# Reassessing Trade Barriers with Global Value Chains

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**Abstract**

This paper provides a systematic, quantitative analysis of the short-run and long-run effects of various trade-restricting policies in the presence of global value chains and multinational production. Using a two-country dynamic stochastic general equilibrium model with endogenous firm entry and exit in both exporting and multinational production, I compare the effects of (i) tariffs on final-good imports, (ii) tariffs on intermediate-input imports, and (iii) barriers to accessing foreign markets.

I show that, in the long run, all three policies lead to a recession in both countries, but the relative effects on the GDP of the two countries vary across policies. At the firm level, less productive exporters exit from the destination market, while the most productive few choose to locate production in the foreign country as multinationals, thereby partially offsetting the loss from exporting. In the short run, the dynamics differ across policies and from their long-run outcomes. Final-good tariffs and market-access barriers lead to a temporary production boom in the policy-imposing country, while intermediate-input tariffs result in an immediate recession in both countries.

JEL codes: F13, F41, F12
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# 1 Introduction

Protectionism has become an important topic of policy discussion in recent years. Early signs of this trend began to appear following the global recession of 2008, when a number of countries implemented trade-restricting measures in order to support their domestic industry (Gamberoni and Newfarmer, 2009; Bussière et al., 2011).[1] More recently, with unilateral impositions of import tariffs by large economies, the renegotiation of the North American Free Trade Agreement (NAFTA), and the negotiation for the impending Brexit, policy discussion surrounding protectionist measures has increased in intensity to a level that has not been seen in recent history. At the same time, the transmission of trade policy has become increasingly complex as international trade in intermediate production inputs has become a key aspect of today's globalized production processes.[2] With interdependent production networks spanning beyond national borders, transmission channels through which different trade policies may affect trade flows and the aggregate economy depend crucially on where the affected products or economic agents stand within such global production chains.

The presence of multinational production adds another dimension to the discussion of global value chains and trade policy. For instance, according to the Japan Automobile Manufacturers Association, 75 percent of Japanese-brand vehicles sold in the United States in 2017 were built in North America, primarily in the United States. This pattern is markedly different from 1986 when 88 percent of Japanese-brand vehicles sold in the United States were imported.[3] For Japanese automakers that now serve the U.S. market predominantly with local production, such as Honda and Toyota, the profitability of their U.S. sales would be more affected by tariffs on intermediate inputs (e.g., steel). In contrast, for automakers that do not currently produce in the United States, such as Mazda, their profits from U.S. sales would be more affected by tariffs on final goods (e.g., autos). Because Mazda is currently planning to open a production facility in the United States in 2021, the type of trade policy that might be in place in the future could have an important impact on their investment in the United States. Given the rising protectionist sentiment in the recent policy debate, a close examination of the dynamic effects of various trade restrictions in the context of global production linkages is essential for better understanding their implications at both firm and aggregate levels.

This paper provides a systematic, quantitative analysis of the short-run and long-run effects of various trade-restricting policies in the presence of global value chains and multinational production. I examine different channels through which each policy affects micro-level firm dynamics and the aggregate economy, using a two-country dynamic stochastic general equilibrium

[1] Between November 2008 and February 2009, 17 of the G20 member countries implemented policy measures that would restrict international trade at the expense of other countries (Gamberoni and Newfarmer, 2009).

[2] For the United States, exports of intermediate goods accounted for 65 percent of total exports in 2014. Data source: World Input-Output Tables, 2016 release.

[3] Source: Japan Automobile Manufacturers Association Inc., "Japanese Brand Automobile and Motorcycle Trends in Japan and the U.S."

(DSGE) model with capital accumulation, forward-looking entry/exit of firms in both exporting and multinational production, and cross-country input-output linkages in production. Using this framework, I analyze the effects of permanent, unilateral impositions of (i) tariffs on final-good imports, (ii) tariffs on intermediate-input imports, and (iii) barriers to accessing foreign markets. In my analysis, in addition to quantifying long-run aggregate implications of these trade policy changes, I study the transition paths of the economy and address intertemporal tradeoffs in the short to medium run that might be of interest to policymakers. As my model economy captures rich micro-foundations in static and dynamic dimensions, it facilitates building intuitions from both macro and trade perspectives.

My model incorporates the observed international input-output linkages by introducing roundabout production technology. In this framework, output of individual firms can be used as production inputs by other firms within and outside the firms' country of origin and also as part of final composite goods that are purchased by households – domestically and abroad. Therefore, there is international trade in both intermediate production inputs and consumer goods. In addition, firms in my model may choose to locate production abroad and serve the foreign market as multinational firms instead of exporting. I follow Helpman, Melitz and Yeaple (2004) wherein relatively more productive firms become exporters and the most productive ones become multinational firms. In order to induce entry and exit of exporting and multinational production, I follow Alessandria and Choi (2007) and introduce sunk costs of entry and per-period fixed costs of continuation, which together influence the time-varying sets of firms that export or produce abroad in any given period. Therefore, individual firms' valuation of exporting or multinational production depends on the status of their activity from the previous period, making their participation decisions forward-looking.

Each of the trade policy scenarios I consider in this paper has a distinct feature that affects international trade flows. Tariffs on final goods affect mainly the purchasing choice of households in the policy-imposing country. For instance, in 2009, Russia increased import tariffs on used foreign cars and trucks. Tariffs on intermediate inputs, such as the recent imposition of import tariffs on aluminum and steel by the U.S. administration, directly affect the cost of production for producers in the policy-imposing country. Barriers to accessing foreign markets affect international trade mainly through the extensive margin of exports, limiting the presence of foreign exporters in the destination economy. For example, Argentina introduced non-automatic licensing requirements on its imports of auto parts, textiles, TVs, toys, shoes and leather goods in 2009.

I calibrate the parameters governing the dynamics of exporting and multinational production as well as the use of intermediate inputs in my model economy in order to match key empirical moments from micro-level data on firm dynamics and the World Input-Output Tables. At the firm level, I target the rates of entry and continuation in the export market, the rate of multinational entry relative to that of exporter entry, the mass of multinationals relative to total enterprises in the economy, and the productivity of exporters relative to that of non-exporters. To capture the flow of final goods and intermediate inputs within and across countries, I target the value of intermediate inputs as a share of total output value, the share of intermediate imports in total imports, and the aggregate imports-to-GDP ratio.

Examining the effects of permanent, unilateral impositions of the three trade-restricting policies, each calibrated to reduce the policy-imposed country's export volume by the same amount, I show that in my baseline calibration, all policies under consideration lead to a recession in both countries in the long run. However, the magnitudes of losses differ across policies and across countries, with final-good tariffs and intermediate-input tariffs resulting in a larger GDP fall in the policy-imposed country (whose exporters are affected by the policy), and market-access barriers resulting in a larger GDP fall in the policy-imposing country (which is restricting its imports from the policy-imposed country). In contrast, the fall in consumption is consistently larger for the policy-imposing country across all three policies. When import restrictions are imposed, there is a large exit of foreign exporters from the policy-imposing country's market. This results in fewer product varieties available for households in that country, leading to a larger consumption loss due to the welfare effects of product variety.

In the policy-imposing country, the long-run decline in GDP is smallest in the case of final-good tariffs where expenditure switching toward domestically produced final goods dampens the fall in the domestic production of final goods, and hence GDP. Such expenditure switching toward domestic products is absent in the case of intermediate-input tariffs because they immediately raise production costs for firms that rely on imported intermediate inputs, which in turn reduces the demand for inputs and production.

In contrast, in the policy-imposed country, the long-run fall in GDP is smallest in the case of market-access barriers. In this case, the contraction in real export revenues is smaller relative to the two tariff cases since the relative producer price of exports increases substantially more. At the firm level, in all three policies, less productive exporters exit from the policy-imposing country's market, while the most productive firms choose to locate production there as multinationals, thereby avoiding trade barriers. Because (potential) multinational firms are relatively more productive than the average local firms or the exiting exporters, the lower relative price of their products and the falling production costs in the policy-imposing country increase the profitability of multinational production and hence the mass of multinational firms there. I find that this is also true when tariffs are imposed on the imports of intermediate inputs.

I then show that the short-run responses to these trade policy changes can be quite different from their long-run outcomes and also across policies. In particular, final-good tariffs and market-access barriers lead to a short-run production boom in the policy-imposing country that we do not see in the long run or with intermediate-input tariffs at any horizons. With final-good tariffs, expenditure switching is stronger in the short run, and we see a positive response in the domestic production of final goods there. With market-access barriers, as some exporters do not exit the foreign market immediately following the policy change, the adjustment in trade is delayed. As agents in the policy-imposing country anticipate a gradual decline of imports in the future, the slow adjustment in trade leads to a temporary increase in investment there.

I further examine the role of multinational firms in influencing the transmission of trade policy changes. I first compare my baseline model with an alternative model without multinational production, and show that long-run losses for the policy-imposing country are larger in the absence of multinational firms. As discussed above, those firms that participate in multinational production are larger and more productive than the average local firms or the average exporters. Therefore, the presence of multinational firms offers an additional set of more efficiently produced varieties that households in the policy-imposing country may partially substitute with in place of (more expensive) imports in response to trade policy changes. The increased presence of these multinational firms as a result of trade barriers then helps to dampen the loss in production, employment and demand for investment in the policy-imposing country that would not otherwise arise in their absence. Given this additional margin of adjustment that multinational firms offer, I then analyze the role of substitutability between a bundle of imported varieties and a bundle of foreign varieties produced locally by multinational firms. I find that increasing their substitutability requires the entry and continuation costs of multinational production to be significantly lower in order to induce the steady-state participation of multinational firms that is consistent with the observed level in data. In my quantitative exercise, the lower costs of multinational operation and the higher elasticity together induce a substantially larger increase in the mass of multinational firms in response to trade policy changes, with the increase being three to five times larger than in my baseline analysis. When the substitutability of imports and multinational products is sufficiently high, the positive effects of such large inflows of multinational firms into the policy-imposing country can more than offset the negative effects of trade barriers there.

Finally, I explore the sensitivity of my baseline results to (i) the presence of trade in intermediate inputs and (ii) the elasticity of substitution between domestic and foreign varieties. When trade in intermediate inputs is eliminated, the responses of the extensive margin of trade are amplified, while the responses of GDP and consumption are dampened for both countries as the share of imports in GDP is reduced. With varying degrees of the elasticity of substitution, the long-run aggregate effects of final-good tariffs are more sensitive to the product substitutability of final goods faced by households, while the aggregate effects of intermediate-input tariffs are more sensitive to the product substitutability of intermediates faced by producers.

The remainder of the paper is organized as follows. In section 2, I review the literature related to my analysis. Section 3 describes my model economy in detail, and the calibration of the model is explained in section 4. I then present my main results in section 5. In section 6, I examine the role of multinational production in influencing the effects of trade policy. In section

7, I examine the sensitivity of the main results to the presence of trade in intermediate inputs and the Armington elasticity of substitution between domestic and foreign varieties. I also compare my baseline results with the effects of iceberg trade costs often considered in the literature. Section 8 concludes.

## 2 Related literature

This paper contributes to the growing literature on the effects of trade policy in the presence of global production linkages and intermediate-input trade.[4] In his influential paper, Yi (2003) examines the role of vertical specialization in explaining the strikingly larger growth in world trade relative to the size of tariff reductions since the 1950s. He develops a two-country Ricardian trade model of international production sequences in which different stages of production take place in various countries, and shows that the model of vertical specialization is able to explain over 50 percent of the growth in international trade.

More recent studies develop multi-country, multi-sector Ricardian trade models with sectoral linkages and international trade in intermediate goods, and highlight the important role of input-output linkages in amplifying and propagating the welfare effects of trade policy changes across countries. Caliendo and Parro (2015) examine the welfare gains from NAFTA's tariff reductions. Extending the input-output structure of Caliendo and Parro (2015) and calibrating it with data for 189 countries and 15 sectors, Caliendo et al. (2017) examine the gains from the Uruguay Round. Auer, Bonadio and Levchenko (2018) focus on the distributional effects of revoking NAFTA across sectors and geographical regions in the United States, Canada and Mexico. These studies quantify the total welfare changes from various trade policies involving multiple countries, both bilateral and multilateral. In my quantitative analysis below, I show that a unilateral trade restriction alone can have sizable negative effects on both the imposing country and the imposed country in the long run. By considering a unilateral imposition of each of various policy types, I compare the relative quantitative effects on the two countries involved. As I show, this distinction is useful since the magnitude of the loss and the most affected sectors vary with whether a country is the imposer or the imposed and with trade-policy types.

My approach to studying the quantitative effects of trade policy using a DSGE model with endogenous export participation is closely related to recent studies by Alessandria and Choi (2014), Alessandria, Choi and Ruhl (2018), Mix (2018), and Barattieri, Cacciatore and Ghironi (2019). These papers build on the endogenous selection of firms into exporting and its implications for the aggregate welfare, as established in a seminal paper by Melitz (2003). Barattieri, Cacciatore and Ghironi (2019) present empirical evidence that the introduction of temporary import tariffs leads to a decline in output and an increase in inflation for the country imposing the trade barriers.

[4]See Goldberg and Pavcnik (2016) for a survey of empirical analyses of the effects of trade policy.

They explain these empirical findings using a small open economy model with endogenous firm entry. Alessandria and Choi (2014) study the effects of tariffs (applied equally to final goods and traded inputs) and iceberg trade costs using a two-sector, two-country model with forward-looking export decisions and trade in production inputs. They show that welfare gains from bilateral tariff eliminations are significantly larger when export decisions are dynamic and that intermediate production inputs and capital accumulation play an important role in generating welfare gains from trade. I extend their framework of dynamic export participation decisions and input-output linkages by introducing dynamic decisions on multinational production, and study unique transmission channels for various types of trade policy. In the models of Alessandria and Choi (2014) and Barattieri, Cacciatore and Ghironi (2019), in response to trade restrictions (liberalization), firm heterogeneity in productivity and endogenous export decisions induce exit (entry) of exporters that are more productive than the average local firms in the destination market. This shifts the available bundle of product varieties to products produced less (more) efficiently, thereby affecting the aggregate price index and hence consumption decisions. My model economy shares this feature of their models, and takes into account the productivity costs of trade barriers arising from the extensive margin adjustment.

My focus in this paper to distinguish the short-run effects and the long-run effects of trade policies is related to Alessandria, Choi and Ruhl (2018) and Mix (2018). Alessandria, Choi and Ruhl (2018) develop a model wherein exporters must continue investing in their foreign-market access in order to expand their exporting capacity. Because the continued investment in exporting lowers their variable export costs only gradually, the trade elasticity increases over time in response to changes in tariffs. Importantly, a reduction in tariffs results in a substitution away from new firm creation toward investment in expanding the export capacity of incumbent exporters, and this leads consumption to overshoot in the short run, which generates significant welfare gains that would not be accounted for in a static comparison of steady-state consumption. Mix (2018) develops a multi-country model in which firms make destination-specific decisions on export entry, and shows that the U.S. economy would experience a sizable loss if it does not take part in tariff reductions occurring in the rest of the world. He shows that, although the long-run steady state would be a better outcome for the U.S. consumption even without participating in the world trade liberalization, the losses in the short run are sufficiently large so that the overall welfare effects are negative, highlighting the importance of the dynamic effects of trade policy changes.

My work also relates to the literature that focuses on the role of multinational firms in affecting the gains from openness in trade and multinational production. Ramondo and Rodríguez-Clare (2013) develop a multi-country Ricardian model of multinational production and international trade in intermediate inputs, and show that the gains from trade can be significantly higher in the presence of multinational production, particularly for countries with larger inward multinational-production flows. Importantly, their model captures both substitutability and complementarity between trade and multinational production. Multinational production may replace exports in order to avoid trade costs, while the dependency of multinational firms on imported intermediates implies complementarity. Ramondo (2014) introduces differences in the extensive margin of multinational production across countries, and shows that the gains from liberalizing access to foreign firms are larger for poorer countries than for richer countries. Wu (2015) examines the welfare effects of openness to trade and multinational production using a growth model with international technology spillovers. He shows that, in the presence of technology spillovers through multinational production with quality improvements, the United States and OECD countries would experience welfare gains as the trade costs are increased to the 1970 level. In his calibration, the exit of less productive exports and the entry of most productive multinational firms raise the quality of technology diffused and lower the costs of innovation, and these positive technology spillovers dominate the loss from the reduced trade. Rodrigue (2014) estimates a model with endogenous entry and exit in exporting and multinational production using Indonesian manufacturing data and finds that existing international trade and multinational production relationships account for a large portion of aggregate productivity in Indonesia. Arkolakis et al. (2018) develop a general equilibrium model of trade and multinational production where innovation occurs through the creation of heterogeneous firms and workers are heterogeneous in their skills for innovation and production. Using this framework, they quantify the welfare implications of specialization in innovation and production arising from openness to trade and multinational production, and show that a reduction in the costs of multinational production leads to greater specialization across countries in innovation and production and higher real incomes.

Finally, my paper is also related to recent developments in the analysis of the macroeconomic effects of various trade policies.[5] Steinberg (2019) quantifies the welfare cost of uncertainty about post-Brexit trade policies using a heterogeneous-firm model with endogenous export participation. Erceg, Prestipino and Raffo (2018) study the short-run effects of (i) import tariffs and export subsidies, (ii) an increase in value-added taxes accompanied by a payroll tax reduction, and (iii) a border adjustment of corporate profit taxes, using a dynamic New Keynesian open-economy model. Alessandria, Choi and Lu (2017) examine the effects of aggregate shocks to trade barriers on China's growth and trade integration, using a two-country dynamic model with dynamic export decisions. They show that changes in trade barriers are an important determinant of China's trade balance and its accumulation of foreign assets, explaining about 70 percent of China's net foreign assets in 2014. Blanchard, Bown and Johnson (2017) show theoretically that optimal tariffs are decreasing in the domestic content of foreign-produced final goods and the foreign content of domestically produced final goods. They confirm this theoretical prediction empirically, showing that governments of major economies have imposed lower tariffs for sectors that are more engaged

[5]A number of recent empirical papers estimate the effects of the on-going trade tensions. See, for example, Amiti, Redding and Weinstein (2019), Fajgelbaum et al. (2019), Cavallo et al. (2019), and Flaaen, Hortaçsu and Tintelnot (2019).

in global value chains over the period between 1995 and 2009. Furceri et al. (2018) report empirical evidence that a tariff increase leads to declines in domestic output and productivity, using a panel of 151 countries over the period from 1963 to 2014.

# 3 Model

There are two symmetric countries: country 1 and country 2. In each country, there is a continuum of identical households and a unit mass of monopolistically competitive firms, each producing a differentiated product. Firms are heterogeneous in terms of productivity levels, which are assumed to be i.i.d. across time, firms and countries. While all firms produce and sell in the domestic market, they may choose to also serve the foreign market by either exporting or producing in the foreign country (multinational production) after paying some costs associated with each activity. I build on the horizontal FDI model of Helpman, Melitz and Yeaple (2004) wherein firms choose to produce abroad when its value exceeds the value of exporting. In order to induce entry and exit of firms in exporting and multinational production, I follow Alessandria and Choi (2007), and introduce separate sunk entry costs to start exporting or multinational production, and separate continuation costs to maintain its activity from the previous period. Therefore, individual firms' current decisions to export or produce abroad are influenced by the status of their activity from the previous period as well as the expected values of these choices in the future.

In firms' production technology, I introduce roundabout production so that firms' output can be purchased by households for consumption and investment in physical capital, or by other firms in the economy - home or abroad - as production inputs. I assume that all prices are perfectly flexible. In this section, I describe the optimization problems and equilibrium conditions for agents in country 1. Analogous conditions hold for country 2.

## 3.1 Consumption-composite goods

Consumption-composite goods (final goods) $F_{1,t}$ are purchased by domestic households and used for consumption and investment in physical capital: $F_{1,t} = C_{1,t} + I_{1,t}$. These consumption-composite goods consist of domestic output $y_t^{D1}(z)$ produced by local firms, imported output $y_t^{X2}(z)$ and multinational output $y_t^{MN2}(z)$ produced by country-2 firms in country 1. Here, importing $y_t^{X2}(z)$ is subject to final-good tariffs, $\tau_t^{y2}$. These products are aggregated with a constant elasticity of substitution:

$$F_{1,t} = \left\{ \omega \left( y_t^{D1} \right)^{\frac{\rho-1}{\rho}} + (1-\omega) \left[ \left( y_t^{X2} \right)^{\frac{\psi-1}{\psi}} + \left( y_t^{MN2} \right)^{\frac{\psi-1}{\psi}} \right]^{\frac{\psi}{\psi-1}\frac{\rho-1}{\rho}} \right\}^{\frac{\rho}{\rho-1}} \tag{1}$$

where

$$
\begin{aligned}
y_t^{D1} &= \left[\int_0^1 y_t^{D1}(z)^{\frac{\gamma-1}{\gamma}} dz\right]^{\frac{\gamma}{\gamma-1}} && (2) \\
y_t^{X2} &= \left[\int_{z\in\Theta_{2,t}} y_t^{X2}(z)^{\frac{\gamma-1}{\gamma}} dz\right]^{\frac{\gamma}{\gamma-1}} && (3) \\
y_t^{MN2} &= \left[\int_{z\in\Omega_{2,t}} y_t^{MN2}(z)^{\frac{\gamma-1}{\gamma}} dz\right]^{\frac{\gamma}{\gamma-1}} && (4)
\end{aligned}
$$

$\omega$ is a bias toward domestic varieties, $\rho$ is the elasticity of substitution between a bundle of domestic varieties and a bundle of foreign varieties, $\psi$ is the elasticity of substitution between a bundle of imported varieties and a bundle of varieties locally produced by foreign multinational firms, and $\gamma$ is the elasticity of substitution between varieties produced within each category. The set of imported variety $\Theta_{2,t}$ and that of multinational products $\Omega_{2,t}$ are time-varying, since firms can enter and exit the export market and multinational production, as described later. Because firms in my model may choose to serve the foreign market by either exporting or multinational production, $\Theta_{2,t}$ and $\Omega_{2,t}$ are mutually exclusive sets of country-2 firms serving country 1.

Let $p_t^{D1}(z)$ denote the price of $y_t^{D1}(z)$, $p_t^{X2}(z)$ be the producer price of $y_t^{X2}(z)$, and $p_t^{MN2}(z)$ be the price of $y_t^{MN2}(z)$. I assume local-currency pricing; therefore, $p_t^{X2}(z)$ is denominated in the currency of country 1. Taking these prices as given, the demand for each of the three types of goods is obtained by minimizing the purchasing costs:

$$
\min_{y_t^{D1}(z), y_t^{X2}(z), y_t^{MN2}(z)} \int_0^1 p_t^{D1}(z) y_t^{D1}(z) dz + \int_{z\in\Theta_{2,t}} \tau_t^{y2} p_t^{X2}(z) y_t^{X2}(z) dz + \int_{z\in\Omega_{2,t}} p_t^{MN2}(z) y_t^{MN2}(z) dz
$$

subject to (1)–(4). Using the first-order conditions from this optimization, we can write the price index of consumption-composite goods $P_{1,t}$:

$$
P_{1,t} = \left\{ \omega^{\rho} \left(p_t^{D1}\right)^{1-\rho} + (1-\omega)^{\rho} \left[ \left(\tau_t^{y2} p_t^{X2}\right)^{1-\psi} + \left(p_t^{MN2}\right)^{1-\psi} \right]^{\frac{1-\rho}{1-\psi}} \right\}^{\frac{1}{1-\rho}}.
$$

where $p_t^{D1} = \left[\int_0^1 p_t^{D1}(z)^{1-\gamma} dz\right]^{\frac{1}{1-\gamma}}$, $p_t^{X2} = \left[\int_{z\in\Theta_{2,t}} p_t^{X2}(z)^{1-\gamma} dz\right]^{\frac{1}{1-\gamma}}$, and $p_t^{MN2} = \left[\int_{z\in\Omega_{2,t}} p_t^{MN2}(z)^{1-\gamma} dz\right]^{\frac{1}{1-\gamma}}$.

## 3.2 Production

When firm $z$ produces in its country of origin, its output is used for domestic consumption composites $y_t^{D1}(z)$ and as intermediate inputs by other firms $z'$ in the domestic economy ($\int_0^1 m_t^{D1}(z,z')dz'$). In addition, if the firm chooses to export its output to country 2 by paying export costs, it is used in foreign consumption composites ($y_t^{X1}(z)$) and as production inputs by firms in country 2 ($\int_0^1 m_t^{X1}(z,z')dz'$). Alternatively, the firm may choose to produce in country 2 using the aggregate productivity and production inputs (labor, capital and intermediate inputs) available there, after paying some costs. In this case, its output is sold to the households in country 2 as final goods $y_t^{MN1}(z)$ and to country-2 firms as intermediate inputs $\int_0^1 m_t^{MN1}(z,z')dz'$.[6]

For both local production ($i = 1$) and multinational production ($i = 2$), firm $z$ has the following Cobb-Douglas production technology:

$$y_{1,t}(z) = e^z A_i \left(K_{i,t}(z)^\alpha L_{i,t}(z)^{1-\alpha}\right)^\sigma M_{i,t}(z)^{1-\sigma}, \tag{5}$$

where $z$ is firm-specific productivity drawn from a time-invariant distribution $G(z)$, $A_i$ is the country-specific productivity, $K_{i,t}(z)$ is capital rented from households, $L_{i,t}(z)$ is labor, and $M_{i,t}(z)$ is a composite of intermediate inputs. This intermediate-input composite $M_{1,t}(z)$ consists of domestic intermediates $m_t^{D1}(\cdot,z)$ produced by local firms, imported intermediates $m_t^{X2}(\cdot,z)$, and intermediates $m_t^{MN2}(\cdot,z)$ produced by multinational firms from country 2 producing in country 1:

$$M_{1,t}(z) = \left\{\theta\left(m_t^{D1}(z)\right)^{\frac{\phi-1}{\phi}} + (1-\theta)\left[\left(m_t^{X2}(z)\right)^{\frac{\mu-1}{\mu}} + \left(m_t^{MN2}(z)\right)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}\frac{\phi-1}{\phi}}\right\}^{\frac{\phi}{\phi-1}} \tag{6}$$

where

$$m_t^{D1}(z) = \left[\int_0^1 m_t^{D1}(z',z)^{\frac{\gamma-1}{\gamma}}dz'\right]^{\frac{\gamma}{\gamma-1}} \tag{7}$$

$$m_t^{X2}(z) = \left[\int_{z'\in\Theta_{2,t}} m_t^{X2}(z',z)^{\frac{\gamma-1}{\gamma}}dz'\right]^{\frac{\gamma}{\gamma-1}} \tag{8}$$

$$m_t^{MN2}(z) = \left[\int_{z'\in\Omega_{2,t}} m_t^{MN2}(z',z)^{\frac{\gamma-1}{\gamma}}dz'\right]^{\frac{\gamma}{\gamma-1}} \tag{9}$$

$\theta$ is a bias toward domestic intermediate varieties, $\phi$ is the elasticity of substitution between a bundle of local intermediate inputs and that of foreign intermediate varieties, $\mu$ is the elasticity of substitution between a bundle of imported intermediates and that of foreign intermediates produced locally by multinational firms, and $\gamma$ is the elasticity of substitution between varieties within each category. Here, imports of goods produced by firms $z'$ in country 2 and used as intermediate inputs by firms $z$ in country 1 ($m_t^{X2}(z',z)$) are subject to intermediate-input tariffs $\tau_t^{m2}$.

Taking the prices and the tariff rate as given, firm $z$'s demand for each variety ($m_t^{D1}(z',z)$,

[6] In my framework, I consider multinational production as an alternative to exporting as in the horizontal FDI model of Helpman, Melitz and Yeaple (2014). Therefore, output of multinational firms produced in the host country is not directly exported back to the parent country. Antràs and Yeaple (2014) report that the primary purpose of multinational affiliates is to serve foreign markets, particularly the host-country market, rather than to find a low cost base and export output back to the parent country. Barefoot and Mataloni (2011) report that, in 2009, 60.8 percent of total sales of goods and services by foreign affiliates of U.S. multinationals went to the host country, and sales to the United States accounted for only 10.4 percent.

$m_t^{X2}(z', z)$, $m_t^{MN2}(z', z)$) is obtained by minimizing the cost:

$$\min \int_0^1 p_t^{D1}(z') m_t^{D1}(z', z) dz' + \int_{z' \in \Theta_{2,t}} \tau_t^{m2} p_t^{X2}(z') m_t^{X2}(z', z) dz' + \int_{z' \in \Omega_{2,t}} p_t^{MN2}(z') m_t^{MN2}(z', z) dz'$$

subject to (6)-(9). This yields the price index for the intermediate-input bundle $M_{1,t}(z)$:

$$P_{1,t}^M = \left\{ \theta^\phi \left( p_t^{D1} \right)^{1-\phi} + (1-\theta)^\phi \left[ \left( \tau_t^{m2} p_t^{X2} \right)^{1-\mu} + \left( p_t^{MN2} \right)^{1-\mu} \right]^{\frac{1-\phi}{1-\mu}} \right\}^{\frac{1}{1-\phi}}.$$

For production, firm $z$ chooses $L_{1,t}(z)$, $K_{1,t}(z)$, and $M_{1,t}(z)$ to minimize production costs:

$$\min w_{1,t} L_{1,t}(z) + r_{1,t} K_{1,t}(z) + \frac{P_{1,t}^M}{P_{1,t}} M_{1,t}(z)$$

subject to the production technology (5), where $w_{1,t}$ is real wage and $r_{1,t}$ is the real return on capital. From the first-order conditions, we can write the real marginal cost of production (before adjusting for firm-level productivity heterogeneity) as $MC_{1,t} \equiv \frac{(w_{1,t})^{\sigma(1-\alpha)} (r_{1,t})^{\alpha\sigma} (P_{1,t}^M / P_{1,t})^{1-\sigma}}{[\sigma(1-\alpha)]^{\sigma(1-\alpha)} (\sigma\alpha)^{\sigma\alpha} (1-\sigma)^{1-\sigma}} \frac{1}{A_1}$.

## 3.3 Prices

Since firms' production technology has constant returns to scale, we can consider separate optimization problems for domestic sales, export sales and multinational sales. We assume that firm $z$ sets separate prices for (i) the domestic market $p_t^{D1}(z)$, (ii) exports $p_t^{X1}(z)$ (if the firm chooses to export), and (iii) multinational production $p_t^{MN1}(z)$ (if the firm chooses to produce abroad), all denominated in the currency of the country where the good is sold. I assume that the same price is used when a good is sold as an intermediate input to other firms or as a final good to households, as long as the transaction occurs in the same country.

Firm $z$ chooses $p_t^{D1}(z)$ to maximize its current profit from domestic sales:

$$\max_{p_t^{D1}(z)} \frac{p_t^{D1}(z)}{P_{1,t}} \left( y_t^{D1}(z) + \int_0^1 m_t^{D1}(z, z') dz' \right) - \frac{MC_{1,t}}{e^z} \left( y_t^{D1}(z) + \int_0^1 m_t^{D1}(z, z') dz' \right)$$

The optimal price chosen by firms with firm-level productivity $z$ is equal to a constant markup times the marginal cost of production: $\frac{p_t^{D1}(z)}{P_{1,t}} = \frac{\gamma}{\gamma-1} \frac{MC_{1,t}}{e^z}$.

Exporting is subject to iceberg trade costs, $\tau_{1,t} \geq 1$, which are common to exports of final goods and intermediate inputs. In the absence of tariffs, these iceberg costs induce some firms to produce abroad instead of exporting, as explained in the next subsection. Firm $z$ chooses its export price $p_t^{X1}(z)$ to maximize its current profit from exporting:

$$\max_{p_t^{X1}(z)} Q_t \frac{p_t^{X1}(z)}{P_{2,t}} \left( y_t^{X1}(z) + \int_0^1 m_t^{X1}(z,z')dz' \right) - \frac{MC_{1,t}\tau_{1,t}}{e^z} \left( y_t^{X1}(z) + \int_0^1 m_t^{X1}(z,z')dz' \right)$$

where $Q_t \equiv e_t \frac{P_{2,t}}{P_{1,t}}$ is the real exchange rate and $e_t$ is the nominal exchange rate (the country 1 currency price of a unit of the country 2 currency). The optimal export price is equal to the domestic price multiplied by the iceberg cost and adjusted by the exchange rate: $\frac{p_t^{X1}(z)}{P_{2,t}} = \frac{\gamma}{\gamma-1} \frac{\tau_{1,t}}{Q_t} \frac{MC_{1,t}}{e^z}$. Since the export price is independent of the costs of entry and continuation in exporting, this optimal price $p_t^{X1}(z)$ is the same for new exporters and incumbent exporters for a given level of $z$.

When firm $z$ produces abroad as a multinational firm, it chooses a price $p_t^{MN1}(z)$ that maximizes the current profit of foreign operation, given the marginal cost of production in the host country:

$$\max_{p_t^{MN1}(z)} \frac{p_t^{MN1}(z)}{P_{2,t}} \left( y_t^{MN1}(z) + \int_0^1 m_t^{MN1}(z,z')dz' \right) - \frac{MC_{2,t}}{e^z} \left( y_t^{MN1}(z) + \int_0^1 m_t^{MN1}(z,z')dz' \right)$$

The optimal price for country 1 multinationals is $\frac{p_t^{MN1}(z)}{P_{2,t}} = \frac{\gamma}{\gamma-1} \frac{MC_{2,t}}{e^z}$. Since this price is independent of the costs of entry and continuation in multinational production, $p_t^{MN1}(z)$ is the same for entrants and incumbents, and also identical to the optimal domestic price chosen by local firms in country 2 for a given level of $z$.

### 3.4 Entry and exit in exporting and multinational production

Both exporting and multinational production entail fixed costs of operation that are paid as labor costs, and these costs depend on a firm's status in the previous period (domestic-only, exporter, or multinational). If a firm was only selling domestically last period, it must pay a sunk entry cost $\eta_{1,t}^X$ to start exporting. Once in the export market, an incumbent exporter must pay a continuation cost $\xi_{1,t}^X$ in order to continue exporting. Similarly, starting to produce in the foreign market as a multinational involves a sunk entry cost $\eta^{MN}$, and there is a per-period continuation cost $\xi^{MN}$ in order to continue operating abroad.

Let $\pi_{1,t}^X(z)$ denote firm $z$'s current real profits of exporting in units of country-1 consumption goods, and $\pi_{1,t}^{MN}(z)$ be its current real profits of multinational production:

$$\begin{aligned}
\pi_{1,t}^X(z) &\equiv Q_t \frac{p_t^{X1}(z)}{P_{2,t}} \left( y_t^{X1}(z) + \int_0^1 m_t^{X1}(z,z')dz' \right) - \frac{MC_{1,t}\tau_{1,t}}{e^z} \left( y_t^{X1}(z) + \int_0^1 m_t^{X1}(z,z')dz' \right) \\
\pi_{1,t}^{MN}(z) &\equiv Q_t \left[ \frac{p_t^{MN1}(z)}{P_{2,t}} \left( y_t^{MN1}(z) + \int_0^1 m_t^{MN1}(z,z')dz' \right) - \frac{MC_{2,t}}{e^z} \left( y_t^{MN1}(z) + \int_0^1 m_t^{MN1}(z,z')dz' \right) \right]
\end{aligned}$$

If a firm was serving only the domestic market in period $t-1$, then its foreign-related value at the beginning of period $t$, given current $z$, is:

$$V_{1,t}^{D}(z) = \max\left\{\beta \mathbf{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{1,t+1}^{D}(z_{t+1}), \quad \pi_{1,t}^{X}(z) - \eta_{1,t}^{X} w_{1,t} + \beta \mathbf{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{1,t+1}^{X}(z_{t+1}), \right.$$
$$\left. \pi_{1,t}^{MN}(z) - Q_t \eta_1^{MN} w_{2,t} + \beta \mathbf{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{1,t+1}^{MN}(z_{t+1}) \right\}. \tag{10}$$

The first element in equation (10) is the value of remaining as a domestic-only producer, and hence there is no current profit from neither exporting nor multinational production. The second element is the value of becoming an exporter in period $t$ by paying a sunk entry cost into exporting $\eta_{1,t}^{X} w_{1,t}$, and the third element is the value of becoming a multinational firm by paying a sunk entry cost into multinational production $Q_t \eta_1^{MN} w_{2,t}$, paid to country 2 labor.

If a firm was an exporter in period $t-1$, then its foreign-related value at the beginning of the current period $t$ is:

$$V_{1,t}^{X}(z) = \max\left\{\beta \mathbf{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{1,t+1}^{D}(z_{t+1}), \quad \pi_{1,t}^{X}(z) - \xi_{1,t}^{X} w_{1,t} + \beta \mathbf{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{1,t+1}^{X}(z_{t+1}), \right.$$
$$\left. \pi_{1,t}^{MN}(z) - Q_t \eta_1^{MN} w_{2,t} + \beta \mathbf{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{1,t+1}^{MN}(z_{t+1}) \right\} \tag{11}$$

In this case, the firm may choose to stop exporting and earn zero current profit from the foreign market (the first element in equation (11)), continue as an exporter by paying a continuation cost $\xi_{1,t}^{X} w_{1,t}$ (the second element), or start multinational production by paying a sunk entry cost $Q_t \eta_1^{MN} w_{2,t}$ (the third element).

If a firm was a multinational firm in period $t-1$, then its foreign-related value at the beginning of the current period $t$ is:

$$V_{1,t}^{MN}(z) = \max\left\{\beta \mathbf{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{1,t+1}^{D}(z_{t+1}), \quad \pi_{1,t}^{X}(z) - \xi_{1,t}^{X} w_{1,t} + \beta \mathbf{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{1,t+1}^{X}(z_{t+1}), \right.$$
$$\left. \pi_{1,t}^{MN}(z) - Q_t \xi_1^{MN} w_{2,t} + \beta \mathbf{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{1,t+1}^{MN}(z_{t+1}) \right\} \tag{12}$$

Here, the firm may stop serving the foreign market altogether and sell only domestically (the first element in equation (12)), stop producing abroad and switch to exporting by paying a cost $\xi_{1,t}^{X} w_{1,t}$ (the second element), or continue multinational production by paying a cost $Q_t \xi_1^{MN} w_{2,t}$ (the third element). I assume that when incumbent multinational firms switch to exporting, they pay $\xi_{1,t}^{X}$, instead of $\eta_{1,t}^{X}$. This assumes that, once a firm gains experiences operating abroad as a multinational, it establishes local distribution networks and gains knowledge about the product market of the host country. Such information could also be used for exporting and reduce the cost of switching to exporting, relative to a new exporter that was only serving its domestic market in the previous period.[7]

Using equations (10)-(12), we can define threshold productivity levels above which firms choose to export or produce abroad, given their activity status from the previous period. Let $z_{1,t}^{ij}$ for $i = (D, X, M)$ and $j = (X, M)$ be the minimum level of productivity with which firms with status $i$ ($D$ = domestic only; $X$ = exporter; or $M$ = multinational) in period $t-1$ export ($j = X$) or produce abroad ($j = M$) in period $t$. For example, using equation (10) for the case of firms that were serving only the domestic market in period $t-1$ ($i = D$), the threshold to start exporting in period $t$, $z_{1,t}^{DX}$, is given by equating the value of no foreign activity in the current period (the first element in equation (10)) and the value of export entry (the second element in equation (10)). Similarly, the threshold productivity level to start multinational production $z_{1,t}^{DM}$ is given by equating the value of export entry (the second element in equation (10)) and the value of multinational entry (the third element in equation (10)). In my calibration, since the entry cost into multinational production $\eta^{MN}$ is larger than the export entry cost $\eta^{X}$, the threshold for starting multinational production $z_{1,t}^{DM}$ is higher than the threshold for starting to export $z_{1,t}^{DX}$. In this case, those firms with productivity levels below $z_{1,t}^{DX}$ continue selling only domestically, those with productivity levels between $z_{1,t}^{DX}$ and $z_{1,t}^{DM}$ start exporting, and those with productivity levels above $z_{1,t}^{DM}$ become multinational firms. In a similar fashion, we can define the threshold productivity levels for incumbent exporters and incumbent multinationals by using equations (11) and (12), respectively.

Once we obtain the productivity thresholds for exporting and multinational production $z_{1,t}^{ij}$ for $i = (D, X, M)$ and $j = (X, M)$, we can use the distribution of $z$, $G(z)$, to get the transition probabilities for foreign activities. Using the above example of firms that were serving only the domestic market in period $t-1$, the probability that these firms start exporting in the current period is $\zeta_{1,t}^{DX} = G(z_{1,t}^{DM}) - G(z_{1,t}^{DX})$, and the probability that they start multinational production is $\zeta_{1,t}^{DM} = 1 - G(z_{1,t}^{DM})$. Therefore, the probability that it remains serving only the domestic market is given by $\zeta_{1,t}^{DD} = 1 - \zeta_{1,t}^{DX} - \zeta_{1,t}^{DM}$.

With the probabilities of exporting and multinational production, we can describe the dynamic evolution of the mass of exporters and multinational firms. Let $N_t^{X1}$ be the mass of incumbent exporters at the beginning of period $t$, and let $N_t^{MN1}$ be the mass of incumbent multinationals at the beginning of period $t$. The evolution of the mass of exporters is given by

$$N_{t+1}^{X1} = \zeta_{1,t}^{DX}\left(1 - N_t^{X1} - N_t^{MN1}\right) + \zeta_{1,t}^{XX} N_t^{X1} + \zeta_{1,t}^{MX} N_t^{MN1}.$$

[7] In my calibration described later in Section 4, this assumption also becomes necessary in order to ensure that there is a positive fraction of incumbent multinational firms that switch to exporting in steady state. If incumbent multinationals need to pay a large sunk entry cost into exporting $\eta_{1,t}^{X}$ when switching from multinational production to exporting, all incumbent multinationals that drop out of multinational activity would choose to serve their domestic market only.

The first term on the right hand side is the mass of firms that were selling only domestically in period $t-1$ and start exporting in period $t$. The second term is the mass of incumbent exporters from period $t-1$ that continue exporting in period $t$. The third term is the mass of firms that were producing abroad in period $t-1$ and switch to exporting in period $t$.

Similarly, the evolution of the mass of multinational firms is given by

$$N_{t+1}^{MN1} = \zeta_{1,t}^{DM}\left(1 - N_t^{X1} - N_t^{MN1}\right) + \zeta_{1,t}^{XM} N_t^{X1} + \zeta_{1,t}^{MM} N_t^{MN1}.$$

The first term is the mass of firms that were selling only domestically in period $t-1$ and become multinational firms in period $t$. The second term is the mass of incumbent exporters from period $t-1$ that start producing abroad in period $t$. Finally, the third term is the mass of incumbent multinational firms from period $t-1$ that continue multinational production in period $t$.

### 3.5 Households

Households in both countries have access to an international financial market in which they can purchase a complete set of state-contingent, one-period nominal bonds denominated in the currency of country 1. These bonds pay one unit of the country 1 currency. Let $B(s^{t+1})$ denote country 1 households' holdings of a nominal bond purchased in period $t$ and state $s^t$ that will pay out in period $t+1$ if the state $s^{t+1}$ realizes, and let $q(s^{t+1}|s^t)$ be its price in units of the currency of country 1 in period $t$ and state $s^t$. Households also receive a nominal government transfer for tariff revenues: $T_{1,t} = (\tau_t^{y2} - 1)p_t^{X2}y_t^{X2} + (\tau_t^{m2} - 1)p_t^{X2}m_t^{X2}$.

A representative household chooses consumption $C_{1,t}$, labor $L_{1,t}$, investment $I_{1,t}$, and bond holdings $B_{1,t+1}(s^{t+1})$ to maximize expected, discounted lifetime utility

$$\max \mathbf{E}_t \sum_{t=0}^{\infty} \beta^t \left[\log C_{1,t} + \chi(1 - L_{1,t})\right],$$

subject to a budget constraint

$$\sum_{s^{t+1}} q(s^{t+1}|s^t)B_1(s^{t+1}) + P_{1,t}C_{1,t} + P_{1,t}I_{1,t} = P_{1,t}w_{1,t}L_{1,t} + P_{1,t}r_{1,t}K_{1,t} + B_1(s^t) + P_{1,t}\Pi_{1,t} + T_{1,t}$$

and the law of motion for capital $K_{1,t+1} = (1-\delta)K_{1,t} + I_{1,t} - \frac{\kappa}{2}\left(\frac{I_{1,t}}{K_{1,t}} - \delta\right)^2 K_{1,t}$.

As in standard open-economy business cycle models with complete international financial markets, the real exchange rate is proportional to the relative marginal utility of consumption between the two countries[8]: $Q_t = e_0 \frac{\lambda_{1,t=0}}{\lambda_{2,t=0}} \frac{P_{2,t=0}}{P_{1,t=0}} \frac{\lambda_{2,t}}{\lambda_{1,t}}$

[8] In my calibration, I normalize $e_{t=0} \frac{\lambda_{1,t=0}}{\lambda_{2,t=0}} \frac{P_{2,t=0}}{P_{1,t=0}}$ to 1.

### 3.6 Aggregate variables

Real GDP is defined as $GDP_{1,t} \equiv C_{1,t} + I_{1,t} + EX_{1,t} - IM_{1,t}$, where $EX_{1,t} = Q_t \frac{p_t^{X1}}{P_{2,t}}(y_t^{X1} + m_t^{X1})$ is real exports in units of country 1 consumption goods, and $IM_{1,t} = \frac{p_t^{X2}}{P_{1,t}}(y_t^{X2} + m_t^{X2})$ is real imports in units of country 1 consumption goods. Net exports as a share of GDP is given by $NX_{1,t} = \frac{EX_{1,t} - IM_{1,t}}{GDP_{1,t}}$. The volume of country 1 exports is given by

$$EX_{1,t}^{vol} = \frac{\int_{z \in \Theta_{1,t}} p_t^{X1}(z) y_t^{X1}(z) dz}{p_t^{X1}} + \frac{\int_{z \in \Theta_{1,t}} \int_0^1 p_t^{X1}(z) m_t^{X1}(z, z') dz' dz}{p_t^{X1}}.$$

## 4 Calibration

The model is calibrated to the quarterly frequency. The household discount factor $\beta$ is set to 0.99 to imply an annual nominal interest rate of 4 percent. The capital depreciation rate $\delta$ is set equal to 0.025 so that the annual depreciation rate is 10 percent. For the elasticity of substitution between varieties $\gamma$, I follow Ghironi and Melitz (2005) and set it equal to 3.8. I assume that the elasticity of substitution between a bundle of domestic varieties and that of foreign varieties ($\rho$ for the consumption composite and $\phi$ for the intermediate composite) is set equal to 1.5, following the international business cycle literature (see, for example, Backus, Kehoe and Kydland (1994), and Chari, Kehoe and McGrattan (2002)). For the elasticity of substitution between a bundle of imported varieties and that of varieties produced locally by foreign multinationals ($\psi$ for the consumption composite and $\mu$ for the intermediate composite), I assume that it is higher than the elasticity of substitution between domestic and foreign bundles ($\rho$ and $\phi$) but lower than the elasticity of substitution between varieties within each bundle $\gamma$, and set it equal to 2 in my baseline calibration. Since there is no clear empirical guidance on this parameter value, I examine the sensitivity of my baseline results by varying this parameter value in subsection 6.2.

The share of capital in the value-added production $\alpha$ is 0.4. The steady-state value of iceberg trade cost is 1.3, following Ghironi and Melitz (2005). I normalize the steady-state level of country-specific productivity $A$ to 1 for both countries. Panel A of Table 1 summarizes these parameter values.

The remaining parameter values are calibrated to match some empirical targets as follows. The weight on leisure in the household utility $\chi$ is 1.35 so that households work one-third of their time. The capital adjustment cost parameter $\kappa$ is set equal to 5.21 which yields the volatility of investment relative to output of 2.91 in line with data.[9] For the share of value-added in production $\sigma$, I target the value of intermediate inputs as a share of total output value, which is 0.434 for the

[9]Business cycle moments of my model economy are obtained by simulating it with shocks to country-level productivity in both countries, which follows an AR(1) process with persistence 0.95. The standard deviation of the shocks is set to 0.007 and the cross-country correlation of the shocks is 0.25, as in Kehoe and Perri (2002). I simulate the model 100 times, each with 1000 periods.

Table 1: Parameter values

A: Parameters

| | | |
|---|---|---|
| Subjective discount factor | $\beta$ | 0.99 |
| Capital depreciation rate | $\delta$ | 0.025 |
| Elasticity of substitution | $\gamma$ | 3.8 |
| Armington elasticity | | |
| in consumption composite | $\rho$ | 1.5 |
| in intermediate composite | $\phi$ | 1.5 |
| Elasticity between imports and MN products | | |
| in consumption composite | $\psi$ | 2 |
| in intermediate composite | $\mu$ | 2 |
| Share of capital in value-added production | $\alpha$ | 0.4 |
| Steady state iceberg cost | $\bar{\tau}$ | 1.3 |
| Country-specific productivity | $A$ | 1 |

B: Parameters for matching empirical targets

| | | (1) Baseline | (2) No multinational | (3) High $\mu$ and $\psi$ |
|---|---|---|---|---|
| Weight on leisure in utility | $\chi$ | 1.35 | 1.27 | 1.32 |
| Capital adjustment cost | $\kappa$ | 5.21 | 5.26 | 5.18 |
| Share of value-added in production | $\sigma$ | 0.411 | 0.411 | 0.411 |
| Home bias | | | | |
| in consumption composite | $\omega$ | 0.802 | 0.8295 | 0.803 |
| in intermediate composite | $\theta$ | 0.746 | 0.782 | 0.749 |
| Steady-state cost of export entry | $\bar{\eta}^X$ | 0.235 | 0.2665 | 0.236 |
| Steady-state cost of export continuation | $\bar{\xi}^X$ | 0.049 | 0.053 | 0.0495 |
| Cost of multinational entry | $\eta^{MN}$ | 2.40 | – | 1.45 |
| Cost of multinational continuation | $\xi^{MN}$ | 0.28 | – | 0.175 |
| Standard deviation of firm-level productivity | $\sigma_z$ | 0.37 | 0.37 | 0.37 |

*Notes:* Column (1): Baseline calibration. Column (2): An alternative model without multinational production. Column (3): An alternative model with a high elasticity of substitution between imported varieties and varieties produced by multinational firms ($\mu = \psi = 3$).

Table 2: Target statistics and model moments

| | Data | Baseline model | |
|---|---|---|---|
| Total imports/GDP | 0.15 | 0.15 | U.S. data (1947Q1-2016Q4) |
| Intermediate inputs/total output value | 0.434 | 0.434 | Input-Output Table (2000-2014) |
| Intermediate imports/total imports | 0.54 | 0.54 | Input-Output Table (2000-2014) |
| Exporter entry rate | 0.037 | 0.039 | Bernard & Jensen (2004) |
| Exporter continuation rate | 0.967 | 0.965 | Bernard & Jensen (2004) |
| No. of multinational entry/no. of exporter entry | 0.19 | 0.21 | Deseatnicov & Kucheryavyy (2017) |
| No. of multinationals/total no. of firms | 0.02 | 0.02 | Antràs & Yeaple (2014) |
| Productivity relative to non-exporters | 1.12-1.18 | 1.12 | Bernard & Jensen (1999) |

United States during the period between 2000 and 2014 from the World Input-Output Tables. In my model, this share is given by $\frac{(1-\sigma)(1-\gamma)}{\gamma}$. Given $\gamma$ equal to 3.8, this yields $\sigma = 0.411$.

I assume that the idiosyncratic firm-level productivity $z$ is normally distributed with zero mean: $G(z) = N(0, \sigma_z)$. With this assumption, the remaining seven parameters ((i) the home bias in the consumer composite $\omega$, (ii) the home bias in the intermediate-input composite $\theta$, (iii) the steady-state value of export entry cost shocks $\bar{\eta}^X$, (iv) the steady state value of export continuation cost shocks $\bar{\xi}^X$, (v) sunk cost of starting as a multinational $\eta^{MN}$, (vi) continuation cost of operating as a multinational $\xi^{MN}$, and (vii) the standard deviation of idiosyncratic firm-level productivity shocks $\sigma_z$), are jointly calibrated so that the steady-state characteristics of my model match key empirical observations from international trade in final goods and intermediate inputs, the dynamics of exporter entry and exit in the U.S. data, and the dynamics of multinational firms. Specifically, total imports as a share of GDP is 0.15, in line with the average value for the United States between 1947Q1 and 2016Q4. The value of intermediate imports as a fraction of total imports is 0.54, as reported in the World Input-Output Tables for the United States over the period from 2000 to 2014. For the exporter dynamics, the rate of export continuation is 96.7 percent and that of exporter entry is 3.7 percent at the quarterly frequency, based on the U.S. manufacturing establishments between 1984 and 1992 (Bernard and Jensen, 2004). These probabilities are 96.5 percent and 3.9 percent in my model, respectively. In my model, exporters are 12 percent more productive than non-exporters, to be in the range of 12-18 percent for U.S. exporters as reported by Bernard and Jensen (1999). For the dynamics of multinationals, Deseatnicov and Kucheryavyy (2017) report that the number of entry for multinationals is, on average, 19 percent of that of exporter entry for Japanese firms between 1995 and 2013. In my model, the number of multinational entry is 21 percent of the exporter entry. The number of multinationals as a share of total number of local firms is 2 percent as observed in France in 2007 (Antràs and Yeaple, 2014). These parameter values are summarized in panel B of Table 1, and the calibration targets and model-implied moments are reported in Table 2.

# 5 Results

In this section, I examine the effects of permanent, unilateral changes in various trade policies on exporter dynamics and the aggregate economy. Specifically, I consider the following three trade policies that are imposed by country 2 in order to reduce its imports from country 1: (i) tariffs on country 2's imports of final goods from country 1, $\tau_t^{y1}$; (ii) tariffs on country 2's imports of intermediate inputs from country 1, $\tau_t^{m1}$; and (iii) barriers for country 1 exporters to access the country 2 market, $\xi_{1,t}^X$ and $\eta_{1,t}^X$. In order to facilitate the comparison across these policy experiments, I choose the magnitude of each shock such that the export volume from country 1 to country 2 falls by 5 percent cumulatively relative to the initial steady state over the first 40 periods (10 years) following each shock. In my baseline analysis, this requires the shock to final-good tariffs to be 4.02917 percent, the shock to intermediate-input tariffs 3.66053 percent, and the shock to entry and continuation costs for exporting (market-access barriers) 7.6402 percent. I assume that economic agents in my model have perfect foresight. Therefore, while each trade policy shock is unanticipated, its future path is known to the agents once the shock arrives.

## 5.1 Long-run effects

I start my analysis with the long-run effects of permanent changes in the three trade policies. Table 3 summarizes the long-run changes in GDP, consumption, investment, the trade balance, the mass of exporters, and the mass of multinational firms in the two countries, expressed as percentage deviations from their initial steady-state levels, for each trade policy change. The trade balance is expressed as a percentage of GDP.

Starting with the long-run effects on GDP (panel A), we see that all policies lead to a recession in both countries in the long run. However, the relative impact on the GDP of the two countries varies across policies, with final-good tariffs and intermediate-input tariffs leading to a larger fall in country 1, while market-access barriers resulting in a larger GDP fall in country 2. In contrast, the effects on consumption are consistently larger for country 2 than for country 1 in all cases (panel B). Consumption falls by 0.74 to 1.02 percent in country 2, while it falls by 0.19 to 0.37 percent in country 1. The larger fall of consumption in the country that imposes these import restrictions (country 2) is attributed mainly to the disappearance of product varieties due to the substantial exit of country 1 exporters from the country 2 market (panel E). Although some of the most productive country-1 exporters continue to serve country 2 by locating production in country 2 (panel F), the least productive exporters exit from the country 2 market. Since households derive utility from having more product variety, the consumption loss is larger for country 2 households.

Table 3: Long-run effects of trade policy

| | Tariffs on final goods | Tariffs on intermediate goods | Barriers to market access |
|---|---|---|---|
| *A: GDP* | | | |
| Country 1 | -0.74 | -0.84 | -0.46 |
| Country 2 | -0.24 | -0.61 | -0.72 |
| *B: Consumption* | | | |
| Country 1 | -0.19 | -0.37 | -0.26 |
| Country 2 | -0.74 | -1.02 | -0.92 |
| *C: Investment* | | | |
| Country 1 | -0.74 | -0.84 | -0.46 |
| Country 2 | -0.51 | -0.90 | -0.72 |
| *D: Trade balance (as % of GDP)* | | | |
| Country 1 | -0.47 | -0.40 | -0.17 |
| Country 2 | 0.47 | 0.40 | 0.17 |
| *E: Exporter mass* | | | |
| Country 1 | -5.19 | -5.01 | -13.18 |
| Country 2 | -0.89 | -1.35 | -0.86 |
| *F: Multinational mass* | | | |
| Country 1 | 3.53 | 2.93 | 5.46 |
| Country 2 | -0.74 | 0.13 | 0.42 |

*Notes:* The reported values are percentage deviations from the initial steady state, except for the trade balance (panel D) which is net exports as a percentage of GDP. For each policy scenario, country 2 imposes the respective trade policy so that the volume of its imports from country 1 declines by 5 percent cumulatively, relative to the initial steady state over the first 40 periods (10 years) following each policy change. For the mass of exporters reported in panel E, the "Country 1" row refers to the mass of country 1 firms exporting their output to country 2. Similarly, for the mass of multinational firms reported in panel F, the "Country 1" row refers to the mass of country 1 firms producing and selling in country 2 as multinationals.

The long-run trade balance improves for the policy-imposing country (country 2) in all three cases, varying from 0.17 to 0.47 percent of GDP (panel D). We see that the changes in net exports tend to be larger with tariffs, with country 2's trade balance improving by 0.47 percent and 0.40 percent with tariffs on final goods and intermediate inputs, respectively, while market-access barriers generate a 0.17 percent surplus in the long run.

Comparing across the three policies, we see that the loss in global GDP is largest in the case of intermediate-input tariffs. The GDP loss for country 1 from intermediate-input tariffs is nearly twice as large as that from market-access barriers, and the GDP loss for country 2 is around 2.5 times larger with intermediate-input tariffs than with final-good tariffs. In my model, intermediate inputs are aggregated using the same elasticities as those in the final-good aggregator. However, with global value chains, intermediate inputs are further combined with value-added in order to produce varieties in the production function, while final goods are purchased directly by households and used for consumption and investment. Therefore, the average elasticity associated with intermediate inputs is lower than the average elasticity associated with final goods, and this leads to larger losses with tariffs on intermediate inputs than with tariffs on final goods.

For the extensive margins of exporting and multinational production (panels E and F), larger shifts are seen for firms originating in country 1 that are directly affected by the changes in trade policy. The import restrictions by country 2 lead less productive country 1 exporters to stop exporting to country 2, and the contraction is largest with market-access barriers (-13.18 percent), which substantially increase the costs of exporter entry and continuation. On the other hand, the most productive exporters from country 1 choose to locate production in country 2 as multinationals, with the mass of country 1 firms that produce in country 2 increasing by 2.93 to 5.46 percent. For (potential) country-1 multinational firms, in addition to the gains from avoiding trade barriers, the declining wages in country 2 lower the costs of multinational operation in country 2, thereby increasing the profitability of locating production there. Moreover, as the least productive country 1 exporters exit from the country 2 market and because the newly entering (potential) multinational firms are more productive than these exiting exporters, the market share for multinational firms is increased, which further increases the profitability of multinational production.

The expansion of country 1 multinational firms operating in country 2 is smaller in the case of intermediate-input tariffs (2.93 percent) relative to the other two cases. Because tariffs on intermediate imports increase the purchasing price of intermediate inputs in country 2, this partially offsets the downward pressure on the marginal cost of production due to the declining costs of labor and capital. The fall in real wages and the rental rate of capital however dominates the increase in the price of imported intermediate inputs, and we see an increase in the number of country 1 multinational firms producing in country 2.

In Table 4, I focus on the long-run effects on country 2 (policy-imposing country) to analyze the transmission channel of each policy. Here, the fall in GDP is smallest (-0.24 percent) in the case

Table 4: Long-run effects on the policy-imposing country (country 2)

| | Tariffs on final goods | Tariffs on intermediate goods | Barriers to market access |
|---|---|---|---|
| GDP | -0.24 | -0.61 | -0.72 |
| Domestic production | | | |
| (i) Final goods | | | |
| by local firms | -0.21 | -0.98 | -0.63 |
| by country 1 multinationals | 2.36 | 0.05 | 0.94 |
| (ii) Intermediate goods | | | |
| by local firms | -0.14 | -0.68 | -0.42 |
| by country 1 multinationals | 1.17 | 1.49 | 1.16 |
| Imports | | | |
| (i) Final goods | -8.92 | -2.03 | -5.35 |
| (ii) Intermediate goods | -2.05 | -7.91 | -5.14 |
| Real wage | -0.74 | -1.02 | -0.92 |
| Intermediate-input price | -0.25 | 0.39 | 0.09 |

*Notes:* The values are percentage deviations from the initial steady state. For each policy scenario, country 2 imposes the respective trade policy so that the volume of its imports from country 1 declines by 5 percent cumulatively relative to the initial steady state over the first 40 periods (10 years) following each policy change.

of final-good tariffs relative to the other two policies (-0.61 percent for intermediate-input tariffs, and -0.72 percent for market-access barriers). In response to final-good tariffs, the country's imports of final goods fall substantially (-8.92 percent). This generates (imperfect) expenditure switching toward domestically produced final goods, and we see a smaller fall in the domestic production of final goods by local firms (-0.21 percent) and a sizable increase in the final-good production by multinationals (2.36 percent) relative to the other two policies. This shift in demand away from imported final goods that are more expensive to domestically produced final goods helps to alleviate the fall in GDP.

In contrast, such expenditure switching is absent in the case of intermediate-input tariffs, and this is due to the global value chain effects. When tariffs are imposed on the country's intermediate-input imports, imports of intermediate inputs fall substantially (-7.91 percent). However, this does not lead to an expenditure switching to domestically produced intermediate products. In fact, the fall in the production of intermediate inputs by domestic firms is largest in the case of intermediate-input tariffs (-0.68 percent), compared with the other two cases (-0.14 percent for final-good tariffs, and -0.42 percent for market-access barriers). The increase in the production

Table 5: Long-run effects on the policy-imposed country (country 1)

| | Tariffs on final goods | Tariffs on intermediate goods | Barriers to market access |
|---|---|---|---|
| GDP | -0.74 | -0.84 | -0.46 |
| Consumption | -0.19 | -0.37 | -0.26 |
| Real export sales | -3.94 | -3.99 | -2.00 |
| Relative producer price of exports | 0.74 | 0.55 | 2.58 |

*Notes:* The values are percentage deviations from the initial steady state. For each policy scenario, country 2 imposes the respective trade policy so that the volume of its imports from country 1 declines by 5 percent cumulatively relative to the initial steady state over the first 40 periods (10 years) following each policy change. Real export sales are expressed in units of country 1 consumer goods, $F_1$. The producer price of exports is expressed as relative to the aggregate price index in country 1 $P_1$.

of intermediate inputs by country-1 multinationals in country 2 (1.49 percent) is not significantly larger than the other two case (1.17 percent for final-good tariffs and 1.16 percent for market-access barriers). With intermediate-input tariffs, the increase in the purchasing price of imported intermediate inputs directly places an upward pressure on the marginal cost of production for firms that rely on these imports in production. As a result, we see an increase in the price of intermediate inputs (0.39 percent) relative to the other two cases in which the changes are negative or negligible (-0.25 percent for final-good tariffs, and 0.09 percent for market-access barriers). The input-output linkages thus amplify the effects of this rising cost of production, further reducing the demand for output and hence aggregate income in country 2.

Turning to the policy-imposed country whose exports are negatively affected by the trade policy changes, I report the long-run effects on country 1 in Table 5. Here, GDP falls by less in response to market-access barriers (-0.46 percent) relative to final-good tariffs and intermediate-input tariffs (-0.74 percent and -0.84 percent, respectively). In country 1, the recessionary effects of trade policy are mainly attributed to a contraction of the export sector, and the fall in real export sales (in units of country 1 consumer goods) is substantially smaller in the case of market-access barriers (-2.00 percent) where the decline is nearly half of the decline with final-good tariffs (3.94 percent) or intermediate-input tariffs (3.99 percent). Note here that, in all policy scenarios, I control for the size of the contraction in the export volume over the first 40 periods; therefore, the differences in the magnitude of the fall in real exports arise primarily from the differences in the relative producer price of exports. We see that the producer price of exports (relative to the aggregate price index) increases significantly more with market-access barriers (2.58 percent) compared with the two tariff cases (0.74 percent for final-good tariffs, and 0.55 percent for intermediate-input

Table 6: Labor reallocation

| | Tariffs on final goods | Tariffs on intermediate goods | Barriers to market access |
|---|---|---|---|
| *A: Country 1* | | | |
| Aggregate labor | -0.87 | -0.76 | -0.40 |
| Labor for domestic production | -0.26 | -0.19 | -0.07 |
| Labor for multinational production | -0.22 | 0.12 | 0.20 |
| Labor for export production | -3.75 | -3.61 | -1.74 |
| *B: Country 2* | | | |
| Aggregate labor | 0.22 | 0.08 | 0.18 |
| Labor for domestic production | 0.23 | 0.15 | 0.21 |
| Labor for multinational production | 1.59 | 1.36 | 1.41 |
| Labor for export production | -0.63 | -0.97 | -0.62 |

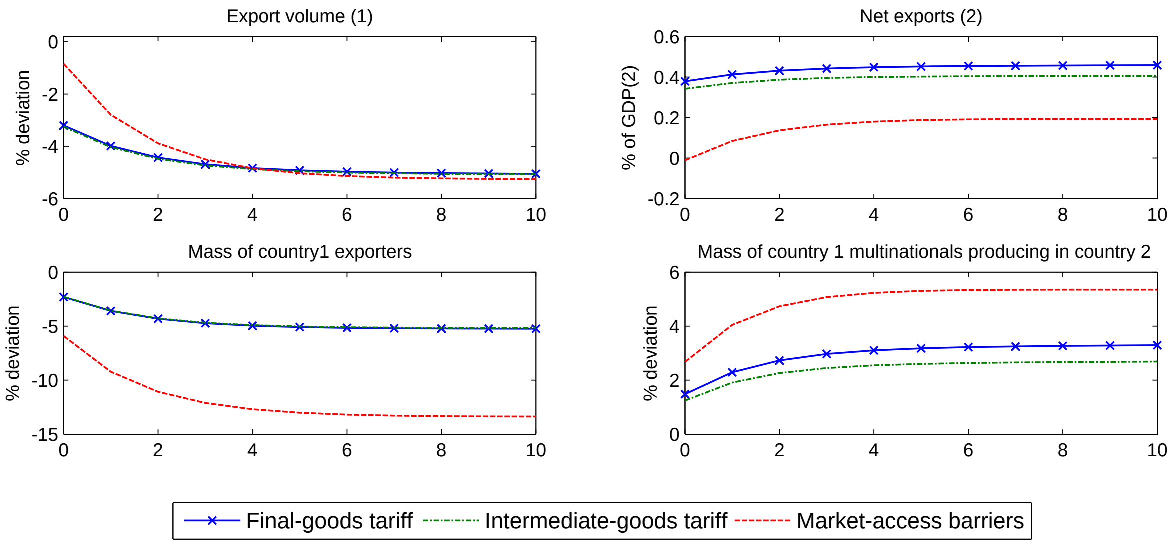
*Notes:* The values are percentage deviations from the initial steady state. For each policy scenario, country 2 imposes the respective trade policy so that the volume of its imports from country 1 declines by 5 percent cumulatively relative to the initial steady state over the first 40 periods (10 years) following each policy change. "Labor for domestic production" refers to local labor used for production by local firms to produce goods sold domestically. "Labor for multinational production" refers to local labor employed by foreign multinational firms producing and selling in the respective host country. "Labor for export production" refers to labor employed by local firms to produce exported products.

tariffs). With market-access barriers, there is a sizable contraction in the export participation among country 1 firms (-13.18 percent in panel E of Table 3). As shown in the literature of product variety and firm entry and exit, fewer product varieties lead to an increase in the producer price index of exports (Feenstra, 1994; Ghironi and Melitz, 2005).[10]

Next, I examine the effects of each trade policy on aggregate labor and its sectoral components, disaggregated into labor used for (i) domestic production (by domestic firms), (ii) production by multinational firms, and (iii) production of exported goods (Table 6). In country 1, where the policy changes result in a large contraction of the country's export sector, we see that the contraction in aggregate labor is attributed primarily to the significant contraction in labor in the export sector. In contrast, in country 2, while the policy changes have smaller effects on aggregate labor relative to country 1, we see a clear reallocation of labor away from the export sector toward domestic production, especially by country-1 multinational firms operating in country 2. In the long run, labor employed by local firms for domestic production increases by 0.15 to 0.23 percent

[10] The long-run effects of trade policy on various GDP components in the two countries are reported in Table B1 in Appendix B.

Figure 1: Impulse responses to trade barriers




*Notes:* Impulse responses to a permanent increase in (i) tariffs on final goods (blue lines with x's), (ii) tariffs on intermediate inputs (green dash-dot lines), and (iii) market-access barriers (red dashed lines). The magnitude of each shock is chosen so that the volume of exports from country 1 to country 2 falls by 5 percent cumulatively over the first 40 periods following the shock.

and labor employed by multinational firms increases by 1.36 to 1.59 percent, while labor used to produce exports falls by 0.62 to 0.97 percent.

## 5.2 Short-run dynamics

Having examined the long-run effects of the three trade policies, we now turn to the transition dynamics of my model economy in response to each policy change. They reveal that the short-run effects are different quantitatively and qualitatively across policies and over time, which cannot be seen in the long-run analysis above.

Figure 1 presents the impulse responses of the volume of country 1 exports, the trade balance of country 2, the mass of country 1 exporters, and the mass of country-1 multinationals producing in country 2, following each of the three trade policy changes under consideration. We see that market-access barriers (red dashed lines) have significantly more gradual effects on trade flows relative to the other two policies during the first few periods. This is due to the hysteresis in exporter dynamics. Because of the presence of large sunk costs of starting to export, firms do not change their export status immediately following the shock, and some incumbent exporters delay their exit, taking into consideration the large cost of re-entering the export market in the future (Baldwin, 1988; Baldwin and Krugman, 1989; and Dixit, 1989a, 1989b). In addition, the larger sunk cost of starting multinational production delays the shift from exporting to multinational production for the most productive exporters, as seen in the lower right panel. Therefore, we see more gradual responses to this policy change.

This slow adjustment of country 1 exports contributes to a negligible change in the trade balance for country 2 at the impact of the shock. While export adjustments are delayed in response to the market-access barriers, investment in country 1 falls immediately following the onset of the shock (Figure C1 in Appendix C), as agents in country 1 expect a large contraction in its export sector in the future. Therefore, exports of country 2 fall as demand in country 1 starts contracting, while imports of country 2 experience a more gradual fall, and we see a delay in the trade balance improvement for country 2.

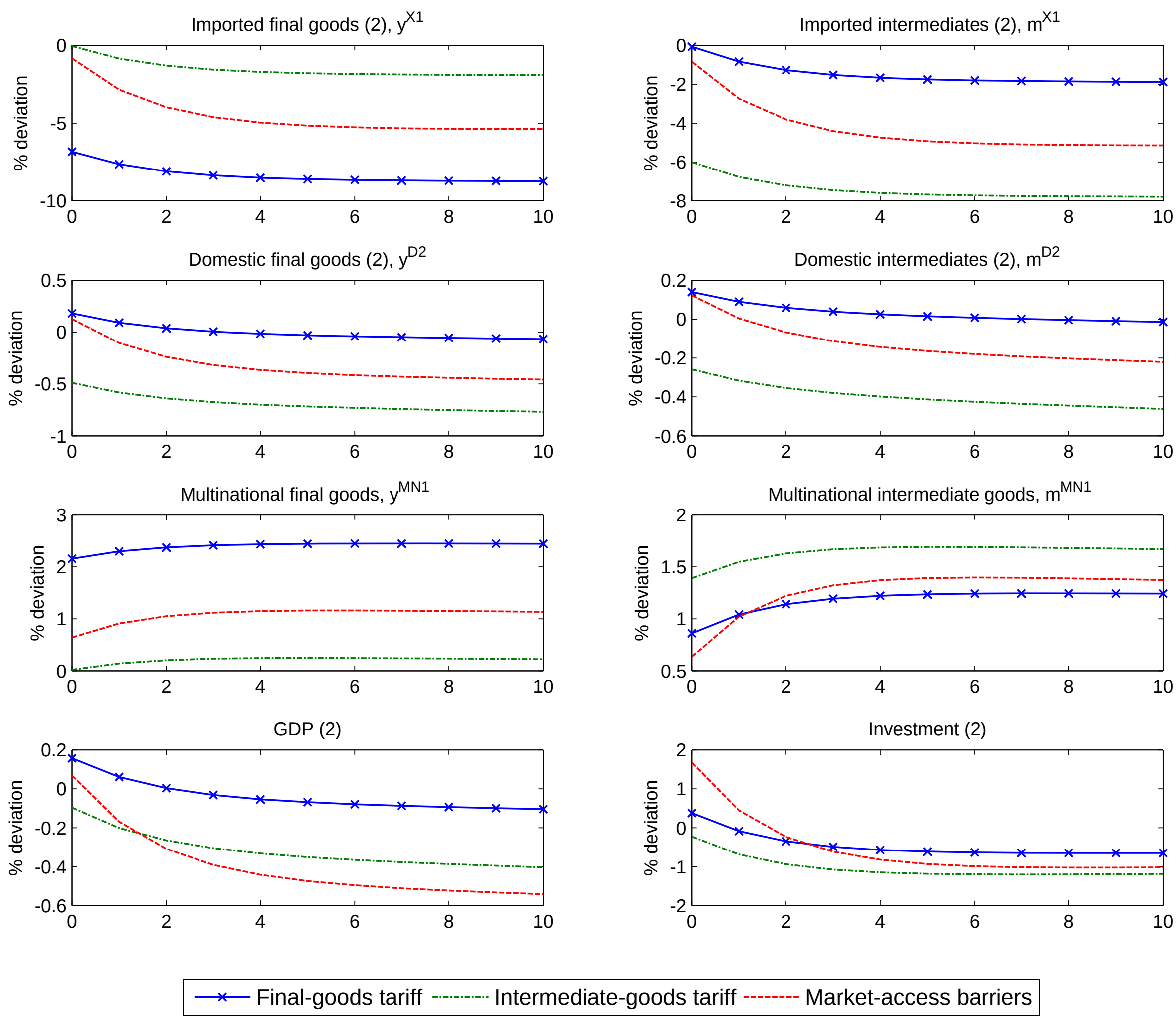
Another short-run observation that departs from the long-run results is that, in contrast to the long-run recessionary effects of the import restrictions we saw in Table 4, we see that final-good tariffs and market-access barriers lead to a temporary boom in country 2 in the short run. Figure 2 presents the dynamic responses of aggregate variables in country 2 (where imports are restricted). When country 2 imposes tariffs on its imports of final goods from country 1 (blue lines with x's), the higher price of imported final goods induces expenditure switching to domestically produced final goods. In the short run, this leads to a slight but persistent increase in the demand for country 2 final goods, $y^{D2}$. At the same time, most productive country-1 firms affected by the tariffs find it more profitable to start producing in country 2, and their production of final goods $y^{MN1}$ increases substantially more relative to the other two cases. The increased production of final goods in country 2 in turn entails an increase in the production of intermediate inputs there, and we see a marginal increase in $m^{D2}$ and a larger increase in the production of intermediate inputs by multinationals $m^{MN1}$ as well. This temporary increase in domestic production leads to a temporary increase in GDP. However, as households expect that the higher price of imported final goods implies a reallocation of their consumption basket to domestic goods produced less efficiently, they recognize that their long-run wealth will be lower.[11] Expecting lower long-run returns on their investment, they start reducing investment in physical capital, which eventually leads to lower production and consumption in the long run.

In the case of market-access barriers (red dashed lines), the responses are more gradual relative to the other two policies, as discussed above. The resulting slow response of trade flows leads to a sizable increase in investment in country 2 in the short run, as households shift expenditures to final goods that are produced using domestic resources ($y^{D2}$ and $y^{MN1}$) and producers shift to domestically sourced intermediate inputs ($m^{D2}$ and $m^{MN1}$).

In contrast to the above two policies, intermediate-input tariffs (green dash-dot lines) lead

[11] In Barattieri, Cacciatore and Ghironi (2019), such reallocation of household expenditures to a set of less efficiently produced domestic goods due to tariffs can have immediate negative effects on the aggregate income even when the tariffs are temporary. These effects are stronger in their model in which exporter entry decisions are static. In my model, following Alessandria and Choi (2014), export entry/exit decisions are dynamic due to the presence of sunk entry costs; therefore, the delay in exporter exit by some firms dampens the effects of expenditure reallocations in the short run.

Figure 2: Impulse responses to various trade barriers (country 2)




*Notes:* Impulse responses of country 2 to a permanent increase in (i) tariffs on final goods (blue lines with x's), (ii) tariffs on intermediate goods (green dash-dot lines), and (iii) barriers to market access (red dashed lines). The magnitude of each shock is chosen so that the volume of exports from country 1 to country 2 falls by 5 percent cumulatively over the first 10 years following the shock. Analogous figures for country 1 are presented in Figure C1 in Appendix C.

to an immediate fall in the production of both domestic final goods $y^{D2}$ and domestic intermediate goods $m^{D2}$ in country 2. As discussed above, tariffs on imported intermediate goods immediately increase the cost of production for country 2 producers that use these imports as production inputs. This translates into a rise in the price of their output, which in turn reduces demand. Because some of their output is used as production inputs by other firms in country 2, these input-output linkages across firms amplify the effects of the tariff shock, and we see an immediate fall in domestic production ($y^{D2}$ and $m^{D2}$).

# 6 The role of multinational firms

One distinct feature of my model economy is the endogenous entry and exit of multinational firms that may choose to produce and sell their output in the foreign market instead of exporting. As shown by Wu (2015), because multinational firms are the most productive firms in the economy, their decisions on entry/exit and production in response to trade policy changes can affect the aggregate economy in a nontrivial way. In particular, when trade policy changes affect the profitability of exporting, the option to relocate production allows firms to avoid trade barriers, while households reallocate their expenditure to a wider variety of output produced with the same level of productivity as exporters or higher. In contrast, in the absence of multinationals, the alternative consumption choices are limited to locally produced products that are on average produced with a lower level of productivity. In this section, I explore the role of multinational firms in my analysis of trade policy changes. To this end, I carry out two exercises. First, I consider an alternative version of my model economy in which there is no multinational production and individual firms make endogenous entry/exit decisions only for exporting. Second, I increase the elasticity of substitution between a bundle of imported varieties and a bundle of varieties produced locally by foreign multinational firms ($\psi$ in the consumption-composite goods in equation (1) and $\mu$ in the intermediate-composite goods in equation (6)). These two alternative specifications highlight the important implications of the dynamics of multinational firms, both quantitatively and qualitatively, in influencing the aggregate effects of trade policy changes.

## 6.1 Comparison to a model without multinational firms

I first compare my baseline results to those obtained from an alternative model without multinational firms. In order to maintain the consistency in the steady-state characteristics of the two models, I recalibrate this alternative model to match the steady-state moments described in Table 2, except for the two target moments related to multinational firms (the number of multinational entry relative to the number of exporter entry and the number of multinationals as a share of total number of firms) that are absent in this alternative model. The recalibrated parameter values are reported in column (2) of panel B in Table 1. The magnitude of each trade shock is also adjusted

Table 7: The role of multinational firms

| | Baseline model | | | No multinational firms | | | High $\mu$ and $\psi$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| | T-F | T-I | MB | T-F | T-I | MB | T-F | T-I | MB |
| *A: Country 1* | | | | | | | | | |
| GDP | -0.74 | -0.84 | -0.46 | -0.76 | -0.92 | -0.45 | -0.72 | -0.72 | -0.49 |
| Production | | | | | | | | | |
| (i) Final goods | | | | | | | | | |
| by local firms | -0.22 | -0.34 | -0.22 | -0.23 | -0.39 | -0.24 | -0.19 | -0.26 | -0.19 |
| by multinationals | -0.20 | 0.07 | 0.14 | – | – | – | 0.55 | 2.40 | 1.80 |
| (ii) Intermediates | | | | | | | | | |
| by local firms | -0.68 | -0.72 | -0.37 | -0.70 | -0.78 | -0.35 | -0.68 | -0.63 | -0.43 |
| by multinationals | -0.66 | -0.31 | -0.01 | – | – | – | 0.06 | 2.03 | 1.56 |
| Mass of country-1 exporters | -5.19 | -5.01 | -13.18 | -5.59 | -5.37 | -15.75 | -5.19 | -5.01 | -10.46 |
| Mass of country-2 MNs | -0.74 | 0.13 | 0.42 | – | – | – | 0.50 | 4.44 | 3.37 |
| *B: Country 2* | | | | | | | | | |
| GDP | -0.24 | -0.61 | -0.72 | -0.44 | -0.84 | -0.97 | 0.07 | -0.28 | -0.32 |
| Production | | | | | | | | | |
| (i) Final goods | | | | | | | | | |
| by local firms | -0.21 | -0.98 | -0.63 | -0.29 | -1.21 | -0.78 | -0.10 | -0.65 | -0.40 |
| by multinationals | 2.36 | 0.05 | 0.94 | – | – | – | 10.38 | 5.76 | 7.63 |
| (ii) Intermediates | | | | | | | | | |
| by local firms | -0.14 | -0.68 | -0.42 | -0.32 | -0.91 | -0.60 | 0.12 | -0.33 | -0.12 |
| by multinationals | 1.17 | 1.49 | 1.16 | – | – | – | 7.70 | 8.81 | 7.91 |
| Mass of country-2 exporters | -0.89 | -1.35 | -0.86 | -0.89 | -1.25 | -0.70 | -1.01 | -1.71 | -1.22 |
| Mass of country-1 MNs | 3.53 | 2.93 | 5.46 | – | – | – | 17.29 | 15.04 | 18.93 |

*Notes:* T-F: tariffs on final goods. T-I: tariffs on intermediate inputs. MB: market-access barriers.
The values are percentage deviations from the respective initial steady state of each model. Columns (1)-(3): results from my baseline model. Columns (4)-(6): results from a model without multinational production. Columns (7)-(9): results from a model with $\mu = \psi = 3$. For each policy scenario, country 2 imposes the respective trade policy so that the volume of its imports from country 1 declines by 5 percent cumulatively relative to the initial steady state over the first 40 periods (10 years) following each policy change.

so that the fall in the volume of country 1 exports is 5 percent over the first 40 periods as in my baseline analysis. For this alternative model, the magnitude of the trade shock is 4.9667 percent for final-good tariffs, 4.4092 percent for intermediate-input tariffs, and 9.16185 for market-access barriers. Table 7 compares the long-run effects of trade policy changes from my baseline model (columns (1)-(3)) with those from the alternative model without multinational production (columns (4)-(6)).

We see that, while the presence of multinational firms has rather negligible effects on the policy-imposed country (country 1), it significantly dampens the contraction in the policy-imposing country (country 2). As discussed above, in my baseline calibration, the costs of entry/continuation for multinational production are higher than those for exporting. Therefore, the average multinational firm is more productive than the average exporter. As we saw in section 5, the rise in the price of country 1 exports and the declining wages in country 2 due to the recessionary effects of the policy changes induce an expansion in multinational activity in country 2, even in the case of intermediate-input tariffs as the fall in the prices of labor and capital dominates the increasing costs of imported intermediate inputs. Because the multinational firms that are newly entering into the country 2 market are more productive than those exporters exiting from the country 2 market or the average local producers in country 2, the increase in the participation, and hence production, of multinationals partially offsets the contractionary effects of import restrictions on country 2.

The dampening effects of multinational firms on country 2 are larger in the case of final-good tariffs because this policy generates stronger expenditure switching away from imported products toward domestically produced goods, which induces a larger expansion in the production by multinational firms in country 2 (Figure 2 and Table 4).

### 6.2 Elasticity of substitution between imports and multinational products

In my baseline calibration, the elasticity of substitution between a bundle of imported varieties and a bundle of varieties produced locally by foreign multinational firms ($\mu$ and $\psi$) is set equal to 2 which is higher than the elasticity of substitution between domestic and foreign varieties ($\rho = \phi = 1.5$) but lower than the elasticity of substitution between varieties within each bundle ($\gamma = 3.8$). In this subsection, I explore the role of $\mu$ and $\psi$ in influencing the predictions of my model economy by increasing the value of $\mu$ and $\psi$ to 3.

When $\psi$ and $\mu$ are increased, the steady-state mass of multinational firms shrinks rapidly. For $\psi$ and $\mu$ equal to 3 while keeping other parameter values unchanged, the mass of multinational firms is only 0.25 percent of total domestic firms, which is significantly smaller than the observed level in data (2 percent), and the model becomes similar to the one without multinational firms as considered above. Therefore, I recalibrate my model given $\psi = \mu = 3$ so that its steady-state characteristics are consistent with my baseline calibration (when $\psi = \mu = 2$) as reported in Table 2. I report the recalibrated parameter values in column (3) of panel B in Table 1. As expected, the recalibrated model for the case of $\psi = \mu = 3$ requires the entry and continuation costs of multinational production to be substantially smaller in order to induce a sufficient mass of multinational firms in steady state. These smaller costs of multinational operation and the higher price elasticity between imports and multinational products together make the entry/continuation decisions for multinational production highly sensitive to the relative changes in the profitability of exporting and multinational production, and we see below that this has quantitative importance.

For this alternative case with $\psi = \mu = 3$, the magnitude of the shock is 2.57485 percent for final-good tariffs, 2.42364 percent for intermediate-input tariffs, and 5.056 percent for market-access barriers so that the volume of country 1 exports declines by 5 percent over the first 40 periods, as in my baseline analysis. The long-run effects of trade policies for this alternative case with $\psi = \mu = 3$ are reported in columns (7)-(9) of Table 7.[12] We see that, when $\psi = \mu = 3$, all three trade barriers imposed by country 2 induce a massive expansion in both the number and production of country-1 firms that operate in country 2. The mass of country-1 multinational firms producing in country 2 (the bottom row of Table 7) increases by 15.04 to 18.93 percent in the alternative model, compared to 2.93 to 5.46 percent in my baseline calibration. Production by these multinational firms increases by 5.76 to 10.38 percent for final goods, and 7.70 to 8.81 percent for intermediate goods. This large inflow of multinational firms contributes to not only expanding their production in country 2 but also dampening the contraction of production by local firms in country 2 for both final goods and intermediate inputs. In fact, in the case of final-good tariffs (column (7)), we see a long-run expansion of 0.12 percent in the production of intermediate inputs by local firms in country 2. As a result, the offsetting effects of multinational firms against the contractionary effects of import restrictions are significantly stronger, and GDP for country 2 increases slightly in the case of final-good tariffs, and the contraction in GDP is substantially dampened for the cases of intermediate-input tariffs and market-access barriers.

The key factor underlying this result is that, as the value of $\mu$ and $\psi$ are raised, the entry and continuation costs for multinational production need to be much lower in order to have a sufficient mass of multinational firms in steady state, which further increases the sensitivity of firms' decisions on exporting versus multinational production to any changes in relative prices. In my baseline calibration, the entry cost of multinational production is 10.2 times larger than that of exporting, whereas in the alternative case the entry cost of multinational production is 6 times larger than exporting. While my results highlight the important implications of production relocation by large, most productive firms in offsetting the negative effects of trade barriers on the policy-imposing country, there may be other economic, political and geographical factors, beyond the financial costs of setting up foreign affiliates, that influence firms' relocation decisions. For example, firms' decisions on multinational operation may depend on resource endowments, available technology, and regulatory constraints in the host country, as well as the availability of production

[12] The patterns of the transition dynamics are similar to the baseline case. A set of impulse responses from a model with $\mu = \psi = 3$, analogous to Figure 1 for the baseline case, is reported in Figure D2 in Appendix D.

hubs in nearby countries. These are all important factors beyond the scope of this paper, and are fruitful areas for further research.

# 7 Sensitivity analysis

## 7.1 The role of trade in intermediate inputs

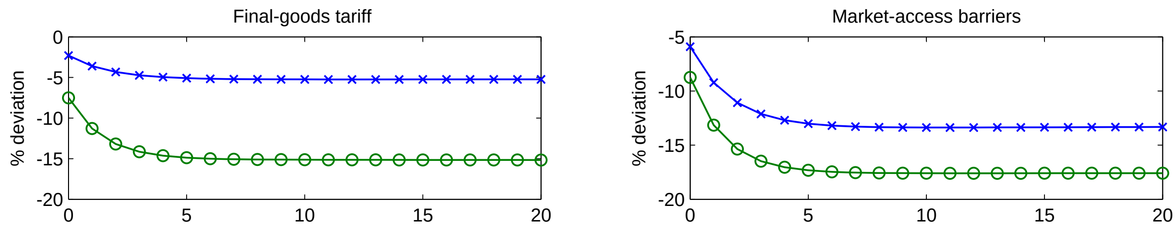
In this subsection, I examine the role of trade in intermediate inputs, by comparing my baseline model with an otherwise identical model in which the home bias in the intermediate-input composite is increased to 1 ($\theta = 1$). In this case, there is no international trade in intermediate inputs ($m_t^{X1}(z) = m_t^{X2}(z) = 0$ for all $z$) and no multinational production of intermediate inputs ($m_t^{MN1}(z) = m_t^{MN2}(z) = 0$ for all $z$). Therefore, I analyze only the effects of final-good tariffs and market-access barriers. All other parameter values and the magnitude of each policy shock remain unchanged from my baseline analysis reported in section 5.

Figure 3 compares the responses from my baseline model (blue lines with x's) with those from the model without international trade in intermediate inputs ($\theta = 1$) (green lines with o's). In Figure 3a, we see that eliminating trade in intermediate inputs amplifies the falls in the extensive margin of exports. For instance, in response to the final-good tariff change of the same magnitude, the number of country 1 exporters falls by 5.19 percent in the long run in my baseline model, whereas the fall is much larger (15.2 percent) in the alternative model. This suggests that engaging in global production chains allows firms to diversify the market demand, and makes their export participation less sensitive to policy changes.

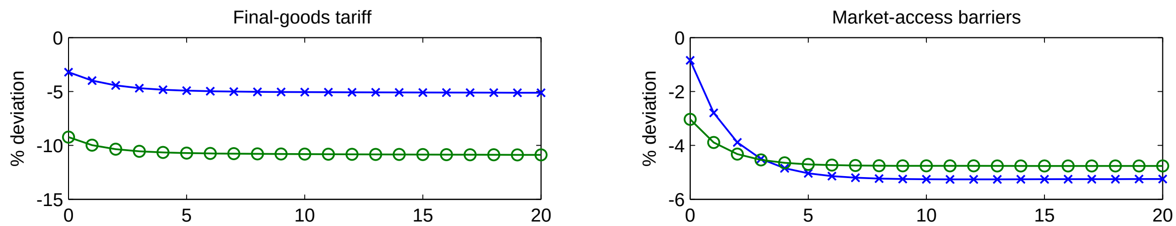
In contrast, the effects of the presence of imported production inputs on the response of the export volume depend on the type of policy changes (Figure 3b). Relative to my baseline model, the fall in the export volume is larger in response to final-good tariffs in the absence of input trade, while the responses are almost similar in the case of market-access barriers. As we saw in Table 4, tariffs on final goods reduce country 2's imports of final goods by 8.92 percent, larger than the 5 percent target for total imports, because the fall in intermediate imports is much smaller (2.05 percent). When tariffs are imposed on country 2's imports of final goods, country 2 households partially switch from imported final goods to domestically produced final goods. In my baseline model, this expenditure switching toward country 2 final goods dampens the fall in country 2's imports of intermediate inputs. When there is no trade in intermediate inputs, and hence final-good tariffs affect only the final-good trade, the fall in the volume of country 1 exports reflects this fall in final goods trade larger than the 5-percent target. In the case of market-access barriers, this policy affects the trade volume of final goods and intermediate goods almost equally (Table 4) because exports of an active exporter can be used as both final goods and intermediate inputs in my model. Therefore, when I shut down the intermediate-input trade, this has much smaller effects on the volume of final good trade, as we see in Figure 3b.

Figure 3: Role of trade in intermediate inputs

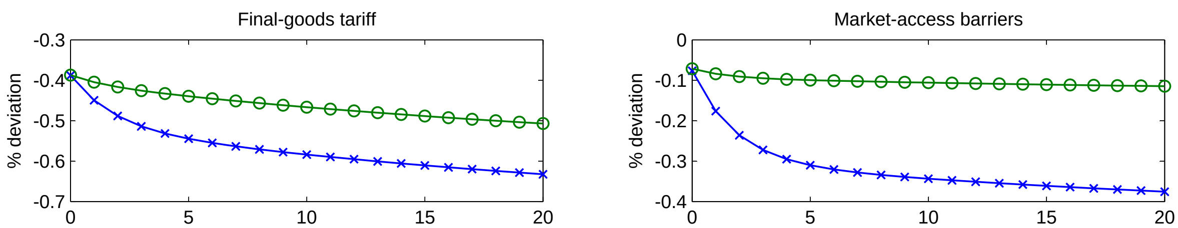
(a) Number of exporters (country 1)



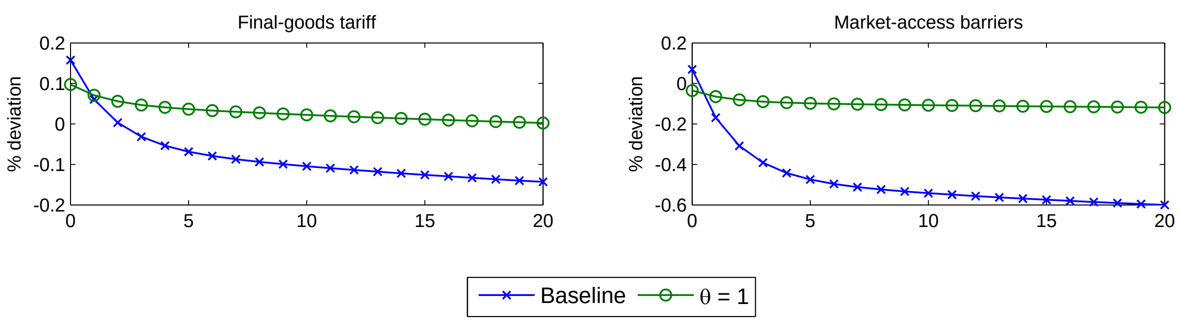

(b) Export volume (country 1)




(c) GDP (country 1)




(d) GDP (country 2)




*Notes:* Impulse responses of the number of country 1 exporters (panel a), the volume of exports from country 1 to country 2 (panel b), GDP in country 1 (panel c), and GDP in country 2 (panel d) to a permanent change in tariffs on final goods (left panels) and market-access barriers (right panels), from my baseline model (blue lines with x's) and from an alternative model without international trade in intermediate inputs ($\theta = 1$) (green lines with o's). The magnitude of each trade policy shock is the same as in the baseline analysis discussed in Section 5.

In Figures 3c and 3d, we see that increasing the value of $\theta$ dampens the responses of the aggregate economy to trade policy changes in both countries. When international trade in intermediate inputs is eliminated ($\theta = 1$), a country's imports as a steady-state share of GDP decline from 15 percent in my baseline model to 6 percent. With a smaller share of imports, the aggregate effects of trade policy also become dampened.

### 7.2 Product substitutability

As described in section 3, my model assumes Armington aggregators for combining domestic and foreign consumption goods (equation (1)) and for combining domestic and foreign intermediate inputs (equation (6)), with exogenously given levels of the elasticity of substitution ($\rho$ and $\phi$, respectively). Therefore, it abstracts from production specialization as in Ricardian trade models. In this setting, the degree of product substitutability between domestic and foreign varieties plays an important role in the quantitative effects of trade policy. In this subsection, I vary these two elasticities of substitution in my model, and analyze their aggregate effects in response to trade policy changes. In steady state, varying the values of $\rho$ and $\phi$ changes the size of trade. Specifically, lowering $\rho$ increases trade in final goods, while lowering $\phi$ increases trade in intermediate goods. I compare my baseline calibration ($\rho = \phi = 1.5$) with three alternative cases: (i) lower substitutability in final goods ($\rho = 0.95$, $\phi = 1.5$); (ii) lower substitutability in intermediate inputs ($\rho = 1.5$, $\phi = 0.9$); and (iii) higher substitutability in both final goods and intermediate inputs ($\rho = \phi = 2.5$).[13]

Figure 4 summarizes the effects of each trade policy for different combinations of $\rho$ and $\phi$ on the GDP of the two countries. In figure 4a, we see that the effects of final-good tariffs become amplified when domestic final goods and foreign final goods are less substitutable (green dash-dot lines for the case of $\rho = 0.95$, $\phi = 1.5$). In this case, as I lower the value of $\rho$, trade in final goods increases in steady state. Total imports in steady state as a share of GDP increase from 15 percent to 21 percent, with final-good trade now accounting for over 60 percent of total trade, compared to 46 percent in the baseline. As a result, final-good tariffs of the same magnitude have stronger aggregate effects for the case with $\rho = 0.95$ than in my baseline calibration.

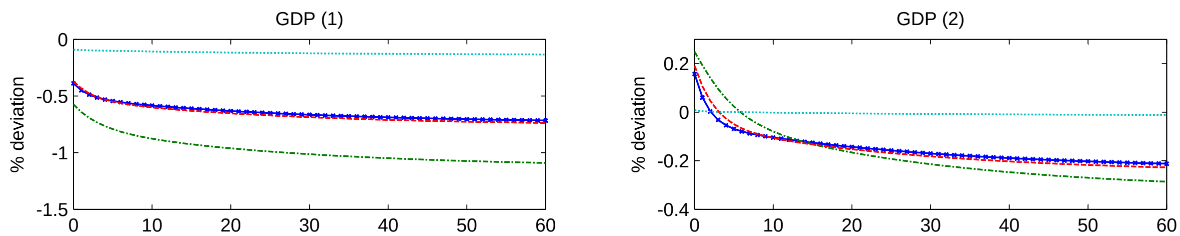
In contrast, we see in figure 4b that the effects of intermediate-input tariffs are amplified when the substitutability of domestic and foreign intermediate inputs is lowered (red dashed lines for the case of $\rho = 1.5$ and $\phi = 0.9$). When $\phi$ is lowered, steady-state trade in intermediate inputs increases. Total imports increase to 20 percent of GDP, with the share of intermediate-input trade increasing from 54 percent in the baseline to 64 percent. This shift in the trade share of intermediate inputs and the low substitutability between domestic and foreign intermediate inputs together amplify the negative effects of intermediate-input tariffs.

Across figures 4a through 4c, we see that when $\rho$ and $\phi$ are both increased to 2.5, the

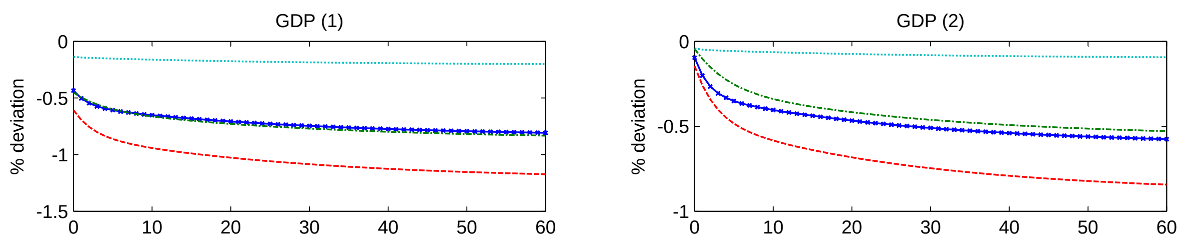
[13] For case (i), lowering $\rho$ beyond 0.95 makes the probability of export continuation reach 1 in which case the model cannot be solved using the linear method I employ. Therefore, I stop at $\rho = 0.95$.

Figure 4: Sensitivity to the elasticity of substitution between domestic and foreign goods

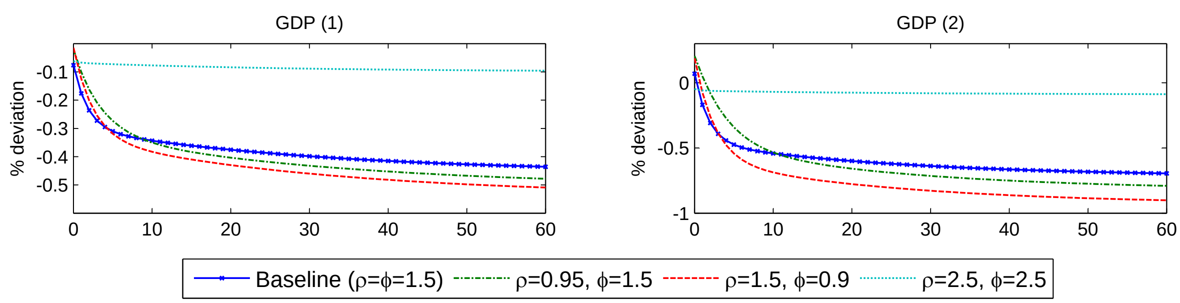
(a) Tariffs on final goods




(b) Tariffs on intermediate inputs

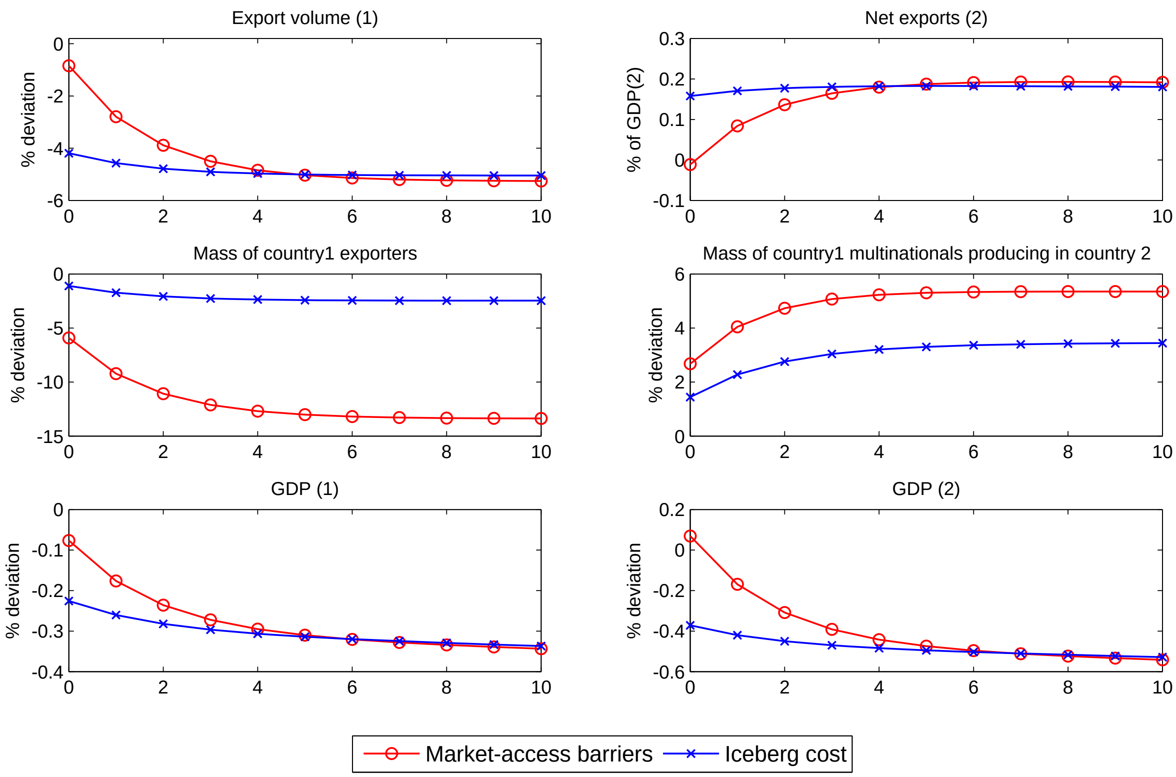



(c) Market access barriers




*Notes:* Impulse responses of GDP in country 1 (left panels) and country 2 (right panels) to a permanent increase in tariffs on final goods (panel a), tariffs on intermediate inputs (panel b), and market-access barriers (panel c) from: my baseline calibration (blue lines with x's); a case for $\rho = 0.95$ and $\phi = 1.5$ (green dash-dot lines); a case for $\rho = 1.5$ and $\phi = 0.9$ (red dashed lines); and a case for $\rho = \phi = 2.5$ (light blue dotted lines). The magnitude of each shock is the same as in my baseline analysis discussed in Section 5.

Figure 5: Comparison to iceberg costs




*Notes:* Impulse responses to a permanent increase in (i) market-access barriers (red lines with o's) and (ii) iceberg costs (blue lines with x's) from my baseline model. The magnitude of each shock is chosen so that the volume of exports from country 1 to country 2 falls by 5 percent cumulatively over the first 40 periods following each shock.

aggregate effects of trade policy changes become negligible in all policy scenarios (light blue dotted lines). As $\rho$ and $\phi$ are both increased, steady-state imports as a share of GDP become increasingly smaller. When $\rho$ and $\phi$ reach 2.5, total imports as a share of GDP is reduced to only 2.4 percent in steady state, compared to 15 percent in my baseline calibration. Therefore, with higher values of $\rho$ and $\phi$, the effects of any trade policy become smaller.[14]

## 7.3 Comparison with iceberg trade costs

Existing studies on trade policy often consider changes in iceberg trade costs as a trade policy tool. In this section, I compare my baseline results to the effects of changes in iceberg trade costs $\tau_{1,t}$ and show that the long-run quantitative effects of changes in iceberg trade costs are similar to those from changes in market-access barriers discussed above, but the speed of convergence to the long-run steady state is significantly faster with iceberg trade costs relative to the market-access

[14] The long run effects of the three trade policies for various combinations of $\rho$ and $\phi$ are reported in Table E2 in Appendix E.

barriers that generate exporter hysteresis. As in my baseline analysis, the magnitude of the shock to the iceberg cost faced by country-1 exporters is chosen such that the cumulative fall in the volume of country-1 exports over the first 40 periods is 5 percent. This requires a positive increase in the iceberg cost by 2.56108 percent.

Figure 5 compares the impulse responses to market-access barriers (red lines with circles) and iceberg trade costs (blue lines with x's). We see that the transition paths for the aggregate variables are quite different during the first few periods following the policy changes because the responses to market-access barriers are substantially delayed. Relative to the market-access barriers, the short-run responses to iceberg costs reach their long-run levels within the first couple of periods following the policy change. When the extensive margin adjustment to the market-access barriers becomes near complete after about 5 periods, however, the two policies yield very similar quantitative effects, except for the responses of the number of exporters and multinationals that experience larger reallocations with market-access barriers.

These two policies yield similar quantitative effects on the aggregate economy because they affect the flows of final-good trade and intermediate-good trade in a similar way in my model. As seen in Table 4, market-access barriers reduce country 1's exports of final goods and its exports of intermediate goods almost equally as these barriers directly affect both flows. Iceberg trade costs also reduce exports of final goods and intermediate goods by an almost equal magnitude, as these costs increase the prices of exports equally for final goods and intermediate goods. Therefore, with the similar contractions in the intensive margin of exports, these two policies yield similar aggregate effects once the extensive margin adjustments become complete.

## 8 Conclusion

This paper examined the dynamic, quantitative effects of three trade-restricting policies in the presence of global value chains and multinational production, and analyzed the channels through which each policy affects micro-level firm dynamics and the aggregate economy. I developed a two-country DSGE model wherein firms make forward-looking decisions on both export participation and multinational production and firms are interdependent within and across countries through input-output linkages in their production. Using this framework, I considered permanent, unilateral impositions of (i) tariffs on final goods, (ii) tariffs on intermediate inputs, and (iii) barriers to access foreign markets.

I have shown that, in my baseline calibration, all three policies under consideration result in a recession in both countries, but the relative effects on the two countries' GDP vary across policies. Final-good tariffs and intermediate-input tariffs lead to a larger GDP fall in the policy-imposed country, while market-access barriers lead to a larger GDP fall in the policy-imposing country. In the short run, final-good tariffs and market-access barriers lead to expenditure switching away from imported products toward domestically produced products, and result in a temporary economic boom in the country imposing these import restrictions. However, the imperfect substitutability of domestic and imported products reduces aggregate demand, and, with the amplification effects of input-output linkages within that country, the economy eventually faces a recession in the long run.

At the firm level, these trade policies lead less productive exporters to exit from the export destination market, but the most productive few choose to expand production into the foreign market as multinationals instead of exporting. The expansion of foreign firms in the policy-imposing country offsets the recessionary effects of trade barriers there, and when the relocation is sufficiently large (more than 15 percent increase in the mass of multinational firms), the policy-imposing country may experience a long-run economic boom as a result of import restrictions.

My findings point to the importance of identifying different channels through which various trade policies affect firm-level export decisions and the aggregate economy. This is highly relevant for current policy discussions in the context of the rising protectionism. First, the interdependence of firms' production beyond national borders increases the complexity of the consequences of trade barriers such that winners and losers from a particular trade policy are no longer defined at a country level. Instead, my analysis suggests that both countries would be worse off at the aggregate level without a massive relocation of large multinational firms, which has important implications for the design of trade policy at the national level as well as for multinational trade regulations such as the WTO rules. Second, my analysis allows for a better understanding of how a trade policy may affect different parts of an economy. As I have shown, within a country, reallocations may arise across sectors (final-good producers versus intermediate-good producers), across GDP components, and among agents (workers in the exporting sector versus those in the domestic production) at various time horizons. This offers a useful guidance in formulating a broader policy framework that supports the economy or mitigates adverse effects of trade restrictions through, for example, fiscal or industrial subsidies and regulations. Moreover, my results highlight that these policy implications are time-varying, as long-run effects can be different from short-run transition dynamics in some policy scenarios. Sectors that may gain in the short run as a result of a certain trade policy can face a loss in the long run, and this is an important factor to be taken into consideration in designing trade policy.

The analysis presented in this paper can be extended in several important ways. One extension would be to embed a Ricardian international trade structure in the dynamic business cycle framework of this paper, and examine how specialization affects firms' participation in global production networks and the transmission of trade policy. This may be of particular importance when, for example, analyzing two asymmetric countries with differences in the availability of country-specific production inputs (i.e., capital and labor). Another area for further research is to introduce the possibility of retaliatory policy responses to a unilateral trade-policy imposition, and consider the resulting strategic interactions between trading partners. Finally, extending the model to include variable markups would allow for an examination of possible strategic pricing, as domestic firms in sectors protected by trade barriers may increase their markup, while exporters affected by trade barriers may reduce their markup. These extensions are important areas for future research.

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# Appendix

## A Additional model details

### A.1 Price index

Using the mass of entrant exporters, that of incumbent exporters and the distribution of firm-level productivity, we can write the price index of exported goods, relative to the aggregate price index in the destination economy, as

$$
\begin{aligned}
\frac{p_t^{X1}}{P_{2,t}} &= \left[\int_{z\in\Theta_{1,t}} \left(\frac{p_t^{X1}(z)}{P_{2,t}}\right)^{1-\gamma} dz\right]^{\frac{1}{1-\gamma}} \\
&= \left[\frac{\zeta_{1,t}^{DX}(1-N_t^{X1}-N_t^{MN1})}{G(z_{1,t}^{DM})-G(z_{1,t}^{DX})}\int_{z_{1,t}^{DX}}^{z_{1,t}^{DM}} \left(\frac{p_t^{X1}(z)}{P_{2,t}}\right)^{1-\gamma} dG(z) + \frac{\zeta_{1,t}^{XX}N_t^{X1}}{G(z_{1,t}^{XM})-G(z_{1,t}^{XX})}\int_{z_{1,t}^{XX}}^{z_{1,t}^{XM}} \left(\frac{p_t^{X1}(z)}{P_{2,t}}\right)^{1-\gamma} dG(z)\right. \\
&\quad \left. + \frac{\zeta_{1,t}^{MX}N_t^{MN1}}{G(z_{1,t}^{MM})-G(z_{1,t}^{MX})}\int_{z_{1,t}^{MX}}^{z_{1,t}^{MM}} \left(\frac{p_t^{X1}(z)}{P_{2,t}}\right)^{1-\gamma} dG(z)\right]^{\frac{1}{1-\gamma}}
\end{aligned}
$$

Similarly, the price index of output produced by multinational firms, relative to the aggregate price index of the host country, is

$$
\begin{aligned}
\frac{p_t^{MN1}}{P_{2,t}} &= \left[\int_{z\in\Omega_{1,t}} \left(\frac{p_t^{MN1}(z)}{P_{2,t}}\right)^{1-\gamma} dz\right]^{\frac{1}{1-\gamma}} \\
&= \left[\frac{\zeta_{1,t}^{DM}\left(1-N_t^{X1}-N_t^{MN1}\right)}{1-G(z_{1,t}^{DM})}\int_{z_{1,t}^{DM}} \left(\frac{p_t^{MN1}(z)}{P_{2,t}}\right)^{1-\gamma} dG(z) + \frac{\zeta_{1,t}^{XM}N_t^{X1}}{1-G(z_{1,t}^{XM})}\int_{z_{1,t}^{XM}} \left(\frac{p_t^{MN1}(z)}{P_{2,t}}\right)^{1-\gamma} dG(z)\right. \\
&\quad \left. + \frac{\zeta_{1,t}^{MM}N_t^{MN1}}{1-G(z_{1,t}^{MM})}\int_{z_{1,t}^{MM}} \left(\frac{p_t^{MN1}(z)}{P_{2,t}}\right)^{1-\gamma} dG(z)\right]^{\frac{1}{1-\gamma}}
\end{aligned}
$$

### A.2 Total intermediate inputs

The total volume of domestically produced intermediate inputs is given by

$$m_t^{D1} = \frac{\int_0^1\int_0^1 p_t^{D1}(z')m_t^{D1}(z',z)dz'dz}{p_t^{D1}}$$

The total volume of country 1's exports of intermediate inputs is given by

$$m_t^{X1} = \frac{\int_{z\in\Theta_{1,t}}\int_0^1 p_t^{X1}(z)m_t^{X1}(z,z')dzdz'}{p_t^{X1}}$$

Finally, the total volume of production by country 1 multinational firms operating in country 2 is given by

$$m_t^{MN1} = \frac{\int_{z\in\Omega_{1,t}} \int_0^1 p_t^{MN1}(z) m_t^{MN1}(z,z')dzdz'}{p_t^{MN1}}$$

## A.3 Labor demand

Aggregate labor demand in country 1 is a sum of (i) labor used for domestic production $L_{1,t}^D(z)$, (ii) labor used for export production $L_{1,t}^X(z)$, (iii) labor used by country 2 multinationals actively producing in country 1 $L_{1,t}^{MN}(z)$, and (iv) the entry and continuation costs of exporting and multinational production $L_{1,t}^C$ (export entry/continuation costs paid by country 1 exporters, and multinational entry/continuation costs paid by country 2 multinationals in country 1):

$$L_{1,t} = \int_0^1 L_{1,t}^D(z)dz + \int_{z\in\Theta_{1,t}} L_{1,t}^X(z)dz + \int_{z\in\Omega_{2,t}} L_{1,t}^{MN}(z)dz + L_{1,t}^C$$

where, using the first-order conditions from the optimization problem in equation (10),

$$L_{1,t}^D(z) = \sigma(1-\alpha)\frac{MC_{1,t}}{e^z w_{1,t}}\left(y_t^{D1}(z) + \int_0^1 m_t^{D1}(z,z')dz'\right)$$

$$L_{1,t}^X(z) = \sigma(1-\alpha)\frac{MC_{1,t}}{e^z w_{1,t}}\tau_{1,t}\left(y_t^{X1}(z) + \int_0^1 m_t^{X1}(z,z')dz'\right)$$

$$L_{1,t}^{MN}(z) = \sigma(1-\alpha)\frac{MC_{1,t}}{e^z w_{1,t}}\left(y_t^{MN2}(z) + \int_0^1 m_t^{MN2}(z,z')dz'\right)$$

and

$$\begin{aligned} L_{1,t}^C \equiv\ & \zeta_{1,t}^{DX}\left(1 - N_t^{X1} - N_t^{MN1}\right)\eta_{1,t}^X + \left[\zeta_{1,t}^{XX} N_t^{X1} + \zeta_{1,t}^{MX} N_t^{MN1}\right]\xi_{1,t}^X \\ & + \left[\zeta_{2,t}^{DM}\left(1 - N_t^{X2} - N_t^{MN2}\right) + \zeta_{2,t}^{XM} N_t^{X2}\right]\eta_2^{MN} + \zeta_{2,t}^{MM} N_t^{MN2}\xi_2^{MN} \end{aligned}$$

# B Long-run effects of trade policies

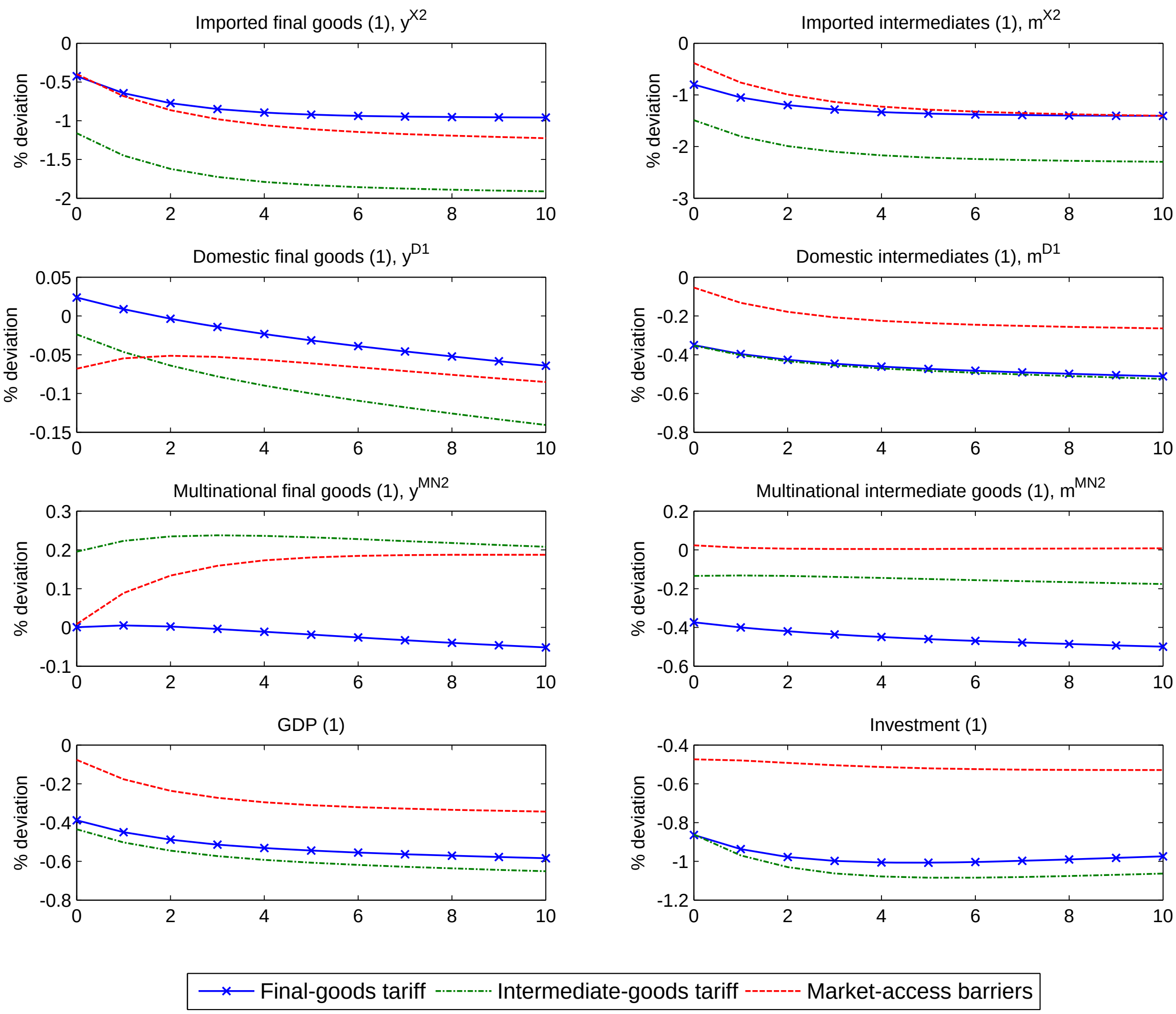
Table B1: Long-run effects

| | (1) Tariffs on final goods | (2) Tariffs on intermediate goods | (3) Barriers to market access |
|---|---|---|---|
| *A: Country 1* | | | |
| GDP | -0.74 | -0.84 | -0.46 |
| Consumption | -0.19 | -0.37 | -0.26 |
| Investment | -0.74 | -0.84 | -0.46 |
| Real exports (in units of $C_1$) | -3.94 | -3.99 | -2.00 |
| Production for domestic use | | | |
| (i) Final goods | | | |
| by domestic firms | -0.22 | -0.34 | -0.22 |
| by country 2 multinationals | -0.20 | 0.07 | 0.14 |
| (i) Intermediate inputs | | | |
| by domestic firms | -0.68 | -0.72 | -0.37 |
| by country 2 multinationals | -0.66 | -0.31 | -0.01 |
| Production for exporting | | | |
| (i) Final goods | -8.92 | -2.03 | -5.35 |
| (ii) Intermediate goods | -2.05 | -7.91 | -5.14 |
| *B: Country 2* | | | |
| GDP | -0.24 | -0.61 | -0.72 |
| Consumption | -0.74 | -1.02 | -0.92 |
| Investment | -0.51 | -0.90 | -0.72 |
| Real exports (in units of $C_2$) | -1.36 | -1.99 | -1.54 |
| Production for domestic use | | | |
| (i) Final goods | | | |
| by domestic firms | -0.21 | -0.98 | -0.63 |
| by country 1 multinationals | 2.36 | 0.05 | 0.94 |
| (ii) Intermediate goods | | | |
| by domestic firms | -0.14 | -0.68 | -0.42 |
| by country 1 multinationals | 1.17 | 1.49 | 1.16 |
| Production for exporting | | | |
| (i) Final goods | -1.00 | -2.11 | -1.50 |
| (ii) Intermediate goods | -1.46 | -2.48 | -1.66 |

*Notes:* The values are percentage deviations from the initial steady state. For each policy scenario, country 2 imposes the respective trade policy so that the volume of its imports from country 1 declines by 5 percent cumulatively relative to the initial steady state over the first 40 periods (10 years) following each policy change.

# C Dynamic responses of country 1

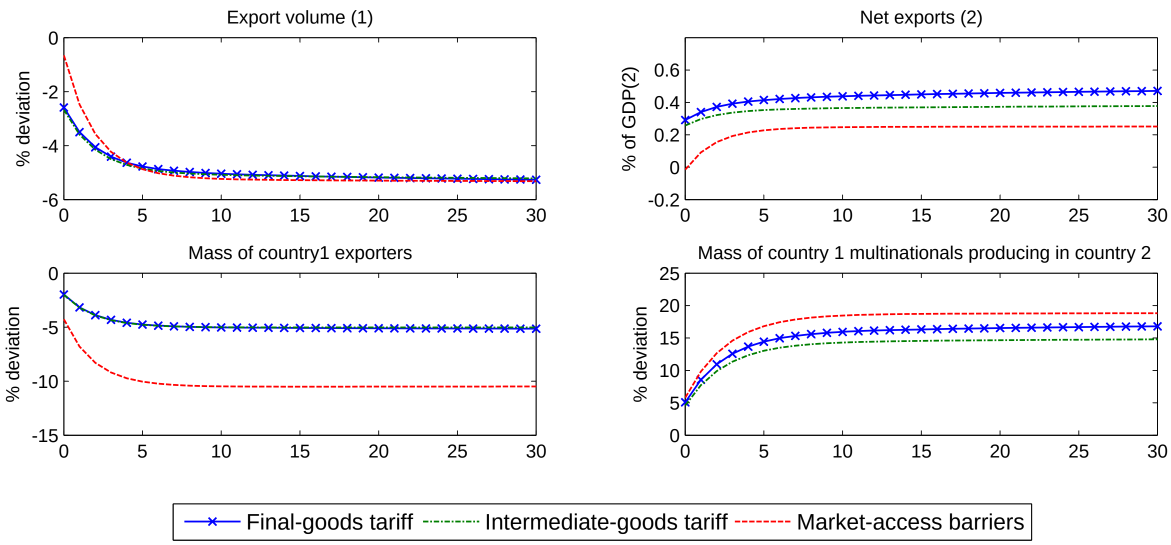
Figure C1: Impulse responses to various trade barriers (country 1)




*Notes:* Impulse responses of country 1 to a permanent increase in (i) tariffs on final goods (blue lines with x's), (ii) tariffs on intermediate inputs (green dash-dot lines), and (iii) barriers to market access (red dashed lines). The magnitude of each shock is chosen so that the export volume for country 1 falls by 5 percent cumulatively over the first 10 years following the shock.

# D Elasticity of substitution

Figure D2: High elasticity for multinational varieties




*Notes:* Impulse responses to a permanent increase in (i) tariffs on final goods (blue lines with x's), (ii) tariffs on intermediate inputs (green dash-dot lines), and (iii) market-access barriers (red dashed lines) from an alternative model in which the elasticity of substitution between imported varieties and varieties produced locally by foreign multinational firms ($\mu$ and $\psi$) is set equal to 3. The magnitude of each shock is chosen so that the volume of exports from country 1 to country 2 falls by 5 percent cumulatively over the first 40 periods following the shock.

# E Sensitivity to the elasticity of substitution between domestic and foreign varieties

Table E2: The role of Armington elasticity

| | Baseline ($\rho = \phi = 1.5$) | | | $\rho = 1.5$, $\phi = 0.9$ | | | $\rho = 0.95$, $\phi = 1.5$ | | | $\rho = \phi = 2.5$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| | T-F | T-I | MB | T-F | T-I | MB | T-F | T-I | MB | T-F | T-I | MB |
| *A: GDP* | | | | | | | | | | | | |
| Country 1 | -0.74 | -0.84 | -0.46 | -0.76 | -1.22 | -0.54 | -1.13 | -0.87 | -0.51 | -0.14 | -0.21 | -0.10 |
| Country 2 | -0.24 | -0.61 | -0.72 | -0.25 | -0.89 | -0.94 | -0.32 | -0.56 | -0.83 | -0.01 | -0.10 | -0.09 |
| *B: Consumption* | | | | | | | | | | | | |
| Country 1 | -0.19 | -0.37 | -0.26 | -0.23 | -0.62 | -0.38 | -0.27 | -0.40 | -0.30 | -0.01 | -0.03 | -0.02 |
| Country 2 | -0.74 | -1.02 | -0.92 | -0.73 | -1.41 | -1.10 | -1.09 | -0.97 | -1.03 | -0.13 | -0.27 | -0.18 |

*Notes:* T-F: tariffs on final goods. T-I: tariffs on intermediate inputs. MB: market-access barriers. The values are percentage deviations from the initial steady state. The magnitude of each trade policy shock is the same as in the baseline analysis discussed in Section 5.