Learning from Multinationals*

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Abstract

Multinational firms account for a large share of global trade and production and have a significant impact on productivity growth across countries. We develop a tractable model of international trade and multinational production (MP) to analyze their effects on productivity growth through knowledge diffusion across countries. We connect the theory to evidence by examining the impact of a 2004–2006 Chinese liberalization of outward investment on the productivity growth of its counterparts. Using an instrumental variable approach, we find a 1 percentage point increase in MP share from China resulted in a 1.85% increase in productivity. Mapping the reduced-form estimates to the rate of idea diffusion from foreign firms, we provide evidence on key parameters used in knowledge diffusion models. While long run productivity growth is primarily driven by domestic firms due to its larger knowledge diffusion parameter, MP can have a sizable impact on productivity growth, particularly when productivity differences between multinational and domestic firms are large. Increases in bilateral trade costs shift firm activity away from exporting to producing abroad, leading to productivity increases in the multinational's production destination at the expense of the exporting nation. We quantify the impacts of Chinese liberalization of trade, as well as inward and outward MP, on the productivity growth of 59 countries.

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1 Introduction

Governments exert significant effort in attracting the investment of large multinational firms in the hopes of generating economic growth effects. Multinational production (MP) has increased to account for 32% of world GDP today. However, empirical evidence toward the efficacy of multinationals in driving productivity spillovers has been mixed.[1] Firms may engage in MP for various reasons, such as expanding to foreign local markets, taking advantage of potential lower production costs, or using a production location as an export platform. What determines which countries trade and with whom and who invests where? Does multinational production contribute to diffusion of knowledge across countries?

To answer these questions, we first build a theory of the knowledge spillover effects of multinational production and trade policies. Knowledge is diffused through the interaction of firms with other producers within a country and increased MP alters the set of producers a firm learns from. We characterize the rates of productivity growth as a function of the equilibrium trade and MP patterns. We then turn to providing evidence of the effect of Chinese multinationals on TFP growth across countries by studying the liberalization of Chinese outward investment in 2005–2006. With a novel instrumental variable approach, we find the causal impact of MP on productivity growth. A key contribution of this paper is to bring empirical evidence from the China shock to discipline key parameters of knowledge diffusion models. The calibrated model allows us to answer questions, such as what have the growth effects of China's liberalization of trade and MP been around the world? What would the global reallocation effects of a US-China trade war be when multinationals can shift across borders?[2]

We develop a multi-country Ricardian trade and multinational production model, in which firms originating from each country can operate and sell in any other country. Producing and selling abroad is subject to MP and trade costs, respectively. Productivities across countries are described by a multivariate Fréchet distribution, which describes the productivity of home and overseas establishments. Learning is

[1] Multinationals are defined as firms with production in multiple countries. We discuss this, and related statistics of multinational production, in Section 3.1. See Alfaro et al. (2004) for a discussion of the mixed empirical findings of foreign direct investment (FDI). We define FDI to be the financial flow that generates subsequent multinational production (MP).

[2] Fajgelbaum et al. (2024) is a recent example considering how a US-China trade war would affect "bystander" countries, in a setting without deflection of MP.

modeled a random process occurring through interactions between firms in a country. We characterize the differential equations that govern the evolution of a country's knowledge stock as a function of trade and MP flows and show that the distribution of firm productivities remains multivariate Fréchet over time.

Changes in trade and MP costs can drive significant diversions in trade, as well as the location of production. Increased trade costs may impact a country-pair directly by driving substitution away from export and towards multinational production. Substituting away from importing to having a multinational produce locally be growth-enhancing if firms learn more from other establishments producing within the same economy than from exporters abroad. However, changes in learning rates caused by increased trade costs are non-monotonic, since trade costs also lower the pro-competitive effects of trade. Increased bilateral trade costs may also indirectly benefit a third nation, as production may be shifted there to serve as an export platform. To discipline the model, we turn to estimating the effects of MP on productivity growth. We study the 2005–2006 case of a Chinese liberalization of outbound investment, when the State Council of the People's Republic of China sanctioned and began granting various incentives to outward investment. In 2006, quotas on the purchase of foreign exchange for Chinese firms were lifted, also significantly reducing barriers to Chinese multinational investing abroad. Using an approach akin to the 'China shock' literature (Acemoglu et al., 2016b), we use China's MP to similar countries and regions as an instrument for the inward MP to each destination. The instrumental variables approach yields an estimate of a 1.83% increase in TFP, for a 1 percentage point increase in the share of country's MP coming from China. The effect is robust to inclusion of pre-trends and significantly stronger when focused on non-mining industries. The model is calibrated to match the reduced-form estimates of the effects of Chinese multinationals abroad. To our knowledge, this is the first attempt to bring estimated causal effects to parametrize knowledge diffusion models. We consider sensitivity to the estimates and show how the implications of the model differ. We undertake counterfactual analysis that fixes the level of trade and MP costs to and from China to their year 2000 level, prior to entry into the World Trade Organization (WTO) and the liberalization to multinational production. This change results in significant changes in trade and multinational production patterns. While MP was substituted away from many countries and towards China, the effects of this have in some countries been offset by greater incoming MP from China.

Additional counterfactual analysis with our calibrated model shows that knowledge diffusion accounts for approximately half of the TFP growth over 2000—2019.

Literature Review

The paper connects to several strands of literature. First, our paper contributes to the large literature on the interaction of countries leading to diffusion of knowledge since the seminal paper by Eaton and Kortum (1999); including Sampson (2016), Benhabib et al. (2021), Bai et al. (2024) and Perla et al. (2021). Modeling the law of motion of an evolving stock of knowledge has been present in works by Coe et al. (1997) and Coe and Helpman (1995), which mostly focus on R&D and the international spillover effects coming of trade. Our work builds on Buera and Oberfield (2020) and when MP costs go to infinity, our model converges to theirs. In addition to adding multinational firms, we also provide a credible estimate of the varying strength of knowledge diffusion based on an empirical strategy. The model shares some features with Cai and Xiang (2022), which have a model of trade and MP with knowledge diffusion. However, we depart from their approach in two important ways. First, we allow for export-platform or 'bridge multinational production,' where a firm locates part of their production process in a third country in order to avoid trade tariffs or other country-pair specific firm regulations. Incorporating this feature allows us to study the subsequent effects of trade and multinational production diversions on knowledge diffusion across countries. Secondly, our model considers the differential strength of idea diffusion for multinationals and domestic firms. We then provide a strategy for mapping rates of knowledge diffusion to empirical estimates of the effect of MP on productivity.

We relate to the strand of literature that discusses the interaction of trade and multinational production, such as Ramondo and Rodríguez-Clare (2013), Irarrazabal et al. (2013), and Tintelnot (2017). Ramondo and Rodríguez-Clare (2013) note that because trade and multinational production have both complementarity and substitutability in their relation, it is crucial to model both when estimating the gains from openness. The key difference between this strand of the literature and our work is that we add a channel for knowledge diffusion to affect productivity dynamically. Additionally, the literature also studies how costs related to trade and multinational production can drive trade/MP deflection. We share some similarity with Arkolakis et al. (2018) in that it has a quantifiable model of trade with multinational production. However, because Arkolakis et al. (2018) divides the countries to innovator countries and production countries, it does not allow for us to observe idea flows and the dynamic that brings into the technologies of respective countries.

Thirdly, we contribute to the empirical literature on the impact of FDI and MP on TFP spillovers, for example Javorcik (2004), Arnold and Javorcik (2009a), and Amiti et al. (2023). Additionally, Keller (2009) provides an overview the findings. Relatively to the empirical work studying FDI and TFP, we contribute by building a framework that allows endogenous FDI/MP and multinational production decisions that in turn determines the TFP level.

Lastly, the empirical exercise taken to estimate the rates of knowledge diffusion relates to the literature on the 'China shock'. The exercise is similar in motivation to Bloom et al. (2016) in that it seeks to investigate the effects of exposure to China on TFP and productivity. However, since their analysis is focused on the firm-level effects and ours at on the industry-level, the methodologies vary greatly. Further, we combine our reduced-form estimates with the structural model to undertake welfare and counterfactual analysis. Our calibration methodology uses techniques from a rich literature advancing the empirical analysis such as Autor et al. (2013a) and particularly Acemoglu et al. (2016b). While their China shock is exposure to China's exports, we instead examine the impact of China's investment abroad and improve upon the estimation of knowledge diffusion strength on the existing literature.

The remainder of the paper is structured as follows. Section 2 highlights the the motivating facts about the effects of tariffs and multinational production on the country's total factor productivity. Section 3 introduces the model of knowledge diffusion. We start from a case of closed economy and later incorporate trade and multinational production to show an exchanges of idea among countries. Empirical methods are discussed in Section 4 including data, calibration and estimation strategy. Section 5 features the quantitative result of our model and describe the trade deflection's effect on knowledge evolution. In Section 6, we undertake counterfactual analysis on the effect of MP and trade on country's knowledge accumulation by examining the TFP effects of China's accession to WTO. Section 7 studies the degree of TFP growth that can be accounted for by models of knowledge diffusion. Section 8 concludes.

2 The Model

We consider a world in which $j = 1, \ldots, N$ countries interact through trade and MP. The static theory we develop builds on Eaton and Kortum (2002) and governs firm decisions on where to undertake production and where to sell to. There are a continuum of goods $s \in [0, 1]$. A household residing in country j buy these goods to maximize CES utility

$$U = \left[\int_0^1 c_j\left(s\right)^{\frac{\sigma-1}{\sigma}} ds \right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where σ denotes the elasticity of substitution across variety of good consumed. Households in country j inelastically supply labor L_j and a earn country-specific wage w_j.

2.1 Production

Firms can produce domestically or abroad. We denote the country of origin with the subscript i and the country of production with subscript l. Production for good s is linear in productivity and labor, where the firm uses the labor of the country of production. A firm can produce in multiple countries simultaneously. We refer to each production location as an *establishment*. The firms from country i has a vector of productivities describing the productivity of each establishment in manufacturing country l, which is described by what we call a *bilateral multivariate Fréchet* random vector. A random vector $(\phi_{1l}, \ldots, \phi_{Nl})$ is drawn from the multivariate distribution given by

$$\begin{aligned} \Pr\left[\Phi_{1i} \leq \phi_{1i}, \ldots, \Phi_{Ni} \leq \phi_{Ni}\right] &= \prod_{l=1}^{N} F\left(G(\lambda_l, \lambda_i), \theta\right) \\ &= \prod_{l=1}^{N} e^{-G(\lambda_l,\lambda_i)\, \phi_{li}^{-\theta}}, \end{aligned} \tag{2}$$

where F is the cumulative distribution function (CDF) of a univariate Fréchet distribution with a constant shape parameter θ and a scale parameter $G\left(\lambda_l, \lambda_i\right)$. The scale parameter is modeled as a weighted geometric mean of the stock of knowledge of the origin and potential manufacturing countries

$$G\left(\lambda_l, \lambda_i\right) = \lambda_l^{\rho} \lambda_i^{1-\rho}, \tag{3}$$

where λ_i is a country-specific parameter measuring the stock of knowledge, and ρ is the weight on the destination knowledge stock. This captures the idea that the establishment may be less productive in an environment with a lower stock of knowledge. For example, this decrease in productivity could result from limited availability of necessary infrastructure to support their usual technologies.

For firms that only produce domestically, the scale parameter simplifies to domestic stock of knowledge $G(\lambda_i, \lambda_i) = \lambda_i$, such that their relevant productivity is described by

$$F_i(\phi) = e^{-\lambda_i \phi^{-\theta}}.$$

The approach differs from that of Lind and Ramondo (2023) who introduce a multivariate Fréchet distribution where the productivity draw is a function of a CES combination of all potential operating locations. The bilateral combination of knowledge stocks will allow for a clear understanding of the contribution of each stock of knowledge to learning.

2.2 Trade and Multinational Production

Following Eaton and Kortum (2002), there is perfect competition for varieties. One firm in each country has the opportunity to produce a variety s. This can also be thought of a firm with the highest domestic productivity of that variety. Due the max-stable property, the productivity of the most productive firm within that industry also follows a Fréchet distribution. In the open economy setting, firms select their production locations and either sell in that production location or export to other nations. Firms compete in head-to-head competition to supply goods to each country. We denote the final destination of the goods as country j. The lowest cost firm in any given product class and country will be the one that sells there. This cost will in part be determined by an iceberg trade cost $\tau_{jl} \geq 1$ of sending goods from l to j, and if they are undertaking multinational production, they will be subjected to multinational production cost $\gamma_{li} \geq 1$. The MP cost can be thought of as a factor which reduces the productivity of a firm producing in country l, away from home i, and is pairwise specific to the country they are investing in.[3] We follow Arkolakis et

[3]The MP cost captures factors such as differences in language, legal institutions, or regulations pertaining to firms from specific countries. For example, investments in many countries are subject to foreign investment committees, often for national security purposes, which can cause frictions to investment from that country.

al. (2018) in assuming there are no fixed costs to setting up production abroad. All costs of engaging in MP are captured via the iceberg MP cost, which is calibrated to match bilateral MP flows. The benefit of abstracting away from fixed costs and relying solely on the wedge approach is that we are able to derive closed form expressions for expenditure shares and rates of learning, which are useful in demonstrating the identification. To clarify terminology, when a firm that manufactures in its origin $l = i$ they incur no MP cost $\gamma_{ii} = 1$ and are referred to as a *domestic firm*. When a firm sells in the same location as its manufacturing $j = l$, $\tau_{jj} = 1$, which we refer to as *local sales*. Exports from a firm that is not producing domestically $i \neq l \neq j$ are called *export platform* sales. The marginal cost of a firm originating in i, producing in l, and exporting to j is a function of the two iceberg costs, the wage in l, and the productivity of the firm from i in l

$$\frac{\tau_{jl}\gamma_{li}w_l}{\phi_{li}}.$$

To determine the expenditure shares in each country, we start by developing a measure of the fraction of goods produced in l by firms from i and sent to j, $\mathcal{F}_{jli}$. This measure is given by the probability that a producer from i, producing in l will be the lowest cost supplier to country j:

$$\mathcal{F}_{jli} = \int_0^{\phi} \prod_{k \neq l} \prod_{m \neq i} F_{k,m}\left(\frac{w_k \tau_{jk} \gamma_{km}}{w_l \tau_{jl} \gamma_{li}} x\right) f_{l,i}\left(x\right) dx \tag{4}$$

where $F_{k,m}$ is a Fréchet cumulative distribution function with scale $G(k, m)$, as described in equation (2), and $f_{l,i}$ is the probability density function of the Fréchet with scale $G(l, i)$. The probability of being the lowest cost supplier is modeled as the probability of having the highest cost-adjusted productivity across origin country and manufacturing location pairs. The lowest cost producer measure is evaluated in Appendix A. Using this measure we can solve for idealized price index

$$\begin{aligned} P_j &= \left(\sum_i \sum_l \int_0^1 p_{jli}(s)^{1-\sigma} ds\right)^{\frac{1}{1-\sigma}} \\ &= \left(\sum_i \sum_l \int_0^{\infty} \left(\frac{w_l \tau_{jl} \gamma_{li}}{\phi}\right)^{1-\sigma} \frac{\partial \mathcal{F}_{jli}}{\partial \phi} d\phi\right)^{\frac{1}{1-\sigma}}. \end{aligned} \tag{5}$$

The price index is the aggregation of the prices of all goods sold within the country. By perfect competition, the price $p_{jli}(s)$ is the marginal cost integrated over the measure of lowest cost suppliers. The price index allows us to solve for the expenditure share of country j on goods produced in country l from firms originating in i, which is given by

$$\pi_{jli} = \frac{\int_{s \in S_{jli}} p_{jli}(s)^{1-\sigma} ds}{P_j^{1-\sigma}}. \tag{6}$$

We use equation (5) to solve for the expenditure share. The derivations of the evaluated expressions are in Appendix A.

2.3 Static Trade and MP Equilibrium

Due to perfect competition, firms make no profits. In the absence of fixed costs and profits, production location decisions, as well as export decisions, solve a static problem at all time. MP and trade decisions are determined by being the lowest cost producer to a given location at time t. This simplifies the problem since firms are not making dynamic decisions regarding production location decisions in order to maximize the learning spillovers in their destination, but rather by locating production in the lowest cost country for a given local sale or export platform flow.

To close the model, we need a notion of market clearing. By assuming that trade is balanced, we write the labor market clearing equation as

$$w_j L_j = \sum_l \sum_i w_l L_l \pi_{jli} \tag{7}$$

The consumers budget constraint, assuming wages are spent domestically, gives total expenditure in i and is given by

$$X_i = w_i L_i. \tag{8}$$

There are no profits, since competition is perfect.

Given scale parameters $(\lambda_1, \ldots, \lambda_N)$, a static trade equilibrium is given by a sequence of wages $(w_1, \ldots, w_N)$ such that labor markets clear in all countries.

2.4 Learning

The equilibrium distributions of trade and MP will determine the set of establishments that firms learn from. In this section, we turn to the dynamics of the model through learning. Firstly, we assume that the initial distribution of productivities follows the multivariate Fréchet described in Section 2.1.

Assumption 1 *The initial distribution of firm productivities in each country follows the multivariate Fréchet distribution*

$$\prod_{l=1}^{N} e^{-G(\lambda_{l0},\lambda_{i0})\,\phi_{li}^{-\theta}}$$

where the productivity for establishments away from their origin is drawn from a standard Fréchet with scale parameter

$$G(\lambda_{l0},\lambda_{i0}) = \lambda_{l0}^{\rho}\lambda_{i0}^{1-\rho}$$

As in Buera and Oberfield (2020), in each country there is an arrive rate of ideas α_{lt}, which is the chance to update the productivity of the establishment in that country according to an insight drawn from another producer and an original idea drawn from an exogenous distribution. We assume that the arrival rate of original ideas is given by the following power law.

Assumption 2 *The arrival rate of ideas with an original component greater than z is given by*

$$A_{it}(z) = \alpha_{it} z^{-\theta}.$$

This assumption allows us to maintain the shape of the productivity distribution in each country over time. The productivity that the firm could choose to adopt for that establishment is given by

$$\phi = z\phi'^{\beta_k}$$

where z is an idea from an exogenous distribution, ϕ' is an insight drawn from another firm, and β_k is the strength of diffusion. The insight from another producer ϕ' is that firms' operating productivity within that country and it is drawn from $H_{lkt}(\phi')$, which are location l and time t specific source distributions. A source distribution for an individual firm is a set of productivities held by firms that the aforementioned firm could learn from. While it is possible for us to consider the source distribution of learning to be coming from sellers, as is done in Buera and Oberfield (2020), we focus on the case where learning comes from other firms producing within the same economy and delegate the seller's case to Appendix B. In the sellers case, a firm would impart the same level of knowledge exporting to a destination as they would setting up production there. As the literature is focused on the direct spillovers from the foreign investment, we argue that the learning from producers case is more relevant for our question. The subscript k represents the possibility of varying intensity of diffusion depending on the source distribution. The higher the parameter β_k, the more significant the insight drawn from the other producer is to the new productivity. The two specific source distributions we consider in the paper are: learning from domestic establishments and from multinational establishments $k \in \{D, F\}$. In both cases, establishments draw insights from establishments producing within the same country, weighted by the measure of production that they undertake. That is, an establishment is more likely to sample an insight drawn from a larger firm. We allow ideas from the two source distributions to be diffused with different intensities. Learning from domestic firms at rate β_D and from foreign multinationals with β_F. In country l, the source distribution of domestic firms is

$$H_{lDt}(\phi) = \sum_j \mathcal{F}_{jll}(\phi) \tag{9}$$

and for multinational firms is

$$H_{lFt}(\phi) = \sum_j \sum_{i \neq l} \mathcal{F}_{jli}(\phi). \tag{10}$$

The new productivity that comes about through this process affects the productivity of the domestic establishment in that country.

Multinational establishment idea evolution

Now we turn to how overseas establishments alter their productivity. Productivity improvements in the origin country can be diffused to establishments abroad. To capture this, we assume establishments away from their origin draw insights from their current location with probability ρ and their origin with probability $1 - \rho$.

The insights drawn from domestic producers of the location of their production are diffused to the multinational establishment with intensity β_D, while all other origins are diffused with intensity β_F.[4] This assumption restated below

Assumption 3 *Establishments from i manufacturing away from the origin $l \neq i$, draw insights from establishments in l with probability ρ and diffuse these insights with strength β_D if the establishments originate from l and with strength β_F otherwise, and they draw from establishments in i with probability $1-\rho$ and diffuse these insights with strength β_D if the establishments originate from i and with strength β_F otherwise.*

When this assumption is satisfied the growth rate of multinational establishments grows at a rate satisfying

$$\frac{G\left(\dot{\lambda_l, \lambda_i}\right)}{G\left(\lambda_l, \lambda_i\right)} = \rho\frac{\dot{\lambda}_l}{\lambda_l} + (1-\rho)\frac{\dot{\lambda}_i}{\lambda_i}.$$

Thus, the scale of the productivity distribution of the multinational establishments will continue to be described by $G(\lambda_l, \lambda_i) = \lambda_l^{\rho}\lambda_i^{1-\rho}$ over time. The combination of these assumptions leads to the main proposition describing the evolution of knowledge stocks

Proposition 1 *When the initial distribution of productivities follows Assumption 1, and firms productivity grows according to the process in Assumptions 2 and 3, then the productivity distributions will remain multivariate Fréchet for all time with scale parameter in each location evolving according to*

$$\dot{\lambda}_l^{producers} = \alpha_{lt} \sum_k \sum_i \sum_j \int_{s \in S_{jli}} \phi^{\beta_k \theta}\, dH_{lkt}(\phi). \tag{11}$$

When the source distributions follow equations (9) and (10), the evolution of the knowledge stock becomes

$$\dot{\lambda}_l = \alpha_l \left(\Gamma(1-\beta_F) \sum_{i \neq l} \sum_j \left(\lambda_l^{\rho}\lambda_i^{1-\rho}\right)^{\beta_F} \pi_{jli}^{1-\beta_F} + \Gamma(1-\beta_D) \sum_j \lambda_l^{\beta_D} \pi_{jll}^{1-\beta_D} \right). \tag{12}$$

[4] Aside from the technical convenience of this assumption, we believe this assumption of asymmetric learning rates for multinationals and the local establishments as capturing selection effects. Since the multinational establishments have selected into a given country, they may have greater knowledge of the business practices of their manufacturing location than local firms do of the practices in the multinationals' origin.

While exports do not directly contribute to the source distribution, the effect of enhanced competition may be to push out unproductive domestic producers and multinational producers to incentivize MP from more productive firms.

2.4.1 Idea Evolution under Autarky

To simplify the intuition, consider a closed economy (to both trade and MP) with a single country source of knowledge H_{iDt}. Since there is no MP, knowledge is diffused only with strength β_D. In the autarkic state, these set of ideas in which a country can draw from is limited to domestic firms. When the arrival rate of ideas from source distribution $H_{iDt}(\phi)$ with it can be shown that the distribution of productivities will remain Fréchet for all t with the knowledge stock parameter evolving according to:

$$\dot{\lambda}_{lt} = \alpha_{lt} \int_0^{\infty} \phi^{\beta_D \theta} dH_{iDt}(\phi) \tag{13}$$

In the autarky case, seller are producers so the each country's learning process comes from the firms that are operating from their respective countries. In other words, the source distribution of where learning can come from in the closed economy case is limited to the domestic firm. However, once we consider an open economy with trade and multinational production the learning process becomes more interesting. More generally, in the case of no multinational production, this model converges to Buera and Oberfield (2020). Multinational production allows for a higher rate of learning compared to solely relying on learning from domestic production. Intuitively, this is because multinational production opens up the potential to learn from the most productive firms from many countries (that is, the max of the maximum of $N-1$ draws). Whereas the domestic learning experiences restrict the channel to learning only from domestic producers.

3 Chinese Outward Investment Shock

In this section we introduce the datasets we used to estimate and validate our model and calibration. With the described data sources we highlight the descriptive evidences on the effect of multinational production on a country' total factor productivity.

3.1 Data Sources

For the data on real GDP, wages and the price index, we turn to Penn World Table 8.0 (Feenstra et al., 2015). The 2023 edition of trade in Employment dataset allowed us to utilize employment data of 59 countries from 1995 to 2020. To align our data period with the dataset of multinational production activity, we take the year 2000 to be the starting period of our analysis. Furthermore, to avoid anomalies associated with the COVID timeline we restrict our ending period to the year 2019. To obtain the multinational production activities of the countries in the industry level, we relied on the 2023 version of Activities of the Multinational Enterprises database (AMNE) provided by the OECD. The AMNE database covers the periods from year 2000 to 2019 and has 41 industries in the ISIC Rev.4 classification and 76 economies, plus a 'rest of the world'. However to complement with the data restriction of the Trade in Employment dataset, we focus our attention on 59 countries. All values are represented in million USD and current prices. In the multinational production data we observe the share of multinational production that is the origin of the firm and the manufactured location. In the model, this is captured by summing the final location of the goods, or $\sum_j \pi_{jli}$ where country i denotes the origin of the firm, l denote the manufactured country and j is the final destination of the manufactured good.

$$\sum_j \pi_{jli} = \pi_{li} = \frac{\text{Production}_{li}}{\text{All Production occurring in } l}$$

Lastly, OECD's 'Inter-Country Input-Output table (ICIO)' is used to gain a better understanding of the international input-output structure on trade and multinational production. We observe the trade shares of 59 countries from 2000 to 2019. This data is captured as $\sum_i \pi_{jli}$ in our model, where the origin country of the firm i is aggregated to represent the expenditure share of good produced in country l being consumed in the final destination country j.

$$\sum_i \pi_{jli} = \pi_{jl} = \frac{\text{Imports}_{jl}}{\text{All production from the world that leads to } j}$$

3.1.1 Formulation of expenditure share

With the observable from the above datasets, we are able to create the expenditure share of country j in terms of goods produced in l and firms originating from i, π_{jli}. This is a key observable for the model given as a multiple of the two respective dataset's observable $\sum_j \pi_{jli} \sum_i \pi_{jli}$.

$$\begin{aligned}
\pi_{jli} &= \sum_j \pi_{jli} \sum_i \pi_{jli} = \pi_{jl}\pi_{li} \\
&= \left[\frac{\text{Imports}_{jl}}{\text{All production from the world that leads to j}}\right]\left[\frac{\text{Production}_{li}}{\text{All Production occurring in l}}\right]
\end{aligned}$$

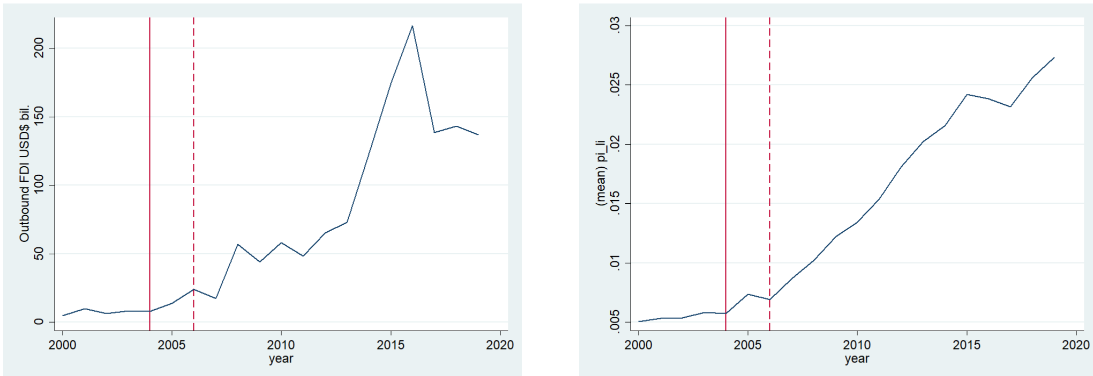
With the observed trade and multinational production flow, we can compute the country's stock of knowledge (λ) needed to match each country's TFP. We measure TFP of country i in the data as a standard Solow residual using real GDP, employment (emp), and average human capital (h) from the PWT 8.0,

$$A_i = \frac{\text{Real GDP}_i}{K_i^{\zeta} \cdot (\text{emp}_i \cdot h_i)^{(1-\zeta)}}$$

where ζ is set to 0.36 to match the corporate labor share in the US in the 2000 by the Karabarbounis and Neiman (2013) calculation.

3.2 China's Multinational Production Shock

While a large body of literature in trade focuses on China's import penetration effect to its trading partners and the inflow of foreign investment into China, an important change that accompanied greater import penetration has been happening the effect of Chinese outward foreign direct investment (FDI). Since 2004, China has been growing their multinational production activities, as the government started promoting overseas investment. According to UNCTAD (2006), measures such as having the states council grant export tax rebates, financial assistance and foreign exchange incentives for outward FDI were some of the policy changes the Chinese government implemented to promote multinational production. In 2005, China lifted restrictions on foreign ownership in a range of industries, including hotels, television and movie production, and banks. Furthermore, in 2006 all quotas on purchase of foreign exchange for overseas investment ended. These policy changes lead to an increased flow of investments and multinational production outward as shown in Figure 1 below.



(a) China's Outward FDI Flows

(b) China's Average MP Share

Figure 1: Chinese outward investment liberalization

We exploit this new type of China shock to analyze how much China's multinational production activity contributes to the growth of the production location's TFP.

3.2.1 Conceptual Framework

The conceptual framework of our empirical work is given by the outline below. We consider decomposing the log output of a country that is invested by China between the periods of 2000 to 2019 to observe the impact of China's multinational production activity to the country.

$$\begin{aligned}\text{Total productivity impact} &= \text{Direct productivity of Chinese multinationals}\\ &+ \text{Indirect learning impact on domestic firms}\\ &+ \text{Indirect impact to linked industries}\end{aligned}$$

The first impact is that when estimating the TFP of the sector, it is changed due to the introduction of a new firm. Secondly, the new establishment can affect the productivity of existing firms through learning. Finally, there may be spillovers to industries that the sector interacts with.[5] However, there might be concern of alternative explanations the govern the changes. Hence, to address the potential endogeneity

[5] Currently, we do not focus on the impact of China's MP on linked industries. Incorporating spillovers across industries is a work in progress.

of faster growing areas also attracting more multinational production, we test for the reduced-form impact of increases in multinational production on TFP. The estimation strategy relies on the exogenous increase in multinational production from China's policy changes to identify the effect of multinational production on TFP and validate the current estimates of β_F. To address the potential endogeniety concerns, use the instrumental variable to indirectly construct a measure for multinational production activity in similar countries. The instrumental variable is created by grouping countries in similar region and income-level to the country l that China is investing in a particular sector. This IV approach is similar to Acemoglu et al. (2016a), who group 8 similar incomes level countries as an instrument to test for effects in the U.S. In our paper, we group countries by income level follows the 'World Bank Group country classifications by income level' for the year 2024 to be: high, upper-middle, lower-middle and low. The regional grouping of countries were by 5 groups: America, Asia, Africa, Europe and West Asia. The table of groupings can be found in Appendix C. By these measures, we can group the relevant countries of interest as country o when we are analyzing China's multinational production activity to a particular sector k of a country l. For instance, if we are interested in China's multinational production activity in Vietnam, we would be grouping the low-income Asian countries to filter out the potential endogeneity of TFP to the multinational production decision by using China's multinational production activities in similar countries. Furthermore, by analyzing in the sector specific level, we claim that the characteristics of the countries bare resemblance from the fact that they are attracting multinational production from China to the same industry. We assume apart from these group's differences the countries within the group have errors that are distributed independently and identically. The equation below showcases the basic technology of our calibration:

$$\Delta \ln \underbrace{Y_{lkt}}_{\substack{\text{output p.w.} \\ \text{in country l, sector k}}} = \xi \underbrace{\Delta \text{MP}^{CH}_{lkt}}_{\substack{\text{MP share of} \\ \text{China in country l, sector k}}} + \underbrace{f_{lt}}_{\text{cty*t f.e.}} + \varepsilon_{lkt}$$

We are interested in the change in log output per worker in country l sector k, which represents the change in TFP when there is a change in the share of multinational production coming from China in the country l's sector k. $\Delta \ln Y_{lkt}$ denote the TFP level of country l sector k at time t, ΔMP_{lkt} indicates the amount of multinational production coming from China to the country l, sector k at time t from the AMNE database and f_{lt} denote the country time fixed effect. Further, we find that trade cost changes are not endogenously changing with the changes in multinational production by observing the annual regressed values of each pairwise countries.

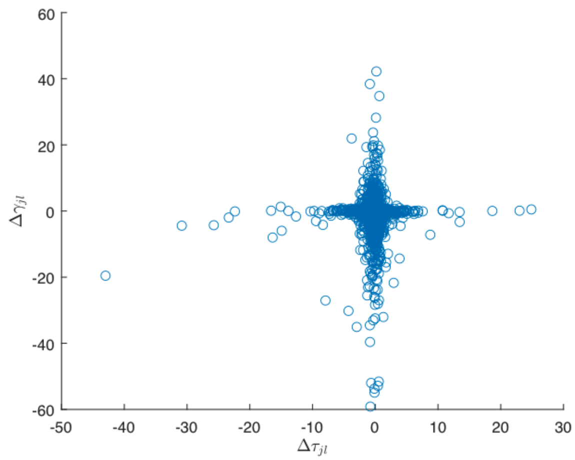


Figure 2: Correlation between annual changes in trade cost and MP cost

Ideally ξ would be able to capture China's multinational production's degree of importance to country l's TFP growth in sector k without endogeneity. However, even with the country time specific fixed effect we might be worried about the unobserved characteristics in the error term ε_{lkt} that might contain some reverse causality of the two variables of interest. To avoid this, we further employ the instrument constructed above of multinational production activities into sector k of similar countries o : $\Delta\text{MP}_{okt}^{CH}$. The correlation between our original variable of interest and our IV is 0.736, which leads us to believe this is a good instrument to use. We conduct the 2SLS estimation with the instrument. The analysis is done by clustering at a one digit industry-by-country level and estimate in 5-year long differences. This allows us to reduce the noise of annual granular sector specific multinational production share levels and focus on the trend of the activity.

	(1)	(2)	(3)	(4)
Method	OLS	IV	IV	IV
$100 \times \Delta \mathrm{MP}_{CHN}$	0.27	1.89*	1.83*	4.89***
	(.15)	(.77)	(.8)	(1.05)
Pretrend	No	No	Yes	No
Country fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Industry	All	All	All	All Excl. Mining
Sample period	2000–2019	2000–2019	2000–2019	2000–2019

standard errors in parentheses $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 1: Reduced-form result

Column (2) of Table 1 shows that a 1 percentage point increase in MP share from China resulted in a 1.89% increase in sectoral TFP. This is a powerful outcome compared to the column (1)'s result that shows the regressed effects of the original variable of interest. With the IV, the effect is seven-folds that of the OLS results of China's MP on the TFP growth of the host countries. We test the strength of the result by introducing checks for industry pretrend as well as country and year fixed effects. Further, we see that the fact that China's investment is concentrated in the mining sector under-emphasizes Chinese MP effect on the host country's TFP growth. Column (4) shows that when we test for Chinese MP changes on excluding the mining sector, the effect of 1 percentage point increase in MP from China results in 4.89% increase in the sectoral TFP of the host country. The mapping of the ξ free from unobserved endogeneity from the Hausman IV to the model allow us to claim that now we are able to observe the effect of China's multinational production to a sector in country l to the stock of TFP. Hence ξ is the explanator of the gap between the data driven TFP for country l after 2004 relative to the model counterfactual scenario where there is no multinational production coming from China.

4 Model Quantification

4.1 Calibration of parameters

To set the curvature of the Fréchet distribution that governs the distribution of knowledge, we look to Simonovska and Waugh (2014) and set $\theta = 4$ as it is in the range consistent with the estimates of trade and multinational production elasticities that is common for all countries. Given θ and observing bilateral trade shares, relative prices and wages overtime, we can derive the iceberg costs (τ_{jl}) of shipping a good to country i from j at time t as well as the multinational production cost (γ_{li}) of implementing ideas at a different country.

Calibrating the ρ

The weight on the geometric mean between knowledge stocks ρ, determines the scale parameter of the Fréchet distribution. We ground our parameter calibration based on the findings of Arnold and Javorcik (2009b), where Indonesian manufacturing firm's foreign ownership enhanced the productivity of the firms by 13.5%. The intuition to align the calibration to this source comes from the fact that ρ determines how much the knowledge of a production's location matters for a firm of the same origin. Using the findings from the paper, we compute the change in the productivity of the Indonesian firms to be represented as below.

$$\frac{\lambda_{IDN}^{\rho}\lambda_{US}^{1-\rho} - \lambda_{IDN}}{\lambda_{IDN}} = 0.135$$

Where the increase in productivity is attributed to the difference between the origin of the firms from Indonesia to U.S. We base our assumption that the ownership changed from Indonesian firms to the U.S. which has approximately 3.21 times higher TFP than Indonesia.[6] This means that normalizing the level of TFP to the U.S., Indonesia has approximately 0.31. Hence, we obtain $\rho = 0.89$. We further conduct robustness tests for the characterization of ρ and find that it does not significantly alter the majority of the country pair's multinational production cost.

[6] We also run a counterfactual with the case that the ownership transpired to a country that has approximately 2.43 times the TFP of Indonesia.

Arrival rate of ideas

In order to find arrival rate of ideas α_{it}, we need to know the evolution of trade and multinational production flows as well as the value for the diffusion of ideas parameter β and γ, the parameter that governs the growth rate of the arrival rate of ideas. First, γ is identified with the average growth rate of the population in US during the interested period. Next, we choose the strength of the diffusion β so that the implied growth rate of arrival rates of ideas for the US is consistent with γ. With the found values, we can use the law of motion of the stock of knowledge ($\dot{\lambda}$) to find the sequence of arrival rates of ideas α_{it}. This is found because α_{it} is the residual needed to describe the gap between the evolution of TFP given the dynamics of the trade costs in the interested period. We assume that α_{it} is a non-negative number. While it is possible to do an maximum likelihood estimation to jointly determine a separate domestic strength of diffusion β_D, and strength of multinational production diffusion β_F, it is more straightforward to assume the US is on the balanced growth path to firstly determine β_D, and then find the β_F which best fits the remaining variance.

Proposition 2 *In a balanced growth path the long run rate of learning is influenced only by the higher rate of learning β_D and not β_F. It is given by*

$$\dot{\lambda} = \frac{\varphi}{1 - \beta_D}$$

where φ is the growth rate of α.

This proposition is key to our identification of the knowledge diffusion parameter. β_D is calibrated to match the level of knowledge diffusion that aligns with the knowledge stock evolution of U.S. Following this procedure we find approximate values of β_D and β_F to be approximately 0.48 and 0.31, respectively. However, we recognize the importance to address the concern that TFP is correlated to the arrival rate of ideas, biasing the results. Thus, in the following subsection, we estimate the reduced-form impact of multinational production on TFP with an instrument variables approach to validate whether the simple estimates lie within the expected range. To our knowledge our paper is the first to estimate the knowledge diffusion parameter based on empirical evidence.

We invert the expenditure share to derive the trade cost τ_{jl} and MP cost γ_{li} as

$$\tau_{jl} = \left[\frac{\pi_{lll}}{\pi_{jll}}\right]^{\frac{1}{\theta}} \frac{P_j}{P_l} \tag{14}$$

$$\gamma_{li} = \left[\left(\frac{\lambda_i}{\lambda_l}\right)^{1-\rho} \frac{\pi_{lll}}{\pi_{lli}}\right]^{\frac{1}{\theta}} \tag{15}$$

Detailed derivation of the expenditure share, trade cost and multinational production cost is illustrated in the Appendix A.

4.2 Mapping the data to the model

To map the ξ found from the reduced form analysis into our model, we setup a model counterfactual that would explain the gap between the data and our model. In the counterfactual, we set the multinational production cost to be the year 2000's level. The idea is to calibrate the β_F so that it will match the reduced-form derived ξ. Our data driven estimates from the Hausman IV allows us to identify the effect of multinational production on the log TFP free of endogeniety concerns. Hence we can say with confidence that the gap between our model counterfactual where there are no multinational production since 2004 and the reality of expansion of overseas foreign investment can be captured with the ξ parameter. We then calibrate the knowledge diffusion parameter of multinational production β_F to match the reduced-form estimates, yielding $\beta_F = 0.31$.

5 Trade deflection and Knowledge evolution

With the change in trade and multinational production barriers across countries some countries may trade more while others engage with the inflow of multinational firm. Following the model mechanism of trade and multinational production occurring with the objective of maximizing firm's profit by minimizing cost to produce, there maybe trade-offs between these activities. Furthermore, since interaction of firms through multinational production and trade have consequences in knowledge spillovers, trade deflection has implication for the evolution of knowledge. An example of how knowledge might spillover between firms through these interaction can vary to be as explicit as the passing of a production blueprint to an indirect transfer of operating systems management.[7] In this section, we demonstrate what the model and data derived parameters can help us understand about the effect of trade deflection on selected country's TFP growth.

5.1 Learning in a Symmetric economy

In order to provide a more tractable analytical solutions without needing to estimate the full trade model is that of symmetric countries, we conduct an exercise in which 40 countries are symmetric in their wages, knowledge stock, trade cost and multinational production cost. Since w, τ,γ, λ are all equal we drop the subscript for this section.

In the case of learning from producers, the growth rate of knowledge stock evolves following the equation below. The case for learning from sellers is illustrated in appendix B.

$$\dot{\lambda}_l = \alpha_l \lambda^\beta \Gamma(1-\beta) \frac{(N-1)\left((N-1)(w\tau\gamma)^{\theta(\beta-1)} + (w\gamma)^{\theta(\beta-1)}\right) + \left((N-1)(w\tau)^{\theta(\beta-1)} + w^{\theta(\beta-1)}\right)}{(N-1)\left((N-1)(w\tau\gamma)^{-\theta} + (w\gamma)^{-\theta}\right) + \left((N-1)(w\tau)^{-\theta} + w^{-\theta}\right)}$$
$$\left[(N-1)\left\{(N-2)(w\tau\gamma)^{-\theta} + (w\tau)^{-\theta} + (w\gamma)^{-\theta}\right\} + (N-1)(w\tau\gamma)^{-\theta} + (w)^{-\theta}\right]^{\beta-1}$$

Through this exercise we want to address the question of how knowledge stock is affected by trade costs and multinational production cost. We compare the baseline scenario of free trade and free multinational production cost to the case with varying cost using the contour plot in Figure 3

[7] We allow for flexibility in the definition of how knowledge spillovers other than the fact that the knowledge transfers happen passively after the decision to conduct the multinational production or trade is made. We do not make any restrictions as to the form in which knowledge transmission takes place between firms through interaction.

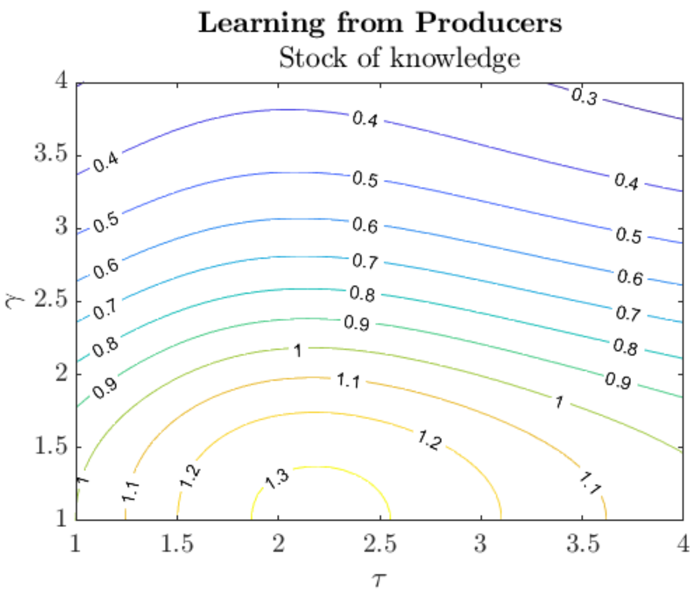


Figure 3: Learning from Producers

The vertical axis denotes the multinational production cost changes that varies from the baseline scenario of free multinational production ($\gamma = 1$) to the extreme case of multinational production cost of $\gamma = 4$. Horizontal axis denotes the varying trade cost ranging from the free trade case of $\tau = 1$ to the case of high trade cost $\tau = 4$. The lower left corner of the plot shows that the level of knowledge stock accumulation with free trade and free multinational production.

There are several important things to note from this exercise. Firstly, the free trade and MP case does not coincide with the maximal level of learning. It can be noted that increasing trade costs from the free trade level can increasing learning by diverting economic activity away from exporting and towards multinational production. Insofar as learning happens through producers, there will be greater learning from multinational production. However, increasing trade costs beyond the optimal level will decrease learning as the increased trade costs reduce the incentives to set up multinational firms for export-platform motive. This deters further inflow of multinational firms from setting up abroad, leading to a decrease in the source of learning. Conversely, declining in multinational production costs monotonically improve learning across countries. When we set the multinational production cost to infinity, the knowledge accumulation follows the Buera and Oberfield (2020)'s case under symmetric economies.

5.2 Deconstructing the source distribution

In Figure 4, we decompose the learning process of different producers that contribute to learning. In the domestic producer's case, they were severely impacted when trade costs and multinational production costs were low because they have more competition. But between multinational production cost and trade cost, they seem to be more unilaterally negatively impacted by the increase in trade cost. On the other hand, in the multinational producers perspective, increase in trade cost encouraged them to move into multinational production so more knowledge accumulation occurred. Whereas, when multinational production cost increased there was a clear decrease in knowledge accumulation stemming from multinational producers.

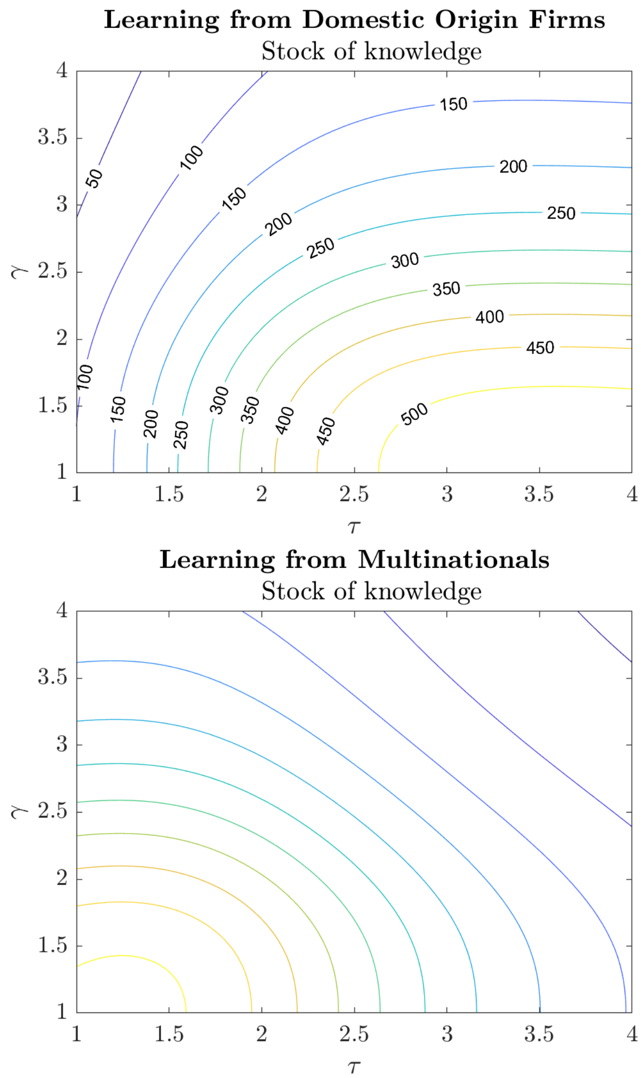


Figure 4: Learning from producers - Multinational producer, Domestic Producers

In Appendix B, we dissect the learning process of different sellers that contribute to learning. In the case of learning from sellers, firms in a country learn from multinational producers, domestic producers and exporters. The increase in multinational production and trade cost both had negative impacts on knowledge accumulation with the effect being slightly more drastic when multinational production cost rose when looking at the contribution of knowledge coming from multinational producers. By contrast, the contribution of knowledge accumulation from domestic producers and exporters were more severely affected by trade costs.

In both cases of learning, when there is separate rates of learning from domestic firms and incoming multinationals, long-run growth is driven solely by domestic firms. Using this, we find the shorter-term impact of multinational on learning. We provide improved calibration/estimation of knowledge diffusion parameters in the literature, by considering separate rates of learning from different source distributions and using causal identification of the effects of MP on learning to identify the model.

5.3 Trade deflection and learning

This exercise allows us to investigate the effect of trade diversions on knowledge accumulation when there exists asymmetric imposition of trade cost to three countries. Countries differ in terms of their initial knowledge stock and for the convenience of labeling, let us denote these countries H (high knowledge stock), M (medium knowledge stock), L (low knowledge stock) respectively. We are interested in analyzing what would be the effect of an increase in trade costs between H and M (τ_{HM}) on trade or multinational production patterns and the TFP growth of L.

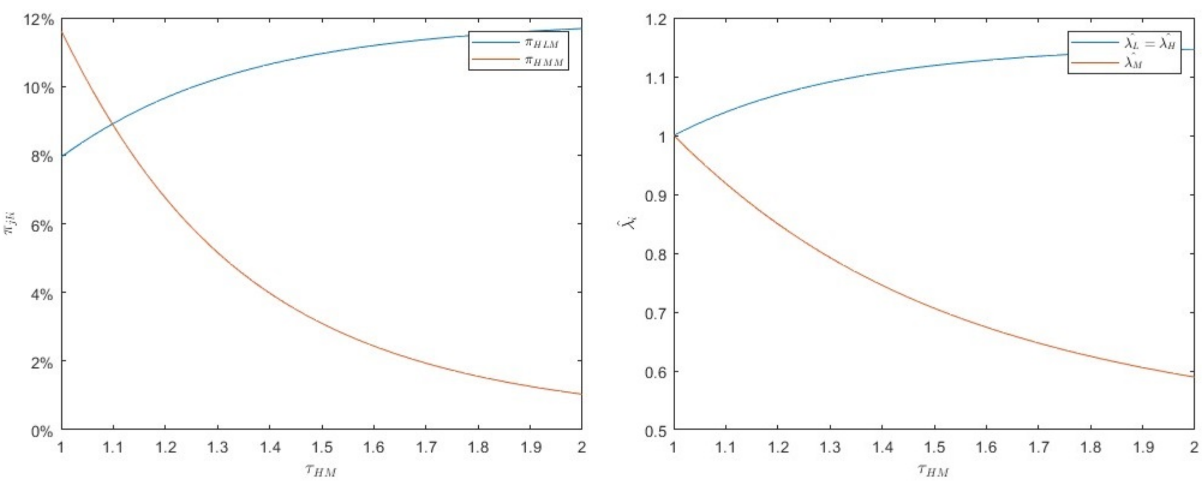


Figure 5: Impact of trade diversion on Knowledge accumulation

The left plot on Figure 5 shows the effect of increase in tariff imposition from the H country to the M country on the share of goods original source country. The blue graph shows that as H country imposes tariff on M country, the share of goods from firms originating from country M but produced in country L increases from 8% to close to 12% with the trade cost 2. On the contrary, the share of goods from firms originating and producing from country M increases from 12% to close to 2% with the trade cost 2. This shows the diversion effect of asymmetric trade cost increase.

The right plot of Figure 5 shows a more interesting result as it demonstrates the effect of increasing trade cost on country M to the detrended knowledge stock ($\hat{\lambda}$) accumulation of country L. With the diversion of trade and multinational production, firms move their production plants from country M to L and H allowing more opportunities to learn for the firms in these new host countries. This in turn contributes to the increasing accumulation of the detrended knowledge stock for country L and H. Similarly, because of the firms migration away from M, country M's detrended knowledge stock suffers.

6 Learning from China

The first counterfactual we consider is impact of Chinese outward MP on various countries. This the main counterfactual used to calibrate the model in Section 4.2. This counterfactual allows us to disaggregate the impact of China's outward MP on individual countries. Table 2 shows the counterfactual changes in TFP if there were no outward Chinese MP, for the 10 largest countries of impact. The full table of results is in Appendix E.

Rank	**Country**	**ΔGDP (%)**	**ΔTFP (%)**
1	Taiwan	-6.48	1.16
2	Brunei	-2.23	-0.68
3	Myanmar	-1.26	0.16
4	Belarus	-1.23	-0.04
5	Vietnam	-1.17	0.28
6	Ukraine	-1.17	-0.46
7	Laos	-1.11	0.50
8	Korea	-1.09	0.01
9	Philippines	-0.96	0.42
10	Cambodia	-0.92	0.12

Table 2: Largest losses from no liberalization of Chinese MP

The countries in Table 2 are sorted in order of largest GDP losses. The impact of Chinese MP has principally affected geographically near countries. The TFP effects do not necessarily align with output and welfare effects, since a nation may benefit from increased activity from Chinese firms, even with low spillovers due to the lower rate of learning from foreign firms, particularly when TFP differences between the two countries small or higher in the destination.

When the counterfactual is run in reverse, that is Chinese *inward* MP costs are fixed to the year 2000 level, the only significantly affected country is China. In this counterfactual, China's TFP is -0.5% smaller. The magnitude of the impact is relatively small to the impacts MP has on other nations because the foreign MP share within China has consistently been small, relative to all production within China.

6.1 Trade liberalization

China's accession to World Trade Organization (WTO) in December 2001, led to large increases in trade and multinational production volumes between China and the rest of the world (Brandt and Morrow, 2017; Brandt et al., 2017). Entry into the WTO resulted in large decreases in trade barriers and FDI through China's commitment to abide by the international trade standards (Rumbaugh and Blancher, 2004). Who benefited, and to what extend, from China's accession is an open question. The impact of WTO entry on China is complex, noting that China had already been growing at rapid speed without being fully integrated to the WTO's system (Lardy, 2004). Similarly, as vast literature on import penetration by China such as Autor et al. (2013b), Bernard et al. (2003) and Iacovone et al. (2013) suggests, the rest of the WTO members may have suffered from increased market competition from China. In this section, we run a counterfactual by keeping the multinational production cost and trade cost at the level of year 2000 to quantitatively analyze who the benefits and loses had China not entered WTO and by how much.

Rank	**Country**	**ΔGDP (%)**	**ΔTFP (%)**
1	Taiwan	-6.48	-0.35
2	Ukraine	-2.30	-1.42
3	Brunei	-1.84	-0.22
4	Cambodia	-1.82	0.31
5	Myanmar	-1.75	0.33
6	Korea	-1.73	0.03
7	Philippines	-1.71	0.34
8	Belarus	-1.70	-0.16
9	Thailand	-1.30	-0.16
10	Saudi Arabia	-1.16	-0.36

Table 3: Largest losses from China's exclusion from WTO

Rank	**Country**	**ΔGDP (%)**	**ΔTFP (%)**
77	Vietnam	12.61	1.42
76	Kazakhstan	10.42	7.73
75	Laos	2.78	0.91
74	Hong Kong	0.82	-1.35
73	Bangladesh	0.82	0.17
72	Romania	0.66	0.36
71	Lithuania	0.31	0.00
70	Bulgaria	0.17	0.05
69	Finland	0.15	-0.05
68	Latvia	0.03	0.01

Table 4: Largest gains from China's exclusion from WTO

Table 3 showcases countries that suffer the greatest as a result of China not joining the WTO and keep their level of inward and outward multinational production cost as well as trade cost at the 2000 level. China suffers the biggest loss with the TFP level differences between the current data and the counterfactual being 1.54%. However, the GDP loss is a much smaller -0.12%. The losses that would arise through lower productivity are offset by higher demand for production within China, pushing up wages. Seven of the ten largest losses in GDP from this counterfactual occur in East Asia; the countries of which are generally the highest recipients of Chinese outward MP. The top 5 benefactors from China's exclusion exhibited greater variance in their gains. Vietnam is the largest beneficiary in the counterfactual, suggesting that a much greater share of economic activity would occur there. Similar deflection is found from Eastern European nations. The results suggest that multinational production and trade activities were deflected to theses countries instead of China due to higher tariffs and multinational production costs.

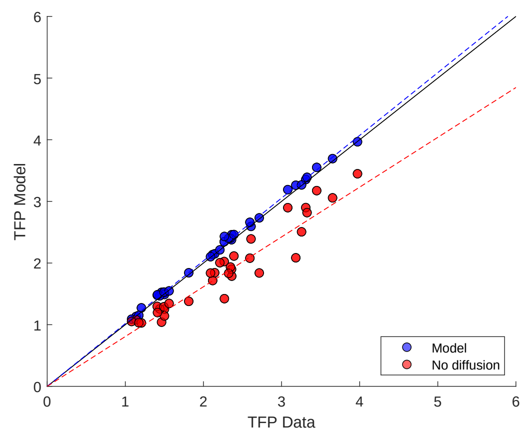
Country	TFP gain (%)
Côte d'Ivoire	-0.41
Senegal	-0.36
Cameroon	-0.36
Tunisia	-0.33
Morocco	-0.3
Egypt	-0.24
Nigeria	-0.24
South Africa	-0.22

Table 5: China's Multinational production in Africa

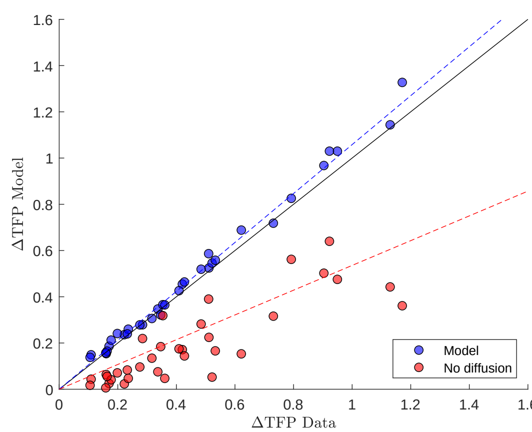
Recently, much attention has centered around the concentration of Chinese foreign direct investment in African countries. Majority of investment headed towards these countries from China is on the mining related sectors which may have different implication for the overall TFP of a country. Table 5 shows the result for fixing outbound multinational production cost to the 2000 year level for countries that are located in the African region among our dataset. Negative TFP gains tells us that all of the African region countries in our sample suffer from a higher outward multinational production cost from China. From these results we can infer that even the regions where majority of the investment is targeted towards mining sector, Chinese multinational production has a positive influence on the TFP of the country.

7 Growth effects of multinational production

In this section, we address the TFP growth effects of our model. By comparing with a model of no diffusion, we show the importance of incorporating trade, multinational production and the knowledge diffusion through these firms in the periods between 2000 and 2019. The black line on the both graphs in figure 6 is a 45 degree line. The model predicted TFP aligning with the TFP data would indicate that the linear line through the plots would be closer to the 45 degree line. The graphs in figure 6 are created by assuming the arrival rate of ideas are fixed as the average of year 2000 and 2019. By setting the knowledge diffusion parameter to be zero, we can decompose the effect of knowledge diffusion to TFP for multiple countries both in terms of levels and changes. Graph (a) of figure 6 shows the relative level of which knowledge diffusion explains the TFP for 74 countries, while the graph (b) shows the changes of TFP. Both graph shows that for the TFP dispersion that occurred during the period, knowledge diffusion played an significant role. Particularly, the right graph of figure 6 shows that the model with knowledge diffusion, trade and multinational production is able to account for about half of the TFP variation from data relative to the model without diffusion. Similar results hold for when we assume that the arrival rate of ideas is fixed to the initial level of 2000 as we show in the Appendix D



(a) TFP Model vs. TFP Data



(b) Change in TFP Model vs. TFP Data

Figure 6: Model vs. Data implied TFP growth with average arrival rates

We focus our attention on Thailand as the country experienced one of the highest influx of Chinese multinational production during the period 2000 to 2019: Cambodia and Thailand. We fix the arrival rate of ideas to their year 2000 level and ask; what does the model predict the growth rate of TFP to be? The results from our counterfactual exercise in the Figure 8 shows that literature that tries to explain the growth of these countries through trade, without knowledge diffusion as an added channel for growth, notably falls short.

We provide evidence that incorporating diffusion into a trade model with multinational production adds to the accounting of TFP, relative to a model with no diffusion and a model with diffusion but without multinational production.

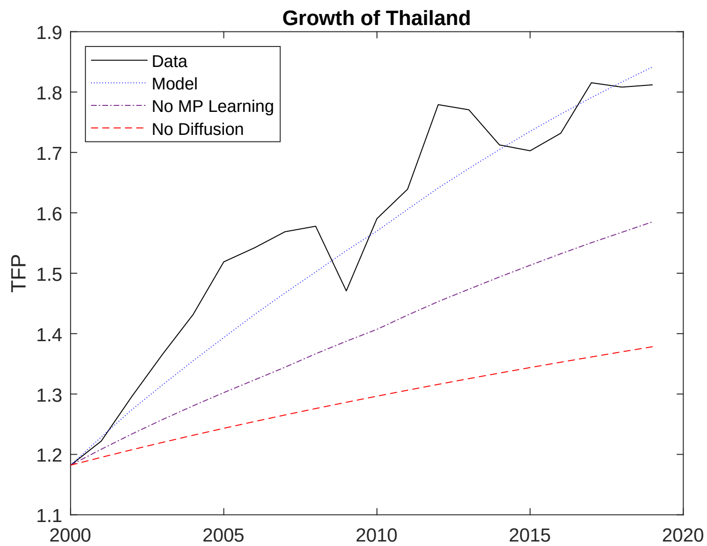


Figure 7: Case of Thailand

Figure 8: Counterfactual accounting for TFP growth

Figure 8 is composed of 4 different line plots: black lines show the data implied TFP over the years 2000 and 2019, red dashed line shows the TFP level implied by model with trade and multinational production but no knowledge diffusion channel, purple dash-dotted line implies the TFP growth of model with trade and knowledge diffusion but without multinational production and blue dotted line is our model's prediction of TFP growth that encompasses trade, multinational production and their knowledge diffusion effect. The plot shows the importance of incorporation of knowledge diffusion in accounting for TFP growth.

8 Conclusion

This paper analyzes the growth effects countries in a globalized world where ideas travel through firms trading and allocating their establishments in foreign countries. We provide a tractable model of international idea diffusion that allows the endogenous decision of who trades with whom and who invests where as well as the resulting evolution of TFP. The dynamic interaction between trade costs and multinational production cost indicate that disregarding one of the two channels poses a threat to correctly estimating the implications for knowledge accumulation. We calibrate the model using the ICIO table and the AMNE database for 59 countries between the periods of 2000 to 2019. We contribute to the literature by providing an IV strategy to bring empirical evidence to knowledge diffusion parameters with the new China shock. Based on the estimation we are able to conduct counterfactual analysis on the gains and losses of countries if China had not joined the WTO, leading to higher trade and multinational production costs. Lastly, we are able to show that a model with multinational production and knowledge diffusion explains approximately half of the variation in TFP growth. We conduct a decomposition exercise of TFP growth for the modern growth episodes country such as Thailand and show that without the knowledge diffusion through multinational production and trade, large portion of Thailand's TFP growth between 2000 and 2019 would have been not accounted for.[8] This shows that knowledge diffusion through multinational production is an important part of host country's TFP growth.

[8] Buera and Oberfield (2020) find that by including diffusion in a growth model we can account for a greater proportion of productivity growth. However, their estimates still fall short in accounting for the data.

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APPENDIX

A Derivations

A.1 Measure of firms

The measure of firms from i produces in country l and sells to country j is represented as below.

$$\begin{aligned}
\mathcal{F}_{jli} &= \int_0^{\phi} \prod_{k\neq l}\prod_{m\neq i} F_{k,m}\left(\frac{w_k\tau_{jk}\gamma_{km}}{w_l\tau_{jl}\gamma_{li}}x\right) f_{l,i}\left(x\right)dx \\
&= \left(\lambda_l^{\rho}\lambda_i^{1-\rho}\right)\theta\int_0^{\phi} e^{-\sum_{k\neq l}\sum_{m\neq i}\left\{\left(\lambda_k^{\rho}\lambda_m^{1-\rho}\right)\left(\frac{w_k\tau_{jk}\gamma_{km}}{w_l\tau_{jl}\gamma_{li}}\right)^{-\theta}+\left(\lambda_l^{\rho}\lambda_i^{1-\rho}\right)\right\}x^{-\theta}} x^{-\theta-1}dx \\
&= \frac{\left(\lambda_l^{\rho}\lambda_i^{1-\rho}\right)}{\sum_k\sum_m\left\{\left(\lambda_l^{\rho}\lambda_i^{1-\rho}\right)\left(\frac{w_k\tau_{jk}\gamma_{km}}{w_l\tau_{jl}\gamma_{li}}\right)^{-\theta}\right\}} e^{-\sum_k\sum_m\left\{\left(\lambda_k^{\rho}\lambda_m^{1-\rho}\right)\left(\frac{w_k\tau_{jk}\gamma_{km}}{w_l\tau_{jl}\gamma_{li}}\right)^{-\theta}\right\}\phi^{-\theta}} \\
&= \frac{G\left(l,i\right)}{\sum_k\sum_m\left\{G\left(k,m\right)\left(\frac{w_k\tau_{jk}\gamma_{km}}{w_l\tau_{jl}\gamma_{li}}\right)^{-\theta}\right\}} e^{-\sum_k\sum_m\left\{G(k,m)\left(\frac{w_k\tau_{jk}\gamma_{km}}{w_l\tau_{jl}\gamma_{li}}\right)^{-\theta}\right\}\phi^{-\theta}}
\end{aligned}$$

The marginal productivity of firms that satisfy this measure is:

$$\frac{\partial\mathcal{F}_{jli}}{\partial\phi} = \lambda_l^{\rho}\lambda_i^{1-\rho}\theta e^{-\sum_k\sum_m\left\{\left(\lambda_k^{\rho}\lambda_m^{1-\rho}\right)\left(\frac{w_k\tau_{jk}\gamma_{km}}{w_l\tau_{jl}\gamma_{li}}\right)^{-\theta}\right\}\phi^{-\theta}} \phi^{-\theta-1}$$

A.2 Price Index

We use the marginal productivity found above to find the price index of country j:

$$\begin{aligned}
P^{1-\sigma} &= \sum_i \sum_l \left(\int_{s \in S_{jli}} p_{jli}(s)^{1-\sigma} ds \right) \\
&= \sum_i \sum_l \left(\int_0^\infty \left(\frac{w_l \tau_{jl} \gamma_{li}}{\phi} \right)^{1-\sigma} \frac{\partial \mathcal{F}_{jli}}{\partial \phi} d\phi \right) \\
&= \sum_i \sum_l \left(\left(\frac{w_l \tau_{jl} \gamma_{li}}{\phi} \right)^{1-\sigma} \left(\lambda_l^\rho \lambda_i^{1-\rho} \right) \theta \int_0^\infty e^{-\sum_k \sum_m \left\{ \left(\lambda_k^\rho \lambda_m^{1-\rho} \right) \left(\frac{w_k \tau_{jk} \gamma_{km}}{w_l \tau_{jl} \gamma_{li}} \right)^{-\theta} \right\} \phi^{-\theta}} \phi^{\sigma-\theta-2} d\phi \right) \\
&= \Gamma \left(\frac{1-\sigma+\theta}{\theta} \right) \sum_i \sum_l \left(w_l \tau_{jl} \gamma_{li} \right)^{1-\sigma} \left(\lambda_l^\rho \lambda_i^{1-\rho} \right) \left(\sum_k \sum_m \left\{ \left(\lambda_k^\rho \lambda_m^{1-\rho} \right) \left(\frac{w_k \tau_{jk} \gamma_{km}}{w_l \tau_{jl} \gamma_{li}} \right)^{-\theta} \right\} \right)^{\frac{\sigma-1}{\theta}-1} \\
&= \Gamma \left(\frac{1-\sigma+\theta}{\theta} \right) \sum_i \sum_l \left(w_l \tau_{jl} \gamma_{li} \right)^{1-\sigma} G(l,i) \left(\sum_k \sum_m \left\{ G(k,m) \left(\frac{w_k \tau_{jk} \gamma_{km}}{w_l \tau_{jl} \gamma_{li}} \right)^{-\theta} \right\} \right)^{\frac{\sigma-1-\theta}{\theta}}
\end{aligned}$$

A.3 Expenditure share

Then the expenditure shares of goods sold to country j from country l originating from country i become the share of the prices of all products that were sold to j, produced in country l and originating from country i over the price index of country j:

$$
\begin{aligned}
\pi_{jli} &= \frac{\int_{s\in S_{jli}} p_{jli}(s)^{1-\sigma} ds}{P_j^{1-\sigma}} \\
&= \frac{\Gamma\left(\frac{1-\sigma+\theta}{\theta}\right)(w_l\tau_{jl}\gamma_{li})^{1-\sigma}\left(\lambda_l^{\rho}\lambda_i^{1-\rho}\right)\left(\sum_k\sum_m\left\{\left(\lambda_k^{\rho}\lambda_m^{1-\rho}\right)\left(\frac{w_k\tau_{jk}\gamma_{km}}{w_l\tau_{jl}\gamma_{li}}\right)^{-\theta}\right\}\right)^{\frac{\sigma-1}{\theta}-1}}{\Gamma\left(\frac{1-\sigma+\theta}{\theta}\right)\sum_i\sum_l(w_l\tau_{jl}\gamma_{li})^{1-\sigma}\left(\lambda_l^{\rho}\lambda_i^{1-\rho}\right)\left(\sum_k\sum_m\left\{\left(\lambda_k^{\rho}\lambda_m^{1-\rho}\right)\left(\frac{w_k\tau_{jk}\gamma_{km}}{w_l\tau_{jl}\gamma_{li}}\right)^{-\theta}\right\}\right)^{\frac{\sigma-1}{\theta}-1}} \\
&= \frac{(w_l\tau_{jl}\gamma_{li})^{1-\sigma}\left(\lambda_l^{\rho}\lambda_i^{1-\rho}\right)\left(\sum_k\sum_m\left\{\left(\lambda_k^{\rho}\lambda_m^{1-\rho}\right)\left(\frac{w_k\tau_{jk}\gamma_{km}}{w_l\tau_{jl}\gamma_{li}}\right)^{-\theta}\right\}\right)^{\frac{\sigma-1}{\theta}-1}}{\sum_i\sum_l(w_l\tau_{jl}\gamma_{li})^{1-\sigma}\left(\lambda_l^{\rho}\lambda_i^{1-\rho}\right)\left(\sum_k\sum_m\left\{\left(\lambda_k^{\rho}\lambda_m^{1-\rho}\right)\left(\frac{w_k\tau_{jk}\gamma_{km}}{w_l\tau_{jl}\gamma_{li}}\right)^{-\theta}\right\}\right)^{\frac{\sigma-1}{\theta}-1}} \\
&= \frac{(w_l\tau_{jl}\gamma_{li})^{1-\sigma} G(l,i)\left(\sum_k\sum_m\left\{G(k,m)\left(\frac{w_k\tau_{jk}\gamma_{km}}{w_l\tau_{jl}\gamma_{li}}\right)^{-\theta}\right\}\right)^{\frac{\sigma-1-\theta}{\theta}}}{\sum_i\sum_l(w_l\tau_{jl}\gamma_{li})^{1-\sigma} G(l,i)\left(\sum_k\sum_m\left\{G(k,m)\left(\frac{w_k\tau_{jk}\gamma_{km}}{w_l\tau_{jl}\gamma_{li}}\right)^{-\theta}\right\}\right)^{\frac{\sigma-1-\theta}{\theta}}} \\
&= \frac{(w_l\tau_{jl}\gamma_{li})^{-\theta} G(l,i)\left(\sum_k\sum_m\left\{G(k,m)(w_k\tau_{jk}\gamma_{km})^{-\theta}\right\}\right)^{\frac{\sigma-1-\theta}{\theta}}}{\sum_i\sum_l(w_l\tau_{jl}\gamma_{li})^{-\theta} G(l,i)\left(\sum_k\sum_m\left\{G(k,m)(w_k\tau_{jk}\gamma_{km})^{-\theta}\right\}\right)^{\frac{\sigma-1-\theta}{\theta}}} \\
&= \frac{(w_l\tau_{jl}\gamma_{li})^{-\theta} G(l,i)}{\sum_i\sum_l(w_l\tau_{jl}\gamma_{li})^{-\theta} G(l,i)}
\end{aligned}
$$

As a result, we get a expenditure share as a function of wages, trade costs, multinational production cost, knowledge stock and parameters.

$$
\pi_{jli} = \frac{(w_l\tau_{jl}\gamma_{li})^{-\theta} G(l,i)}{\sum_i\sum_l(w_l\tau_{jl}\gamma_{li})^{-\theta} G(l,i)}
$$

A.4 Trade cost, Multinational production cost

To back out the trade cost and multinational production cost as a function of observables, we use the expenditure share of domestic firms selling locally

$$
\pi_{lll} = \frac{w_l^{-\theta}\lambda_l}{\sum_i\sum_l(w_l\tau_{jl}\gamma_{li})^{-\theta}\lambda_l^{\rho}\lambda_i^{1-\rho}}
$$

as well as the expenditure share of local sales of multinationals

$$\pi_{lli} = \frac{(w_l \gamma_{li})^{-\theta} G(l,i)}{\sum_i \sum_l (w_l \tau_{jl} \gamma_{li})^{-\theta} \lambda_l^{\rho} \lambda_i^{1-\rho}}$$

By taking a ratio of the two objects above, we are able to solve for trade costs

$$\frac{\pi_{jli}}{\pi_{lli}} = \frac{(w_l \tau_{jl} \gamma_{li})^{-\theta} G(l,i)}{\sum_i \sum_l (w_l \tau_{jl} \gamma_{li})^{-\theta} G(l,i)} \frac{\sum_i \sum_l (w_l \tau_{jl} \gamma_{li})^{-\theta} \lambda_l^{\rho} \lambda_i^{1-\rho}}{(w_l \gamma_{li})^{-\theta} G(l,i)} = \tau_{jl}^{-\theta}$$

Then rearranging the above equation gives:

$$\tau_{jl} = \left[\frac{\pi_{lli}}{\pi_{jli}}\right]^{\frac{1}{\theta}}$$

Now using the other objects to arrive at the multinational production cost, $\gamma_l i$:

$$\begin{aligned}
\frac{\pi_{lli}}{\pi_{lll}} &= \frac{\frac{(w_l \gamma_{li})^{-\theta} G(l,i)}{\sum_i \sum_l (w_l \tau_{jl} \gamma_{li})^{-\theta} \lambda_l^{\rho} \lambda_i^{1-\rho}}}{\frac{w_l^{-\theta} \lambda_l}{\sum_i \sum_l (w_l \tau_{jl} \gamma_{li})^{-\theta} \lambda_l^{\rho} \lambda_i^{1-\rho}}} \\
&= \frac{(w_l \gamma_{li})^{-\theta} \lambda_l^{\rho} \lambda_i^{1-\rho}}{w_l^{-\theta} \lambda_l} \\
&= \lambda_l^{\rho-1} \lambda_i^{1-\rho} \gamma_{li}^{-\theta} \\
&= \left(\frac{\lambda_i}{\lambda_l}\right)^{1-\rho} \gamma_{li}^{-\theta}
\end{aligned}$$

Taking the ratio of domestic firm again:

$$\frac{\pi_{iii}}{\pi_{lll}} = \frac{w_i^{-\theta} \lambda_i}{w_l^{-\theta} \lambda_l}$$

rearranging the above,

$$\frac{\lambda_i}{\lambda_l} = \frac{\pi_{iii}}{\pi_{lll}} \left(\frac{w_l}{w_i}\right)^{-\theta}$$

combining with the equation for $\frac{\pi_{lli}}{\pi_{lll}}$,

$$\frac{\pi_{lli}}{\pi_{lll}} = \left(\frac{\pi_{iii}}{\pi_{lll}} \left(\frac{w_l}{w_i}\right)^{-\theta}\right)^{1-\rho} \gamma_{li}^{-\theta}$$

we get the γ_{li} as a function of observables.

$$\gamma_{li} = \left[\frac{\pi_{lll}}{\pi_{lli}} \left(\frac{\pi_{iii}}{\pi_{lll}} \left(\frac{w_l}{w_i} \right)^{-\theta} \right)^{1-\rho} \right]^{\frac{1}{\theta}}$$

A.5 Ratio of wage

In this section we show that the ratio of wages can be solved for using the expenditure share of domestic firms in two different countries.

$$\frac{\pi_{iii}}{\pi_{lll}} = \frac{w_i^{-\theta} \lambda_i}{w_l^{-\theta} \lambda_l}$$

Rearranging the above ratio,

$$\frac{\pi_{iii}}{\pi_{lll}} \frac{\lambda_l}{\lambda_i} = \left(\frac{w_i}{w_l} \right)^{-\theta}$$

we arrive at the wage of country i as a function of expenditure share, knowledge stocka and the country l's wages.

$$w_i = \left(\frac{\pi_{lll}}{\pi_{iii}} \frac{\lambda_i}{\lambda_l} \right)^{\frac{1}{\theta}} w_l$$

A.6 Evolution of knowledge equilibrium

Rearranging π_{jli} we get the expression below which we use to evaluate the evolution of knowledge equation:

$$\sum_i \sum_l \left(w_l \tau_{jl} \gamma_{li} \right)^{-\theta} G\left(l, i\right) = \frac{\left(w_l \tau_{jl} \gamma_{li} \right)^{-\theta} G\left(l, i\right)}{\pi_{jli}}$$

In the world where we learn from producers (people that produce in your country l, whether selling there or elsewhere) the knowledge stock of country l evolves as a function of the marginal productivity of the firms operating in the country l:

$$
\begin{aligned}
&\dot{\lambda}_l^{\text{producers}} \\
&= \sum_n \int x^{\beta_n \theta} \frac{\partial \mathcal{F}_{jli}(n)}{\partial \phi} d\phi \\
&= \int \phi^{\theta(\beta-1)-1} G(l,i)\, \theta e^{-\sum_k \sum_m \left\{ \left(\lambda_k^{\rho} \lambda_m^{1-\rho}\right) \left(\frac{w_k \tau_{jk} \gamma_{km}}{w_l \tau_{jl} \gamma_{li}} \right)^{-\theta} \right\} \phi^{-\theta}} d\phi \\
&= \alpha_l \Gamma(1-\beta) \sum_i \sum_j \left(w_l \tau_{jl} \gamma_{li} \right)^{-\theta(1-\beta)} G(l,i) \left(\sum_m \sum_k \left\{ G(k,m) \left(w_k \tau_{jk} \gamma_{km} \right)^{-\theta} \right\} \right)^{\beta-1} \\
&= \alpha_l \Gamma(1-\beta) \sum_i \sum_j \left(w_l \tau_{jl} \gamma_{li} \right)^{-\theta(1-\beta)} G(l,i) \left(\frac{\left(w_l \tau_{jl} \gamma_{li} \right)^{-\theta} G(l,i)}{\pi_{jli}} \right)^{\beta-1} \\
&= \alpha_l \Gamma(1-\beta) \sum_i \sum_j \left(w_l \tau_{jl} \gamma_{li} \right)^{\theta\beta-\theta+(\theta-\beta\theta)} G(l,i)^{\beta} \left(\frac{1}{\pi_{jli}} \right)^{\beta-1} \dot{\lambda}_l^{\text{producers}} \\
&= \alpha_l \Gamma(1-\beta) \sum_i \sum_j G(l,i)^{\beta} \pi_{jli}^{1-\beta}
\end{aligned}
$$

B Learning from Sellers

When trade and multinational production is introduced to the model, there are three sources from which learning from sellers can occur: exporter, domestic producer and firms that have multinational production set up in that country. Learning rates from sellers are given by:

$$
\dot{\lambda}_j^{\text{sellers}} = \alpha_j \sum_i \sum_l \left(\int_{s \in S_{jli}} \phi^{\beta\theta} ds \right)
$$

Using the measures from the previous section we find this equates to:

$$
\dot{\lambda}_j^{\text{sellers}} = \alpha_j \Gamma(1-\beta) \sum_i \sum_l G(l,i) \left(\sum_m \sum_k \left\{ G(k,m) \left(\frac{w_k \tau_{jk} \gamma_{km}}{w_l \tau_{jl} \gamma_{li}} \right)^{-\theta} \right\} \right)^{\beta-1} \tag{16}
$$

The equation above shows that where firms in j draw insights from other firms in accordance with the measure they sell in j. As we focus on the final destination of the sales as the thing that determines the learning process we aggregate up the origin of the production firm i and the location of production l. Notice that as multinational production becomes prohibitive (that is, $\gamma_{li} \to \infty$) we converge to the case of Buera and Oberfield (2020). This result is shown in Figure 9.

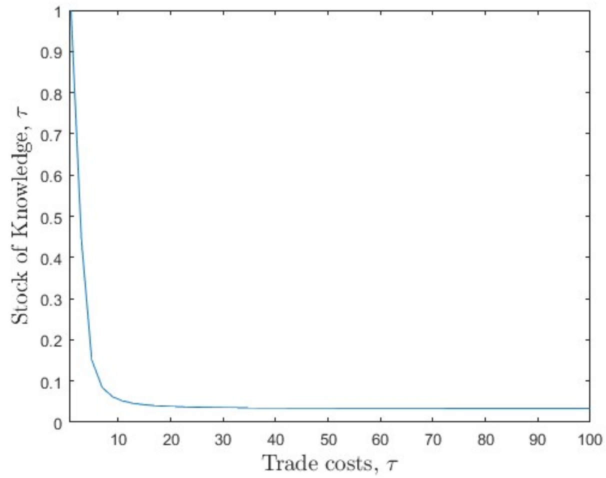


Figure 9: Learning with infinite multinational production costs

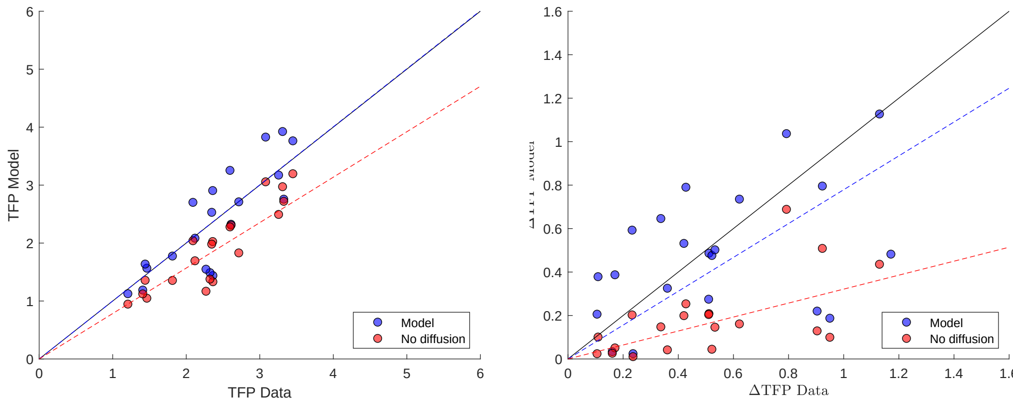
In the numerical exercise with symmetric countries, the growth rate of knowledge stock coming from the sellers are as follows:

$$\dot{\lambda_j} = \alpha_j \lambda^\beta \Gamma(1-\beta)\left[(N-1)\left\{(N-1)(w\tau\gamma)^{\theta(\beta-1)} + (w\tau)^{\theta(\beta-1)}\right\} + (N-1)(w\gamma)^{\theta(\beta-1)} + (w)^{\theta(\beta-1)}\right]$$
$$\left[(N-1)\left\{(N-2)(w\tau\gamma)^{-\theta} + (w\tau)^{-\theta} + (w\gamma)^{-\theta}\right\} + (N-1)(w\tau\gamma)^{-\theta} + (w)^{-\theta}\right]^{\beta-1}$$

C Grouping for IV

We group countries by income level follows the 'World Bank Group country classifications by income level' for the year 2024 to be: high, upper-middle, lower-middle and low. The regional grouping of countries were by 5 groups: America, Asia, Africa, Europe and West Asia. Some countries were grouped into closest neighbor for the convenience of analysis i.e. Australia and New Zealand as Asia, Russia and Europe.

D Initial arrival rate of ideas



(a) TFP Model vs. TFP Data

(b) Change in TFP Model vs. TFP Data

Figure 10: Model vs. Data implied TFP growth with initial arrival rates

E Counterfactual Results – Detail