for the estimation of asymmetric barriers of foreign production that is consistent with the pattern of prices and income data. There are three empirical observations of importance. First, there is home bias for all countries regardless of their level of development. This means that countries produce the majority of their goods using their own technologies (i.e., produced by local producers). The important observation is that there is little variation in the $\frac{I_{hh}^j}{I_h^j}$, relative to

[51] Appears that there is no precedent in the estimation of multinational production asymmetric barriers at the aggregate or sectoral level. Previous efforts assumed a symmetric specification, where the cost that country s faces to produce in country h is equal to the cost country h faces to produce in country s. See Ramondo and Rodriguez-Clare (2012), Costinot et al. (2010), and Ramondo (2012), among others.

income per worker.

$$ln\left(\frac{I^j_{hh}}{I^j_h}\right) = \beta_0 + \beta_1 ln\left(y_h\right) + u_h$$

Rich countries produce slightly more producing own technologies, but the difference in magnitude is small. The second observation is that there is a systematic correlation between bilateral MP shares and relative level of development.

$$ln\left(\frac{I^j_{hs}}{I^j_{sh}}\right) = \beta_0 + \beta_1 ln\left(\frac{y_s}{y_h}\right) + u_{sh}$$

The third and last observation is that the tradable and non-tradable prices are positively related with the level of income. Using data from the United Nations International Comparison Program, Waugh, as well as Klenow (2004), document a similar relationship between non-tradable prices and level of development. In the model, the former observations yield straightforward implications for MP cost. Manipulation of equations (1) and (2) yields the following relationship between home MP shares, bilateral MP shares, sectoral prices, and MP costs:

$$\frac{I^j_{hs}}{I^j_{ss}} = (\widetilde{h}^j_{hs})^{-\frac{1}{\theta}}\left(\frac{p_s}{p_h}\right)^{-\frac{1}{\theta}}$$

$$\frac{I^j_{hs}}{I^j_{ss}} = (h^j_{hs})^{-\frac{1}{\theta}}\left(\frac{p_s/c_s}{p_h/c_h}\right)^{-\frac{1}{\theta}}\left(\frac{\psi^j_h}{\psi^j_s}\right)$$