Multinational Entry and Exit, Technology Transfer, and International Business Cycles

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Abstract

I develop a general equilibrium model of trade and horizontal multinational production (MP) with firm heterogeneity, market access frictions including export and MP sunk costs, multinational parent-to-affiliate technology transfer, and capital. I find that pro-cyclical MP exit (i.e., MP extensive margin) plays an important role in increasing macroeconomic volatility and reducing international correlations. When calibrated to match US data, I approximate that at least 15% of the change between a no-MP model and the MP model can be attributed to MP extensive margin. Overall, the paper highlights the importance of firm extensive margin, in particular that of MP, in aggregate business cycle dynamics.

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1 Introduction

How does multinational production (MP), where firms produce in multiple countries, affect international real business cycles (IRBC)? The theoretical research on this is limited (with the exceptions of Contessi (2010, 2015); Zlate (2016)), in spite of the fact that world affiliates sales as a share of world gross domestic product (GDP) was twice as much as the share of world trade in world GDP in 2007 (Ramondo (2014)). Instead, theoretical IRBC research is tilted towards evaluating exports as a driver of aggregate business cycle dynamics.[1] Furthermore, recent empirical evidence shows that multinationals are important channels for cross-border spillovers (di Giovanni & Levchenko (2010); Cravino & Levchenko (2017); di Giovanni *et al.* (2017, 2018); Boehm *et al.* (2019); Bena *et al.* (2021)).

There are at least three reasons why MP could impact IRBC more than trade. First, MP affiliates' entry and exit (i.e., the extensive margin) can have a larger impact than the extensive margin of exporters on account of there being a shift in production location only in the case of MP. For example, when an exporter decides to serve foreign market by MP instead, a part of the production shifts abroad. There is outflow of capital during this process and the affiliate inherits a part of its parent's productivity. But when a domestic firm starts exporting abroad, the increase in production occurs only at home; any impact on foreign is through prices and increased variety as documented in Liao & Santacreu (2015). Second, as mentioned above, affiliate sales surpass exports two-to-one as a way to serve foreign markets. Third, productivity shocks to MP firms could matter more à la Gabaix (2011) because multinationals are larger than exporters (Doms & Jensen (1998)).

In this paper, I develop a model of trade and horizontal MP and show that when calibrated to account for the characteristics of exporters and MP firms, it generates a significant role for MP extensive margin in affecting business cycles. In particular, I find that MP exit is pro-cyclical, which increases macroeconomic volatility and decreases international correlations.[2] Technology transfer dampens the MP extensive margin channel-there is lower volatility and higher international correlations at higher levels of technology transfer. In a broader sense, the paper highlights the importance of extensive margin of firms in international markets on business cycle variables.[3]

[1] Quantitative trade models have attempted to replicate the observed business cycle moments including (but not limited to) cross-country output correlation and the real exchange rate-net exports relationship. See Backus *et al.* (1994); Ghironi & Melitz (2005); Kose & Yi (2006); Alessandria & Choi (2007); Johnson (2014), and Liao & Santacreu (2015).

[2] These results appear counter-intuitive in the context of several empirical papers that have found MP to increase international output correlation (I refer back to the list of papers cited above). But the empirical papers do not distinguish between horizontal versus vertical MP. The impact of horizontal MP, which I model for reasons explained below, on international business cycles is therefore an open empirical question. On the theory side too our understanding the impact of horizontal MP is lacking which this paper addresses.

[3] The last two decades have seen a number of papers have built on seminal works by Melitz (2003), Alessandria & Choi (2007), and Ghironi & Melitz (2005) that emphasise the role of extensive margin.

The following empirical facts serve as guideposts while developing the quantitative MP model. First, even among firms that sell to foreign markets (i.e., exporters and MP firms), multinationals belong to a larger firm size category (Doms & Jensen (1998)). Second, there is a non-zero transition probability into and out of MP status (Boehm *et al.* (2020)). Although the probabilities are not large in absolute value, these transitions turn out to be quantitatively important given the larger size of the MP firms. Third, multinational affiliate and headquarter sales move together, which is interpreted to be a consequence of headquarter to affiliate technology transfer (Cravino & Levchenko (2017)).[4] Fourth, multinationals between developed economies are of horizontal market-seeking nature wherein MP affiliates substitute trade (Markusen (1995); Swenson (2004)) as opposed to cheaper-labor-seeking vertical MP observed between developed and developing economies.

I incorporate these features in to the Alessandria & Choi (2007) model of heterogeneous firms and market access frictions augmented to include MP. Firms differ by their productivity, own their physical capital stock, and are subject to aggregate and idiosyncratic shocks to their total factor productivity (TFP). Market access frictions, modelled as fixed and sunk costs of exporting and conducting MP, reduce firms' profits from engaging in these activities. This results in the segregation of firms into domestic, export, and MP based on their idiosyncratic productivities and last-period export and MP statuses. On average, in the cross section, the most productive firms conduct MP, firms with intermediate productivities export, and the least productive firms serve only the domestic market. In addition to this cross sectional separation, the sunk costs add persistence to firms' export and MP statuses. Over time, a firm's status changes as the aggregate shocks shift the entry and exit productivity thresholds and as its idiosyncratic TFP changes. In sum, a firm's status is a function of current macroeconomic conditions, its idiosyncratic productivity, and its past export and MP statuses.

I mimic the observed parent to affiliate technology transfer by following a combination of approaches in existing quantitative MP models (Contessi (2010, 2015); Zlate (2016) and Cravino & Levchenko (2017)). Contessi and Zlate assume that affiliate idiosyncratic productivity is the same as that of its parent (i.e., full transfer of idiosyncratic productivity) while the aggregate productivity is that of the host country (i.e., zero transfer of aggregate productivity). Following Cravino & Levchenko (2017), I allow for a partial transfer (governed by a technology transfer parameter) of the parent country's aggregate shock to the affiliate in addition to the full transfer of headquarter idiosyncratic productivity.

Among international business cycle models, Liao & Santacreu (2015) and Zlate (2016), have highlighted the role of extensive margins in increasing output comovement across countries.

[4] This paper only focuses on technology transfer *within* multinationals - i.e., from parent to affiliates. I do not explicitly model the well documented spillovers from affiliates of multinationals to local firms in the host country.

This paper focuses on how affiliates' entry and exit alter business cycle dynamics. When a new affiliate is set up, it brings some capital from its parent and it brings its own idiosyncratic technology along with home country's aggregate technology. The general equilibrium impact of this can be summarised as follows. Compared to the no-MP model, because MP exit is pro-cyclical, macro variables are more volatile and are less correlated across countries; technology transfer dampens the main channel.

One can understand the reasons for pro-cyclical MP exit by tracing impulse responses to a positive aggregate shock in one country (Home). On the one hand, exporting (MP) becomes more attractive for Home (Foreign) firms relative to MP (exporting) as Home effective wage rate falls. These Home firms want to shut their Foreign affiliate and export from Home instead. On the other hand, technology transfer makes MP (exporting) more attractive as Home (Foreign) firms can carry their productivity advantage (disadvantage) abroad. The impact on the MP productivity thresholds is a result of these two opposite forces. In the net in the calibrated model, technology transfer channel is not powerful enough to overcome the cheaper production cost in Home. As a result, there is an increase in the number of affiliates in Home and a decrease in Foreign. There is greater volatility in the number of firms and capital stock in each country which translates to greater macroeconomic volatility. In a zero technology transfer regime, as the force of cheaper Home wage is not counteracted, there is even greater macroeconomic volatility. The international correlations are also lower in the zero technology transfer regime.

To quantify these channels, I calibrate the model to match the United States (US) business cycle at quarterly frequency. I match exactly all the firm transition rates between domestic, export, and MP statuses reported in Boehm *et al.* (2020). I set the technology transfer level to the mid-point 30% of bounds estimated in Cravino & Levchenko (2017) in my benchmark simulations. I find that the volatilities of all variables except consumption and real exchange rates are higher in the MP model compared to the re-calibrated no-MP Alessandria & Choi (2007) model. The international correlations of output, consumption, investment, and employment are all lower in the MP model. The deviations between no-MP and MP models are higher when technology transfer is shut down, indicating that technology transfer dampens the role of MP extensive margin.

I simulate two sets of models to approximate the contribution of MP extensive margin. I first simulate the benchmark MP model with all the cutoffs fixed to their steady state values (model one) and then simulate a model where only the MP cutoffs are allowed to vary (model two). The difference in outcomes between in model two and model one approximates the role of MP extensive margin. Note that there is still entry and exit even with all the cutoffs fixed in model one because of changes in firms' idiosyncratic productivities and due to aggregate shocks. The strength of the MP extensive margin in effect here is largely due to a modelling assumption– the Alessandria & Choi (2007)-based assume firm productivity to be i.i.d. across firms and over time. In reality, given that firm productivities exhibit some degree of persistence, the likelihood of a change in a firm's status purely based on firm level shocks will be lower. In model two firms' status change due to change in MP cutoffs *in addition* to the factors above. The difference between in outcomes between the two models therefore places a lower bound on the role of MP extensive margin. I find that at least 23% of the total increase in volatility between no-MP and MP models is coming from this component.

One issue with the parameterization above is that technology transfer can confound the estimate of lower bound by affecting aggregate outcomes in two ways. First, it affects the MP-export trade-off and reduces the volatility of MP cutoffs. Second, it directly affects foreign Solow residual on account of the fact that affiliate production takes place in that country. If the second factor is quantitatively important, a part of the contribution attributed to fluctuations in MP cutoffs above could be coming from the impact of higher ζ on foreign Solow residual. I address this by conducting the same set of exercises with the technology transfer parameter set to zero. As suspected, I find the MP cutoffs account for a smaller 15% of the total increase in output volatility. I take this 15% number as the main estimate of the lower bound. It is likely to be higher in the data given that firm productivities, although not i.i.d., are not permanent either.

As alluded to in a footnote above, the result that MP reduces international correlations appears counter-intuitive. For example, Zlate (2016) finds MP entry to be pro-cyclical, which increases cross-country output comovement in a model with vertical MP. In my model with horizontal MP, however, MP *exit* is pro-cyclical. For reasons explained above, this reduces international output correlation.

The main contribution of this paper is to build a model of horizontal MP that brings together different features of the data. Its motivation is similar to Contessi (2010) in looking at the effect of horizontal multinational activity on international business cycle moments. The MP model here makes improvements along four dimensions. In particular, there are: i. sunk costs of export and MP, ii. MP parent to affiliate technology transfer, iii. endogenous labor supply, and iv. physical capital. In contrast to this paper and Contessi (2010), Zlate (2016) looks at the effect of north-south type of vertically fragmented MP and its effects on international business cycles. His paper is motivated by the US-Mexican maquiladora relationship where US multinationals produce in Mexico, but the affiliate output is shipped back to the US. This type of MP increases output comovement across countries because there is a direct spillover of US demand on production in the maquiladoras. My paper focuses on the effects of the more dominant type of MP between high-income countries (i.e, of the north-north type) and its effect on international business cycles. Finally, Imura (2019) extends the Alessandria & Choi (2007) to include MP in a world with global value chains (GVCs). Although the model in her paper does include aggregate shocks, she does not conduct business cycle simulations in the exercises; she studies how tariff shocks propagate across the GVC in the presence of

MP firms. This paper is also related to the expanding literature on the effect of MP on business cycle dynamics (see Budd *et al.* (2005); Buch & Lipponer (2005); Desai & Foley (2006); Burstein *et al.* (2008); Desai *et al.* (2009); Contessi (2010, 2015); Kleinert *et al.* (2015); Zlate (2016), Cravino & Levchenko (2017), di Giovanni *et al.* (2018), and Boehm *et al.* (2019)).

The rest of the paper is organized as follows - Section 2 proposes a business cycle model with heterogeneous firms, trade, and horizontal MP; Section 3 details the calibration procedure; Section 4 provides the results and intuition, and Section 5 concludes.

2 Model

In this section, I develop a model of trade and horizontal MP with firm heterogeneity and market access frictions. There are two countries denoted by Home and Foreign. Within each country and each period, there are intermediate good producers of unit measure. Infinitely lived representative household chooses how much to consume and work and to save given an array of state contingent internationally traded bonds. Shocks in a particular period t are encapsulated in the term s_t, while the history of shocks until that period are given by the set $s^t = (s_0, s_1, ..., s_t)$.

2.1 Households

I follow the Alessandria & Choi (2007) notation closely and denote variables corresponding to Foreign with an asterisk. Households in Home maximize expected discounted lifetime utility by choosing consumption, labor supply, and bond holdings.

$$U(s_0) = \max_{C(s^t),L(s^t),B(s^t)} \sum_{t=0}^{\infty} \sum_{s^t} \beta^t \pi(s^t|s_0) \frac{\left[C(s^t)^\gamma (1 - L(s^t))^{1-\gamma}\right]^{1-\sigma}}{1 - \sigma}$$

where β is the discount factor, $\pi(s^t|s_0)$ is the conditional probability of s^t given s_0, $C(s^t)$ is Home consumption, $L(s^t)$ is Home labor supply, and γ and σ are consumption share in composite commodity and the intertemporal elasticity respectively. The intertemporal budget constraint for this Home household is given by,

$$P(s^t)C(s^t) + \sum_{s^{t+1}} Q(s^{s+1}|s^t)B(s^{t+1}) = P(s^t)W(s^t)L(s^t) + B(s^t) + \Pi(s^t)$$

where $P(s^t)$ is the price of aggregate final good, $Q(s^{t+1})$ is the price of state-contingent bond $B(s^{t+1})$ at time t, $W(s^t)$ is the real wage, and $\Pi(s^t)$ is the total profits of intermediate good producers owned by Home households. The Foreign utility function and the budget constraint are defined similarly using $e(s^t)$ as the nominal exchange rate between the two countries. The Foreign household's budget constraint is,

$$P^*(s^t)C^*(s^t) + \sum_{s^{t+1}} \frac{Q(s^{s+1}|s^t)}{e(s^t)} B^*(s^{t+1}) = P^*(s^t)W^*(s^t)L^*(s^t) + \frac{B^*(s^t)}{e(s^t)} + \Pi^*(s^t)$$

The first-order conditions for the Home household are,

$$\frac{U_L(s^t)}{U_C(s^t)} = W(s^t) \tag{1}$$

$$Q(s^{t+1}|s^t) = \beta\pi(s^{t+1}|s^t)\frac{U_C(s^{t+1})}{U_C(s^t)}\frac{P(s^t)}{P(s^{t+1})} \tag{2}$$

where $W(s^t)$ is the real wage rate in Home and $Q(s^{t+1}|s^t)$ is the stochastic discount factor.

2.2 Final good producer

The Home final good producer combines all the varieties available in Home. The production function is given by,

$$D(s^t) = \left[\delta_h \left[\int_{i=0}^{1} y_h(i,s^t)^\theta di\right]^{\frac{\rho}{\theta}} + \delta_x \left[\int_{\xi^{X*}(s^t)} y_{xf}(i,s^t)^\theta di\right]^{\frac{\rho}{\theta}} + \right.$$
$$\left. (1-\delta_h-\delta_x)\left[\int_{\xi^{M*}(s^t)} y_{mf}(i,s^t)^\theta di\right]^{\frac{\rho}{\theta}}\right]^{\frac{1}{\rho}}$$

where $D(s^t)$ the output of the final good, $y_h(i,s^t)$ is the intermediate Home variety sold domestically, $y_{xf}(i,s^t)$ is the intermediate variety exported from Foreign, and $y_{mf}(i,s^t)$ is the intermediate from Foreign multinationals produced at Home; δ_h and δ_x are home bias and import share parameters; $\xi^{X*}(s^t)$ and $\xi^{M*}(s^t)$ are respectively the set of varieties exported and served by multinationals from Foreign. Note that both $\xi^{X*}(s^t)$ and $\xi^{F*}(s^t)$ are sets of Foreign varieties sold in Home, but the production location is different for the two sets. Given the production function above, the elasticity of substitution between two varieties from the same country is $\frac{1}{1-\theta}$; the elasticity between varieties from different countries is $\frac{1}{1-\rho}$.

Let $P_h(i,s^t)$, $P_h(s^t)$, $P_{xf}(s^t)$, and $P_{mf}(s^t)$ be the Home price of a Home-produced variety i, the aggregate price these varieties, the aggregate price of Foreign exported varieties sold in Home, and the aggregate price of Foreign multinational varieties sold in Home respectively.[5] Then the demand for a given variety from the Home final good

[5] $P_h(s^t) = \left[\int_0^1 P_h(i,s^t)^{\frac{\theta}{\theta-1}} di\right]^{\frac{\theta-1}{\theta}}$, $P_{xf}(s^t) = \left[\int_{\xi^{X*}(s^t)} P_{xf}(i,s^t)^{\frac{\theta}{\theta-1}} di\right]^{\frac{\theta-1}{\theta}}$, $P_{mf}(s^t) = \left[\int_{\xi^{M*}(s^t)} P_{mf}(i,s^t)^{\frac{\theta}{\theta-1}} di\right]^{\frac{\theta-1}{\theta}}$

producer is,

$$y_h(i,s^t) = \delta_h^{\frac{1}{1-\rho}} \left[\frac{P_h(i,s^t)}{P(s^t)}\right]^{\frac{1}{\theta-1}} \left[\frac{P_h(s^t)}{P(s^t)}\right]^{\mu} D(s^t) \tag{3}$$

$$y_{xf}(i,s^t) = \delta_x^{\frac{1}{1-\rho}} \left[\frac{P_{xf}(i,s^t)}{P(s^t)}\right]^{\frac{1}{\theta-1}} \left[\frac{P_{xf}(s^t)}{P(s^t)}\right]^{\mu} D(s^t) \tag{4}$$

$$y_{mf}(i,s^t) = (1-\delta_h-\delta_x)^{\frac{1}{1-\rho}} \left[\frac{P_{mf}(i,s^t)}{P(s^t)}\right]^{\frac{1}{\theta-1}} \left[\frac{P_{mf}(s^t)}{P(s^t)}\right]^{\mu} D(s^t) \tag{5}$$

where $\mu = 1/(1-\theta) - 1/(1-\rho)$ is the difference in elasticities between domestic and foreign aggregates. Since exporting involves an iceberg cost, an exporter's price is higher compared to the case when it were to set up an affiliate. Given everything else, this implies that a firm faces higher demand if it were to conduct MP. Finally, the aggregate price in Home is a combination of domestic, imported, and foreign affiliate prices,

$$P(s^t) = \left[\delta_h^{\frac{1}{1-\rho}} P_h(s^t)^{\frac{\rho}{\rho-1}} + \delta_x^{\frac{1}{1-\rho}} P_{xf}(s^t)^{\frac{\rho}{\rho-1}} + (1-\delta_h-\delta_x)^{\frac{1}{1-\rho}} P_{mf}(s^t)^{\frac{\rho}{\rho-1}}\right]^{\frac{\rho-1}{\rho}} \tag{6}$$

2.3 Intermediate producers

2.3.1 Production function

The production function for the intermediate varieties at any given location is a Cobb-Douglas combination of appropriate capital & labor inputs, and a TFP,

$$y^a(i,s^t) = A^a(i,s^t)K^a(i,s^t)^{\alpha}L^a(i,s^t)^{1-\alpha}$$

where $y^a(i,s^t)$ is the total output in mode $a \in \{domestic(D), export(X), MP(F)\}$, for firm i with capital $K^a(i,s^t)$ and labor $L^a(i,s^t)$.

Production by MP affiliates: I assume that an MP affiliate must purchase its capital from the host market and that the purchase must be financed by the parent. This is achieved by selling a part of the parent entity's capital stock in the home final good market and purchasing the equivalent real exchange rate adjusted amount in the host final good market. For example, consider a firm that wants to split a total stock K of capital between parent and affiliate. Assuming that the firm wants to retain K^D at the parent location (K^D is endogenous in the model), it liquidates $K - K^D$ in the home final good market, earning $P \times (K - K^D)$ from this liquidation. It transfers this amount abroad at the going exchange rate e and purchases foreign final good at price $P^\star$ to be deployed as affiliate capital.[6] Therefore, by selling $K - K^D$ units of capital at home, the firm can purchase $K^F = \frac{P}{eP^\star} \times (K - K^D) = \frac{K-K^D}{q}$ units abroad. Overall, this structure

[6]So there is transfer of financial capital in the background when an MP affiliate is operating, which gets reflected in the capital account.

mimics foreign direct investment in the data where financial capital from parent firms finances purchase of locally produced goods as affiliate capital. Affiliate production then occurs with capital produced in the host country and a mix of home and host technologies (the technology aspect will be clearer below). Production then must occur subject to the following capital constraint for each firm:

$$K^D(i, s^t) + K^X(i, s^t) + q(s^t)K^F(i, s^t) \leq K(i, s^{t-1}) \tag{7}$$

The objects on the left hand side of the above equation are denoted in the current time, while the right hand side is in the last-period notation. This is simply to emphasize the fact that a firm can choose today the capital it allocates to different activities (objects in the lhs), but the capital stock itself was carried over from the previous period (the rhs).

The interaction of firm-owned capital and multinational production generates interesting features that are the focus of this paper. Equation 7 assumes that capital market must clear within each firm: if a firm then decides to be a multinational, its capital must come from its parent entity and the sum of the parent's and affiliate's capital must in equilibrium equal the total capital a firm is born with. If, on the other hand, a firm decides not to conduct MP, its problem is identical to that in firm-owned capital models without MP, such as Alessandria & Choi (2007). This way of modelling firm owned capital and MP mimics the idea that multinationals have internal capital markets, which I extend to a business cycle context.[7,8]

Affiliate technology: The MP technology transfer is a combination of Cravino & Levchenko (2017), Zlate (2016), and Contessi (2010). Cravino & Levchenko (2017) model affiliate productivity as a combination of aggregate and idiosyncratic components of parent and affiliate entities. For computational simplicity, I assume that idiosyncratic productivity is transferred fully across borders as in Zlate (2016) and Contessi (2010). The productivity term $A_{jk}(i, s^t)$, where j is the source country and k is the destination, therefore involves home and host aggregate and idiosyncratic components,

$$A_{jk}(i, s^t) = \exp\left(\zeta Z_j(s^t) + (1 - \zeta)Z_k(s^t) + \eta(i, s^t)\right) \tag{8}$$

where $Z_j(s^t)$ and $Z_k(s^t)$ are home- and destination-specific aggregate productivities re-

[7]Existing corporate finance literature points to two reasons why internal capital markets are optimal for multinational firms: i. to move investments from lagging production units to more productive ones, i.e, conduct "winner-picking", which improves the global diversification premium they can offer to their investors (Stein (1997); Sturgess (2016)), and ii. to reduce dependence on external financing when financial markets and underdeveloped and institutions are weak.

[8]Alternatively, one can think of the firm capital to be an amalgam of tangible and intangible components and technology capital. Helpman (1984), for example, models these components explicitly, where the main feature is that technology capital is firm specific but can be used in multiple locations. While I do not model technology capital and its accumulation, thinking of firm capital as an amalgamation of tangible and intangible sub-components helps in rationalising how capital moves across countries at business cycle frequencies in the model.

spectively, $\eta(i, s^t)$ is the firm's idiosyncratic productivity, and ζ is the technology share parameter such that a fraction ζ of parents' productivity spills over to the affiliates. Referring to the notation above, productivity by activities $A^D(i, s^t)$ and $A^X(i, s^t)$ are obtained by setting $j = k$, while the MP affiliate productivity $A^F(i, s^t)$ is obtained by plugging in appropriate values for j and k.

The aggregate productivities follow a vector auto-regressive process. In the matrix form,

$$Z(s^t) = MZ(s^{t-1}) + \nu(s^t), \quad \nu(s^t) \overset{i.i.d.}{\sim} N(0, \Omega)$$

Where M is the matrix of AR1 parameters, and ν is the innovation to aggregate productivity, assumed to be i.i.d. across countries and over time. The firm specific productivity, η, is also distributed i.i.d. across firms and over time $\eta \overset{i.i.d.}{\sim} N(0, \sigma_\eta^2)$.

2.3.2 Costs

Because there are no additional frictions to serve the domestic market, all intermediate firms serve the domestic market. However, firms must pay different fixed and sunk costs if they wish to serve the foreign market either by exporting or by conducting MP. I deviate from standard quantitative trade IRBC models by allowing the costs to depend on past MP and export statuses. Modelling the costs in this way allows me to calibrate exactly to the observed transition rates between domestic, export, and MP statuses (I explain calibration in detail in Section 3). Making costs dependent on past status helps to capture the fact that it is difficult to transition in one go from domestic to MP status or vice versa. This happens rarely in the data. In reality, firms use exporting as a "stepping stone" to conducting MP; and exiting MP firms continue to export (Gumpert *et al.* (2020)). Note that all fixed and sunk costs are denoted in labor units in the country being served. Next, I explain the fixed and sunk costs in more detail.

Costs to export: A continuing exporter pays only an export fixed cost F_1^X. If the firm served only the domestic market last period and wishes to export in the current period, it must pay an export sunk cost F_0^X in addition to the export fixed cost F_1^X. A last period MP firm, similar to the last period domestic firm, must also pay incur both the export sunk cost and the export fixed cost if it wants to export in the current period, but it has an advantage over the domestic firm owing to having already served the foreign market. I assume that this advantage translates to costs in that the export fixed and sunk costs are lower by a factor ϕ_{fx}. So a firm that conducted MP in the past and exports today pays $\frac{F_0^X + F_1^X}{\phi_{fx}}$ as export sunk and fixed costs.[9] In effect, the parameter ϕ_{fx} drives a cost

[9] Note that an MP firm gets this "discount" only in the first period. In the subsequent periods, this firm must pay the full export fixed cost F_1^X if it wants to continue exporting. As a result, the model delivers one period ahead transition rates in accordance with the data, but transition rates in the later periods are not necessarily in line with the data. A richer cost structure will incorporate costs to vary by age in a particular mode in addition to past status in that mode (see Gumpert *et al.* (2020)). Adding

wedge between last period MP and non-MP firms that export today.

Costs to conduct MP: The fixed and sunk costs of conducting MP also vary depending on past status. A last period MP firm pays an MP fixed cost F_1^F to continue conducting MP. A last period domestic firm pays an MP sunk cost F_0^F *in addition* to the MP fixed cost to set up a new affiliate, so its cost is $F_1^F + F_0^F$. A last period exporter, on account of having served the foreign market, has an advantage in serving that market by MP. In particular, its MP fixed and sunk costs are lower by a factor of ϕ_{xf}, so they pay $\frac{F_0^F + F_1^F}{\phi_{xf}}$. In effect, the parameter ϕ_{xf} drives a cost wedge between last period exporter and non-exporter firms that conduct MP today.

2.3.3 Firm value

Total value of a firm i originating in Home is the sum of its discounted expected profits across all activities. For a given period, firms' state variables are: 1. Idiosyncratic productivity (η), 2. Capital stock of the firm, 3. MP choice last period, and 4. The aggregate macroeconomic conditions. Firms choose the markets to serve, the mode of serving the foreign market conditional on the foreign market being served, optimal allocation of capital across production units, quantity sold in each market, and the level of investment. In the recursive form, firms' problem can be written as,

$$\begin{aligned} V(\eta, K((b, s^{t-1})), b, s^t) = \max \Pi^D(i, s^t) + m^X(i, s^t)\Pi^X(i, b, s^t) + m^F(i, s^t)\Pi^F(i, b, s^t) \\ - P(s^t)x(i, s^t) + \sum_{s^{t+1}} \sum_{\eta'} Q(s^{t+1}|s^t) Pr(\eta') V(\eta', K', m^{F'}, s^{t+1}) \end{aligned} \tag{9}$$

where η is firm's idiosyncratic productivity, $b \in \{D, X, F\}$ is last period status, $m^X(i, s^t)$ and $m^F(i, s^t)$ are indicators that equal 1 if a firm i exports or conducts MP in the current period, $x(i, s^t)$ denotes investment. For every firm, the capital accumulation equation is satisfied, and the capital equilibrium condition holds:

$$(1 - \delta_k)K(i, s^{t-1}) + x(i, s^t) = K(i, s^t) \tag{10}$$

$$K^D(i, s^t) + K^X(i, s^t) + q(s^t)K^F(i, s^t) = K(i, s^{t-1}) \tag{11}$$

The domestic, export, and MP profits, in terms of the Home currency are,

$$\Pi^D(i, s^t) = P_h(i, s^t)y^D(i, s^t) - P(s^t)W(s^t)L^D(i, s^t) \tag{12}$$

such a cost structure in the presence of aggregate shocks further complicates the model solution, and is out of the scope of this paper.

$$\Pi_b^X(i,b,s^t) = e(s^t)P_h^{X\star}(i,s^t)y^X(i,s^t) - P(s^t)W(s^t)L^X(i,s^t) - \\ e(s^t)P^\star(s^t)W^\star(s^t)\frac{F_1^X + I_{b\neq X}F_0^X}{I_{b\neq F} + I_{b=F}\phi_{fx}} \quad (13)$$

$$\Pi_b^F(i,b,s^t) = e(s^t)\Big[P_h^{F\star}(i,s^t)y^F(i,s^t) - \\ P^*(s^t)W^*(s^t)\left\{L^F(i,s^t) + \frac{F_1^F + I_{b\neq F}F_0^F}{I_{b\neq X} + I_{b=F}\phi_{xf}}\right\}\Big] \quad (14)$$

where $b \in \{D, X, F\}$ denotes last period status and $I_{b=a}$ is an indicator that takes value one if b is equal to a.

2.3.4 Productivity cutoffs and choices

Every firm produces in the domestic market, but the set of exporters and affiliates is endogenous. I denote $\eta_b^X(s^t)$ and $\eta_b^F(s^t)$ as the export and MP productivity thresholds respectively among firms with last-period status $b \in \{D, X, F\}$. I denote by $V^D(i,s^t)$, $V^X(i,s^t)$, and $V^F(i,s^t)$ the values of a given firm i given its state variables by choosing to serve only the domestic market, being exporter, and conducting MP respectively. Formally, I define the marginal exporter, given MP status last-period, as the firm for which value from serving only the domestic market is equal to the value from exporting:

$$V^D(\eta_b^X, K(b,s^{t-1}), m^F, s^t) = V^X(\eta_b^X, K(b,s^{t-1}), m^F, s^t) \quad (15)$$

And for the marginal MP firm, given status last period, the value from exporting is equal to the value from conducting MP:

$$V^X(\eta_b^F, K(b,s^{t-1}), m^F, s^t) = V^F(\eta_b^F, K(b,s^{t-1}), m^F, s^t) \quad (16)$$

2.3.5 Aggregation

Given the cutoffs, the laws of motion for number of exporters and MP firms originating in each country, $N^X(s^t)$ and $N^F(s^t)$, can be written as,

$$N^F(s^t) = \sum_{b\in\{D,X,F\}} [1 - \Phi(\eta_b^F(s^t))]N^b(s^{t-1}) \quad (17)$$

$$N^X(s^t) = \sum_{b\in\{D,X,F\}} \left[\Phi(\eta_b^F(s^t)) - \Phi(\eta_b^X(s^t))\right] N^b(s^{t-1})$$

where $\Phi(\cdot)$ is the cumulative density function of η. Because the firms' idiosyncratic distribution is assumed to be i.i.d., firms' expectation of the future profits are entirely determined by their export and MP statuses in the current period and by their expectations of the aggregate shock next period. Consequently, every firm that has status $b \in \{D, X, F\}$ today expects the same profit tomorrow (expectations about the aggregate state does not depend on the state), and decides on the same level of capital stock for tomorrow (denoted $K(b, s^t)$). The aggregate end of the period capital stock and investment can then be written as,

$$K(s^t) = \sum_{b \in \{D,X,F\}} N^b(s^t) K(b, s^t)$$

$$X(s^t) = K(s^t) - (1 - \delta_k) K(s^{t-1})$$

The aggregates for labor demand, price indexes, and profits are derived in Appendix A.

2.4 Equilibrium

The equilibrium in the economy is a set of quantities of labor $\{L(s^t), L^\star(s^t)\}$; consumption $\{C(s^t), C^\star(s^t)\}$; bond holdings $\{B(s^t), B^\star(s^t)\}$; investment $\{X(s^t), X^\star(s^t)\}$; output $\{D(s^t), D^\star(s^t)\}$, capital choices $\{K_0(s^t), K_0^\star(s^t), K_1(s^t), K_1^\star(s^t)\}$, number of exporters and affiliates $\{N^X(s^t), N^{X\star}(s^t), N^F(s^t), N^{F\star}(s^t)\}$, aggregate profits $\{\Pi(s^t), \Pi^\star(s^t)\}$, and prices $\{q(s^t), P_h(s^t), P_f(s^t), P_h^\star(s^t), P_f^\star(s^t), P(s^t), P^\star(s^t), W(s^t), W^\star(s^t)\}$ such that in each country and in each period,

1. Households bond holdings first order condition (FOC) and labor supply FOC are satisfied
2. Households' budget constraints are satisfied
3. Firms' investment FOC holds
4. International bond market clears
5. Labor market, intermediate goods markets, and the final good market clear in each country
6. Marginal exporters and MP firms' conditions are satisfied
7. Firms' capital allocation equation 11 is satisfied for each firm

Mathematical derivations for the model equations are in Appendix A.

3 Calibration

The model is calibrated to mimic key features of MP in the United States at quarterly frequency. I focus on MP firms' size and their transition rates. A list of the twenty one model parameters and their values under the benchmark calibration are given in Table 1.

Parameter	Description	Value	
	Parameters		Source
β	Time preference	0.99	Annual return = 4%
γ	Share of consumption	0.303	Alessandria & Choi (2007)
σ	Inter-temporal elasticity	2	$\in [1, 5]$
α	Capital share	0.36	$\in [0.35, 0.4]$
θ	Domestic elasticity	0.9	Alessandria & Choi (2007)
ρ	International elasticity	1/3	Alessandria & Choi (2007)
δ_k	Depreciation rate	0.025	$\in [0.02, 0.04]$
M_{11}, M_{22}	Own persistence	0.95	Alessandria & Choi (2007)
M_{12}, M_{21}	Cross persistence	0	Alessandria & Choi (2007)
Ω_{12}, Ω_{21}	SE, aggregate shock	0.007	Alessandria & Choi (2007)
ζ	MP technology transfer	30%	Assumed
	Calibrated		Targets
δ_h	Home preference	0.5897	MP empl. share = 26%
δ_x	Import preference	0.2142	Import share of GDP = 15%
F_0^X	Export sunk cost	0.1272	D to X trans. rate = 1.5%
F_1^X	Export fixed cost	0.0165	X to D trans. rate = 3.45%
F_0^F	MP sunk cost	1.3139	MP to D trans. rate = 0.09%
F_1^F	MP fixed cost	0.0386	MP to X trans. rate = 0.5%
ϕ_{xf}	Exporter MP advantage	2.92	D to MP trans. rate = 0.01%
ϕ_{fx}	MP firm export advantage	8.98	X to MP trans. rate = 0.22%
σ_η	SE, idiosyncratic shock	0.6736	Exporter premium = 12-18%

This table lists model parameters, their value in the benchmark model, and how they are calibrated. Data firm transition rates between domestic, export, and MP statuses are from from Boehm *et al.* (2020). The MP employment share is from Antras & Yeaple (2014). Exporter productivity premium is from Bernard & Jensen (1999).

Table 1: Benchmark Parameter Values

I set fourteen parameters based on their values in existing literature. Among the demand side parameters, I set β equal to $\frac{1}{1+r/4}$ so that the annual real return $r = 4\%$. Consumption share in composite commodity, γ equals 0.303 and intertemporal elasticity equals two as in Alessandria & Choi (2007). Capital share and the depreciation rate for capital is standard across growth and business cycle literature: $\alpha = 0.36$ and $\delta_k = 0.025$. Domestic and international elasticity parameters, θ and ρ, are set to 0.9 and 0.33; own and cross aggregate shock persistence parameters are 0.95 and zero respectively; and the standard errors of the innovation to aggregate shocks are set to 0.007, all following Alessandria & Choi (2007). For the technology transfer parameter, ζ, the closest estimate is from Cravino & Levchenko (2017), but their model does not map one-to-one with the model in this paper. In the baseline, I assume $\zeta = 30\%$m, which is the midpoint of 20-40% estimated in Cravino & Levchenko (2017), and compare the results with technology transfer shut down ($\zeta = 0$).

The nine remaining parameters are calibrated to jointly match nine moments in the data. In particular, I target: i. MP employment share equal to 26%, import to GDP ratio equal to 15%, exporter productivity premium relative to domestic firms equal to 15%, and six transition rates between domestic, exporting, and MP statuses. MP employment share is from Antras & Yeaple (2014), imports to GDP ratio is from post-war US data until 2016, and the exporter productivity premium is from Bernard & Jensen (1999). The six firm transition rates are from Boehm *et al.* (2020).[10] Table 2 shows that the model mimics these key moments in the data.

4 Results

In this section, I discuss the results from the quantitative exercises. I begin by discussing how macro moments change when MP is allowed and then discuss the mechanisms. Table 3 lists the macro moments of interest under different model scenarios and lists the data values of these moments. The numbers reported in Table 3 are averages across 1000 simulations where each variable is HP filtered with a smoothing parameter of 1600. Figures 1 and 2 are useful for understanding the mechanisms.

Moment	**Target**	**Model**
MP employment share	26%	26%
Import share of GDP	15%	15%
D to X transition rate	1.5%	1.5%
X to D transition rate	3.45%	3.45%
MP to D transition rate	0.09%	0.09%
MP to X transition rate	0.5%	0.5%
D to MP transition rate	0.01%	0.01%
X to MP transition rate	0.22%	0.22%
Exporter productivity premium	12%-18%	15%

Table 2: Calibration - Model and the Data

Aggregate variables. Columns 2 and 3 of Table 3 list the values of aggregate international business cycle moments under the benchmark MP calibration and the no-MP model. For the no-MP model, I re-calibrate Alessandria & Choi (2007) to match the exporter transition rates that are used in the MP model. Data values for the US (taken from Kehoe & Perri (2002)) are in column 1. I focus on business cycle moments related to output, consumption, investment, employment, net exports, and real exchange rate. For these variables, I report their standard deviations, correlations with output, persistence, and international correlations where appropriate.

Volatility. The standard deviations of all the variables except consumption and real exchange rate are higher in the benchmark MP calibration than in the no-MP model.

[10] I describe my calculations in Appendix B. Boehm *et al.* (2020) report average annual transition probabilities for US firms and foreign multinationals operating in the US calculated over 1993-2011. I account for exit while calculating the transition probabilities.

The volatility of output (I use output volatility as a reference to understand impact of MP) is higher in the MP model by thirteen percentage points. I simulate two sets of models to approximate the contribution of MP extensive margin. I first simulate my MP model with all the cutoffs fixed to their steady state values (model one for quick reference); a fixed cutoffs no-MP model shows little to no change in outcomes compared to the full no-MP model (columns six and seven). I then simulate a model where only the MP cutoffs are allowed to vary (model two). The difference in outcomes between model two and model one approximates the role of MP extensive margin. Note that there is still entry and exit even with all the cutoffs fixed because of changes in firms' idiosyncratic productivities and due to aggregate shocks. The MP extensive margin in effect here is largely due to a modelling assumption– the Alessandria & Choi (2007)-based assume firm productivity to be i.i.d. across firms and over time. In reality, given that firm productivities likely exhibit some degree of persistence, the likelihood of a change in a firm's status purely based on firm level shocks will be lower. In model two firms' status change due to change in MP cutoffs *in addition* to the factors above. The difference between in outcomes between the two models therefore places a lower bound on the role of MP extensive margin. I find that at least 23% of the total increase in volatility between no-MP and MP models is coming from this component. Model one accounts for ten of the thirteen points increase in output volatility (column seven) between no-MP and benchmark MP models. This shows the strength of MP extensive margin driven by the i.i.d. productivity assumption. Between the models in column seven and eight output volatility is higher by three percentage points, meaning that 23% of the total increase in volatility between no-MP and MP models is coming from model two.

Technology transfer- One issue with the simulations above is that technology transfer via multinationals affects aggregate outcomes in two ways. First, it affects the MP-export trade-off and reduces the volatility of MP cutoffs. Second, it directly affects foreign productivity on account of the fact that affiliate production takes place in that country. If the second channel is quantitatively important, a part of the contribution attributed to fluctuations in MP cutoffs above could be coming from the impact of higher ζ on foreign productivity. In columns nine and ten, I account for this by simulating models one and two above with $\zeta = 0$. Out of the total increase in output volatility of twenty percentage points between no-MP and MP model with $\zeta = 0$ (columns three and five), three percentage point increase (or 15%) is due to endogenous MP cutoffs. As suspected, fluctuations in MP cutoffs contributes less to total increase in volatility when $\zeta = 0$ even though the cutoffs fluctuate more. I take this as the main estimate of the impact of MP extensive margin. It is likely to be higher in the data given that firm productivities, although not i.i.d., are not permanent either.

Domestic correlations. Among the domestic correlations, the MP model generates identical results except for net exports and real exchange rate. There is a larger negative

	Data	MP	No MP		No Tech. Transfer	Fixed Cutoffs				
			σ_η = 0.5	σ_η = 0.67	(ζ = 0)	(No MP)	(MP)	(MP*)	(MP) ($\zeta = 0$)	(MP*) ($\zeta = 0$)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Standard deviation (in percent)										
Y	1.72	1.42	1.29	1.30	1.49	1.29	1.38	1.41	1.45	1.48
nx	0.46	0.24	0.17	0.17	0.27	0.15	0.19	0.21	0.21	0.23
Standard deviation (relative to output)										
C	0.79	0.34	0.35	0.35	0.33	0.35	0.34	0.33	0.34	0.33
X	3.25	3.44	3.36	3.37	3.47	3.30	3.44	3.39	3.48	3.41
L	0.85	0.48	0.46	0.46	0.49	0.46	0.46	0.46	0.46	0.47
q	2.81	0.31	0.32	0.32	0.34	0.33	0.32	0.31	0.36	0.34
Domestic Correlations with Output										
C	0.83	0.95	0.95	0.95	0.95	0.95	0.95	0.94	0.95	0.95
X	0.93	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
L	0.85	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
nx	-0.38	-0.63	-0.51	-0.51	-0.67	-0.50	-0.59	-0.62	-0.63	-0.66
q	0.16	0.65	0.57	0.57	0.69	0.57	0.63	0.65	0.68	0.69
q, nx	0.07	-0.67	-0.52	-0.51	-0.70	-0.50	-0.64	-0.65	-0.66	-0.68
Persistence										
Y	0.87	0.70	0.69	0.69	0.71	0.69	0.69	0.70	0.7	0.7
C	0.91	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
X	0.84	0.71	0.68	0.68	0.71	0.68	0.70	0.70	0.71	0.7
L	0.95	0.70	0.68	0.68	0.71	0.68	0.68	0.69	0.69	0.69
nx	0.9	0.76	0.72	0.72	0.76	0.71	0.71	0.72	0.72	0.72
q	0.81	0.78	0.79	0.79	0.77	0.78	0.77	0.78	0.76	0.77
International Correlations										
Y	0.51	0.01	0.19	0.20	-0.10	0.2	0.06	0.01	-0.05	-0.09
C	0.32	0.44	0.54	0.54	0.32	0.54	0.47	0.45	0.34	0.34
X	0.29	-0.21	-0.01	-0.01	-0.30	0.03	-0.16	-0.18	-0.27	-0.27
L	0.43	-0.09	0.20	0.20	-0.20	0.20	0.02	-0.05	-0.09	-0.15

*: column seven contains results from a simulation where I fix all export cutoffs to their steady state values, but the MP cutoffs are endogenous. This isolates the effect of the extensive margin of MP compared to a no-MP Alessandria & Choi (2007) model with fixed cutoffs (column five).

Table 3: Comparison of Business Cycle Statistics

shock to net exports in response to a positive aggregate shock at home, which leads to a larger negative correlation between output and net exports. The real exchange rate depreciates more, so its correlation with output is more positive. Like in the case of volatility, a big part of these changes can be explained by just adding MP into the trade model (column six and seven).

Persistence. The MP model generates small increases in persistence of output, investment, and employment and a slightly higher increase in the persistence of net exports. The persistence of output, investment, and employment are all higher by one percentage point. Persistence of net exports increases the most (four percentage points). Persistence of consumption is unchanged while that of real exchange rate increases by two percentage points not in accordance with the data.

International correlations. Finally, I report the international correlations of output, consumption, investment, and employment. Correlations of all of these variables are lower in the MP model. In the case of consumption, however, the fall in correlation makes the model more in line with the data. However, the fall in correlations of output, investment, and employment makes the model less aligned with the data.

Overall, these results contribute to the literature that show that firm extensive margins have significant impact on business cycle fluctuations, and it shows why MP extensive margin is *special* – when a firm enters or exits MP status, there is actual relocation of production and capital which leads to a bigger jump in GDP. Liao & Santacreu (2015) make the argument for a significant role for extensive margin in a model with only exporters. The fact that exporter extensive margin does not play a big role in my simulations is rather a model feature- Alessandria & Choi (2007) show that low markups and love for variety make the exporter dynamics matter very little for the aggregates. My MP model model is built on Alessandria & Choi (2007) and is calibrated similarly, which explains why exporter dynamics plays a small role, if any.[11] On the other hand, MP extensive margin plays a significant role *in spite* of the low markups and love for variety. In a broader sense, my results tell us that MP extensive margin can play a role *in addition* to the exporter extensive margin as in Liao & Santacreu (2015).

Sensitivity Test

Firm productivity distribution. It is possible that increase in volatility is driven by the fact that the firm productivity (σ_η) is more dispersed in the MP model compared to the no-MP model. The standard deviation of productivity in the MP model is 0.67 where as in the no-MP Alessandria & Choi (2007) model it is 0.5. This is purely an outcome of the calibration exercise. With higher σ_η, firm idiosyncratic shocks could impact outcomes more. To test this, I simulate the no-MP model with $\sigma_\eta = 0.67$ (column four). All the macro variables look nearly identical to their counterparts in column three, meaning that the differences between the no-MP and the MP models are not due to higher σ_η in the MP model.

4.1 Channels

The previous section showed how entry and exit of firms, in particular that of MP firms, impacts business cycle moments. In what follows, I explain this channel in the context of all the channels that affect aggregate dynamics.

There are three channels in the benchmark model that affect IRBC dynamics. Consider responses by variables to a positive aggregate productivity shock in Home. First,

[11] Endogenizing exporter cutoff increases output volatility by one percentage point in the MP model. In column eight, I allow for MP cutoffs to change but the exporter cutoffs are fixed. The full model with where all cutoffs vary is in column two. The difference in output volatility between the two columns is attributable to varying exporter cutoffs.

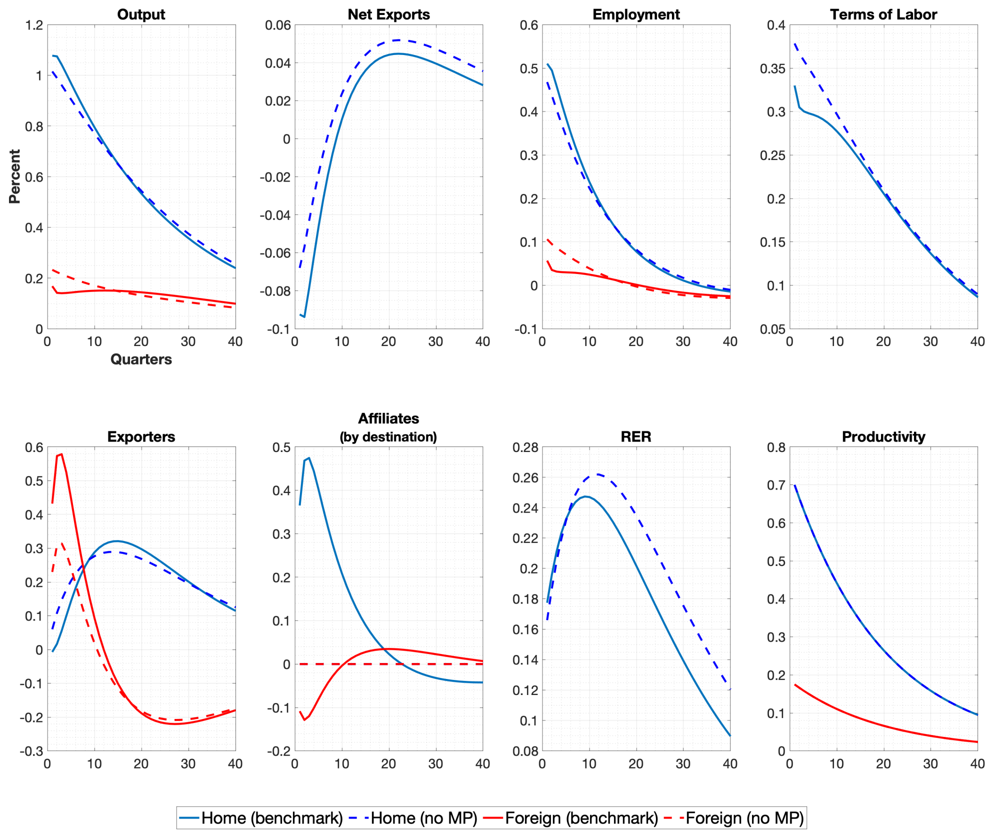

Figure 1: Impulse Responses for the MP and No-MP Models

there is an inflow of MP firms into the country that experiences an aggregate technology improvement (Home)– there is an increase in Foreign firms' affiliates and a drop in Home firms' affiliates abroad. In other words, MP exit is pro-cyclical. As these firms bring in capital, there is an inflow of physical capital to Home. This is the novel "resource transfer" channel via multinationals. Home output expands both because there is greater economic activity with more resources (i.e., capital) with MP firms' technology, and because of the greater number of varieties being produced. Under the benchmark calibration, there is a small decrease in the mass of Home owned affiliates in Foreign, and a bigger 0.4% increase in the mass of Foreign owned affiliates in Home. The no-MP economy, by definition, does not generate any variation in the number of affiliates, so the dashed impulse response lines in sub-figure six Figure 1 is flat at zero.

The increase (decrease) in Foreign (Home) affiliates in Home (Foreign) is driven by both static and dynamic factors. The Foreign firms pay higher fixed cost compared to export fixed cost (and new affiliates pay sunk cost in addition to that), but they are compensated for by higher operational profits due to more favorable terms of labor in Home. To show this more clearly, I plot Home terms of labor defined as the effective wage rate in Foreign relative to Home. An increase (interpreted as a depreciation) implies an increase in the relative cost of producing in Foreign. It captures the wage differential as experienced by a Foreign firm contemplating between exporting from Foreign versus conducting MP:

$$ToL = \frac{q(s^t)W^\star(s^t)}{Z^\star(s^t)} \times \frac{Z(s^t)}{W(s^t)}$$

Sub-figure four of Figure 1 shows Home terms of labor to improve by nearly 0.33% upon impact. This discourages firms from producing abroad to sell in Home. As a result, fewer Home multinationals want to continue operating affiliates abroad and more Foreign firms want to set up affiliates in Home. In addition to improving the static profits, new Foreign multinationals see a benefit in incurring the MP sunk cost when it is cheaper to do so. The associated fall in MP entry and exit cutoffs in Foreign increase the chances of staying on as a multinational in the future, so the value of conducting MP increases. Given everything else, this leads to greater increase in Home output and a smaller increase in Foreign output, resulting in lower output comovement. In addition, because firms relocate, the volatilities of macro variables are higher.

MP extensive margin versus technology transfer: The impact of the two forces can be summarized as follows. Compared to the no-MP model, the MP extensive margin makes macro variables less correlated across countries and more volatile; technology transfer dampens this channel. Referring to the Home aggregate shock above, on the one hand, exporting (MP) is more attractive for Home (Foreign) firms relative to MP (exporting) as Home effective wage rate falls. On the other hand, technology transfer makes MP (exporting) more attractive as Home (Foreign) firms can carry their productivity advantage (disadvantage) abroad. The impact on the number of MP firms is a result of these two opposite forces. In the net in the calibrated model, technology transfer channel is not powerful enough to overcome the cheaper production cost in Home. In a business cycle sense, there is greater volatility in the number of firms and capital stock in each country which translates to greater macroeconomic volatility.

Second, like in the trade models, entry and exit of exporters contributes to comovement (solid lines in sub-figure five, Figure 1) but this channel is weaker in the MP model. The number of Home exporters increases because cheaper production costs and higher productivity increase their profits abroad. Consequently, high productivity domestic firms and low productivity MP firms now turn to exporting. Foreign firms on the other hand benefit from an increased demand from Home which sufficiently counteracts their productivity deficit. The increase in mass of Home exporters means that the foreign final good producer has more varieties to choose from. As shown in Liao & Santacreu (2015), this "variety-effect" is quantitatively important and contributes to an increase in Foreign output. The no-MP model generates qualitatively the same dynamics of the mass of exporting firms as in the benchmark case– both Home and Foreign see an increase in the number of exporters.

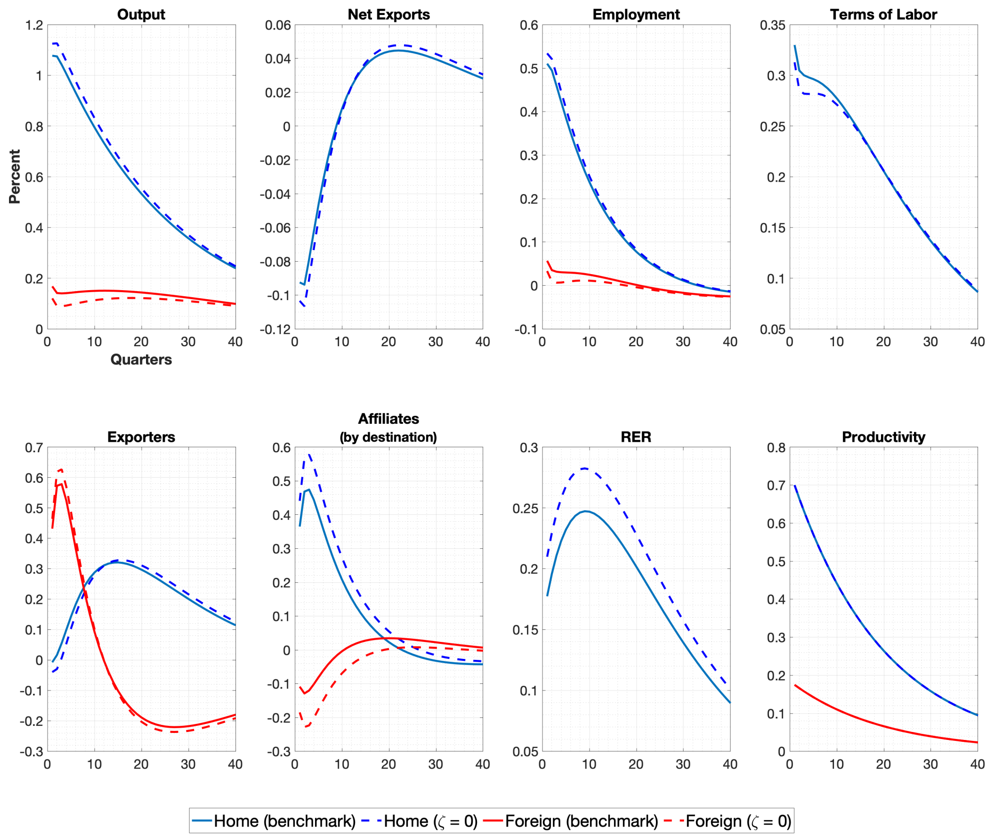

Figure 2: Impulse responses with Different Technology Transfer Levels

Third, international risk sharing with complete markets results in the standard resource transfer towards Home. This channel, where relatively higher investment in Home leads to divergent paths for capital, is present in early quantitative trade models with a single producer (for example, Backus *et al.* (1994), as noted in Kose & Yi (2006)). The differences in investments is driven by a persistent Home productivity shock that promises higher returns into the future. This leads to Home accumulating a bigger stock of capital than Foreign, so the two countries' output comove negatively as a result.

The resource transfer channel via multinationals, a new channel in this paper, therefore differs from those in trade models where households own capital stock (Kose & Yi (2006)). The mechanism in trade-only models is gradual and is a result of household investment decisions: Home households borrow internationally to invest more while the Foreign households lower their investments, and the two countries' stock of capital diverge over time. This too reduces output comovement, as shown by Kose & Yi (2006). In the MP model in this paper, the traditional resource transfer channel is further strengthened by multinationals as transfer of capital stock towards Home is instantaneous. The immediate relocation of capital adds to macroeconomic volatility.

5 Conclusions

Even though multinational activity (primarily of horizontal type) has seen a dramatic rise since 1990, much more so than trade during the same period, international business cycle research has largely ignored multinational production as a spillover channel. I develop a quantitative model of MP and trade with firm heterogeneity, technology transfer via MP firms, physical capital, market access frictions including sunk and fixed costs of export and MP. I use this model to test how MP affects business cycle dynamics.

The main finding from model simulations is that MP firms' entry and exit has a quantitatively important impact on business cycle variables. In particular, MP increases macroeconomic volatility and reduces international correlations of output, consumption, investment, and employment. These results are driven by pro-cyclicality of MP exit- the country that experiences favorable aggregate shock sees inflow of affiliates. This adjustment is instant and causes bigger deviations in macroeconomic variables between countries compared to a no-MP model. Technology transfer channel dampens the MP extensive margin by discouraging MP exit and by impacting foreign productivity directly. In the net, however, the technology transfer channel is not powerful enough to overcome the resource transfer channel.

In trying to understand the role of firm extensive margin, this paper has abstracted from a number of relevant features of the data. For instance, I do not take into account spillovers arising in a multi-country setting or the more complex options available to firms that are substitutes to MP such as offshoring. I leave these issues for future research.

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A Technical Appendix

Firm prices. Given the monopolistic competitive market structure, an intermediate producer's price in different markets, conditional on the mode of serving those markets, is a constant markup ($= 1/\theta$) above the marginal cost of production. Because the firm can only change labor input to change the output, cost of producing one additional unit is equal to wage times inverse of marginal product of labor:

$$\frac{P_h(i,s^t)}{P(s^t)} = \frac{W(s^t)}{\theta F_l^D(i,s^t)} \tag{18}$$

$$\frac{P_{xf}^\star(i,s^t)}{P^\star(s^t)} = \frac{P_h(i,s^t)}{P(s^t)}\frac{\tau}{q(s^t)} \tag{19}$$

$$\frac{P_{mf}^\star(i,s^t)}{P^\star(s^t)} = \frac{W^\star(s^t)}{\theta F_l^M(i,s^t)} \tag{20}$$

$F_l^D(i,s^t)$, and $F_l^M(i,s^t)$ are marginal labor productivities in the domestic and the foreign plant, $P_{xf}^\star(i,s^t)$ and $P_{mf}^\star(i,s^t)$ are the prices charged by the Home firm i if it exported or if it conducted MP respectively.[12]

Firm labor demand. Because capital is fixed, firms can only adjust the labor in their production function to meet the demand for their variety. For a current non-multinational ($m^{M'}(i,s^t) = 0$), the total labor demand can then be derived by equating the firm output to the demand it faces: $A_{hh}(i,s^t)K(i,s^{t-1})^\alpha L(i,s^t)^{1-\alpha} = y_h(i,s^t) + m^X(i,s^t)\tau y_{xf}^\star(i,s^t)$. Plugging in demands for variety from 3 and 5 and prices 18 and 19 in the rhs, and collecting labor terms together, I get,

$$L_{m^F=0}(i,s^t) = H_{hx}(s^t) \times A(i,s^t)^{\frac{1-\nu}{\alpha}} K(i,s^{t-1})^{1-\nu} \tag{21}$$

where $\nu = (1-\theta)/[1-\theta(1-\alpha)]$ is a constant, and

$$H_{hx}(s^t) = \left[H_h(s^t)^{1/\nu} + m^X(i,s^t)H_x^\star(s^t)^{1/\nu}\right]^\nu \tag{22}$$

$$H_h(s^t) = \left[\delta^{\frac{1}{1-\rho}}\left(\frac{P_h(s^t)}{P(s^t)}\right)^\mu D(s^t)\right]^\nu \left(\frac{W(s^t)}{\theta(1-\alpha)}\right)^{\frac{\nu}{\theta-1}} \tag{23}$$

$$H_x^\star(s^t) = \left[\delta_x^{\frac{1}{1-\rho}}\left(\frac{\tau^\theta}{q(s^t)}\right)^{\frac{1}{\theta-1}}\left(\frac{P_{xf}^\star(s^t)}{P^\star(s^t)}\right)^\mu D^\star(s^t)\right]^\nu \left(\frac{W(s^t)}{\theta(1-\alpha)}\right)^{\frac{\nu}{\theta-1}} \tag{24}$$

$$H_m^\star(s^t) = \left[(1-\delta_h-\delta_x)^{\frac{1}{1-\rho}}\left(\frac{P_{mf}^\star(s^t)}{P^\star(s^t)}\right)^\mu D^\star(s^t)\right]^\nu \left(\frac{W^\star(s^t)}{\theta(1-\alpha)}\right)^{\frac{\nu}{\theta-1}} \tag{25}$$

are macroeconomic aggregates for Home-owned firms in Home and Foreign respectively. These aggregate do not carry any economic interpretation- they are collections of prices, real wage and the final good output, and come out of the demand functions in 3 and 5 and after collecting the labor terms together.

Allocation of capital between multinational parent and affiliate. Next consider a firm that has chosen to be a multinational ($m^F(i,s^t) = 1$). Because it operates in both the countries, I have to specify separately the labor demands in each country. Moreover, the firm can reallocate its capital across the two production locations. Capital allocation affects labor productivities, which impacts the prices charged by the firm and the demand it faces in both the countries. I will take a step back and start by writing labor demands given the capital allocation decision, and then use appropriate first order conditions to find optimal allocations of capital later (see eq. 28 and 30). I will denote by $L^D(i,s^t)$ and $L^{D\star}(i,s^t)$ the labor demands in Home and Foreign for a Home-owned firm. Using the demand for a variety from 3 (given firm's price), and equating it to the production function for MP parents and

[12] It is necessary to distinguish between labor productivities in parent and affiliate entities when conducting MP is a possibility. An MP firm can vary its price by varying these productivities in the two production locations. For example, an MP firm can move capital between the production locations, and thus affect prices in both markets.

collecting the labor terms together, I get,

$$L^D_{m^F=1}(i, A^D, K^D) = H_h(s^t) A_{hh}(i, s^t)^{\frac{1-\nu}{\alpha}} K^D(i, s^t)^{1-\nu} \tag{26}$$

is the labor demand in the domestic market given the capital $K^D(i, s^t)$ allocated to that market. Similarly, the conditional labor demand for the affiliate can be derived by equating 5 (using MP price 20) to MP affiliate's production function **??**, and collecting the labor terms together,

$$L^{D\star}_{m^F=1}(i, A_{hf}, K^D) = H^\star_m(s^t) A_{hf}(i, s^t)^{\frac{1-\nu}{\alpha}} \left(\frac{K(i, s^{t-1}) - K^D(i, s^t)}{q(s^t)} \right)^{1-\nu} \tag{27}$$

where $A^D(i, s^t)$ and $A^{D\star}(i, s^t)$ are productivities of the MP parent and affiliate defined in 8.

Next, I solve for the capital allocations of an MP firm across parent and affiliate entities. Allocation of capital affects pricing (by changing the marginal product of labor), and hence the demand that the firm faces in each market. Because there are no frictions while transferring capital across countries, it is allocated to maximize joint profits period by period (i.e., it is a static decision). Condensing the fixed and sunk costs into a single term, the total static profit of a multinational can be written as,

$$\Pi(total) = \Pi(Parent) + \Pi(Affiliate)$$

$$= P_h(i, s^t) y^D(i, s^t) - P(s^t) W(s^t) L^D(i, s^t) \\ + e(s^t) \left[P^{F\star}_h(i, s^t) y^F(i, s^t) - P^\star(s^t) W^\star(s^t) L^{D\star}(i, s^t) \right] - FC$$

Plug the production functions in 2.3.1, and the capital quantity constraint 7 to get,

$$\Pi(total) = P_h(i, s^t) A^D(i, s^t) K^D(i, s^t)^\alpha L^D(i, s^t)^{1-\alpha} - P(s^t) W(s^t) L^D(i, s^t) + \\ e(s^t) \Big[P^{F\star}_h(i, s^t) A^{D\star}(i, s^t) \left(\bar{K}(i, s^t) - K^D(i, s^t) \right)^\alpha L^{D\star}(i, s^t)^{1-\alpha} - P^\star(s^t) W^\star(s^t) L^{D\star}(i, s^t) \Big] - FC$$

$$= \frac{1 - \theta(1-\alpha)}{\theta(1-\alpha)} P(s^t) W(s^t) \left[L^D(i, s^t) + \frac{q(s^t) W^\star(s^t)}{W(s^t)} L^{D\star}(i, s^t) \right] - FC$$

Plugging in the labor demand functions in 26 and 27, and differentiating the above function with respect to domestic capital utilization $K^D(i, s^t)$, it can be written as a function of the capital stock that the firm is born with and macroeconomic aggregates in both the markets,

$$K^D_{m^F=1}(i, s^t) = \frac{K(i, s^{t-1})}{1 + G(s^t)} \tag{28}$$

where

$$G(s^t) = \left(\frac{q(s^t) W^\star(s^t)}{W(s^t)} \frac{H^\star_m(s^t)}{H_h(s^t)} \right)^{1/\nu} \frac{1}{q(s^t)^{(1-\nu)/\nu}} \exp\left(\frac{(1-\nu)(1-\zeta)(Z^\star(s^t) - Z(s^t))}{\nu\alpha} \right) \tag{29}$$

is another macroeconomic aggregate which corresponds to foreign country's relative cost and demand advantage over the home country for MP firms.

The capital stock allocated to the MP firm's affiliate is given by $K^{D\star}_{m^F=1}(i, s^t) = K(i, s^{t-1}) - K^D_{m^F=1}(i, s^t)$, which equals,

$$K^{D\star}_{m^F=1}(i, s^t) = \frac{G(s^t)}{1 + G(s^t)} \frac{K(i, s^t)}{q(s^t)} \tag{30}$$

Clearly, the capital utilization functions 28 and 30 are independent of firms' idiosyncratic productivity. This result simplifies computation greatly, because it implies that every MP firm from Home employs the same fraction of its initial stock in the Home market. When the two countries are identical- i.e., they have the same aggregate states, wages, masses of exporters and MP firms, the MP firms use half of their capital in either location. Whenever one of the countries has lower effective wage, that country receives a greater share of the capital.

Note that the labor demands for MP firms derived in 26 and 27 took the capital allocations as given. So we can plug 28 and 30 back into these functions to get labor demands.

Capital and investment. The assumption that firm productivity η is distributed i.i.d. simplifies computation. It implies that every firm has the same expectation for η next period. All current MP firms then have the same (and higher) expected value tomorrow on account of having already paid the MP sunk cost. As a result, these firms choose the same capital stock for tomorrow, denoted $K_F(s^t)$. Current exporters have a value below current MP firms but above the value of domestic firms and they all choose the same capital for next period ($K_X(s^t)$). For the current domestic firms, the expected value tomorrow is lower, and they invest to have a lower capital stock tomorrow, denoted $K_D(s^t)$.

$$K(i, s^t) = 1 \begin{cases} K_D(s^t) & \text{if} \quad m^X(i, s^t) = 0 \; \& \; m^F(i, s^t) = 0 \\ K_X(s^t) & \text{if} \quad m^X(i, s^t) = 1 \; \& \; m^F(i, s^t) = 0 \\ K_F(s^t) & \text{if} \quad m^X(i, s^t) = 0 \; \& \; m^F(i, s^t) = 1 \end{cases} \tag{31}$$

These are the capital stocks that firms are born with in the next period. The levels should satisfy the first order optimality condition which equates expected return from investment with cost of investment good. Given the current status $b \in \{D, X, M\}$, the optimality condition is:

$$1 = \sum_{st+1} Q(s^{t+1}|s^t) \frac{P(s^{t+1})}{P(s^t)} \left[\frac{\alpha}{1-\alpha} \frac{W(s^{t+1}) \bar{L}_b(s^{t+1})}{K_b(s^t)} + (1 - \delta_k) \right] \tag{32}$$

where $\bar{L}_b(s^{t+1}) = \bar{L}_b(s^{t+1}) + \frac{q(s^{t+1}) W^\star(s^{t+1})}{W(s^{t+1})} L_b^{D\star}(s^{t+1})$ is the average labor demand (in home and foreign). The averages are given by 41 and 43.

Given that both the current and the next period's level of capital are specified, investment can take six values depending on the current state and the choice of domestic/exporter/MP firm for next period.

A.1 Cutoffs

There are six cutoffs: export and MP cutoffs each for last period domestic firms, exporters, and MP firms. Each cutoff is identified by a condition equating the value of conducting one activity versus another. Before writing these six equations, I write down the values of operating domestically, becoming and exporter, and becoming an MP firm conditional on firm state variables and aggregate state.

A.1.1 Recursive formulation

Value from operating only domestically. Let $b \in \{D, X, M\}$ denote last period status of the firm. Then value of choosing to produce only domestically is:

$$V^D(\eta, b, s^t) = \frac{1 - \theta(1-\alpha)}{\theta(1-\alpha)} P(s^t) W(s^t) L_b^D(i, s^t) - P(s^t) \left[K_D(s^t) - (1 - \delta_k) K_b(s^{t-1}) \right] \\ + \sum_{s^{t+1}} \sum_{\eta'} Q(s^{t+1}|s^t) Pr(\eta') V(\eta', D, s^{t+1}) \tag{33}$$

Value from being an exporter.

$$V^X(\eta, b, s^t) = \frac{1 - \theta(1-\alpha)}{\theta(1-\alpha)} P(s^t) W(s^t) L_b^X(i, s^t) - q(s^t) P(s^t) W^\star(s^t) \left(\frac{F_1^X + I_{b \neq X} F_0^X}{I_{b \neq F} + \phi_{fx} I_{b=F}} \right) \\ - P(s^t) \left[K_X(s^t) - (1 - \delta_k) K_b(s^{t-1}) \right] + \sum_{s^{t+1}} \sum_{\eta'} Q(s^{t+1}|s^t) Pr(\eta') V(\eta', X, s^{t+1}) \tag{34}$$

Value from being an MP firm.

$$V^F(\eta,b,s^t)=\frac{1-\theta(1-\alpha)}{\theta(1-\alpha)}P(s^t)W(s^t)\left[L_b^D(i,s^t)+\frac{q(s^t)W^\star(s^t)}{W(s^t)}L_b^{D\star}(i,s^t)\right]$$
$$-q(s^t)P(s^t)W^\star(s^t)\left[\frac{F_1^F+I_{b\neq F}F_0^F}{I_{b\neq X}+\phi_{xf}I_{b=X}}\right]-P(s^t)\left[K_F(s^t)-(1-\delta_k)K_b(s^{t-1})\right]+$$
$$\sum_{s^{t+1}}\sum_{\eta'}Q(s^{t+1}|s^t)Pr(\eta')V(\eta',M,s^{t+1}) \quad (35)$$

A.1.2 Marginal Firm Conditions

For a firm that had status $b\in\{D,X,F\}$ last period, the current period export cutoff $\eta_b^X(s^t)$ is obtained by equating domestic and exporter value functions:

$$V^X(\eta_b^X,b,s^t)-V^D(\eta_b^X,b,s^t)=0$$
$$\Longrightarrow \frac{1-\theta(1-\alpha)}{\theta(1-\alpha)}P(s^t)W(s^t)\left[L_b^X(i,s^t)-L_b^D(i,s^t)\right]-q(s^t)P(s^t)W^\star(s^t)\left(\frac{F_1^X+I_{b\neq X}F_0^X}{I_{b\neq F}+\phi_{fx}I_{b=F}}\right)$$
$$-\left(K_X(s^t)-K_D(s^t)\right)+\sum_{s^{t+1}}Q(s^{t+1}|s^t)\left[\bar V_X(s^{t+1})-\bar V_D(s^{t+1})\right]=0 \quad (36)$$

For a firm that had status $b\in\{D,X,F\}$ last period, the current period MP cutoff $\eta_b^F(s^t)$ is obtained by equating exporter and MP value functions:

$$V^F(\eta_b^F,b,s^t)-V^X(\eta_b^F,b,s^t)=0$$
$$\Longrightarrow \frac{1-\theta(1-\alpha)}{\theta(1-\alpha)}P(s^t)W(s^t)\left[L_b^D(i,s^t)+\frac{q(s^t)W^\star(s^t)}{W(s^t)}L_b^{D\star}(i,s^t)-L_b^X(i,s^t)\right]-$$
$$q(s^t)P(s^t)W^\star(s^t)\left(\frac{F_1^F+I_{b\neq F}F_0^F}{I_{b\neq X}+\phi_{xf}I_{b=X}}-\frac{F_1^X+I_{b\neq X}F_0^X}{I_{b\neq F}+\phi_{fx}I_{b=F}}\right)-\left(K_F(s^t)-K_X(s^t)\right)+$$
$$\sum_{s^{t+1}}Q(s^{t+1}|s^t)\left[\bar V_M(s^{t+1})-\bar V_X(s^{t+1})\right]=0 \quad (37)$$

Where the last terms contain average value next period of current D,X, and F firms given by 53.

A.2 Aggregation

Number of exporters

$$N^X(s^t)=\sum_{b\in\{D,X,F\}}\left[\Phi(\eta_b^F(s^t))-\Phi(\eta_b^X(s^t))\right]N^b(s^{t-1}) \quad (38)$$

Number of MP firms

$$N^F(s^t)=\sum_{b\in\{D,X,F\}}\left[1-\Phi(\eta_b^F(s^t))\right]N^b(s^{t-1}) \quad (39)$$

A.2.1 Aggregate Investments

$$X(s^t)=K_D(s^t)\left[\sum_{b\in\{D,X,F\}}N_b(s^{t-1})\Gamma(\eta_b^X(s^t))\right]+K_X(s^t)\left[\sum_{b\in\{D,X,F\}}N_b(s^{t-1})\left(\Gamma(\eta_b^F(s^t))-\Gamma(\eta_b^X(s^t))\right)\right]+$$
$$K_F(s^t)\left[\sum_{b\in\{D,X,F\}}N_b(s^{t-1})(1-\Gamma(\eta_b^F(s^t)))\right]-(1-\delta_k)\left[\sum_{b\in\{D,X,F\}}N_b(s^{t-1})K_b(s^{t-1})\right] \quad (40)$$

A.2.2 Total labor demand

Domestic firms. Average labor demands in the domestic market from firms with last period status $b \in \{D, X, F\}$ is:

$$\bar{L}_b(s^t) = K_b(s^{t-1})^{1-\nu} \exp\left(Z(s^t)\frac{1-\nu}{\alpha}\right) \left\{ H_h(s^t) \int_{-\infty}^{\eta_b^X(s^t)} \exp\left(\eta \frac{1-\nu}{\alpha}\right) \gamma(\eta) d\eta + \right.$$
$$\left. H_{hx}(s^t) \int_{\eta_b^X(s^t)}^{\eta_b^F(s^t)} \exp\left(\eta \frac{1-\nu}{\alpha}\right) \gamma(\eta) d\eta + \frac{H_h(s^t)}{(1+G(s^t))^{(1-\nu)}} \int_{\eta_b^F(s^t)}^{\infty} \exp\left(\eta \frac{1-\nu}{\alpha}\right) \gamma(\eta) d\eta \right\} \quad (41)$$

Total labor demand from domestic firms is then,

$$L^D(s^t) = N_D(s^{t-1})\bar{L}_D(s^t) + N_X(s^{t-1})\bar{L}_X(s^t) + N_M(s^{t-1})\bar{L}_M(s^t) \quad (42)$$

Affiliates of foreign multinationals. Total labor demand from affiliates of foreign multinationals in the domestic market is:

$$L^F(s^t) = H_m(s^t) \left(\frac{1}{q(s^t)} \frac{G^\star(s^t)}{1+G^\star(s^t)}\right)^{1-\nu} \exp\left(\frac{1-\nu}{\alpha}(\zeta Z^\star(s^t) + (1-\zeta)Z(s^t))\right) \times$$
$$\left\{ N_D^\star(s^{t-1})K_D^\star(s^{t-1})^{1-\nu} \int_{\eta_D^{F\star}(s^t)}^{\infty} \exp\left(\eta \frac{1-\nu}{\alpha}\right) \gamma(\eta) d\eta + N_X^\star(s^{t-1})K_X^\star(s^{t-1})^{1-\nu} \int_{\eta_X^{F\star}(s^t)}^{\infty} \exp\left(\eta \frac{1-\nu}{\alpha}\right) \gamma(\eta) d\eta \right.$$
$$\left. + N_F^\star(s^{t-1})K_F^\star(s^{t-1})^{1-\nu} \int_{\eta_F^{F\star}(s^t)}^{\infty} \exp\left(\eta \frac{1-\nu}{\alpha}\right) \gamma(\eta) d\eta \right\} \quad (43)$$

Fixed and sunk cost payments. Fixed and sunk costs are paid in home by foreign exporters and multinationals.

$$L^C(s^t) = (F_0^X + F_1^X) \left\{ N_D^\star(s^{t-1})[\Gamma(\eta_D^{F\star}) - \Gamma(\eta_D^{X\star})] + \frac{N_F^\star(s^{t-1})}{\phi_{fx}}[\Gamma(\eta_F^{F\star}) - \Gamma(\eta_F^{X\star})] \right\} +$$
$$F_1^X N_X^\star(s^{t-1})[\Gamma(\eta_X^{F\star}) - \Gamma(\eta_X^{X\star})] + (F_0^F + F_1^F) \left\{ N_D^\star(s^{t-1})[1 - \Gamma(\eta_D^{F\star})] + \frac{N_X^\star(s^{t-1})}{\phi_{xf}}[1 - \Gamma(\eta_X^{F\star})] \right\} +$$
$$F_1^F N_F^\star(s^{t-1})[1 - \Gamma(\eta_F^{F\star})] \quad (44)$$

Total labor demand.

$$L(s^t) = L^D(s^t) + L^F(s^t) + L^C(s^t) \quad (45)$$

A.2.3 Aggregate Profits

First, I derive average profits by last period status $b \in \{D, X, M\}$.

$$\bar{\pi}_b = \frac{1-\theta(1-\alpha)}{\theta(1-\alpha)} P(s^t)W(s^t) \left[\bar{L}_b + \frac{q(s^t)W(s^t)}{W^\star(s^t)} \int_{\eta_b^F(s^t)}^{\infty} L_b^{F\star}(i, s^t)\gamma(\eta) d\eta \right] -$$
$$q(s^t)P(s^t)W^\star(s^t) \left[\frac{F_1^X + I_{b \neq X} F_0^X}{I_{b \neq F} + \phi_{fx} I_{b=F}} (\Gamma(\eta_b^F(s^t)) - \Gamma(\eta_b^X(s^t))) + \frac{F_1^F + I_{b \neq F} F_0^F}{I_{b \neq X} + \phi_{xf} I_{b=X}} (1 - \Gamma(\eta_b^F(s^t))) \right] -$$
$$P(s^t) \left[K_D(s^t)\Gamma(\eta_b^X(s^t)) + K_X(s^t)(\Gamma(\eta_b^F(s^t)) - \Gamma(\eta_b^X(s^t))) + K_F(s^t)(1 - \Gamma(\eta_b^F(s^t))) - (1-\delta_k)K_b(s^{t-1}) \right] \quad (46)$$

Aggregate profits.

$$\pi(s^t) = N_D(s^{t-1})\bar{\pi}_D + N_X(s^{t-1})\bar{\pi}_X + N_F(s^{t-1})\bar{\pi}_F$$
$$= \frac{1-\theta(1-\alpha)}{\theta(1-\alpha)} P(s^t)W(s^t)\left[L^D(s^t) + \frac{q(s^t)W^\star(s^t)}{W(s^t)} L^{F\star}(s^t)\right] - q(s^t)P^\star(s^t)W^\star(s^t)L^{C\star}(s^t) - P(s^t)X(s^t) \tag{47}$$

A.2.4 Aggregate Prices

Aggregate price is given by

$$1 = \delta_h^{\frac{1}{1-\rho}}\left(\frac{P_h(s^t)}{P(s^t)}\right)^{\frac{\rho}{\rho-1}} + \delta_x^{\frac{1}{1-\rho}}\left(\frac{P_{xf}(s^t)}{P(s^t)}\right)^{\frac{\rho}{\rho-1}} + (1-\delta_h-\delta_x)^{\frac{1}{1-\rho}}\left(\frac{P_{mf}(s^t)}{P(s^t)}\right)^{\frac{\rho}{\rho-1}} \tag{48}$$

Domestic firms. I will start with the following identity for the average domestic price of home firms:

$$\begin{aligned}\left(\frac{P_h(s^t)}{P(s^t)}\right)^{\frac{\theta}{\theta-1}} &= \int_i \left(\frac{P_h(i,s^t)}{P(s^t)}\right)^{\frac{\theta}{\theta-1}} di \\ &= \sum_{b\in\{D,X,F\}} N_b(s^{t-1}) \int_{i\in\Xi(b,s^{t-1})} \left(\frac{P_h(i,s^t)}{P(s^t)}\right)^{\frac{\theta}{\theta-1}} di \\ &= \sum_{b\in\{D,X,F\}} N_b(s^{t-1}) \left(\overline{\frac{P_{hb}(s^t)}{P(s^t)}}\right)^{\frac{\theta}{\theta-1}} \end{aligned} \tag{49}$$

Where average price index by last period status $b \in \{D, X, M\}$ is

$$\left(\overline{\frac{P_{hb}(s^t)}{P(s^t)}}\right)^{\frac{\theta}{\theta-1}} = \left(\frac{W(s^t)}{\theta(1-\alpha)}\right)^{\frac{\theta}{\theta-1}} K_b(s^{t-1})^{1-\nu} \exp\left(Z(s^t)\frac{1-\nu}{\alpha}\right) \times \left\{ H_h(s^t)^{\frac{\nu-1}{\nu}} \int_{-\infty}^{\eta_b^X(s^t)} \exp\left(\eta\frac{1-\nu}{\alpha}\right)\gamma(\eta)d\eta + H_h^x(s^t)^{\frac{\nu-1}{\nu}} \int_{\eta_b^X(s^t)}^{\eta_b^F(s^t)} \exp\left(\eta\frac{1-\nu}{\alpha}\right)\gamma(\eta)d\eta + \frac{H_h(s^t)^{\frac{\nu-1}{\nu}}}{(1+G(s^t))^{1-\nu}} \int_{\eta_b^F(s^t)}^{\infty} \exp\left(\eta\frac{1-\nu}{\alpha}\right)\gamma(\eta)d\eta \right\} \tag{50}$$

Price of imports.

$$\left(\frac{P_{xf}(s^t)}{P(s^t)}\right)^{\frac{\theta}{\theta-1}} = \left(\frac{W^\star(s^t)q(s^t)}{\theta(1-\alpha)}\tau\right)^{\frac{\theta}{\theta-1}} \exp\left(Z^\star(s^t)\frac{1-\nu}{\alpha}\right) H^\star_{hx}(s^t)^{\frac{\nu-1}{\nu}} \left\{ N_D^\star(s^{t-1})K_D^{\star(1-\nu)}(s^{t-1}) \times \int_{\eta_D^X(s^t)}^{\eta_D^F(s^t)} \exp\left(\eta\frac{1-\nu}{\alpha}\right)\gamma(\eta)d\eta + N_X^\star(s^{t-1})K_X^{\star(1-\nu)}(s^{t-1}) \int_{\eta_X^X(s^t)}^{\eta_X^F(s^t)} \exp\left(\eta\frac{1-\nu}{\alpha}\right)\gamma(\eta)d\eta + N_F^\star(s^{t-1})K_F^{\star(1-\nu)}(s^{t-1}) \int_{\eta_F^X(s^t)}^{\eta_F^F(s^t)} \exp\left(\eta\frac{1-\nu}{\alpha}\right)\gamma(\eta)d\eta \right\} \tag{51}$$

Price of affiliates of foreign firms.

$$\left(\frac{P_{mf}(s^t)}{P(s^t)}\right)^{\frac{\theta}{\theta-1}} = \left(\frac{W(s^t)}{\theta(1-\alpha)}\right)^{\frac{\theta}{\theta-1}} H_m(s^t)^{\frac{\nu-1}{\nu}} \left(q(s^t)\frac{G^\star(s^t)}{1+G^\star(s^t)}\right)^{1-\nu} \exp\left(\frac{1-\nu}{\alpha}(\zeta Z^\star(s^t) + (1-\zeta)Z(s^t))\right) \times \left\{ N_D^\star(s^{t-1})K_D^{\star(1-\nu)}(s^{t-1}) \int_{\eta_D^F(s^t)}^{\infty} \exp\left(\eta\frac{1-\nu}{\alpha}\right)\gamma(\eta)d\eta + N_X^\star(s^{t-1})K_X^{\star(1-\nu)}(s^{t-1}) \int_{\eta_X^F(s^t)}^{\infty} \exp\left(\eta\frac{1-\nu}{\alpha}\right)\gamma(\eta)d\eta + N_F^\star(s^{t-1})K_F^{\star(1-\nu)}(s^{t-1}) \int_{\eta_F^F(s^t)}^{\infty} \exp\left(\eta\frac{1-\nu}{\alpha}\right)\gamma(\eta)d\eta \right\} \tag{52}$$

A.2.5 Difference in Average Value

Average value by last period status:

$$
\begin{aligned}
\bar{V}_b(s^t) &= \frac{\int_{i\in\xi(D,s^{t-1})} V(i,b,s^t)di}{N_D(s^{t-1})} \\
&= \int_{-\infty}^{\eta_D^X(s^t)} V^D(\eta,b,s^t)\Gamma(\eta)d\eta + \int_{\eta_D^X(s^t)}^{\eta_D^F(s^t)} V^X(\eta,b,s^t)\Gamma(\eta)d\eta + \int_{\eta_D^F(s^t)}^{\infty} V^F(\eta,b,s^t)\Gamma(\eta)d\eta \\
&= \frac{1-(\theta(1-\alpha))}{\theta(1-\alpha)} P(s^t)W(s^t)\left[\bar{L}_b + \frac{q(s^t)W^\star(s^t)}{W(s^t)}\int_{\eta_b^F(s^t)}^{\infty} L_b^{D\star}(\eta,b,s^t)\Gamma(\eta)d\eta\right] -
\end{aligned}
$$
$$
q(s^t)P(s^t)W^\star(s^t)\times\left[\Big(\frac{I_{b\neq X}F_0^X+F_1^X}{I_{b\neq F}+\phi_{fx}I_{b=F}}\Big)\Big(\Gamma(\eta_b^F(s^t))-\Gamma(\eta_b^X(s^t))\Big) + \frac{I_{b\neq F}F_0^F+F_1^F}{I_{b\neq X}+\phi_{xf}I_{b=X}}\Big(1-\Gamma(\eta_b^F(s^t))\Big)\right]
$$
$$
-P(s^t)\left[K_D(s^t)\Gamma(\eta_b^X(s^t))+K_X(s^t)\Big(\Gamma(\eta_b^F(s^t))-\Gamma(\eta_b^X(s^t))\Big)+K_F(s^t)\Big(1-\Gamma(\eta_b^F(s^t))\Big)-(1-\delta_k)K_b(s^{t-1})\right]
$$
$$
+\sum_{s^{t+1}} Q(s^{t+1}|s^t)\left[\Gamma(\eta_b^X(s^t))\bar{V}_D(s^{t+1})+\Big(\Gamma(\eta_b^F(s^t))-\Gamma(\eta_b^X(s^t))\Big)\bar{V}_X(s^{t+1})+\Big(1-\Gamma(\eta_b^F(s^t))\Big)\bar{V}_F(s^{t+1})\right] \tag{53}
$$

This can be plugged into marginal firms' conditions 36 and 37 to get the cutoffs.

A.3 Market Clearing Conditions

Goods market clearing:

$$
\begin{aligned}
D(s^t) + \frac{G(s^t)}{1+G(s^t)} \sum_{b\in\{D,X,M\}} N_b(s^{t-1})K_b(s^{t-1})[1-\gamma(\eta_b^F(s^t))] &= \\
C(s^t)+X(s^t)+q(s^t)\frac{G^\star(s^t)}{1+G^\star(s^t)}\sum_{b\in\{D,X,M\}} N_b^\star(s^{t-1})K_b^\star(s^{t-1})[1-\gamma(\eta_b^{F\star}(s^t))] & \qquad (54)
\end{aligned}
$$

Aggregate capital and investments:

$$
K(s^t) = N_D(s^t)K_D(s^t) + N_X(s^t)K_X(s^t) + N_F(s^t)K_F(s^t) \tag{55}
$$
$$
X(s^t) = K(s^t) - (1-\delta_k)K(s^{t-1}) \tag{56}
$$

Computing Net Exports and Real Gross Domestic Product
Real domestic production, exports and imports:

$$
Y_d(s^t) = \int_i \frac{P_h(i,s^t)y_h(i,s^t)}{P_h(s^t)} = \delta_h^{\frac{1}{1-\rho}}\left(\frac{P_h(s^t)}{P(s^t)}\right)^{\frac{1}{\rho-1}} D(s^t) \tag{57}
$$

$$
Y_{ex}(s^t) = \int_{i\in\xi^X(s^t)} \frac{e(s^t)P_{xf}^\star(i,s^t)y_{xf}^\star(i,s^t)}{e(s^t)P_{xf}^\star(s^t)} = \delta_x^{\frac{1}{1-\rho}}\left(\frac{P_{xf}^\star(s^t)}{P^\star(s^t)}\right)^{\frac{1}{\rho-1}} D^\star(s^t) \tag{58}
$$

$$
Y_{im}(s^t) = \int_{i\in\xi^{X\star}(s^t)} \frac{P_{xf}(i,s^t)y_{xf}(i,s^t)}{P_{xf}(s^t)} = \delta_x^{\frac{1}{1-\rho}}\left(\frac{P_{xf}(s^t)}{P(s^t)}\right)^{\frac{1}{\rho-1}} D(s^t) \tag{59}
$$

Gross Domestic Product
I compute real gross domestic product (GDP) similar to Alessandria & Choi (2007). Nominal GDP is is

the sum of sales of all goods produced domestically.

$$P_G(s^t)Y(s^t) = \int_0^1 [P_h(i,s^t)y_h(i,s^t) + e(s^t)P^\star_{xf}(i,s^t)Y_{ex}(i,s^t)]di + \int_{i\in\xi^{F\star}(s^t)} P_{mf}(i,s^t)y_{mf}(i,s^t)di \quad (60)$$

where the GDP deflator $P_G(s^t)$ is is an aggregation of domestic, export, and foreign MP price indexes,

$$P_G(s^t) = \chi_d(x^t)P_h(s^t) + \chi_x(x^t)P^\star_{xf}(s^t) + [1-\chi_d(x^t)-\chi_x(x^t)]P_{mf}(s^t) \quad (61)$$

The weights on domestic and export price indexes are their respective shares in GDP: $\chi_d(s^t) = \frac{P_h(s^t)y_h(s^t)}{P_G(s^t)Y(s^t)}$ and $\chi_x(s^t) = \frac{e(s^t)P^\star_{xf}(s^t)Y_{ex}(s^t)}{P_G(s^t)Y(s^t)}$.

B Calculating Data Transition Rates

I calculate transition probabilities using Tables 1 and 6 in Boehm *et al.* (2020). They provide transition probabilities separately for US headquarterd multinationals and affiliates of foreign multinationals. The transition probabilities for these two types of firms are in the same ballpark, so I take a weighted average of the two types of firms to get a more representative picture. Alternatively, one could simply calculate and plug in the entry and exit rates for US multinationals from Table 6, but this approach leads to very similar transition probabilities (explained below), and the quantitative results do not change.

From Table 1, I calculate the numbers of MP firms as the sum of US multinationals and foreign multinationals. There are two years to choose the number of firms from-1993 and 2011. The number of US multinationals were 2.8 times the number of foreign multinationals in 1993 (17119 US multinationals and 6178 foreign multinationals), compared to 1.5 times in 2011 (13488 US multinationals and 8952 foreign multinationals). By choosing 2011 numbers therefore, the weighted average transition rates are closer to the transition rates of foreign multinationals.

Dealing with exit: Table 6 provides annual transition probabilities by activity averaged over the 1993-2011 time period. Because I do not model exit, I only calculate transition probabilities for surviving firms. 6.06% of US multinationals and 5.7% of foreign multinationals exit. This gives the weighted average survival rate of 94.08%. Similarly, the number of surviving domestic firms and exporters are 90.07% and 94.71% respectively.

Calculating MP exit rate: Among all US multinationals, 0.27% enter domestic only market and 1.85% become exporters. Among all foreign multinationals, 0.45% enter domestic only market and 1.94% become exporters. The weighted average transition probability to domestic only market is 0.37% after accounting for exit. The weighted average transition probability to export market is 2%. The MP exit rate, which is the sum of transition probabilities to domestic only market and export market, is therefore 2.37%, which in quarterly terms is 0.5919%.

Calculating MP entry rate: Firms can enter MP status from past domestic or export statuses. The calculation here is simpler because I do not need to consider transition probabilities of foreign firms or the number of foreign firms. Among all domestic only firms, 0.03% become US multinationals; among all exporters, 0.84% become US multinationals. The weighted average MP entry rate, as a fraction of surviving domestic-only firms and exporters, is therefore 0.2952% per year. In quarterly terms, it is 0.0738% per year.