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Foreign Direct Investment Competitions in a Three-Country Dynamic Stochastic General Equilibrium Model

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Using heterogeneous firms and public infrastructure assumptions, this study explores the consequences of FDI competition between two countries in a three-country DSGE model. Two countries compete for FDI by providing public infrastructure, reducing taxes, or offering subsidies to foreign investors. We find that an increase in public infrastructure attracts more FDI if the government finances the public investment expenditures via labor income tax hikes, import tariffs, or government consumption reductions. Increasing public infrastructure also increases domestic production and results in an appreciation in the real exchange rate and a deterioration in terms of trade. However, the increase in public infrastructure results in a higher relative domestic labor cost, impeding foreign FDI and reducing the effect of the policies that attract FDI. Reducing the corporate tax rate is another effective way to draw FDI. However, corporate tax reductions do not work if the public infrastructure decreases along with the reduction of the corporate tax rate. Finally, permanent deregulation in the host country improves social welfare regardless of the policies that the host government uses to attract FDI.

Keywords: foreign direct investment, heterogeneous firms, public infrastructure, tax competition
JEL classification: E32, E62, F23, H25

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1 Introduction

In this study, we analyze the policy competition between two countries both of which are aiming to attract foreign direct investment (FDI) from a third economy through providing financial subsidies or reducing corporate tax levied on FDI or increasing domestic public infrastructure, which enhances firm productivity. Our major interest is to explore the impact of competing for FDI, focusing specifically on the consequences on welfare and macroeconomic variables, such as output, the real exchange rate, and the structure of international trade.

India's Finance Minister, Arun Jaitley, has announced a reduction in corporate tax rates from 30 percent to 25 percent. The lower rate, designed to attract Foreign Direct Investment (FDI), places the Indian rate at the same level of China and is expected to be active from the fiscal year 2016–17.

-The India Briefing, November 25^{th}, 2015.

The shortcomings of India's infrastructure are often lamented. But through the lens of statistical aggregates, the South Asian nation has caught up to - or even surpassed - China in some respects. In other areas, it is not far behind. The primary gap is in India's energy sector, which appears more than a generation behind its East Asian rival. This is where Prime Minister Narendra Modi faces the greatest challenges and opportunities in building a path toward stronger growth and higher living standards.

-Bloomberg, October 9^{th}, 2015.

In some developing countries, governments are improving the physical infrastructure, offering subsidies to lure foreign direct investment, or reducing taxes. The aim is to promote the country's economic performance. Besides, governments of these countries often claim that foreign investment brings other benefits, including the possibility of transferring advanced technology, infusing much-needed capital, substituting of imports, and creating jobs. Therefore, competing to attract mobile capital among countries is pervasive and has been on the rise in the last two decades resulting from the barriers to international investment and the importance of market size reduction as the globalization of the world economy (Oman, 2000).[1]

[1]According to the database of UNCTAD, the global stock of FDI in 2013 rose about threefold in current U.S. dollars in 2001.

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As more countries engage in competition for FDI, the body of literature on the phenomenon of tax competition among countries has also increased in volume. Some literature has focused on countries trying to attract internationally mobile capital through reductions in taxation. Many studies have analyzed whether and when competition among countries is wasteful or welfare-increasing (Ferrett and Wooton, 2010; Kind, Knarvik, and Schjelderup, 2000; Ottaviano and Van Ypersele, 2005; Wilson, 1991, 1999; Zodrow and Mieszkowski, 1986). Later, certain empirical evidence has shown that additional factors affect the location decisions of foreign investors. Alongside differential tax rates, market size, transportation costs, and public input are all the importance (Devereux and Griffith, 1998; Grubert and Mutti, 2000). Some studies have considered the tax competition between asymmetric countries, and in particular on the ability of such competition to attract foreign-owned firms. Besides, some literature investigates which country wins the competition and under what conditions (Barros and Cabral, 2000; Bjorvatn and Eckel, 2006; Dembour and Wauthy, 2009; Fumagalli, 2003; Haaparanta, 1996; Haufler and Wooton, 1999; King, McAfee, and Welling, 1993; Olsen and Osmundsen, 2003; Pieretti and Zanaj, 2011; Walz and Wellisch, 1996). In this study, we follow the approach that many factors would influence the locational decisions of multinational firms and focus on the consequences of competing for FDI.

It is well-acknowledged that low tax rates and a high level of public spending are the most common policy strategies used for attracting FDI (Goodspeed, Martinez-Vazquez, and Zhang, 2006). Early tax competition models reveal that tax competition among countries leads to a situation that inefficiently low tax rates and low levels of public expenditure if corporate tax is the only way to finance their expenditures (Wilson and Wildasin, 2004). However, the empirical evidence of the "race to the bottom" in corporate tax rates seems to be fairly weak (Mintz and Smart, 2004; Stewart and Webb, 2006). Two reasons can explain the lack of evidence to support the stronger versions of the "race to the bottom" hypotheses. First, foreign firms pay attention not only to tax burdens but also to the benefits that accrue to them from the government spending financed by those taxes. Thus, a decline in the fiscal burden in a country might not result in a dramatic increase in the number of foreign subsidiaries in that country. In this vein, several tax competition studies show that competition in public goods induces both a reduction in the intensity of tax competition and negative consequences for efficiency (Hindriks, Peralta, and Weber, 2008; Zissimos and Wooders,

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2008). Another reason for the lack of evidence to support the "race to the bottom" hypotheses is that corporate tax is not the only way to finance public expenditures. When other forms of taxation bear an increasing share in the financing of public investment, public infrastructure is productive enough to compensate for the required increase in corporate taxation (Bénassy-Quér, Gobalraja, and Trannoy, 2007). A few studies have stated that the host country finances public expenditures not only by raising corporate taxes but also by raising other taxes (Laussel and Breton, 1998; Peralta and Van Ypersele, 2006). Thus, this work shows that the impact of competing for FDI on economies depends on the policy interventions chosen by the host country.

How to attract more FDI? Since the choice of firms to serve a foreign market via exports or horizontal FDI is driven by the proximity-concentration trade-off, the government can use some fiscal policies to alter the profit of firms from foreign markets through local subsidiary sales, and then foreign firms might switch from being exporters to become multinationals.[2] When fiscal policies encourage more foreign firms to serve the host country's market via FDI, the relocation of production lowers the prices that foreign firms charge in the host country's market for the savings on cross-border transport costs.[3] Besides, the beneficial or harmful effects brought about by FDI inflows will intensify when the number of multinationals is endogenously determined. Although firm heterogeneity is relevant for international tax competition, theoretical discussions have mainly focused on models with homogeneous firms. Recent novel additions to the literature on international tax competition have incorporated heterogeneous firms into models of imperfect competition that previously assumed identical firms (Bauer, Davies, and Haufler, 2014; Chor, 2009; Davies and Eckel, 2010; Krautheim and Schmidt-Eisenlohr, 2011; Pflüger and Südekum, 2013).

Empirical studies reveal several features of firms' behavior. These features are not well explained by existing theories of international trade. One of the most noticeable features is that firms show heterogeneity in productivity, size, and other economic characteristics. According to empirical studies using microdata, a firm's participation in international commerce is rela-

[2]Horizontal FDI refers to a firm's foreign market strategy of duplicating roughly the same activities designed to serve the host country's market.

[3]Exporting firms are subject to per-unit transportation costs and the small fixed costs of entering a foreign market. Instead, horizontal FDI saves on transport costs but requires higher fixed costs to duplicate production facilities in the host country.

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tively rare and is associated with superior values of productivity and other measures of economic performance (Melitz and Redding, 2014). Therefore, theoretical research in international trade has increasingly emphasized the decisions of individual firms in understanding the causes and consequences of aggregate trade.

In a seminal paper on heterogeneous firms in international trade, Melitz (2003) proposed a dynamic industry model with firm heterogeneity in productivity, focusing on the steady-state equilibrium. The Melitz model shows that a change in the costs of international trade drastically affects how the impact of international trade is distributed across different firms. Ghironi and Melitz (2005) incorporated these microeconomic features, such as heterogeneous firms and entry costs, into an open economy's macroeconomic framework. They developed a two-country Dynamic Stochastic General Equilibrium (DSGE) model of international trade and macroeconomics. Their model shows that an endogenous firm's entry into domestic and export markets has important effects on macroeconomic variables, such as real exchange rates and terms of trade. Besides, the Melitz model can be generalized to handle horizontal FDI.[4] Helpman, Melitz, and Yeaple (2004) extended this framework to explain why only a fraction of firms operate with foreign affiliates instead of exporting. They showed that a firm's heterogeneity plays a key role in explaining the structure of international commerce. In equilibrium, only the more productive firms serve the foreign markets, and the most productive among this group further serve the overseas market via local subsidiary sales.

This paper contributes to an extensive literature on the competition for FDI by presenting a first attempt (to the best of our knowledge) at applying a dynamic general equilibrium framework to deal with this policy topic. The model developed in this work allows firms to choose whether and how to serve foreign markets endogenously, based on the assumptions of firm heterogeneity in productivity and the proximity-concentration trade-off of international commerce. Thus, the model has the advantage that it allows us to analyze the impact of competing for FDI on key variables, such as consumption and the amount of FDI in each country and the optimal subsidy level varying in response to the difference between the competing countries or the investing country. Focusing on the welfare cost of FDI subsidies to at-

[4]Contessi (2010) incorporates the endogenous entry of multinationals into a two-country DSGE model to explain the observed patterns of the real exchange rate.

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tract FDI, we show that the wealth reallocation effect may offset the selection effect, leading to a decline in consumption. We also illustrate that increasing public infrastructure attracts more firms to produce goods and accompanies real exchange rate appreciation. These results also echo the empirical evidence found by Bénassy-Quér, Gobalraja, and Trannoy (2007). Besides, our analysis shows that the consumption of the host country's households falls as the host country decreases its public investment in response to attract FDI by reducing the corporate tax rate on FDI. The decrease in consumption implies that the host country does not have the incentive to attract FDI by using such a policy. This result matches the empirical evidence that the "race to the bottom" in corporate tax rates seems to be fairly weak.

In Section 4, we analyze the effect of offering fiscal policies to attract more FDI on aggregate consumption, exchange rates, and other keys. Then, we present the variation of the optimal FDI subsidy for the structural parameters of the model, such as demand elasticity and the fixed costs of servicing the foreign market in Section 5. In our three-country model, we also investigate the change of the optimal FDI subsidy when some business characteristics are different among countries, such as the aggregate productivity and firm entry cost. We are interested in analyzing how welfare in a country is affected when that country offers an import subsidy. An import subsidy will lure some foreign firms to service the home market through exports and induce an increase in the variety of imports available for domestic households, delivering positive consumption gains for the domestic country. However, an import subsidy also prompts some less-productive foreign firms to switch from horizontal FDI back to exporting, causing a negative selection effect on domestic consumption. An import subsidy causes wealth reallocation across countries if the number of firms in each country is determined endogenously. Because the net impact of an import subsidy on welfare is ambiguous, we examine the welfare impact of either a fixed or variable cost subsidy to imports in Section 5.

We organize the rest of the paper as follows. Section 2 introduces the model. The parameter values and the impulse responses of productivity shock are described in Section 3. Section 4 analyzes the effect of using fiscal policy to attract FDI. Section 5 discusses the welfare implication of FDI competition. This section also includes the analysis of optimal expenditure and an import subsidy. In section 6, we provide our conclusions.

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2 The Model

We extend the essential model developed by Ghironi and Melitz (2005) into a three-country DSGE framework of monopolistic competition with heterogeneous firms. In this three-country model, we assume that two countries (home and competitor) can export their products to foreign customers and compete for FDI from the third country (investor), which can be involved in foreign markets either by exports or by local subsidiary sales.[5] The three countries are labeled as Country A (the home country), Country B (the competing country), and Country C (the investing country). Because the composition of the consumption basket in each country can change over time, money is introduced as a convenient unit of account for contracts. All contracts and prices in the world are written in nominal terms and prices are assumed to be fully flexible.[6] Therefore, we can solve for the real variables in the model without incorporating the demand for cash currency. It allows us to focus on the impact of the fiscal policy on the real variables when the governments adopt fiscal policies to compete for FDI. We consider a world with partial financial integration that agents only can trade bonds domestically and internationally so we can concentrate on the impact of the policy attracting more foreign FDI on domestic households.[7]

2.1 Government expenditure

We assume that the government is involved in the provision of physical infrastructure, which increases the productivity of domestic effective labor units, as per Turnovsky and Fisher (1995) and Ganelli and Tervala (2010). The government in Country i divides public expenditures between productivity-enhancing physical investments and utility-enhancing consumption. The government finances spending through the payroll tax, sales tax, and import tariffs. Public investment is used to construct and repair public infrastructure. The law of motion for public infrastructure stock is therefore given by:

$$K^i_{t+1} = (1-\xi)K^i_t + G^i_{I,t}, \quad i \in (A, B, C), \tag{1}$$

[5] We exclude exports by foreign subsidiaries.

[6] Money, therefore, plays no role in the three-country model; this model can be understood as a cashless economy as in Woodford and Walsh (2005).

[7] Following Hamano (2015), we can extend our model into a full financial integration one that bond and equity both can be traded internationally.

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where K_t^i denotes the accumulated stock of public infrastructure; $\xi \in (0, 1)$ is the depreciation rate of public infrastructure; and $G_{I,t}^i$ denotes the government expenditure on public investment in Country i at period t. The public expenditure is defined over a continuum of Ω: $G_t^i = G_{I,t}^i + G_{C,t}^i = [\int_{\omega\in\Omega} g_t^i(\omega)^{(\theta-1/\theta)} d\omega]^{(\theta/\theta-1)}$, where G_t^i denotes the public expenditure, $G_{C,t}^i$ denotes the government expenditure on public consumption, and $\theta > 1$ is the elasticity of substitution across goods.

2.2 Household preference

Each country is populated by a unit mass of atomistic homogenous households. The representative household in Country i maximizes the expected intertemporal utility function:

$$U = E_t\left[\Sigma_{s=t}^{\infty}\beta^{s-t}\left[\frac{\left(C_s^i + \zeta G_{C,s}^i\right)^{1-\gamma}}{1-\gamma} - \frac{\left(L_s^i\right)^2}{2}\right]\right], \quad i \in (A, B, C),$$

where $\beta \in (0, 1)$ is the subjective discount factor; $\gamma > 0$ is the inverse of the intertemporal elasticity of substitution; ζ is the marginal rate of substitution between private and public consumption; C_t^i denotes a private consumption basket that aggregates domestic and imported goods; and L_t^i denotes the effective units of labor supply. The private consumption basket is also defined on a continuum of Ω: $C_t^i = [\int_{\omega\in\Omega} c_t^i(\omega)^{\theta-1/\theta} d\omega]^{\theta/\theta-1}$, where $\theta > 1$ is the symmetric elasticity of substitution across goods. Following Ghironi and Melitz (2005), we assume that only a subset of goods $\Omega_t^i \subset \Omega$ is available and that the subset of goods can differ from the one in the other country at time t.

Let $p_t^i(\omega)$ denote Country i's nominal price for the good $\omega \in \Omega_t^i$. Then, the price index for Country i can be denoted by $P_t^i = [\int_{\omega\in\Omega} p_t^i(\omega)^{1-\theta} d\omega]^{1/1-\theta}$. The demand function of government for each good is given by $g_t^i(\omega) = [p_t^i(\omega)/P_t^i]^{-\theta} G_t^i$ and the demand function of the household for each good is $c_t^i(\omega) = [p_t^i(\omega)/P_t^i]^{-\theta} C_t^i$.

2.3 Firm behavior

There is a mass of firms with heterogeneous productivity in each country. Each firm produces a different variety of ω, and its product can be sold at home or in foreign countries. Labor is hired by firms with the government-provided physical infrastructure to produce goods, assumed to be immobile

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across borders. The production function in Country i is given by:

$$y^i_{\omega,t} = Z^i_t \left(K^i_t\right)^{\alpha} z_\omega l^i_{\omega,t}, \quad i \in (A, B, C), \tag{2}$$

where $y^i_{\omega,t}$ denotes the goods produced by firm ω; Z^i_t denotes the total factor productivity common to all firms that produce in Country i; α is the productivity of public infrastructure; z_ω denotes the idiosyncratic productivity of firm ω, which implies that firms are heterogeneous as they produce with different technologies; and $l^i_{\omega,t}$ denotes the quantity of labor hired by firm ω to produce goods in Country i. Firm ω, with relative productivity z_ω, produces $Z^i_t(K^i_t)^\alpha z_\omega$ units of output per unit of labor used in Country i. The more stock of public infrastructure in a country, the more good firms can produce in that country.

Although firms are non-homogeneous and produce via different technologies, indexed by relative productivity z, all firms behave symmetrically with the same productivity in the equilibrium. Thus, we index firms by z from now on, omitting the variety index ω. Before entry, prospective entrants are identical before they enter the market and face a sunk-entry cost of $f^i_{E,t}$ in terms of effective units of labor. Upon entering the market, new firms draw their productivity level z from a common distribution $H(z)$ with support on $[z_{\min}, \infty)$ and then produce one period later.[8] The relative productivity level remains fixed thereafter. Assuming no overhead production costs, both new firms and incumbents produce every period until they are hit by an exogenous exit shock. This shock occurs with probability $\delta \in (0, 1)$ in each period and is independent of the firm's productivity level, so $H(z)$ also represents the productivity distribution of all producing firms (see also Ghironi and Melitz (2005)).

2.3.1 Firm's choice in two competition countries

Firms in the two competing countries (Country A and B) can serve the foreign market and the domestic market through exports. We assume that all firms face a residual demand with constant elasticity in all markets and that they set flexible prices that reflect the same proportional markup $\theta/\theta-1$ over the marginal cost. However, exporting to another country is costlier

[8] Following Ghironi and Melitz (2005), we assume that $H(z) = 1-(z_{\min}/z)^k$ is a Pareto distribution with low bond $z_{\min}$ and shape parameter κ.

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than selling goods domestically. It involves both a melting-iceberg trade cost τ and a fixed cost of $f^j_{Xi,t}$ in terms of effective units of labor.[9]

The nominal prices set by firms are given by:

$$p^j_{D,t}(z) = \frac{\theta}{\theta - 1} \frac{W^j_t}{Z^j_t \left(K^j_t\right)^{\alpha}} \frac{1}{z},$$

$$p^j_{Xi,t}(z) = \frac{1}{E^j_{i,t}} \frac{\theta}{\theta - 1} \tau \frac{W^j_t}{Z^j_t \left(K^j_t\right)^{\alpha}} \frac{1}{z},$$

$$j \in (A, B), \quad i \in (A, B, C), \quad i \neq j,$$

where $p^j_{D,t}(z)$ denotes the domestic price of a Country j's firm; $p^j_{Xi,t}(z)$ denotes the export price of a Country j's exporter in Country is market; W^j_t denotes the nominal wage rate of workers in Country js market; $E^j_{i,t}$ is the nominal exchange rate in units of Country js currency per unit of Country is.

Since exports are costly, firms with low productivity might not earn non-negative profits from exporting. Thus, some might only sell goods domestically while others export.[10] So, a firm's total nominal profit $D^j_t(z)$ can be decomposed into the portions earned from domestic sales $D^j_{D,t}(z)$ and from potential export sales $D^j_{Xi,t}(z)$. Total nominal profits in period t are given by:

$$D^j_t(z) = D^j_{D,t}(z) + \Sigma_i D^j_{Xi,t}(z), \quad j \in (A, B), \quad i \in (A, B, C), \quad i \neq j,$$

where

$$D^j_{D,t}(z) = \left(\frac{1}{\theta} - \mu^j_{D,t}\right) \left[p^j_{D,t}(z)\right]^{1-\theta} \left(C^j_t + G^j_t\right),$$

$$D^j_{Xi,t}(z) = \begin{cases} \left(\frac{1}{\theta} - \mu^i_{X,t}\right) E^j_{i,t} \left[p^j_{Xi,t}(z)\right]^{1-\theta} \left(C^i_t + G^i_t\right) \\ \quad - \frac{W^j_t}{Z^j_t \left(K^j_t\right)^{\alpha}} f^j_{Xi,t}, \\ \text{if firms export to Country } i \ 0, \text{ otherwise,} \end{cases}$$

[9] A melting-iceberg trade cost means that $\tau^j_{Xi,t}$ units must be shipped from Country j to Country i for one unit of goods to be delivered. Firms in Country j also require to pay a sunk cost of $f^j_{Xi,t}$ in every period while exporting their goods to Country i. $f^j_{Xi,t}$ can be regarded as the cost of forming a distribution and service network in a foreign country.

[10] See Figure 1.

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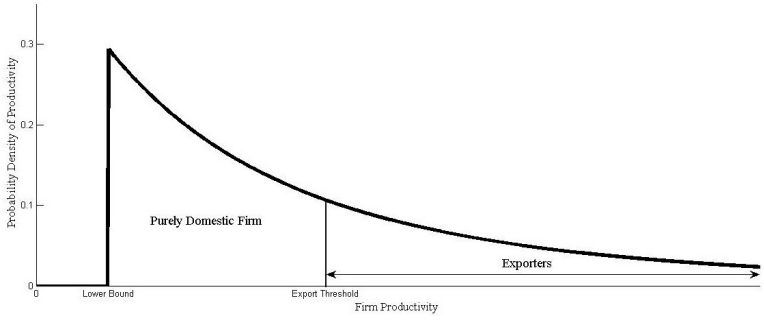


Figure 1: The behavior of firms in two competing countries

and $\mu^j_{D,t}$ is the sales tax levied on firms' domestic sales in Country j; $(C^j_t + G^j_t)$ is the aggregate demand in Country j; and $\mu^i_{X,t}$ is the import tariff charged by Country i's government.

Firms shall not export to other countries unless they are earning non-negative profits. Firms shall become exporters only if their idiosyncratic productivity z are above a cutoff level $z^j_{Xi,t} = \inf\{z : d^j_{Xi,t}(z) > 0\}$. We can calculate the export cutoff level for firms in Country j exporting to Country i:

$$z^j_{Xi,t} = \frac{\theta}{\theta - 1}\tau \left(\frac{\theta}{1 - \theta\mu^i_{X,t}} \frac{f^j_{Xi,t}}{C^i_t + G^i_t} \right)^{\frac{1}{\theta-1}} \left[\frac{1}{E^j_{i,t}} \frac{W^j_t}{Z^j_t \left(K^j_t\right)^{\alpha}} \right]^{\frac{\theta}{\theta-1}},$$
$$j \in (A, B), \quad i \in (A, B, C), \quad i \neq j. \tag{3}$$

2.3.2 Firm's choice in the third country

We assume that only firms in Country C can serve foreign markets, either through exports or local subsidiary sales (horizontal FDI). If one firm opts to export, it bears additional fixed costs per foreign market with a melting-iceberg trade cost. If it opts to serve a foreign market via local subsidiary sales, it bears additional higher fixed costs $f^C_{Fj,t}$ in terms of effective units of labor in every foreign market.[11] This choice is driven by the proximity-concentration tradeoff (Helpman, Melitz, and Yeaple, 2004): relative to ex-

[11] The fixed costs $f^C_{Fj,t}$ include not only the cost of forming a distribution and servicing network but also the costs of establishing a subsidiary in a foreign country.

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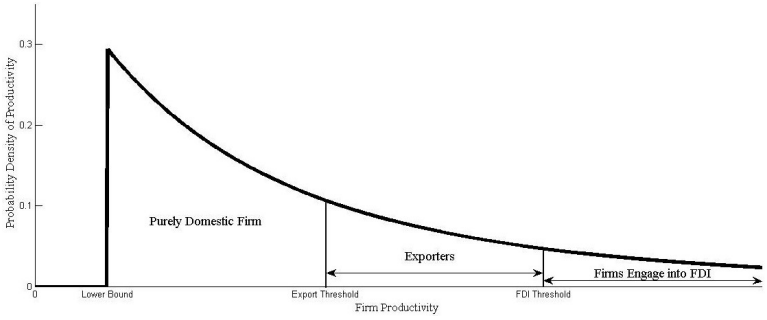


Figure 2: The behavior of firms in the investing country

ports, FDI saves on transport costs but duplicates production facilities and thus requires higher fixed costs. In equilibrium, no firm engages in both activities for the same foreign market.[12] Let $p^C_{D,t}(z)$ denotes the domestic price of a Country C's firm; $p^C_{Xj,t}(z)$ denotes the export price of a Country C's exporter in Country j's market; $p^C_{Fj,t}(z)$ denote the prices set by Country C's firms that serve Country j's market via FDI and $s^j_{V,t}$ denotes a variable cost subsidy offered by Country j; they are given by:

$$p^C_{D,t}(z) = \frac{\theta}{\theta-1}\frac{W^C_t}{Z^C_t\left(K^C_t\right)^{\alpha}}\frac{1}{z},\ p^C_{Xj,t}(z) = \frac{1}{E^C_{j,t}}\frac{\theta}{\theta-1}\tau\frac{W^C_t}{Z^C_t\left(K^C_t\right)^{\alpha}}\frac{1}{z},$$

$$p^C_{Fj,t}(z) = \frac{\theta}{\theta-1}\frac{\left(1-s^j_{V,t}\right)W^j_t}{Z^j_t\left(K^j_t\right)^{\alpha}}\frac{1}{z},\quad j\in(A,B).$$

When deciding to serve another country via local subsidiary sales, a firm in Country C decomposes its total profit into portions earned from domestic sales, potential export sales, and potential local subsidiary sales. Total profits in period t are given by:

$$D^C_t(z) = D^C_{D,t}(z) + \Sigma_j D^C_{Xj,t} + \Sigma_j D^C_{Fj,t}(z),\quad j\in(A,B),$$

where

$$D^C_{D,t}(z) = \left(\frac{1}{\theta}-\mu^C_{D,t}\right)\left[p^C_{D,t}(z)\right]^{1-\theta}\left(C^C_t+G^C_t\right),$$

[12] See Figure 2.

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$$D^C_{Xi,t}(z) = \begin{cases} \left(\frac{1}{\theta} - \mu^j_{X,t}\right) E^C_{j,t}\left[p^C_{Xj,t}(z)\right]^{1-\theta}\left(C^j_t + G^j_t\right) \\ \quad -\frac{W^C_t}{Z^C_t (K^C_t)^\alpha} f^C_{Xj,t}, \\ \text{if export to Country } j \ 0, \text{otherwise,} \end{cases}$$

$$D^C_{Fj,t}(z) = \begin{cases} E^C_{j,t}\left\{\left(\frac{1}{\theta} - \mu^j_{F.t}\right)\left[p^C_{Fj,t}(z)\right]^{1-\theta}\left(C^j_t + G^j_t\right)\right. \\ \quad \left. -\frac{W^j_t}{Z^j_t\left(K^j_t\right)^\alpha}\left(1 - s^j_{F,t}\right) f^C_{Fj,t}\right\}, \\ \text{if do FDI in Country } j \ 0, \text{otherwise,} \end{cases}$$

where $\mu^j_{F.t}$ is the sales tax levied by the government in Country j, and $s^j_{F,t}$ denotes a fixed cost subsidy offered by Country j.

A firm serves Country j by local subsidiary sales if and only if it would earn more profits from subsidiary sales then export to the market in Country j. For firms in Country C, this would be the case so long as productivity z is above the cutoff level: $z^C_{Fj,t} =\in f\{z : d^C_{Fj,t}(z) > d^C_{Xj,t}(z)\}$. We define $\mathrm{TOL}^i_{k,t} = E^i_{k,t}[(W^k_t/Z^k_t(K^k_t)^\alpha)/(W^i_t/Z^i_t(K^i_t)^\alpha)]$ $(k \in i, k \neq i)$ to be the terms of labor between Country i and the other Country k, allowing us to measure the relative cost of effective units of labor between countries. Then, we also can calculate the FDI cutoff level for firms to engage in FDI in Country j:

$$z^C_{Fj,t} = \frac{\theta}{\theta - 1}\left[\frac{\left(1 - s^j_{F,t}\right) f^C_{Fj,t} - \frac{f^C_{Xj,t}}{\mathrm{TOL}^C_{j,t}}}{\left(1 - s^j_{V,t}\right)^{1-\theta}\left(\frac{1}{\theta} - \mu^j_{F,t}\right) - \left(\frac{1}{\theta} - \mu^j_{X,t}\right)\left(\frac{\tau}{\mathrm{TOL}^C_{j,t}}\right)^{1-\theta}}\right.$$
$$\left.\frac{1}{C^j_t + G^j_t}\right]^{\frac{1}{\theta-1}}\left[\frac{W^j_t}{Z^j_t\left(K^j_t\right)^\alpha}\right]^{\frac{\theta}{\theta-1}}, \quad j \in (A, B). \tag{4}$$

2.4 Firm averages

Given a distribution $H(z)$, there is a mass $N^j_{D,t}$ of firms producing goods with a distribution of productivity levels over $[z_{\min}, \infty)$ in Country j every period. Among these firms $N^j_{D,t}$, there are only $N^j_{Xi,t} = [1 - H(z^j_{Xi,t})]N^j_{D,t}$ exporters to service Country i because exporting is costly and only the firm

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with productivity higher than the cutoff productivity can earn nonnegative profit from doing so. Thus, we defined two average productivity levels: One is an average productivity level ($\tilde{z}_D^j$) for all of Country j's firms producing domestic goods. The other is an average productivity level ($\tilde{z}_{Xi,t}^j$) for all of Country j's exporters serving Country i, given by:

$$z_D^j = \left[\int_{z_{\min}^j}^{\infty} z^{\theta-1} dH(z)\right]^{\frac{1}{\theta-1}},$$

$$z_{Xi,t}^j = \left[\frac{1}{1-H\left(z_{Xi,t}^j\right)}\int_{z_{\min}^j}^{\infty} z^{\theta-1} dH(z)\right]^{\frac{1}{\theta-1}},$$

$$j \in (A, B), \quad i \in (A, B, C), \quad j \neq i.$$

In contrast, there are $N_{Xj,t}^C = [H(z_{Fj,t}^C) - H(z_{Xj,t}^C)]N_{D,t}^C$ firms in Country C exporting to Country j and $N_{Fj,t}^C = [1 - H(z_{Fj,t}^C)]N_{D,t}^C$ firms serving Country j via FDI among the mass $N_{D,t}^C$ of Country C's producing firms because the firm in Country C can service foreign markets via FDI if it can earn more profits than exporting. We also define three average productivity levels.[13] One is an average productivity level ($\tilde{z}_D^C$) for all the firms of the third country producing domestic goods. One is an average productivity level ($\tilde{z}_{Xj,t}^C$) for all exporters serving Country j. The last one is an average productivity level ($\tilde{z}_{Fj,t}^C$) for all firms engaging into FDI in Country j, given by:

$$\tilde{z}_D^C = \left[\int_{z_{\min}^C}^{\infty} z^{\theta-1} dH(z)\right]^{\frac{1}{\theta-1}},$$

$$\tilde{z}_{Xj,t}^C = \left[\frac{1}{H\left(z_{Fj,t}^C\right) - H\left(z_{Xj,t}^C\right)}\int_{z_{\min}^C}^{\infty} z^{\theta-1} dH(z)\right]^{\frac{1}{\theta-1}},$$

[13] Since these average productivity levels which based on weights proportional to relative firm output shares summarize all of the information about the distribution of productivities, our model is similarity to one where $N_{D,t}^i$ firms with productivity level $\tilde{z}_D^i$ produce domestically, and $N_{Xk,t}^i$ firms with productivity level $\tilde{z}_{Xk,t}^i$ export to the Country k's market and $N_{Fj,t}^C$ with productivity level $\tilde{z}_{Fj,t}^C$ do FDI in the Country j's market.

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$$\tilde{z}^C_{Fj,t} = \left[\frac{1}{1 - H\left(z^C_{Fj,t}\right)} \int_{z^C_{\min}}^{\infty} z^{\theta-1} dH(z) \right]^{\frac{1}{\theta-1}}, \quad j \in (A, B).$$

Given these averages, we use $\tilde{p}^i_{D,t} \equiv p^i_{D,t}(\tilde{z}^i_D)$ to represent the average price of Country i's firms in their domestic market and $\tilde{p}^i_{Xk,t} \equiv p^i_{Xk,t}(\tilde{z}^i_{Xk,t})$ to represent the average price of Country i's exporters serving Country k. We define $\tilde{p}^C_{Fj,t}$ to represent the average price set by Country C's firms serving Country j's market via local subsidiary sales. Therefore, the price index for Country j reflects the prices of $N^j_{D,t}$ domestic firms (with an average price $\tilde{p}^j_{D,t}$), the $N^i_{Xj,t}$ exporters from Country i (with an average price $\tilde{p}^i_{Xj,t}$) and the $N^C_{Fj,t}$ local subsidiaries from Country C (with an average price $\tilde{p}^C_{Fj,t}$). We can write the price index in Country j as:

$$N^j_{D,t}\left(\tilde{p}^j_{D,t}\right)^{1-\theta} + \Sigma_i N^i_{Xj,t}\left(\tilde{p}^i_{Xj,t}\right)^{1-\theta} + N^C_{Fj,t}\left(\tilde{p}^C_{Fj,t}\right)^{1-\theta} = P_t^{j},$$
$$j \in (A, B), \quad i \in (A, B, C), \quad j \neq i,$$

The price index in Country C can be written as:

$$N^C_{D,t}\left(\tilde{p}^C_{D,t}\right)^{1-\theta} + \Sigma_j N^j_{XC,t}\left(\tilde{p}^j_{XC,t}\right)^{1-\theta} = P_t^{C}, \quad j \in (A, B).$$

These price indices are equivalent to:

$$N^j_{D,t}\left(\tilde{\rho}^j_{D,t}\right)^{1-\theta} + \Sigma_i N^i_{Xj,t}\left(\tilde{\rho}^i_{Xj,t}\right)^{1-\theta} + N^C_{Fj,t}\left(\tilde{\rho}^C_{Fj,t}\right)^{1-\theta} = 1,$$

$$N^C_{D,t}\left(\tilde{\rho}^C_{D,t}\right)^{1-\theta} + \Sigma_j N^j_{XC,t}\left(\tilde{\rho}^j_{XC,t}\right)^{1-\theta} = 1,$$

where $\tilde{\rho}^j_{D,t} \equiv (p^i_{D,t}(\tilde{z}^i_D)/P^i_t)$ denotes the average real price of Country j's firms in their domestic market, and $\tilde{\rho}^i_{Xj,t} \equiv (p^i_{Xj,t}(\tilde{z}^i_{Xj,t})/P^j_t)$ denotes the average real price of Country i's exporters serving Country j and $\tilde{\rho}^C_{Fj,t} \equiv (p^C_{Fj,t}(\tilde{z}^C_{Fj,t})/P^j_t)$ denotes the average real price set by Country C's firms serving Country j's market via FDI.[14]

[14] $\rho^i_{D,t}(z^i_D) = (p^i_{D,t}(z^i_D)/P^i_t)$, $\rho^i_{Xk,t}(z^i_{Xk,t}) = (p^i_{Xk,t}(z^i_{Xk,t})/P^k_t)$ and $\rho^C_{Fj,t}(z^C_{Fj,t}) = (p^C_{Fj,t}(z^C_{Fj,t})/P^j_t)$ denote the real price of good, expressed in real terms relative to the price index in the destination market.

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Also, we use $\tilde{d}^i_{D,t} \equiv (d^i_{D,t}(\tilde{z}^i_D)/P^i_t)$ to represent the firm's average real profit from domestic sales for all of Country i's producers, and $\tilde{d}^i_{Xk,t} \equiv (d^i_{Xk,t}(\tilde{z}^i_{Xk,t})/P^i_t)$ to represent the firm's average real export profits for all Country is exporters serving to Country k. $\tilde{d}^C_{Fj,t} \equiv (d^C_{Fj,t}(\tilde{z}^C_{Fj,t})/P^C_t)$ is the firm's average real profits earned from FDI sales in Country j.[15] Thus, $\tilde{d}^j_t$ represents the average real total profits of Country j and $\tilde{d}^C_t$ represents the average real total profits of Country C, given by:

$$\tilde{d}^j_t \equiv \tilde{d}^j_{D,t} + \Sigma_i \left[1 - H\left(z^j_{Xi,t}\right)\right] \tilde{d}^i_{Xj,t}, \quad j \in (A, B), \quad i \in (A, B, C), \quad j \neq i,$$

$$\tilde{d}^C_t \equiv \tilde{d}^C_{D,t} + \Sigma_j \left[H\left(z^C_{Fj,t}\right) - H\left(z^C_{Xj,t}\right)\right] \tilde{d}^C_{Xj,t} + \Sigma_j \left[1 - H\left(z^C_{Fj,t}\right)\right] \tilde{d}^C_{Fj,t}, \quad j \in (A, B).$$[16]

2.5 Firm entry and exit

Using a stochastic discount factor for domestic households adjusted by exogenous exit shock, the prospective entrants compute the stream of their expected profits $\{\tilde{d}^i_s\}^{\infty}_{s=t+1}$. The expected value is given by:

$$\tilde{v}^i_t = E_t \left[\Sigma^{\infty}_{s=t+1} [\beta(1-\delta)]^{s-t} \left[\frac{C^i_{t+1} + \zeta \psi^i_{t+1} G^i_{t+1}}{C^i_t + \zeta \psi^i_t G^i_t} \right]^{-\gamma} \tilde{d}^i_s \right], \quad i \in (A, B, C).$$

Entry occurs until this expected value equalizes the entry cost, leading to the free entry condition:

$$\tilde{v}^i_t = \frac{w^i_t}{Z^i_t \left(K^i_t\right)^{\alpha}} f^i_{E,t}.$$

The number of Country is firms producing during period $t+1$ is equal to the number of survivors from the set of firms in the previous period:

$$N^i_{D,t+1} = (1-\delta)(N^i_{D,t} + N^i_{E,t}), \quad i \in (A, B, C),$$

[15] $d^i_{D,t}(z^i_D) = (D_(D,t)^i(z^i_D)/P^i_t)$, $d^i_{Xk,t}(z^i_{Xk,t}) = (D^i_{Xk,t}(z^i_{Xk,t})/P^i_t)$ and $d^C_{Fj,t}(z^C_{Fj,t}) = (D^C_{Fj,t}(z^C_{Fj,t})/P^C_t)$ denote the real profit from each sale, expressed in real-term units of the consumption basket in the firm's home country.

[16] $[1 - H(z^j_{Xi,t})]$ represent the proportion of Country j's firms that export to Country i and earn export profits. $[H(z^C_{Fj,t}) - H(z^C_{Xj,t})]$ and $[1 - H(z^C_{Fj,t})]$ denote the proportion of Country C's firms that export to Country i or do FDI in Country i.

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where $N^i_{E,t}$ denotes the new entry firms at time t.

2.6 Household budget constraint

The representative household lives for an infinite number of periods and can invest in two types of assets: shares in the mutual fund of domestic firms and bonds traded domestically and internationally. The mutual fund pays a total profit in each period equal to the average total profit earned by all home firms in that period. The Country i's mutual fund finances all of Country i's incumbent firms and new entrants during period t because the representative household does not know the exogenous exit shock will hit which firms at the end of period t. Let x^i_t be the shares in Country i's mutual fund held by Country i's representative household at entering period t. Country i's representative household buys x^i_{t+1} shares in Country i's mutual fund of $N^i_{H,t} = N^i_{D,t} + N^i_{E,t}$ firms, but only $(1-\delta^i)$ of these firms will produce and pay dividends at period $t+1$. The price of a claim to the future profit stream of the mutual fund is equal to the average price of claims to the future profits of Country i's firms at period t.

We also assume that international bond markets are incomplete, so that only risk-free bonds are traded across countries. The bonds issued by Country i's households are denominated in Country i's currency. Country i's households are charged fees by Country i's financial intermediaries when households adjust their bond holdings. These fees are calculated via a quadratic function of the stock of bond holdings.[17] To focus on the impact of fiscal policy, we simplify the functions of financial intermediaries. Hence, we assume that Country i's financial intermediaries rebate all revenues from bond-adjustment fees to Country i's households at the end of every period.

The budget constraint in period t is:

$$\begin{aligned} & C^i_t + x^i_{t+1} N^i_{H,t} \tilde{v}^i_t + B^i_{i,t+1} + \frac{\eta}{2}\left(B^i_{i,t+1}\right)^2 \\ & \quad + \Sigma_i \left[Q^i_{k,t} B^k_{i,t+1} + \frac{\eta}{2} Q^i_{k,t} \left(B^k_{i,t+1}\right)^2 \right] \\ & \qquad = \left(1-\mu^i_{W,t}\right) w^i_t L^i_t + x^i_t N^i_{D,t} \left(\tilde{v}^i_t + \tilde{d}^i_t\right) + \left(1+r^i_t\right) B^i_{i,t} \end{aligned}$$

[17] We assume that households must pay fees to domestic financial intermediaries when adjusting their bond holdings. Under this assumption, it is not only sufficient to uniquely pin down the steady-state and deliver stationary model dynamics in response to temporary shocks but also induces a very small impact on model dynamics.

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$$+ \Sigma_i \left[Q^i_{k,t} \left(1 + r^k_t\right) B^k_{i,t} \right] + T^i_t - LS^i_t,$$
$$i \in (A, B, C), \quad k \in (A, B, C), \quad k \neq i,$$

where $B^i_{i,t+1}$ denotes the holdings of bonds issued by Country i's households; $B^k_{i,t+1}$ denotes holdings of bonds issued by Country k's households; $\eta/2(B^i_{i,t+1})^2$ is the cost of adjusting the holdings of bonds issued by Country i's households; $\eta/2Q^i_{k,t}(B^k_{i,t+1})^2$ is the cost of adjusting the holdings of bonds issued by Country k's households; $T^i_t = \Sigma_i[(\eta/2)Q^i_{k,t}(B^k_{i,t+1})^2]$ denotes the fee rebate to the representative household; $\mu^i_{w,t}$ is the payroll tax levied on the domestic labor supply by Country i's government; LS^i_t is a lump-sum tax levied on the domestic households by Country i's government; r^i_t is the risk-free interest rate on holding Country i's bonds between period $t-1$ and t; r^k_t is the risk-free interest rate on holding Country k' bonds between period $t-1$ and t; and $Q^i_{k,t} \equiv E^i_{k,t}(P^k_t/P^i_t)$ is the real exchange rate.

The representative household maximizes the lifetime expected discounted utility subject to the budget constraint. The first-order conditions for C^i_t, L^i_t, $B^i_{i,t}$, $B^k_{i,t}$, and x^i_t are given by:

$$1 + \eta B^i_{i,t+1} = \beta \left(1 + r^i_{t+1}\right) E_t \left[\left(\frac{C^i_{t+1} + \zeta \psi^i_{t+1} G^i_{t+1}}{C^i_t + \zeta \psi^i_t G^i_t} \right)^{-\tau} \right], \quad (5)$$

$$1 + \eta B^k_{i,t+1} = \beta \left(1 + r^k_{t+1}\right) E_t \left[\frac{Q^i_{k,t+1}}{Q^i_{k,t}} \left(\frac{C^i_{t+1} + \zeta \psi^i_{t+1} G^i_{t+1}}{C^i_t + \zeta \psi^i_t G^i_t} \right)^{-\tau} \right]. \quad (6)$$

$$\tilde{v}^i_t = \beta(1-\delta) E_t \left[\left(\tilde{v}^i_{t+1} + \tilde{d}^i_{t+1} \right) \left(\frac{C^i_{t+1} + \zeta \psi^i_{t+1} G^i_{t+1}}{C^i_t + \zeta \psi^i_t G^i_t} \right)^{-\tau} \right], \quad (7)$$

$$L^i_t = \left(1 - \mu^i_{w,t}\right) w^i_t \left(C^i_t + \zeta \psi^i_t G^i_t\right)^{-\tau}. \quad (8)$$

Equations (5) and (6) are the Euler equations for holding bonds; Equation (7) is the Euler equation for holding shares; Equation (8) is the optimal labor supply in Country i.

2.7 Government budget constraint

We assume that to finance expenditure, the government levies three kinds of taxes; payroll tax-which is imposed on the domestic labor supply; sales tax-which is imposed on firms' domestic sales and local subsidiary sales; and a

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tariff which imposed on import goods. The government uses tax revenues to fund the public expenditure of these same goods. The government's budget constraints in each country are:

$$\begin{aligned} G_t^j + S_t^j = {} & LS_t^j + \mu_{w,t}^j w_t^j L_t^j + \mu_D^j N_{D,t}^j \left(\tilde{\rho}_{D,t}^j\right)^{1-\theta} \left(C_t^j + G_t^j\right) \\ & + \Sigma_i \mu_X^j N_{Xj,t}^i \left(\tilde{\rho}_{Xj,t}^i\right)^{1-\theta} \left(C_t^j + G_t^j\right) \\ & + \mu_F^j N_{Fj,t}^C \left(\tilde{\rho}_{Fj,t}^C\right)^{1-\theta} \left(C_t^j + G_t^j\right), \\ & j \in (A, B), \quad i \in (A, B, C), \quad j \neq i, \end{aligned} \tag{9}$$

$$\begin{aligned} G_t^C = {} & LS_t^C + \mu_{w,t}^C w_t^C L_t^C + \mu_D^C N_{D,t}^C \left(\tilde{\rho}_{D,t}^C\right)^{1-\theta} \left(C_t^C + C_t^C\right) \\ & + \Sigma_j \mu_X^C N_{XC,t}^j \left(\tilde{\rho}_{XC,t}^j\right)^{1-\theta} \left(C_t^C + G_t^C\right), \end{aligned} \tag{10}$$

where S_t^j denotes the fiscal cost of offering FDI subsidies by Country j.

2.8 General equilibrium and net foreign asset dynamics

The supplied labor units L_t^j are required by firms using to cover all fixed costs, including entry, export, and FDI, and to produce goods in Country j. This implies that:

$$\begin{aligned} L_t^j = {} & N_{E,t}^j \frac{f_{E,t}^j}{Z_t^j \left(K_t^j\right)^{\alpha}} + N_{D,t}^j \tilde{l}_{D,t}^j + \Sigma_i N_{Xi,t}^j \left[\tilde{l}_{Xi,t}^j + \frac{f_{Xi,t}^j}{Z_t^j \left(K_t^j\right)^{\alpha}}\right] \\ & + N_{Fj,t}^C \left[\tilde{l}_{Fj,t}^C + \frac{f_{Fj,t}^C}{Z_t^j \left(K_t^j\right)^{\alpha}}\right], \end{aligned}$$

where $\tilde{l}_{D,t}^j$ denotes the average variable labor demand for Country j's domestically producing firms, and $\tilde{l}_{Xi,t}^j$ denotes the average variable labor demand of Country j's exporting firms to service Country i's market in and $\tilde{l}_{Fj,t}^C$ denotes the average variable labor demand of Country C's firms to service Country j's market via FDI.

Similar, the supplied labor units L_t^C are demanded by firms using to cover the fixed costs of firm creation and exporting, and to produce goods in Country C, given as:

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$$L_t^C = N_{E,t}^C \frac{f_{E,t}^C}{Z_t^C \left(K_t^C\right)^\alpha} + N_{D,t}^C \tilde{l}_{D,t}^C + \Sigma_j N_{Xj,t}^C \left[\tilde{l}_{Xj,t}^C + \frac{f_{Xj,t}^C}{Z_t^C \left(K_t^C\right)^\alpha}\right],$$

where $\tilde{l}_{D,t}^C$ denotes the average variable labor demand of domestically producing firms in Country C, and $\tilde{l}_{Xj,t}^C$ denotes the average variable labor demand of Country C's exporting firms to service Country j's market. Using production function, the profit functions, and the pricing equations, we have:

$$\tilde{l}_{D,t}^i = \frac{\theta - 1}{1 - \theta \mu_{D,t}^i} \frac{1}{w_t^i} \tilde{d}_{D,t}^i, \tilde{l}_{Xk,t}^i = \frac{\theta - 1}{1 - \theta \mu_{X,t}^k} \left[\frac{1}{w_t^i} \tilde{d}_{Xk,t}^i + \frac{f_{Xk,t}^i}{Z_t^i \left(K_t^i\right)^\alpha}\right],$$

$$\tilde{l}_{Xj,t}^C = \frac{\theta - 1}{1 - \theta \mu_{F,t}^j} \left[\frac{1}{Q_{j,t}^C} \frac{1}{w_t^j} \tilde{d}_{Fj,t}^C + \frac{f_{Fj,t}^C}{Z_t^j \left(K_t^j\right)^\alpha}\right].$$

Since we assume that only Country i's households can issue Country i's currency bonds and households in Country i are identical and make identical choices, it requires that bonds issued by each country be in zero net supply worldwide in the equilibrium. The net supply of each bond equals zero:

$$B_{A,t+1}^A + B_{B,t+1}^A + B_{C,t+1}^A = 0, \tag{11}$$

$$B_{A,t+1}^B + B_{B,t+1}^B + B_{C,t+1}^B = 0, \tag{12}$$

$$B_{A,t+1}^C + B_{B,t+1}^C + B_{C,t+1}^C = 0. \tag{13}$$

The model is completed by considering net foreign asset dynamics. We can aggregate the budget constraint across households in Country i and impose the equilibrium condition ($x_{t+1}^i = x_t^i = 1$) to derive aggregate accountings of Country i:

$$\begin{aligned} &B_{A,t+1}^A + Q_{B,t}^A B_{A,t+1}^B + Q_{C,t}^A B_{A,t+1}^C \\ &\quad = \left(1 + r_t^A\right) B_{A,t}^A + Q_{B,t}^A \left(1 + r_t^B\right) B_{A,t}^B + Q_{C,t}^A \left(1 + r_t^C\right) B_{A,t}^C \\ &\qquad + \left(1 - \mu_{w,t}^A\right) w_t^A L_t^A + N_{D,t}^A \tilde{d}_t^A - N_{E,t}^A \tilde{v}_t^A - LS_t^A - C_t^A, \end{aligned} \tag{14}$$

$$\begin{aligned} &B_{B,t+1}^B + \frac{1}{Q_{B,t}^A} B_{B,t+1}^A + Q_{C,t}^B B_{B,t+1}^C \\ &\quad = \left(1 + r_t^B\right) B_{B,t}^B + \frac{1}{Q_{B,t}^A} \left(1 + r_t^A\right) B_{B,t}^A + Q_{C,t}^B \left(1 + r_t^C\right) B_{B,t}^C \end{aligned}$$

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$$+\left(1-\mu_{w,t}^{B}\right)w_t^B L_t^B + N_{D,t}^B \tilde{d}_t^B - N_{E,t}^B \tilde{v}_t^B - LS_t^B - C_t^B, \quad (15)$$

$$\begin{aligned} &B_{C,t+1}^C + \frac{1}{Q_{C,t}^A} B_{C,t+1}^A + \frac{1}{Q_{C,t}^B} B_{C,t+1}^B \\ &= \left(1+r_t^C\right) B_{C,t}^C + \frac{1}{Q_{C,t}^A}\left(1+r_t^C\right) B_{C,t}^A + \frac{1}{Q_{C,t}^B}\left(1+r_t^B\right) B_{C,t}^B \\ &\quad + \left(1-\mu_{w,t}^{C}\right)w_t^C L_t^C + N_{D,t}^C \tilde{d}_t^C - N_{E,t}^C \tilde{v}_t^C - LS_t^C - C_t^C. \end{aligned} \quad (16)$$

Since the whole world can be understood as a closed economy, world consumption must equal world labor income plus world net investment income.

Given the equilibrium conditions (11), (12), (13) and $Q_{C,t}^A = Q_{B,t}^A Q_{C,t}^B$, we multiply (15) times $Q_{B,t}^A$ and (16) times $Q_{C,t}^A$, then we subtract the resulting equations from (14) to yield an expression for Country A's net foreign asset accumulation as a function of interest income and the cross-country differentials between labor income, net investment income, and consumption:

$$\begin{aligned} &B_{A,t+1}^A + Q_{B,t}^A B_{A,t+1}^B + Q_{C,t}^A B_{A,t+1}^C \\ &\quad = \left(1+r_t^A\right) B_{A,t}^A + Q_{B,t}^A\left(1+r_t^B\right) B_{A,t}^B + Q_{C,t}^A\left(1+r_t^C\right) B_{A,t}^C \\ &\qquad + \frac{1}{2}\left[\left(1-\mu_{w,t}^{A}\right)w_t^A L_t^A - Q_{B,t}^A\left(1-\mu_{w,t}^{B}\right)w_t^B L_t^B\right. \\ &\qquad \left. - Q_{C,t}^A\left(1-\mu_{w,t}^{C}\right)w_t^C L_t^C\right] \\ &\qquad + \frac{1}{2}\left(N_{D,t}^A \tilde{d}_t^A - Q_{B,t}^A N_{D,t}^B \tilde{d}_t^B - Q_{C,t}^A N_{D,t}^C \tilde{d}_t^C\right) \\ &\qquad - \frac{1}{2}\left(N_{E,t}^A \tilde{v}_t^A - Q_{B,t}^A N_{E,t}^B \tilde{v}_t^B - Q_{C,t}^A N_{E,t}^C \tilde{v}_t^C\right) \\ &\qquad - \frac{1}{2}\left(LS_t^A - Q_{B,t}^A LS_t^B - Q_{C,t}^A LS_t^C\right) \\ &\qquad - \frac{1}{2}\left(C_t^A - Q_{B,t}^A C_t^B - Q_{C,t}^A C_t^C\right). \end{aligned}$$

Similarly, Country B's net foreign asset accumulation can be expressed as:

$$\begin{aligned} &B_{B,t+1}^B + \frac{1}{Q_{B,t}^A} B_{B,t+1}^A + Q_{C,t}^B B_{B,t+1}^C \\ &\quad = \left(1+r_t^B\right) B_{B,t}^B + \frac{1}{Q_{B,t}^A}\left(1+r_t^A\right) B_{B,t}^A + Q_{C,t}^B\left(1+r_t^C\right) B_{B,t}^C \end{aligned}$$

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$$
\begin{aligned}
&+\frac{1}{2}\left[\left(1-\mu_{w,t}^{B}\right)w_t^B L_t^B-\frac{1}{Q_{B,t}^{A}}\left(1-\mu_{w,t}^{A}\right)w_t^A L_t^A\right.\\
&\left.-Q_{C,t}^{B}\left(1-\mu_{w,t}^{C}\right)w_t^C L_t^C\right]\\
&+\frac{1}{2}\left(N_{D,t}^{B}\tilde{d}_t^B-\frac{1}{Q_{B,t}^{A}}N_{D,t}^{A}\tilde{d}_t^A-Q_{C,t}^{B}N_{D,t}^{C}\tilde{d}_t^C\right)\\
&-\frac{1}{2}\left(N_{E,t}^{B}\tilde{v}_t^B-\frac{1}{Q_{B,t}^{A}}N_{E,t}^{A}\tilde{v}_t^A-Q_{C,t}^{B}N_{E,t}^{C}\tilde{v}_t^C\right)\\
&-\frac{1}{2}\left(LS_t^B-\frac{1}{Q_{B,t}^{A}}LS_t^A-Q_{C,t}^{B}LS_t^C\right)\\
&-\frac{1}{2}\left(C_t^B-\frac{1}{Q_{B,t}^{A}}C_t^A-Q_{C,t}^{B}C_t^C\right).
\end{aligned}
$$

2.9 Exchange rate and terms of trade

The official statistics use consumer price indexes (CPI) to calculate the real exchange rate. However, the CPI-based price indexes do not account for changes in the number of product variety available to consumers. Under the constant elasticity of substitution product differentiation, the welfare-based price indexes can be decomposed into components reflecting average prices and product variety: $P_t^i=(N_t^i)^{1-\theta}\tilde{P}_t^i$, where N_t^i is the number of products available in Country i and reflects product variety in Country i; $\tilde{P}_t^i$ is an average nominal price for all available products sold in Country i.

Since the variety of products is determined endogenously in our model, we can not only define the CPI-based real exchange rate but also define the welfare-based real exchange rate. By definition, the CPI-based real exchange rate, $(\tilde{Q}_{k,t}^i=E_{k,t}^i(\tilde{P}_t^k/\tilde{P}_t^i))$, can deviate from the welfare-based real exchange rate, $(Q_{jk,t}^i=E_{k,t}^i(P_t^k/P_t^i))$. More precisely, the deviation is because of the relative changes in product variety: $Q_{k,t}^i=(N_t^i/N_t^k)^{1/\theta-1}\tilde{Q}_{k,t}^i$. Because endogenous entry crucially affects the evolution terms of trade, we also denote the terms of trade (the relative price of exports in terms of imports) as $\mathrm{TOT}_{k,t}^i=E_{k,t}^i(\tilde{P}_{Xk,t}^i/\tilde{P}_{Xi,t}^k)=(1/\mathrm{TOL}_{k,t}^i)(\tau_{Xk,t}^i/\tau_{Xi,t}^k)(\tilde{z}_{Xi,t}^k/\tilde{z}_{Xk,t}^i)$.

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Table 1: Parameter values in the DSGE model

Parameter	Description	Value
α	The productivity of public infrastructure	0.1
β	Discount factor	0.99
γ	Constant risk aversion	2
δ	Death shock	0.025
ζ	Substitution rate between private and public consumption	0.4
η	Adjusting costs of bond holdings	0.0025
θ	The elasticity of substitution among varieties	3.8
κ	Shape parameter	3.4
ξ	The depreciation rate of public infrastructure	0.05
τ	Coefficients of melting-iceberg trade cost	1.3

3 Labor Productivity Innovation

In this section, we explore the properties of our model via a numerical example. We compute impulse responses to a labor productivity shock because it is a common way in the DSGE model to discuss the model properties. Analyzing the dynamic response paths of labor productivity shock allows us to focus on the impact of productivity enhanced by an increase in public infrastructure, without considering the effect of fiscal cost. First, we adopt standard parameter choices in line with the literature, computing the values of endogenous variables in the long-run steady-state. Then, we log-linearize the system of equations around the long-run steady-state, numerically solving for the dynamic responses to exogenous shocks.

3.1 Calibration

Table 1 summarizes the parameter values using in the model. We define a period as a quarter and set the subjective discount factor (β) to 0.99. This is the standard choice for quarterly business cycle models and implies that the steady-state value of the interest rate (r) is 1%. As we interpret periods as quarters, the parameter of relative risk aversion (γ) is 2; this is also the standard choice. We assume that the utility provided by public consumption is low compared to that provided by private consumption and set the marginal rate of substitution between private and public consumption (ζ) equals 0.4

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(as in Ganelli and Tervala (2010)). The parameter for the bond adjustment cost (η) is 0.25%, which is small enough to avoid overstating the role of this friction in determining the dynamics but sufficient to generate stationarity in response to transitory shocks of our model. In the government sector, the productivity of public infrastructure, α, is set to 0.1 and the depreciation rate of public infrastructure, ξ, is to 5%, as in Rioja (2003). We assume that the initial stock of public infrastructure is 1 and the government levies lump-sum tax on domestic households to cover the level of maintenance expenditure.

In the firm sector, as per Ghironi and Melitz (2005), the elasticity of substitution among goods (θ) is 3.8, implying that the constant mark-up over the marginal cost is 35.7%.[18] The probability of a firm's bankruptcy (δ) is 2.5%, implying that the level of job destruction is 10% per year. The shape parameter of the Pareto distribution (κ) is 3.4. The parameter for the melting-iceberg trade cost (τ) is 1.3. We also set the fixed FDI cost faced by firms in Country C ($f^C_{Fj,t}$) equal to 62.5 percent of the per-period, one-quarter, amortized flow value of the entry cost and the fixed export cost faced by firms in Country C ($f^C_{Xj,t}$) equal to that is 16.2%.[19] Based on these values, the proportion of Country C's exporters matches the number reported in Bernard et al. (2003), while Bernard and Jensen (2007) report that only 1% of firms successfully undertake FDI. We set the fixed cost ($f^A_{Xi,t}$) faced by Country A's firms to export their goods equal to 0.8% of $(1-\beta(1-\delta)/\beta(1-\delta)f^A_{E,t}$ to roughly fit China's macro trade data that the ratio of export to GDP equal to 22%. Similarly, we calibrate the values of fixed costs of Country B's exporters ($f^B_{Xi,t}$) to match India's macro trade data.[20] If we maintain the same ratio of $f_{X,t}/f_{E,t}$ and $f_{F,t}/f_{E,t}$, the change in the value of the entry cost ($f_{E,t}$) does not affect any of the impulse responses. Thus, we set $f_{E,t}$ to 1 and normalize Z and $z_{\min}$ to 1 without loss of generality.

[18] Since we want to analyze the impact that Country A and B induce more Country C's firms in to become multinational corporations, the characteristics of firms in Country C play a key role in the simulation results. Country C can be regarded as a developed country in the real world in our theoretical model. Therefore, we calibrate the parameters of Country C's firms to match the empirical findings of Bernard et al. (2003).

[19] The amortized flow value of the entry cost is equal to $(1-\beta(1-\delta)/\beta(1-\delta))f^C_{E,t}$ for each period.

[20] We use the quarterly data in the gross domestic product and export from the IMF database.

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3.2 Impulse responses for the home country's labor productivity innovation

The solid lines in Figure 3 and 4 show the responses (percent deviations from steady-state) to a permanent 1% innovation in labor productivity in the home country (Country A). The vertical axis represents percentage deviations from the steady-state, and the horizontal axis shows the number of periods after the shock.

First, we consider the long-run impact of the home country's labor productivity innovation on key variables at home in the new steady-state. As higher productivity increases the profitability of firms producing at home, the home market becomes more attractive to prospective entrants relative to the last steady-state. The home market attracts a permanently higher number of entrants and then translates into the market with a permanently higher number of producers. As prospective entrants prefer to enter the home market, home labor units must appreciate relative to those in foreign countries to keep foreign labor used. These changes in terms of labor cause the relative price of non-traded goods at home to increase relative to those in foreign markets, leading to an appreciation of the CPI-based real exchange rate. The higher relative labor costs at home reduce the profitability of firms producing in the home market, but conversely increases that of firms producing in foreign markets. Hence, the cutoff for home firms to export to the competing country and the investing country both increase in the long-run. Conversely, the cutoffs for foreign firms to export to the home country drop in the long-run.

Then, because the shock is persistent, a positive wealth effect increases the demand for both domestic and foreign goods. The cutoff for firms in the investing country to serve the home market through local subsidiary sales also drops in the long-run because the higher relative labor costs at home are dominated by an increase in home aggregate demand. Only the domestic firms with relatively higher productivity export to the foreign market; foreign firms with relatively less productivity can earn positive profits from serving the home market through exports or local subsidiary sales. Changes in export cutoffs cause the average real price of imported goods to increase relative to foreign prices, leading to an appreciation in the CPI-based real exchange rate. Although the domestic exporters with relatively less productivity exit the market, the increase in $N^A_{D,t}$ leads to an overall increase in the number of $N^A_{XB,t}$ and $N^A_{XC,t}$. As an increase in the variety of products for

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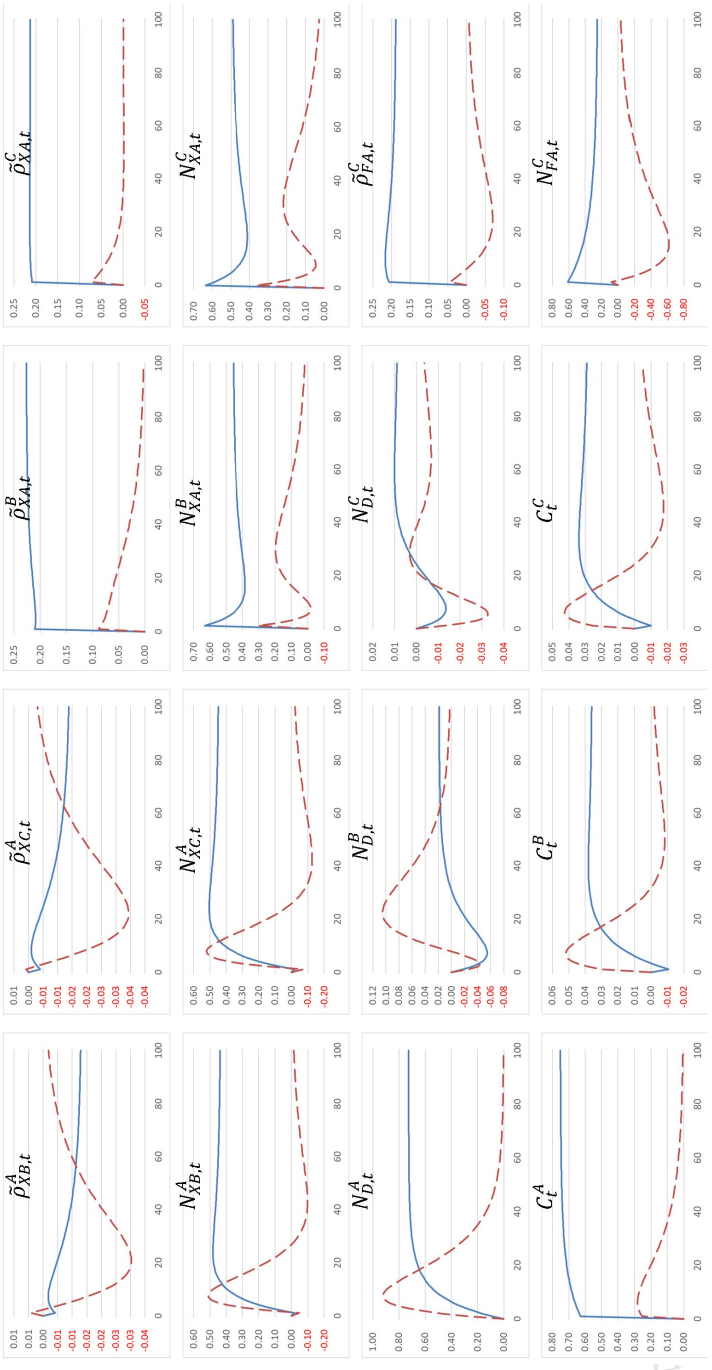


Figure 3: Impulse response to innovation in domestic labor productivity

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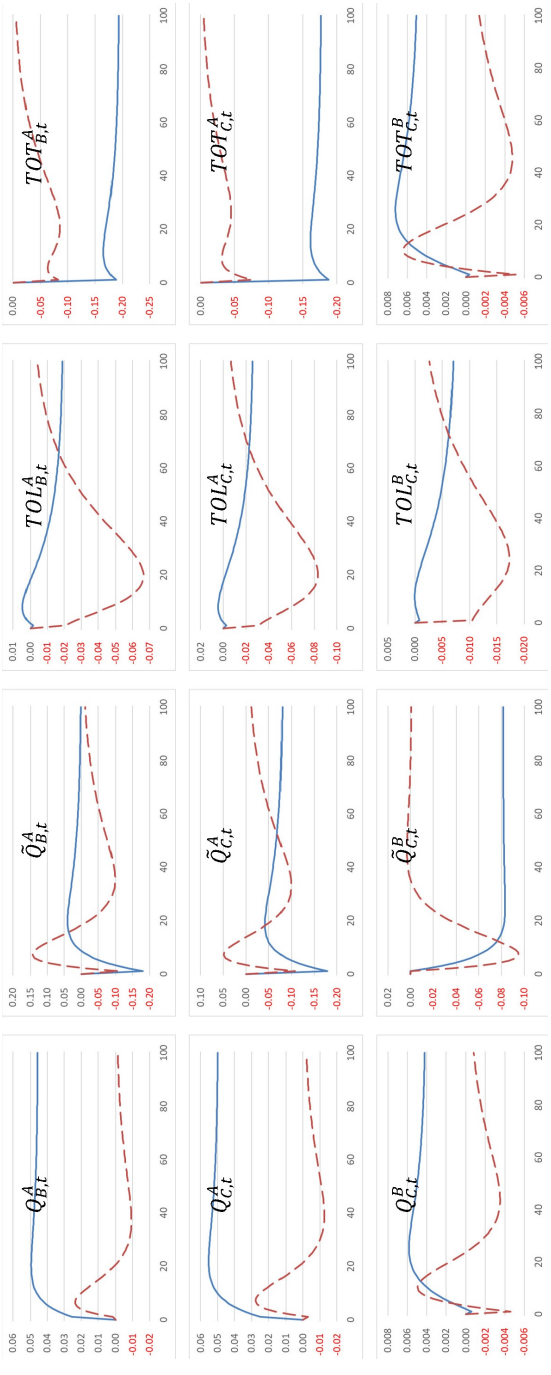


Figure 4: Impulse response to innovation in domestic labor productivity

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home consumers is generated by more entrants, home consumers switch their expenditures toward home-produced goods, leading to an appreciation of the CPI-based real exchange rate. Besides, the home market attracts more importers and foreign subsidiaries, because of the decreases in exports and FDI cutoffs for foreign firms.

As previously mentioned, a permanent increase in the home labor productivity induces appreciations in $\tilde{Q}^A_{B,t}$ and $\tilde{Q}^A_{C,t}$ in the long-run.[21] In our simulation, however, $Q^A_{B,t}$ and $Q^A_{C,t}$ still depreciate in the long run because the increase in product variety for home consumers dominates the appreciation of average price. The differences between these two real exchange rates imply that all consumers in the world prefer to spend a nominal expenditure in the home market, even if the average prices are relatively higher. The higher relative labor cost at home increases the export cutoffs at home and removes the relatively less productive firms from export markets. This effect increases the average productivity of home exporters and then induces a decrease in the average prices of home exporters in foreign markets. Conversely, the lower relative foreign labor cost reduces the average productivity of foreign exporters in the home market, inducing an increase in the average prices of foreign exporters in the home market. Changes in the average prices of exported and imported goods at home corrode $\mathrm{TOT}^A_{B,t}$ and $\mathrm{TOT}^A_{C,t}$ in the long-run.

Next, we analyze the transitional changes at home in response to a permanent innovation in the labor productivity of the home country. After the shock, relative higher labor productivity creates a more favorable business environment at home and induces home households to borrow from abroad to finance their extra higher investment demand. Although we assume that only bonds can be traded across countries and that foreigners cannot hold shares in the mutual funds of home firms, foreign households share the benefits of higher home labor productivity by lending to the households in the home country. This is because the return on holding a home bond is tied to the return on holding a share in home firms by no-arbitrage condition be-

[21] Ghironi and Melitz (2005) point out three important channels for real exchange rate changes. First, a change in the relative cost of effective labor units leads to relative price differences for nontraded goods among countries. Second, a change in the export productivity cutoffs results in changes in relative import prices. Third, a change in the relative availability of domestic and imported varieties induces expenditure switching effects for the real exchange rate.

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tween bonds and shares within the home country. As home households have a motivation to borrow from abroad; foreign households have an incentive to invest in higher productivity firms. The home country runs a current account deficit and accumulates a net foreign debt after the shock. Thus, a greater number of home entrants induce an instant relative increase in the home labor demand and grows home labor units relative to foreign labor units. These changes in terms of labor immediately escalate $\tilde{Q}^A_{B,t}$ and $\tilde{Q}^A_{C,t}$. In our model, however, $Q^A_{B,t}$ and $Q^A_{C,t}$ still depreciate in the short-run because of the increase in product variety, for home consumers dominates the average price appreciation.

We consider the long-run impact of the home country's labor productivity innovation on the key variables in foreign countries. As previously described, an increase in home labor productivity raises the profitability of foreign firms exporting to the home market, encouraging more foreign producers to serve the home market. Besides, the home country attracts more foreign producers to serve its market through local subsidiary sales. These results increase the average total profit of foreign producers, attracting some entrants into the foreign market. This leads to an increase in the number of foreign producers. Hence, the labor demand generated by more producers in each foreign country appreciates the costs of labor units. The increase in foreign labor cost reduces the profitability of foreign producers serving the other foreign market and therefore enhances the export and FDI cutoffs. As the cutoffs rise, exporters and subsidiaries decline in number. Because only the investor's producers can serve other countries through exports and local subsidiarity sales, the average total profit of the investor's firms increases more than that of the competitor's firms after the innovation of home labor productivity. Therefore, the investor's market attracts more new entrants and induces more labor demand than does the competitor's market. This result grows the investor's labor units and shrinks both $\tilde{Q}^B_{C,t}$ and $Q^B_{C,t}$ in the long-run. The appreciation of the investor's labor units also leads to the deterioration of $\mathrm{TOT}^B_{C,t}$ because relatively less productive firms can profitably engage in FDI in the competitor's market as the relatively lower labor costs there.

We describe the transitional changes in the foreign country in response to a permanent innovation in the labor productivity of the home country. After a shock, foreign households transfer their savings from their domestic mutual funds to the home country's bonds. This immediately reduces the numbers of foreign entrants relative to the last steady-state, withdraw-

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ing many producers in the foreign market in the short-run. Although the home market becomes a more attractive place after labor productivity increases, this attractiveness is immediately offset by the higher relative cost of labor units in the home country. Foreign households have an incentive to adjust their net foreign asset positions to smooth the effect of a transitory fluctuation in income. Thus, foreign private consumption decreases instantly. From this point, the depreciation of foreign labor units reverse the initial change in $N^B_{E,t}$ and $N^C_{E,t}$. This is because the lower relative cost of labor units increases the profitability of foreign firms and encourages foreign households to hold more shares in the mutual fund of foreign firms. It also reverses the initial change in C^B_t and C^C_t.

Finally, we describe the endogenous persistence properties of our model by illustrating the impulse responses to a transitory increase in home labors' productivity. We assume that labor productivity is time-variant and that it follows an auto-regressive process of degree one in each country: $Z^i_t = 0.9Z^i_{t-1}$, $\forall t > 0$. The persistence factor equaling 0.9 implies that the impacts are reabsorbed forty periods (i.e., ten years) after the shock. The broken line in Figure 3 and 4 shows the impulse responses of key endogenous variables to a transitory 1% increase in home labor productivity. Because all endogenous variables are stationary in response to stationary exogenous shocks, the transitory increase in labor productivity of the home country has no permanent effect. However, the effect of the home labor productivity shock on key endogenous variables persist than forty periods. It is because an exogenous increase in labor productivity enhances the accumulation of public infrastructure, and the increase in the accumulation of public infrastructure raises home labor productivity again.

4 The Effect of Using Fiscal Policy to Attract FDI

To attract FDI, host governments offer many forms of investment incentives. A higher level of public spending and lower tax rates are the most common policy strategies for countries used to promote local competitiveness in the real world. In the first subsection, we analyze the effect of a permanent increase in public investment on the amount of FDI, aggregate consumption, and other keys. We assume that to increase public investment, a government decreases public consumption, increases the payroll tax, or raises the import tariff. In the second subsection, we analyze the effect of tax reduction and FDI subsidy on the amount of FDI, aggregate consumption, and other key

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variables.

4.1 Public investment

The home country can provide a higher level of infrastructure, which enhances firm productivity by increasing public investment. In this subsection, we assume that a government finances the expenditure on public investment by reducing public consumption, by increasing the payroll tax, or by raising the import tariff. Figure 5 and 6 illustrates the responses to a permanent increase in the home country's public investment. Solid lines show a permanent 1% increase in the rate of public expenditure on public investment, which is financed by a permanent 1% decrease in the rate of public expenditure on public consumption. Broken lines show a permanent 1% increase in the payroll tax rate that finances the increase in public expenditure. Dotted lines show a permanent 1% increase in the import tariff rate, which finances the increase in public expenditure.

When the home country increases public investment by reducing public consumption or by increasing the payroll tax, the shock increases the productivity of firms producing at home. Because of a permanent increase in productivity, the long-run impact on the key variables is qualitatively similar to that of a permanent innovation to labor productivity. As earlier alluded to, the home market becomes a relatively more attractive business environment, luring more entrants. The labor demand generated by a greater number of home firms increases the number of home labor units, increasing the cutoff for home exporters in the long-run. These results lead $\tilde{Q}^A_{B,t}$ and $\tilde{Q}^A_{C,t}$ to appreciate, while $\mathrm{TOT}^A_{B,t}$ and $\mathrm{TOT}^A_{C,t}$, deteriorate in the long-run. However, $Q^A_{B,t}$ and $Q^A_{C,t}$ still depreciate in the long run because the increase in product variety for home consumers dominates the appreciation of average price.

By general intuition, an increase in the accumulation of public infrastructure enhances the profitability of firms producing in the home market and encourages more foreign firms to engage in FDI in the home country. The increase in home aggregate demand (private consumption plus public consumption) caused by the shock also attracts more foreign firms to serve the domestic market. However, the rise in home labor units caused by the shock raises the FDI cutoff, impeding foreign FDI in the domestic market. In our simulation, the net result of increasing public investment attracts more FDI, but the effect is reduced by the appreciation of home labor units.

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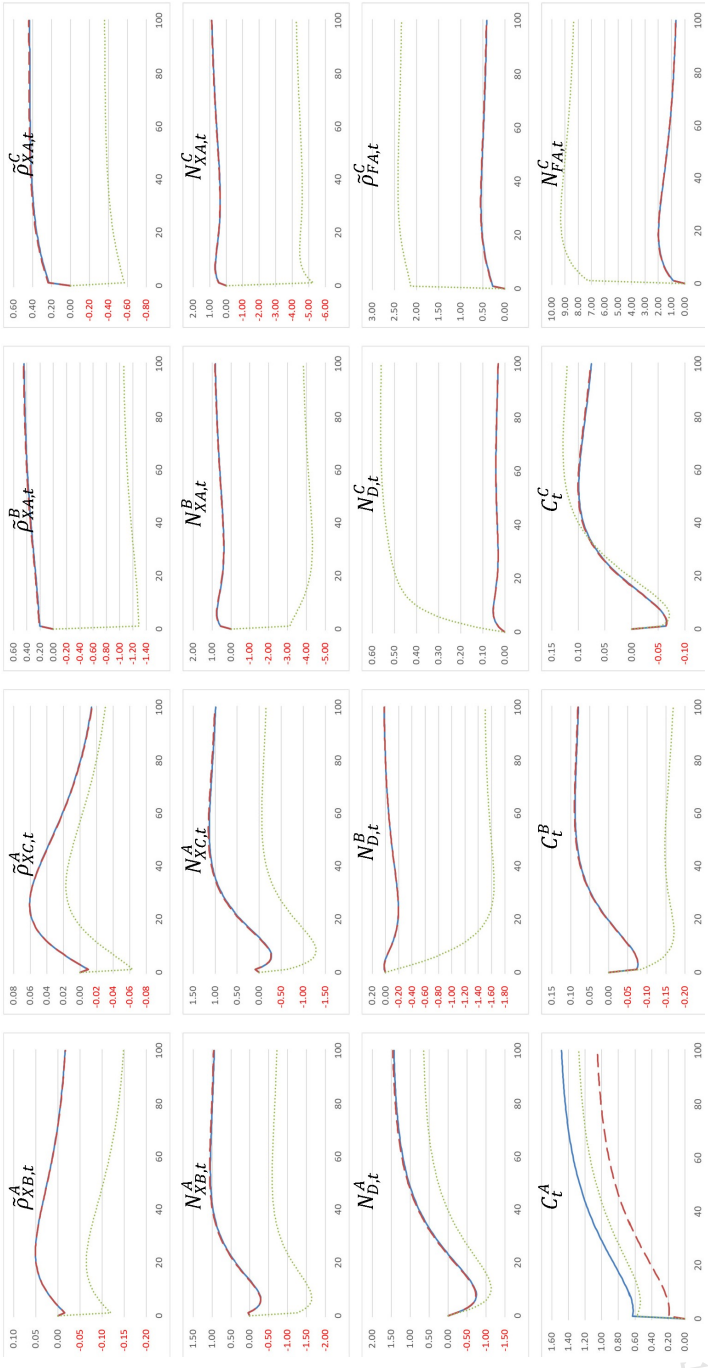


Figure 5: Impulse response to a permanent increase in domestic public investment

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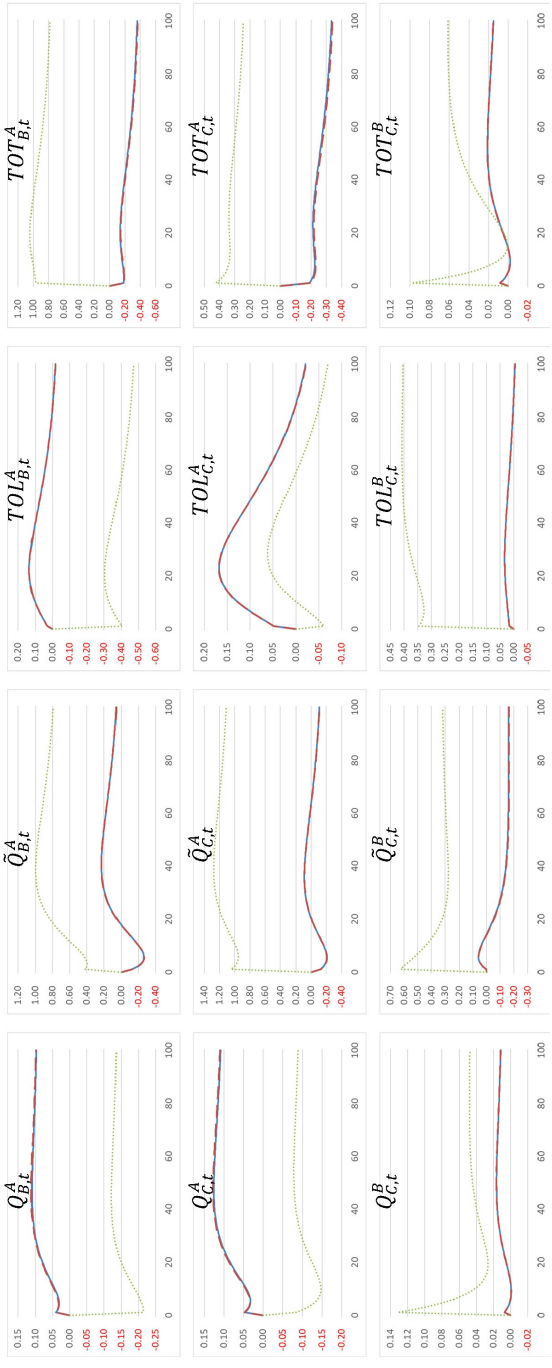


Figure 6: Impulse response to a permanent increase in domestic public investment

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If the home labor supply is inelastic, the rise in home labor units can even counteract the increase in home public infrastructure, reducing the amount of FDI in the home country. An increase in public investment can impede foreign firms to engage in FDI in the home country, which depends on incorporating endogenous entry in our model. Without endogenous entry, the number of home labor units would depreciate in response to an increase in aggregate productivity caused by more public investment. Here, the home country would attract more FDI. Our simulations also show that an increase in home aggregate demand and an appreciation of home labor units lead the terms of trade to deteriorate further, but the depreciation of the welfare-based real exchange rates has the opposite effect.

A permanent increase in labor productivity of the home country has notable consequences at home and in the competitor's country. After the shock, the home country attracts more FDI whereas the amount of FDI decreases in the competitor's country in the long-run. The aggregate production and aggregate demand at home both increase and the rates of this increase are larger than those for the competitor's country. When public investment increases via a reduction in public consumption, the amount of private consumption at home and in the competitor's country both increase. Only the home country's private consumption decreases when public investment increases via a payroll tax raise. The international trade between the home country and the investor's country becomes more active than that between the competitor and the investor's country. The terms of trade, $\mathrm{TOT}^{A}_{C,t}$, deteriorates, and the rate of decrease is larger than that of $\mathrm{TOT}^{B}_{C,t}$. The CPI-based real exchange rate $\tilde{Q}^{A}_{C,t}$ appreciates, but the CPI-based real exchange rate $\tilde{Q}^{B}_{C,t}$ depreciates.

Although an increase in the import tariff also enhances the productivity of firms producing at home, the long-run impact of the increased import tariff differs from those of a permanent innovation in labor productivity. A higher tax burden on importers decreases the profitability of foreign firms serving the host market through exports, increasing the import cutoffs for foreign firms importing to the host country. This result forces low-productivity importers to withdraw and high-productivity importers to engage in FDI. The decrease in the number of importers at home implies a smaller import tariff base and a slight increase in the revenue levied by the home government. So, public investment increases, and the effect of enhancing productivity on foreign firms' behavior becomes dominated by the increase in the import tariff rate. The aggregate profit repatriations of

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importers decrease as the number of importers and their profits both decrease. This leads $Q^A_{B,t}$ and $Q^A_{C,t}$ to appreciate, growing home labor units more quickly relative to foreign labor units. The higher relative labor costs at home increase the cutoff for the exporters there. The price of attracting more FDI in this scenario is that the number of exporters and importers both decrease. These effects combine to induce a long-run depreciation of $\tilde{Q}^A_{B,t}$ and $\tilde{Q}^A_{C,t}$ and an improvement in $\mathrm{TOT}^A_{B,t}$ and $\mathrm{TOT}^A_{C,t}$. As the number of home firms decreases, $Q^A_{B,t}$ and $Q^A_{C,t}$ appreciate in the long-run. As in the findings in the previous scenarios, an increase in home aggregate demand attracts more foreign firms to serve the domestic market, but the appreciation of the home labor units impedes foreign firms to engage in FDI in the home country. The net result is that the home country still attracts more FDI. Although the increase in home aggregate demand, the appreciation of the welfare-based real exchange rate, and the appreciation of home labor units deteriorate terms of trade, terms of trade still improve significantly. Terms of trade improve because the cutoff of foreign exporters in the home market rises by the increase in home import tariff and then induces an increase in the average prices of foreign exporters in the home market.

A permanent increase in the home import tariff harms foreign firms exporting to the home market. After the shock, both the home country and the competitor's country attract more FDI in the long-run. Domestic aggregate production and private consumption decline, and the rates of this decline are larger than those in the competitor's country. All international trade becomes less active. The terms of trade, $\mathrm{TOT}^A_{C,t}$, improves, and the rate of increase is larger than that for $\mathrm{TOT}^B_{C,t}$. The CPI-based real exchange rates, $\tilde{Q}^A_{C,t}$ and $\tilde{Q}^B_{C,t}$, both depreciate.

A permanent increase in home public infrastructure induces several notable transitional changes at home. When the home government finances their increasing public investments by reducing public consumption or by increasing the payroll tax rate, the accumulation of home public infrastructure enhances the level of home productivity and devalues home labor units relative to those in the competitor's country. However, the increase in the home country's productivity also encourages firms to enter the home country's market, and induces an increase in labor demand, growing home labor units relative to the competitors. The paths of endogenous variables depend on the net results of home labor units. The home country runs a current account deficit in response to the shock, accumulating a net foreign debt because the home country's households borrow from abroad to deal with the

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shortage of domestic investment. If the home government finances the expenditure on public investment by increasing the import tariff, it decreases the aggregate profit repatriations of the importers and immediately raises $Q^A_{B,t}$ and $Q^A_{C,t}$. With the appreciation of the real exchange rate, the cost of home labor moves higher relative to that of the competitor's.

Because only firms in the investing country can serve the home market through subsidiary sales, the improvement in home productivity increases the average total profit of firms in the investing country. This leads the investing country to attract more entrants and increase labor demand, raising the investing country's labor units relative to those of the competing country. The higher relative labor cost in the investing country increases the cutoff for its firms to export to the competing country. These effects combine to induce a long-run depreciation of $\tilde{Q}^B_{C,t}$.

4.2 Tax reduction and FDI subsidy

The home country can also attract FDI by reducing the corporate tax rate on FDI or by offering subsidies to investors.[22] Figure 7 and 8 shows the responses to a permanent decrease in the home country's public investment. Solid lines show a permanent 1% decrease in the home country's corporate tax rate on FDI. Broken lines show a permanent 1% variable fixed cost subsidies offered to foreign local subsidiaries at home.[23]

A decrease in the tax rate directly increases the profitability of local foreign subsidiaries and attracts more foreign firms serving the home market via FDI. However, a reduction in tax revenues decreases domestic public investment and impedes the accumulation of domestic public infrastructure. The reduction in the home country's public infrastructure makes the home market become a less attractive location for prospective entrants in the long run. Home labor units must depreciate relative to the foreign market for home labor to remain used. A lower relative labor cost at home decreases the export cutoffs of home firms. These effects combine to induce a depreciation of $Q^A_{C,t}$. Although the decrease in both home aggregate demand and

[22] We consider two types of FDI subsidy. The first one is a fixed cost subsidy used to reduce the per-period fixed cost of foreign firms to do FDI in the host market and the second one is a variable cost subsidy targeted towards the variable costs of foreign firms' production in the host country's market. See also Chor (2009); Wu, Chen, and Chang (2019).

[23] Since the dynamic response paths of using a fixed cost subsidy are similar to that of using a variable cost subsidy, we only report the result of a variable cost subsidy.

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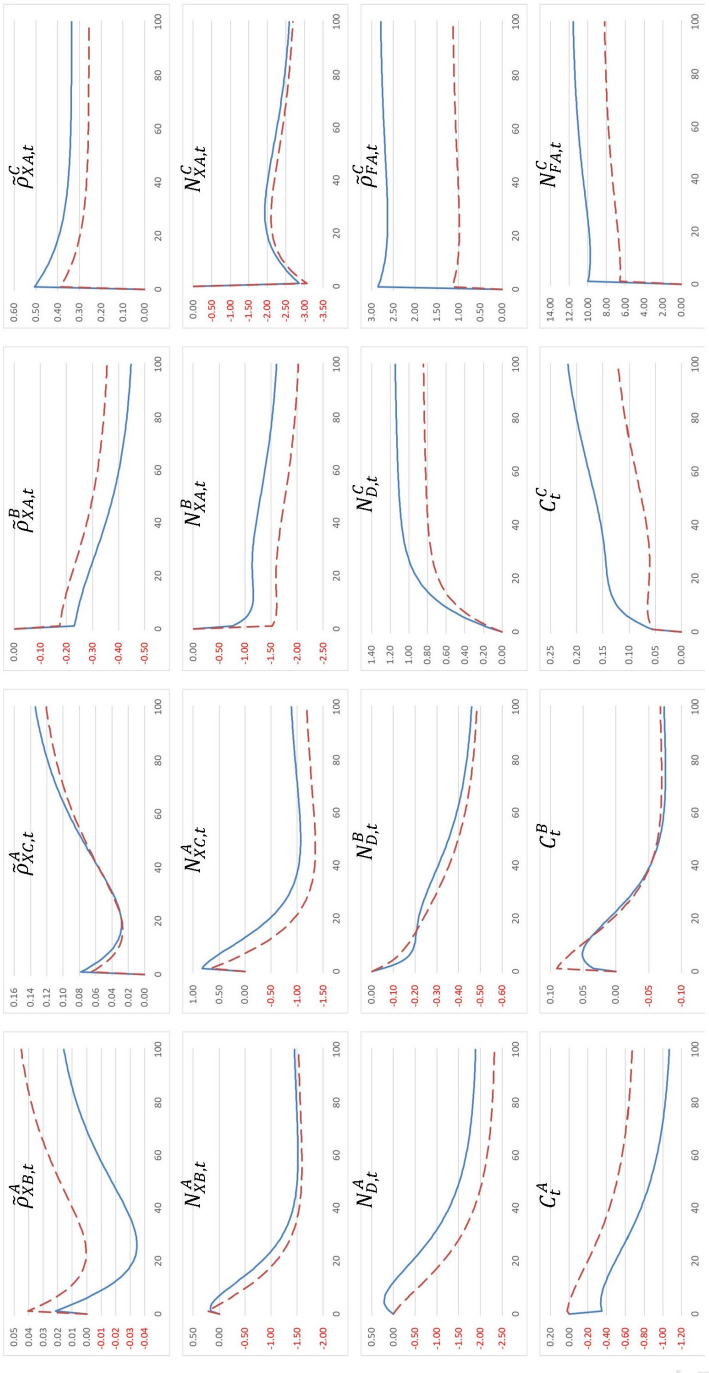


Figure 7: Impulse response to tax reduction and FDI subsidy

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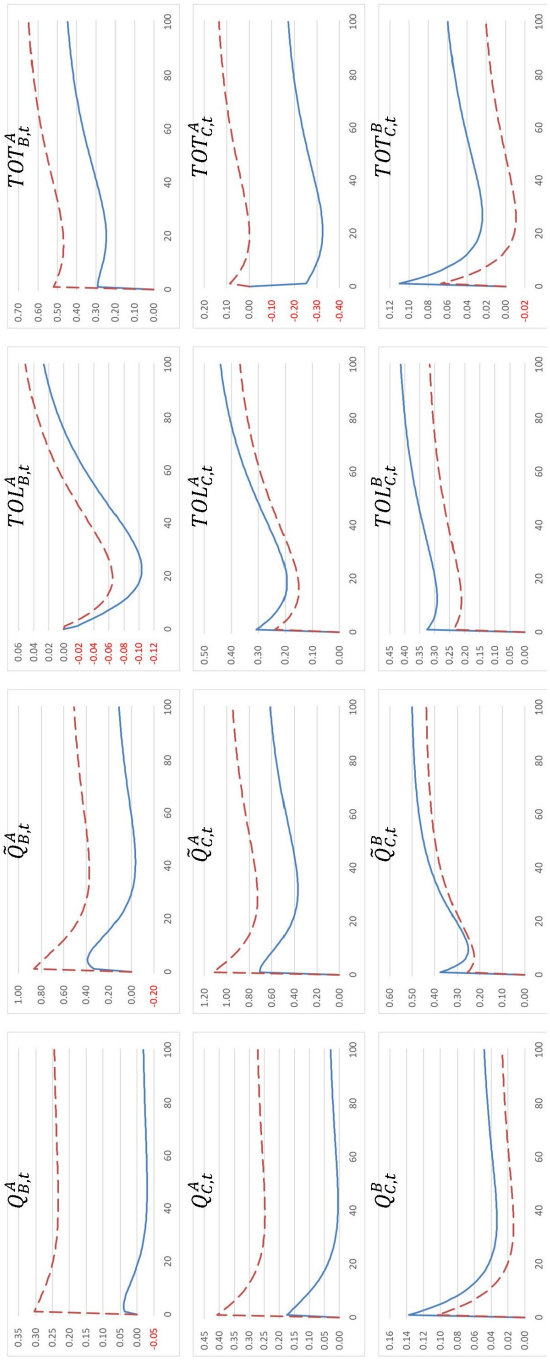


Figure 8: Impulse response to tax reduction and FDI subsidy

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the stock of home public infrastructure impede foreign FDI in the home country, the home country still attracts more FDI. Our simulation also shows that the depreciation of home labor units leads to terms of trade $\mathrm{TOT}^{A}_{C,t}$ to improve further. Next, we compare the effects on several key endogenous variables at home to those of the competitor. Since the home country reduces corporate tax on FDI, the investor country's firms earn more profit via FDI, leading to an increase in their average aggregate profit. The investor country's market becomes a relatively more attractive business environment, drawing a permanently higher number of $N^{C}_{E,t}$, which translates into a permanently higher number of $N^{C}_{D,t}$. After the shock, both the home country and the competitor's country attract more FDI as the number of $N^{C}_{D,t}$ increases in the long-run. The aggregate consumption reduces in both the home country and the competitor's country, but the aggregate production increases for the competitor. All international trade becomes less active. The terms of trade, $\mathrm{TOT}^{B}_{C,t}$, improves, and the rate of increase is larger than that for $\mathrm{TOT}^{A}_{C,t}$.

When the home government offers subsidies for local subsidiaries and finances the fiscal cost by reducing public investment, the reduction in home public infrastructure is counteracted by the increase in subsidies, leading the home market to attract more FDI. However, a decrease in home public infrastructure reduces domestic firms' productivity and the total average profit, plus reducing the number of entrants. Home labor units must depreciate relative to the foreign market for home labor to remain used. A reduction in the relative labor cost at home decreases the export cutoffs of home firms. These effects combine to induce a depreciation of $Q^{A}_{B,t}$ and $Q^{A}_{C,t}$, and depreciation in $\mathrm{TOT}^{A}_{B,t}$ and $\mathrm{TOT}^{A}_{C,t}$. Although the decline of the home labor units reduces the FDI cutoff and hence encourages foreign firms to engage in FDI in the home country, the decrease in home aggregate demand reduces the FDI's profitability. The net result enhances the effect of the financial subsidy policy. Our simulation also shows that the reduction of home labor units and the decrease in home aggregate demand lead the terms of trade to improve further. Then, we consider the effects of the home government increasing subsidies for local subsidiaries on several key endogenous variables at home to the effects in the competitor's country. After the shock, both the home country and the competitor's country attract more FDI in the long run. The aggregate production and aggregate demand both reduce at home and in the competitor's country. All international trade becomes less active. The terms of trade, $\mathrm{TOT}^{A}_{C,t}$, and $\mathrm{TOT}^{B}_{C,t}$ deteriorate.

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A small FDI subsidy offered by the home country will reduce the distortions caused by the fixed cost for foreign firms to engage in FDI and increase the home country's consumption when firms are heterogeneous. However, Wu, Chen, and Chang (2019) find that offering FDI subsidies may induce another distortion that causes a serious negative effect on the consumption of the offering subsidy country. The FDI subsidies increase the profits local subsidiaries earn in the home country and make the market of the investing country become a more attractive location for prospective entrants. In our simulations, a permanently higher number of firms drawn by the investing country decreases the number of firms in other countries. The decrease in the number of home firms then reduces the aggregate profit of home firms (returned to households as dividends). Then, this negative wealth effect decreases the household's consumption, offsets the selection effect, and induces a decline in consumption for the subsidy-offering country when the government offers FDI subsidies to fixed costs. This negative wealth effect even dominates the production effect and the selection effect when the home country offers FDI subsidies to variable costs and leads to a decrease in consumption for the home country.

4.3 Sensitivity analysis

A permanent decrease in costs to enter the home market can lead the import and FDI cutoffs to drop and encourage more foreign firms to serve the home market. Thus, we concluded our study with a sensitivity analysis for various entry costs for the home market. To analyze the impact of various competition policies on social welfare, we assumed that social welfare is equal to the household's expected inter-temporal utility and defined the initial value of social welfare to be the household's expected inter-temporal utility with no shock. In Table 2, we report the results of the sensitivity analysis of various home market entry costs. Our simulations suggest that permanent deregulation in the host country improves social welfare regardless of the policies the host government uses to attract FDI.

5 The Welfare Implication of Competition FDI

Follow Schmitt-Grohé and Uribe (2007), we compute the welfare cost to carry out policy evaluations of various fiscal policies adopted by countries to attract FDI. The welfare cost is defined as the percentage of initial con-

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Table 2: Result of the sensitivity analysis on home market entry cost

		Productivity	Public investment	Payroll tax	Import tariff	Subsidy	Corporate tax
$f_E^A = 0.9$*	Country A	0.7791	0.2418	−0.0291	0.0017	−0.0158	0.0252
	Country B	0.0227	0.0065	0.0017	−0.0184	0.0006	0.0024
	Country C	0.0282	0.0114	0.0025	0.0020	0.0367	0.0233
$f_E^A = 1$	Country A	0.7768	0.2411	−0.0293	0.0012	−0.0155	0.0229
	Country B	0.0227	0.0064	0.0016	−0.0175	0.0005	0.0029
	Country C	0.0303	0.0121	0.0026	0.0028	0.0379	0.0251
$f_E^A = 1.1$	Country A	0.7744	0.2405	−0.0296	0.0008	−0.0149	0.0206
	Country B	0.0226	0.0062	0.0016	−0.0168	0.0003	0.0032
	Country C	0.0322	0.0127	0.0027	0.0033	0.0384	0.0267

Note: The negative sign indicates social welfare decreasing after the shock. * We interpret a permanent decrease of f_E^A as permanent deregulation.

sumption that the representative household would be willing to be compensated for in period 0 to maintain the original level of welfare after the government adopts a competition policy. Let φ denote the percentage of consumption that the representative household receives in each period to maintain its original level of welfare. Thus, we compute the value of φ in the following equation:

$$V_0^{FP} = E_t\left[\Sigma_{s=t}^{\infty}\beta^{s-t}\left(\frac{\left[(1-\varphi)\left(\breve{C}_s^i + \breve{G}_{C,s}^i\right)\right]^{1-\gamma}}{1-\gamma} - \frac{\left(\breve{L}_s^i\right)^2}{2}\right)\right]$$
$$= E_t\left[\Sigma_{s=t}^{\infty}\beta^{s-t}\left(\frac{\left(\bar{C}_s^i + \bar{G}_{C,s}^i\right)^{1-\gamma}}{1-\gamma} - \frac{\left(\bar{L}_s^i\right)^2}{2}\right)\right] = \bar{V}_0,$$

where V_0^{FP} and $\bar{V}_0$ are the expected lifetime utility of the representative household, discounted back to period 0; $\breve{C}_t^i$, $\breve{G}_{C,s}^i$, and $\breve{L}_t^i$ are the endogenous variables under the fiscal policy; and $\bar{C}_t^i$, $\bar{G}_{C,s}^i$, and $\bar{L}_t^i$ represent the endogenous variables with no fiscal policies.

5.1 The optimal expenditure

In this subsection, we focus on the fiscal policies that are financed by the wage tax to analyze the optimal expenditure. Figure 9 shows the welfare cost

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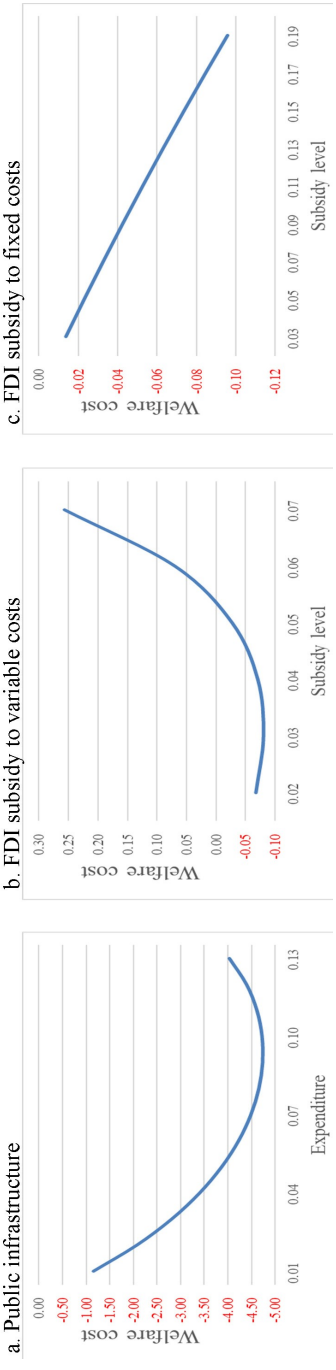


Figure 9: Welfare cost as a function of the expenditure or subsidy level
The negative sign indicates welfare improvement.

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functions of the home country in each fiscal policy scenario. The optimal expenditure is unique with increasing public infrastructure (panel *a*) because it can lead to consumption gains by enhancing the productivity of firms producing in the domestic market until the point where the margin effect is offset by the margin expenditure. When the FDI variable cost subsidy is offered (panel *b*), the welfare cost function is convex because each local subsidiary can receive a smaller and smaller share of the subsidies as the number of firms engaging in FDI increases. Beyond the optimal subsidy level, the marginal consumption gain of the selection and production effect is dominated by the marginal consumption loss of the wealth reallocation effect. Panel *c* shows that a small FDI fixed cost subsidy delivers a welfare improvement for the host country, and this outcome is in line so of Chor (2009).

Next, we analyze how the optimal subsidy level to variable costs varies in response to shifts in demand elasticity, shape parameter, and trade cost in the model. Figure 10 shows the optimal subsidy function when a parameter varies. In panel *d*, the high demand elasticity raises the optimal subsidy level by amplifying the selection effect. When some exporters switch to FDI and save transport costs, the decrease in prices induces more demand under higher demand elasticity. In panel *h*, a higher value of the Pareto shape parameter lowers the optimal subsidy level because fewer firms might engage in FDI as less mass is placed on the right tail of the productivity distribution (more productivity). As higher transport costs and fixed costs of exports impede foreign firms from servicing the home market via export but assists them to engage in FDI, the home country will experience a welfare gain from attracting foreign firms to switch to FDI. Panels *e* and *l* show that the optimal subsidy level is higher when the barriers faced by importers are higher. Conversely, a higher fixed cost of FDI hinders foreign firms from servicing the home market through local subsidiary sales. The optimal subsidy level decreases with the increase in fixed cost because a given FDI subsidy will be less effective to encourage foreign firms to engage in FDI (panel *i*).

Our model allows us to analyze how the optimal subsidy level shifts in the difference among countries. When the entry costs in other countries are higher than that in the home country, the wealth reallocation effect caused by an FDI subsidy will be less severe for the home country because the higher entry cost impedes new firms from entering the market of other countries. Panel *f* shows that a higher entry cost in the competing country raises the

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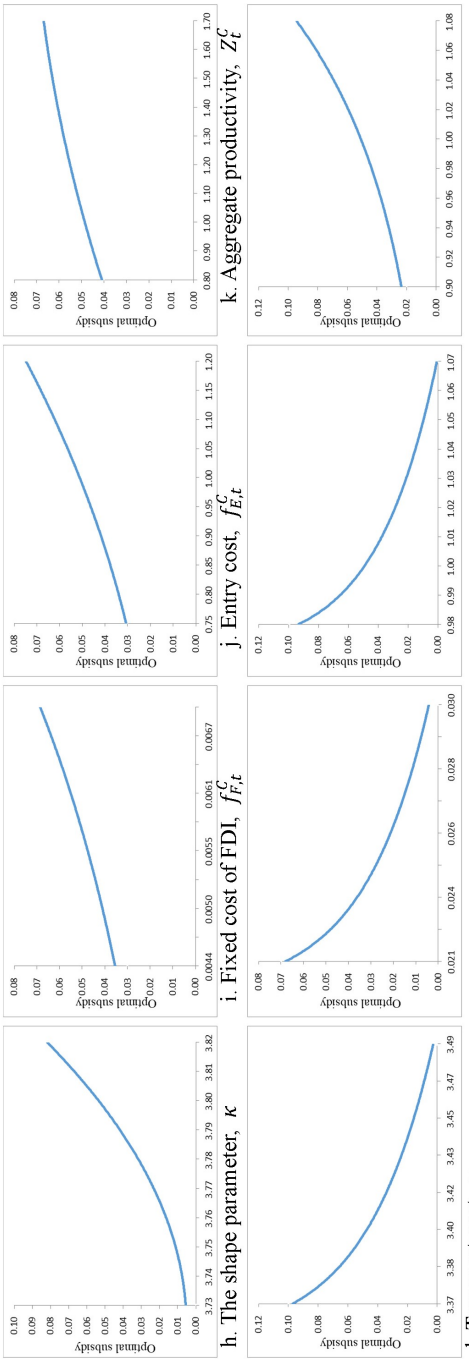


Figure 10: Optimal subsidy

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optimal subsidy level. However, panel *j* shows that a higher entry cost in the investing country lowers the optimal subsidy level. The reason is that the number of firms in the investing country also decreases with the higher entry cost, and fewer firms might engage in FDI. A given FDI subsidy will be less effective at attracting FDI when the number of potential firms engaging in FDI is not too high. In panels *g* and κ, we see that higher aggregate productivity in a country raises the optimal subsidy level. Since higher aggregate productivity in a country will increase the wealth in that country and then raise the demand for all existing goods sold in its market, this leads to an increase in all importers' profits. The number of firms in each country increases. A given FDI subsidy will be more effective at attracting FDI when the number of potential firms engaging in FDI is large. The impact is more significant when the investing country's aggregate productivity is higher than that of the home country.

The model also allows us to analyze the impact of policy competition on each country's welfare. First, we consider the welfare cost of the home and competing countries when they use different fiscal policies to compete for FDI. Assume that the cost of fiscal policies is financed by levying the same amount of lump-sum tax in each country. Table 3 shows the welfare cost of Country *A* and *B* in each scenario. The first number of each payoff represents the welfare cost of Country *B* and the second number of each payoff represents the welfare cost of Country *A*. *A* Nash equilibrium exists that both Country *A* and *B* offer a fixed cost subsidy. It means that no country has an incentive to deviate it when they choose the fiscal policy under the Nash equilibrium. In contrast, choosing other fiscal policies may induce higher welfare improvement for these two countries, but each country has the incentive to deviate its initial choice to gain more welfare, such as Country *A* and *B* both enhance their public infrastructure to attract more FDI. However, if Country *A* and *B* can negotiate before adopting any fiscal policy, increasing public investment would be the best choice for both countries. Second, we investigate the welfare cost of the home and investing country when they adopt the fiscal policy. Table 4 shows the welfare cost of Country *A* and *C* in each scenario. Similarly, the cost of fiscal policies is financed by levying the same amount of lump-sum tax in each country. A Nash equilibrium exists that Country *A* offers a fixed cost subsidy and Country *C* enhances domestic public infrastructure.

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Table 3: The welfare cost of Country A and B

Country A / Country B	No fiscal policy	Public investment	Tax reduction	Subsidy to fixed costs	Subsidy to variable costs
No fiscal policy	(0,0)	(−0.001, −0.014)	(−0.001, 0.004)	(0.023, −0.026)	(−0.001, −0.002)
Public investment	(−0.014, −0.001)	(−0.015, −0.015)	(−0.014, 0.003)	(0.010, −0.027)	(−0.015, −0.003)
Tax reduction	(0.004, −0.001)	(0.003, −0.014)	(0.004, 0.004)	(0.027, −0.026)	(0.003, −0.002)
Subsidy to fixed costs	(−0.026, 0.023)	(−0.027, 0.010)	(−0.026, 0.027)	**(−0.002, −0.002)***	(−0.027, 0.022)
Subsidy to variable costs	(−0.002, −0.001)	(−0.003, −0.015)	(−0.002, 0.003)	(0.022, −0.027)	(−0.003, −0.003)

Note: Welfare cost: (Country B, Country A). The payoff with a notation (*) is a Nash equilibrium. The negative sign indicates welfare improvement because that the percentage of initial consumption that the representative household would be willing to give up for in period 0 to maintain the original level of welfare after the government adopts a competition policy.

Table 4: The welfare cost of Country A and C

Country A / Country B	No fiscal policy	Public investment	Tax reduction	Subsidy to fixed costs	Subsidy to variable costs
No fiscal policy	(0, 0)	(−0.001, −0.014)	(−0.005, 0.004)	(−0.058, −0.026)	(−0.004, −0.002)
Public investment	(−0.013, −0.001)	(−0.014, −0.014)	(−0.019, 0.003)	**(−0.071, −0.026)***	(−0.018, −0.002)

Note: Welfare cost: (Country C, Country A). The payoff with a notation (*) is a Nash equilibrium.

5.2 Import subsidy

Since the FDI fixed cost prevents a segment of foreign firms from servicing the domestic market directly through FDI, the FDI subsidy to fixed costs encourages the most productive exporters to switch to horizontal FDI and leads to a direct consumption gain stemming from the savings on cross-border transport costs. In this context, we are interested in analyzing how welfare in a country is affected when it offers an import subsidy. Under a framework with heterogeneous firms, the import subsidy will lure some for eign firms to service the domestic market through exports and induce an increase in the variety of imports available for domestic households, delivering positive consumption gains for the domestic country. However, an import subsidy also prompts some less productive foreign firms to switch from horizontal FDI back to exporting, causing a negative selection effect on domestic consumption. An import subsidy may cause wealth reallocation across countries if the number of firms in each country is determined endogenously. So far, the net impact of an import subsidy on welfare is ambiguous. Therefore, we follow steps analogous to the previous analysis and examine the welfare impact of either a fixed or variable cost subsidy to imports in this subsection.

Consider a permanent import subsidy offered by a country. Offering importers a subsidy to reduce their per-period fixed costs or variable costs of production increases the profitability of importers and leads more foreign firms to service the domestic market through exports. The fixed cost prevents a segment of foreign firms from serving the domestic market. By reducing the cost barrier, even less productive foreign firms can export to the domestic market, increasing the variety of imports for domestic consumers. We assume that foreign firms engage in international trade only if doing so will lead to the earning of non-negative profits, which implies that even the less productive importers will still enjoy higher productivity than some domestic producers. When domestic households switch their expenditures toward import goods, they can consume more goods, leading to positive consumption gains. As the increase in the number of importers increases the profit repatriation to the firms' home country, the real exchange rate between the domestic and foreign countries depreciates. The depreciation of the real exchange rate increases domestic exporters' expected profits, drawing a permanently higher number of prospective entrants, which translates into a permanently higher number of producers. This result causes an increase in

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Table 5: The welfare cost in each country after Country A executes an import subsidy policy

	Import subsidy to fixed costs	Import subsidy to variable costs
Payroll tax	(−0.04, −0.05, 0.49)	(−0.10, −0.15, 0.59)
Corporation tax	(−0.34, −0.05, −0.98)	(−0.40, −0.15, −0.88)
Import tariff	(−0.07, 0.14, 0.33)	(−0.14, 0.04, 0.43)

Note: Welfare cost: (Country A, Country B, Country C).

the dividend income of domestic households and reallocates wealth among countries, delivering positive consumption gains for the domestic country. A variable cost subsidy to importers also delivers a welfare improvement by partially counteracting the inefficiency stemming from the firms' monopoly pricing power, by reducing the effective price markup of importers. Table 5 shows the welfare cost in each scenario. Our simulations show that an import subsidy raises welfare in the domestic country, no matter whether it is a fixed cost or a variable cost subsidy, with the consumption gains from attracting more importers and wealth reallocation exceeding the direct cost of funding the subsidy program through a tax. This result is in line with that of Chor (2009).

6 Conclusion

With a three-country DSGE model with heterogeneous firms and under public infrastructure assumptions, we analyze the effects of fiscal policies used to attract more FDI from the source country with a competitor. Over the past decade, the main economic policies for attracting FDI have been improving public infrastructure, reducing corporate tax rates, and offering subsidies. To understand a firm's specific FDI behaviors, we followed Ghironi and Melitz (2005) in assuming a mass of firms with different productivity levels in each country and that each firm export to or engage in FDI in other countries. The home country competes in FDI with a foreign country by providing public infrastructure, reducing corporate tax rates, or offering subsidies. And so, only the third country can serve the foreign markets through exports or local subsidiary sales.

The main findings follow. First, an increase in public physical infrastruc-

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ture attracts more FDI for the home country when the spending is financed via increasing the labor income tax, import tariffs, or reducing government consumption. Increasing public infrastructure also raises domestic production and results in an appreciation of the real exchange rate and terms of trade deterioration. These results support the findings of Bénassy-Quér, Gobalraja, and Trannoy (2007). However, the appreciation of home labor units caused by the increase in public infrastructure impedes foreign FDI and reduces the effect of policies meant to attract more FDI. If the home labor supply is elastic, the appreciation of home labor units can even dominate the increase in home public infrastructure, reducing the amount of FDI in the home country. Second, our simulations suggest that tax competition does not work well if the physical infrastructure decreases along with the reduction of the corporate tax rate for foreign firms. Finally, offering FDI subsidies may induce consumption loss, even in the scenario where only a small subsidy is offered by the home country.

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競爭外人直接投資之三國動態隨機一般均衡模型分析

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在考慮廠商生產力異質性及公共基礎設施有助於廠商生產的假設下, 我們利用一個三國隨機動態一般均衡模型去分析兩國競爭外人直接投資的情況。兩國藉由提供公共基礎設施、減少稅收或向外國投資者提供補貼等來爭奪外國直接投資。我們發現, 如果政府經由提高勞動所得稅、進口關稅或減少政府消費爲公共投資支出提供資金, 則公共基礎設施的增加將吸引更多的外國直接投資。公共基礎設施的增加也提高了國內生產, 並導致實質匯率升值和貿易條件惡化。但是, 公共基礎設施的增加導致相對較高的國內勞動力成本, 從而阻礙了外國直接投資並降低了吸引外國直接投資的政策效果。降低公司稅率是吸引外國直接投資的另一種有效方法。但是, 如果公共基礎設施隨著公司稅率的降低而減少, 則公司稅率的降低無法有效吸引外來投資。最後, 無論地主國政府採取何種政策吸引外國直接投資, 地主國的永久性放鬆管制都會改善社會福利。

關鍵詞: 外人直接投資, 異質性廠商, 公共建設, 賦稅競爭
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