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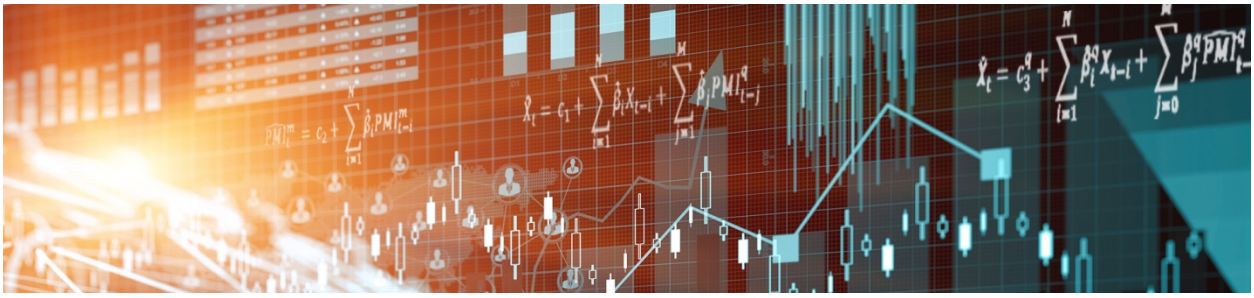
Reassessing Trade Barriers with Global Value Chains



by Yuko Imura

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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 find it profitable to locate production in the foreign country as multinationals, thereby partially recovering 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. The latter also discourages multinational operation over the short run when the input tariffs dominate the declining costs of labor and capital.

Bank topics: Firm dynamics: International topics; Trade integration; Business fluctuations and cycles
JEL codes: F13; F41; F12

Résumé

Dans cette étude, je procède à une analyse quantitative systématique des effets à court et à long terme de diverses mesures de restriction des échanges en présence de chaînes de valeur mondiales et d'internationalisation de la production. Je m'appuie sur un modèle d'équilibre général dynamique et stochastique à deux pays dans lequel les décisions d'entrée et de sortie en tant qu'exportateur ou en tant que multinationale sont endogènes pour comparer les effets : a) de droits de douane sur les importations de biens finaux; b) de droits de douane sur les importations d'intrants intermédiaires; et c) de barrières à l'entrée.

Je montre qu'à long terme, les trois mesures font entrer les deux pays en récession, mais que les effets relatifs sur le PIB des deux pays varient d'une mesure à l'autre. S'agissant des entreprises, les exportateurs les moins productifs finissent par sortir du marché de destination, alors qu'il devient rentable pour le petit groupe des plus productifs d'entre eux de s'implanter comme multinationales dans le pays étranger, ce qui leur permet de compenser en partie les pertes de recettes d'exportation. Les mesures diffèrent de par leurs conséquences à long terme, mais aussi

de par leur dynamique à court terme. Les droits de douane sur les biens finaux et les barrières à l'entrée engendrent un boom temporaire de la production dans le pays qui les impose, tandis que les droits de douane sur les intrants intermédiaires font immédiatement plonger les deux pays dans la récession. Ces dernières mesures découragent l'internationalisation de la production dans un premier temps, tant que les effets de ces droits restent plus importants que ceux de la baisse des coûts de la main-d'œuvre et du capital.

Sujets : Dynamique des entreprises; Questions internationales; Intégration des échanges; Cycles et fluctuations économiques
Codes JEL : F13; F41; F12

Non-technical summary

In recent years, policy discussion surrounding protectionist measures has increased its 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 global value chains and multinational production characterize the highly interdependent nature of today's globalized production processes.

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 develop a two-country dynamic stochastic general equilibrium model with capital accumulation, forward-looking entry and exit of firms in exporting and multinational production, and cross-country input-output linkages. Using this framework, I consider permanent, unilateral impositions of (i) tariffs on final-good imports, (ii) tariffs on intermediate-input imports, and (iii) barriers to access a foreign market, and examine different channels through which each policy affects micro-level firm dynamics and the aggregate economy. As my model economy captures rich micro-foundations in both static and dynamic dimensions, it facilitates building intuitions from both macro and trade perspectives.

I show that 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, and market-access barriers resulting in a larger GDP fall in the policy-imposing country. At the firm level, while all three policies lead to the exit of less productive exporters from the policy-imposing country's market, the falling production costs in that country induce the most productive firms to locate production as multinationals, thereby partially recovering the loss from exporting.

In contrast, in the short run, final-good tariffs and market-access barriers lead to a temporary production boom in the policy-imposing country. 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, exporter hysteresis delays the adjustment in trade, which leads to a temporary rise in investment. On the other hand, intermediate-input tariffs immediately raise the price of imported production inputs in the policy-imposing country, and this rise dominates the more gradual fall of the prices of labor and capital, resulting in a temporary fall in the mass of multinational firms in the short run.

Finally, the presence of multinational firms is shown to dampen the long-run losses in the policy-imposing country, though these offsetting effects are not sufficient to generate a long-run economic boom in any policy scenario. Because multinational firms are relatively larger and more productive than the average local firms or the average exporters, the long-run increase in their participation offers an additional set of more efficiently produced varieties that households in the policy-imposing country may substitute with in place of (more expensive) imports in response to trade barriers. My findings therefore offer support with greater certainty for the argument that import restrictions, both tariffs and non-tariffs, are not likely to improve the economic well-being in the long run.

1 Introduction

Protectionism has become an important topic of policy discussion in recent years. Incipient 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).[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.

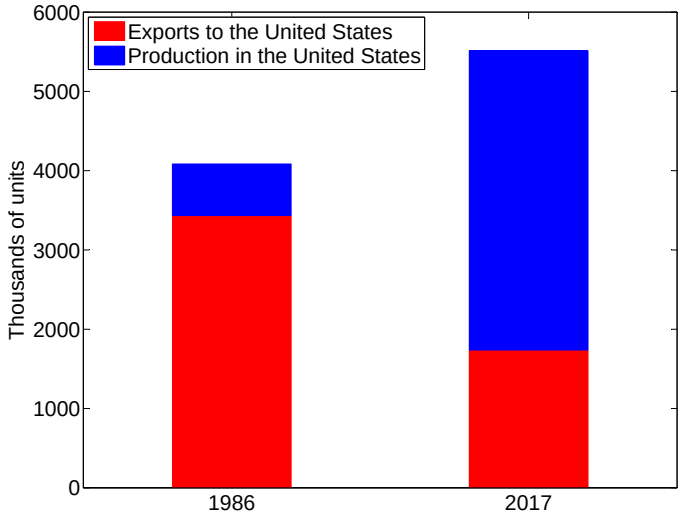
The presence of multinational production adds another dimension to the discussion of global value chains and trade policy. For instance, in 2017, nearly 70 percent of Japanese-brand vehicles sold in the United States were produced in the United States (Figure 1). This pattern is markedly different from 1986, when more than 85 percent of Japanese-brand vehicles sold in the United States were imported. 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 (DSGE) model with capital accumulation, forward-looking entry/exit of firms in 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

[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.

Figure 1: Japanese-brand vehicles sold in the United States



Notes: The number of units of Japanese-brand vehicles sold in the United States in 1986 and 2017. The red areas represent the number of Japanese-brand vehicles exported to and sold in the United States, and the blue areas represent the number of Japanese-brand vehicles produced and sold in the United States. Data source: Japan Automobile Manufacturers Association, Inc.

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 both 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 order to induce entry and exit of exporting and multinational production in my model, 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 participate in exporting or locate production in the foreign country in any given period.

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 share of value-added trade 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 non-exporters. To capture the flow of final goods and intermediate goods within and across countries, I target the value of intermediate inputs relative to total output value, the share of imported intermediate inputs in total intermediate inputs, and the aggregate imports-to-GDP ratio.

Examining the effects of permanent, unilateral impositions of the three trade-restricting policies, I show that 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, with their losses being three to five times larger than in the policy-imposed country. 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, while all three policies lead to the exit of less productive exporters from the policy-imposing country's market, the most productive firms find it profitable to locate production in the foreign country as multinationals, thereby partially recovering the loss from exports.

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 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.

The short-run dynamics of the extensive margin of multinational production also varies across policies. With final-good tariffs and market-access 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 multinationals there. With intermediate-input tariffs, however, the immediate rise in the price of imported intermediate inputs in the policy-imposing country dominates the gradual fall of the prices of other production inputs (i.e., labor and capital), and curtails the value of multinational operation. This results in a temporary fall in the mass of multinational firms in the short run, until the prices of labor and capital fall sufficiently, which eventually encourages some firms' participation in multinational production.

I further examine the role of multinational firms in influencing the transmission of trade policy changes, by comparing my baseline model with an alternative model without multinational production. I show that the model without multinational firms predicts significantly larger long-run losses for the policy-imposing country. As discussed above, those firms that participate in multinational production are larger and more productive than the average local firms or the average exiting exporters. Therefore, the presence of multinational firms offers an additional set of more efficiently produced varieties that households in the policy-imposing country may substitute with in place of (more expensive) imports in response to trade policy changes. The increased presence of these multinational firms in the long run as a result of trade barriers then helps to dampen the loss in productivity, employment and demand for intermediate inputs in the policy-imposing country that would not otherwise arise in their absence. However, these offsetting effects are not sufficient to generate an investment boom in the long run, and we still see long-run reductions in GDP, consumption and investment for both countries in all policy cases under consideration. My findings therefore offer support with greater certainty for the argument that import restrictions, both tariffs and non-tariffs, are not likely to improve the economic well-being in the long run.

Finally, I explore the sensitivity of my baseline results to alternative values of the share of imported intermediate inputs and the elasticity of substitution between domestically produced goods and imported goods. 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 productivity substitutability of intermediates faced by producers. When compared against each other, the product substitutability of intermediates has significantly stronger effects than that of final goods, for the same degree of variation in substitutability, highlighting the importance of global value chains in determining the quantitative impact of trade policies.

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 discuss the role of multinational production in influencing the effects of trade policy. In section 7, I examine the sensitivity of the main results to alternative parameterizations of the share of imported intermediate goods and the elasticity of substitution. Finally, I compare my baseline results to the effects of standard iceberg trade costs typically considered in the literature in section 8. Section 9 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.[3] In his influential paper, Yi (2003) analyzes the role of vertical specialization in propagating the growth in international trade in response to tariff reductions since the early 1960s. He argues that the strikingly larger growth in world trade relative to the size of tariff reductions since the 1950s was due to international production sequences in which different stages of production take place in various countries. He develops a two-country Ricardian trade model of vertical specialization, and shows that the model is able to explain over 50 percent of the trade growth.

The importance of input-output linkages in amplifying the welfare effects of tariff reductions is highlighted in the quantitative analysis of NAFTA by Caliendo and Parro (2015). They developed a Ricardian model with sectoral linkages and international trade in intermediate goods, and show that the welfare gains from NAFTA's tariff reductions are underestimated in the absence of input-output linkages. Extending the analysis of Caliendo and Parro (2015), Caliendo et al. (2017) report that tariff reductions from the Uruguay Round generated mutual gains for participating countries. Auer, Bonadio and Levchenko (2018) examine the effects of revoking NAFTA using a multi-country, multi-sector model with global input-output linkages, and show that revoking NAFTA would reduce

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

the welfare of the three countries involved, with the real wage in the United States falling more in the districts that voted more for pro-protectionist candidates.

My approach to studying the quantitative effects of trade policy using a dynamic business cycle model with exporter entry and exit is closely related to recent studies by Alessandria and Choi (2014) and Barattieri, Cacciatore and Ghironi (2019). Barattieri, Cacciatore and Ghironi (2019) present empirical evidence that the introduction of temporary import duties leads to a decline in output and an increase in inflation for the country imposing the trade barriers. They then develop a small open economy model with firm entry and show that the model is able to reproduce these empirical findings. 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 dynamic export decisions and input trade. 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 considering separate tariffs for final goods and intermediate inputs.

My work also relates to the literature that examines the effects of liberalization in trade and multinational production. Ramondo and Rodriguez-Clare (2013) study the gains from openness to trade and multinational production using a Ricardian model of international trade and show that the gains from trade in a model with multinational production can be twice as large as those from trade-only models. 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 dynamic effects of liberalizing trade and multinational production, and shows that, when both trade and multinational production are shut down, the United States would experience a welfare cost equivalent to a 39-percent fall in consumption, of which more than 40 percent is accounted for by dynamic effects. 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. More recently, 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. 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 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, exporting and multinational production are costly and entail additional costs that depend on individual firms' status for these activities in the previous period. In order to enter the export market, potential entrants must pay a sunk entry cost. Once in the export market, incumbent exporters must pay a fixed continuation cost every period in order to continue exporting. In addition to local production and exporting, firms may also produce and sell consumption-composite products in the foreign market, using the aggregate productivity and production inputs available in the host country. I assume that output of multinational production is used for consumption goods only, and cannot be shipped back to the parent country or used as intermediate inputs by other firms in the economy.[4] For multinational production, a firm must pay a sunk entry cost to start producing in the host country and a per-period fixed cost in order to continue producing there. I assume that once a firm exits from exporting or multinational production, it must repay a respective sunk entry cost upon returning to exporting or multinational production. All prices are perfectly flexible. In this section, I describe the optimization problems and equilibrium conditions

[4] Antràs and Yeaple (2014) report that the primary purpose of multinational affiliates is to serve 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.

for agents in country 1. Analogous conditions hold for country 2.

3.1 Consumption-composite goods

Consumption-composite 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 domestically produced output $y_t^{D1}(z)$, imported output $y_t^{X2}(z)$ and multinational output $y_t^{MN2}(z)$ produced by country 2 firms in country 1. These products are aggregated with a constant elasticity of substitution:

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

where

$$y_t^{D1} = \left[\int_0^1 y_t^{D1}(z)^{\frac{\gamma-1}{\gamma}} dz\right]^{\frac{\gamma}{\gamma-1}}, \tag{2}$$

$$y_t^{X2} = \left[\int_{z\in\Theta_{2,t}} y_t^{X2}(z)^{\frac{\gamma-1}{\gamma}} dz\right]^{\frac{\gamma}{\gamma-1}}, \tag{3}$$

$$y_t^{MN2} = \left[\int_{z\in\Omega_{2,t}} y_t^{MN2}(z)^{\frac{\gamma-1}{\gamma}} dz\right]^{\frac{\gamma}{\gamma-1}}, \tag{4}$$

ρ is the elasticity of substitution between different composites, and γ is the elasticity of substitution between goods produced within the same country. 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 each period, as described later. There is a tariff τ_t^{y2} on imports of final goods $y_t^{X2}(z)$.

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. 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). This yields the following demand for $y_t^{D1}(z)$, $y_t^{X2}(z)$ and $y_t^{MN2}(z)$:

$$y_t^{D1}(z) = \omega^\rho \left(\frac{p_t^{D1}(z)}{p_t^{D1}}\right)^{-\gamma} \left(\frac{p_t^{D1}}{P_{1,t}}\right)^{-\rho} F_{1,t} \tag{5}$$

$$y_t^{X2}(z) = \psi^\rho \left(\frac{p_t^{X2}(z)}{p_t^{X2}}\right)^{-\gamma} \left(\tau_t^{y2} \frac{p_t^{X2}}{P_{1,t}}\right)^{-\rho} F_{1,t} \tag{6}$$

$$y_t^{MN2}(z) = (1-\omega-\psi)^\rho \left(\frac{p_t^{MN2}(z)}{p_t^{X1}}\right)^{-\gamma} \left(\frac{p_t^{MN2}}{P_{1,t}}\right)^{-\rho} F_{1,t}, \tag{7}$$

where $P_{1,t} \equiv \left[\omega^\rho \left(p_t^{D1}\right)^{1-\rho} + \psi^\rho \left(\tau_t^{y2} p_t^{X2}\right)^{1-\rho} + (1-\omega-\psi)^\rho \left(p_t^{MN2}\right)^{1-\rho}\right]^{\frac{1}{1-\rho}}$ is the consumer price index in country 1, $p_t^{D1} = \left[\int_0^1 p_t^{D1}(z)^{1-\gamma} dz\right]^{\frac{1}{1-\gamma}}$ is the price index of domestically produced goods, $p_t^{X2} = \left[\int_{z\in\Theta_{2,t}} p_t^{X2}(z)^{1-\gamma} dz\right]^{\frac{1}{1-\gamma}}$ is the price index of imported goods, and $p_t^{MN2} = \left[\int_{z\in\Omega_{2,t}} p_t^{MN2}(z)^{1-\gamma} dz\right]^{\frac{1}{1-\gamma}}$ is the price index of multinational output.

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 respective export costs, it is used in foreign consumption composites ($y_t^{X1}(z)$) and as production inputs by firms in country 2 ($\int_0^1 m_t^{X1}(z,z')dz'$).

In addition to the local production, firm z from country 1 may produce in country 2 using the aggregate productivity and production inputs available in country 2 (the host country) after paying some operation costs. Such multinational output is sold to the households in the host country as final goods, $y_t^{MN1}(z)$.

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

$$y_{1,t}(z) = e^z A_i \left(K_{i,t}(z)^\alpha L_{i,t}(z)^{1-\alpha}\right)^\sigma M_{i,t}(z)^{1-\sigma}, \tag{8}$$

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 domestically produced intermediates $m_t^{D1}(\cdot,z)$ and imported intermediates $m_t^{X2}(\cdot,z)$:

$$M_{1,t}(z) = \left[\theta \left(\int_0^1 m_t^{D1}(z',z)^{\frac{\gamma-1}{\gamma}} dz'\right)^{\frac{\gamma}{\gamma-1}\frac{\phi-1}{\phi}} + (1-\theta)\left(\int_{z'\in\Theta_{2,t}} m_t^{X2}(z',z)^{\frac{\gamma-1}{\gamma}} dz'\right)^{\frac{\gamma}{\gamma-1}\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}, \tag{9}$$

where γ is the elasticity of substitution between outputs produced in the same country, ϕ is the elasticity of substitution between domestically produced intermediate inputs and imported intermediate inputs, and θ is the bias toward domestically produced intermediate inputs in $M_{1,t}(z)$.

For the local production, firm z chooses $L_{1,t}(z)$, $K_{1,t}(z)$, $m_t^{D1}(z',z)$ and $m_t^{X2}(z',z)$ to minimize production costs:

$$\min w_{1,t}L_{1,t}(z) + r_{1,t}K_{1,t}(z) + \int_0^1 p_t^{D1}(z')m_t^{D1}(z',z)dz' + \int_{z'\in\Theta_{2,t}} \tau_t^{m2}p_t^{X2}(z')m_t^{X2}(z',z)dz' \quad (10)$$

subject to equations (8) and (9), where $w_{1,t}$ is real wage and $r_{1,t}$ is the real return on capital. Imports of goods produced in country 2 and used as intermediate inputs in country 1 are subject to an intermediate-input tariff τ_t^{m2}. This minimization problem yields firm z's demand for $m_t^{D1}(z',z)$ and $m_t^{X2}(z',z)$:

$$m_t^{D1}(z',z) = \left(\frac{p_t^{D1}(z')}{p_t^{D1}}\right)^{-\gamma}\left(\frac{1}{\theta}\frac{p_t^{D1}}{P_{1,t}^M}\right)^{-\phi} M_{1,t}(z) \quad (11)$$

$$m_t^{X2}(z',z) = \left(\frac{p_t^{X2}(z')}{p_t^{X2}}\right)^{-\gamma}\left(\frac{1}{1-\theta}\frac{\tau_t^{m2}p_t^{X2}}{P_{1,t}^M}\right)^{-\phi} M_{1,t}(z), \quad (12)$$

where $P_{1,t}^M = \left[\theta^\phi(p_t^{D1})^{1-\phi} + (1-\theta)^\phi(\tau_t^{m2}p_t^{X2})^{1-\phi}\right]^{\frac{1}{1-\phi}}$ is the price index of the intermediate composite $M_{1,t} \equiv \int_0^1 M_{1,t}(z)dz$.

Analogously, for the multinational production, firm z from country 1 producing in country 2 would choose $L_{2,t}(z)$, $K_{2,t}(z)$, $m_t^{D2}(z',z)$ and $m_t^{X1}(z',z)$ to minimize its production costs in the host country.

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 intermediate inputs 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 domestic profit:

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

subject to (5) and (11), where $MC_{1,t} \equiv \frac{(w_{1,t})^{\sigma(1-\alpha)}(r_{1,t})^{\alpha\sigma}(P_{1,t}^M/P_{1,t})^{1-\sigma}}{[\sigma(1-\alpha)]^{\sigma(1-\alpha)}(\sigma\alpha)^{\sigma\alpha}(1-\sigma)^{1-\sigma}}\frac{1}{A_1}$ denotes the marginal cost of production. 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 goods. Therefore, firm z chooses its export price $p_t^{X1}(z)$ to maximize its current export profit:

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

subject to (6) and the $m_t^{X1}(z,z')$ analog of (12), 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 entry cost and the continuation cost in the profit function, this optimal price $p_t^{X1}(z)$ is the same for entrants and incumbents for a given level of z.

When firm z also produces abroad as a multinational producer, it chooses a price $p_t^{MN1}(z)$ to solve

$$\max_{p_t^{MN1}(z)} \frac{p_t^{MN1}(z)}{P_{2,t}} y_t^{MN1}(z) - \frac{MC_{2,t}}{e^z} y_t^{MN1}(z)$$

subject to (7). The optimal price for country 1 multinationals is equal to the domestic price chosen by country 2 firms: $\frac{p_t^{MN1}(z)}{P_{2,t}} = \frac{\gamma}{\gamma-1} \frac{MC_{2,t}}{e^z}$. Since the multinationals' price is independent of the entry cost and the continuation cost in the profit function, this optimal price $p_t^{MN1}(z)$ is the same for entrants and incumbents for a given level of z.

3.4 Entry and exit

3.4.1 Exporting

The cost of exporting depends on a firm's export status in the previous period. If a firm did not export 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. These costs are paid as the units of local labor required to be active as an exporter.

The export-related value of a potential entrant entering this period with z after choosing $p_t^{X1}(z)$ is given by

$$V_t^{E1}(z) = \max \left\{ Q_t \frac{p_t^{X1}(z)}{P_{2,t}} \left(y_t^{X1}(z) + \int_0^1 m_t^{X1}(z,z')dz' \right) - \frac{MC_{1,t}\tau_{1,t}}{e^z} \left(y_t^{X1}(z) + \int_0^1 m_t^{X1}(z,z')dz' \right) \right.$$
$$\left. -\eta_{1,t}^X w_{1,t} + \beta \mathbf{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{t+1}^{X1}(z_{t+1}), \quad \beta \mathbf{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{t+1}^{E1}(z_{t+1}) \right\}. \quad (13)$$

By equating the value of entry (the first element of the binary choices in (13)) and the value of no-entry in the current period (the second element in (13)), we can define the threshold productivity level z_t^{E1} above which non-incumbents enter the export market. Using the distribution of z, $G(z)$,

and the entry threshold z_t^{E1}, the probability of entering the export market is $\zeta_t^{E1} = 1 - G\left(z_t^{E1}\right)$.

The export-related value of an incumbent exporter with current firm-level productivity z, after choosing $p_t^{X1}(z)$, is given by

$$V_t^{X1}(z) = \max\left\{ Q_t \frac{p_t^{X1}(z)}{P_{2,t}} \left(y_t^{X1}(z) + \int_0^1 m_t^{X1}(z,z')dz' \right) - \frac{MC_{1,t}\tau_{1,t}}{e^z} \left(y_t^{X1}(z) + \int_0^1 m_t^{X1}(z,z')dz' \right) \right.$$
$$\left. -\xi_{1,t}^X w_{1,t} + \beta \mathbf{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{t+1}^{X1}(z_{t+1}), \quad \beta \mathbf{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{t+1}^{E1}(z_{t+1}) \right\}. \quad (14)$$

The threshold productivity level z_t^{X1} above which incumbents continue exporting equates the value of continuation (the first element of the binary choices in equation (14)) and the value of exiting the export market and becoming a potential entrant in the next period (the second element in equation (14)). Using z_t^{X1}, the probability of remaining in the export market is $\zeta_t^{X1} = 1 - G\left(z_t^{X1}\right)$.

Once we derive the probabilities of entry and continuation in exporting, we can describe the dynamic evolution of the mass of exporters. Let N_t^1 be the mass of incumbent exporters starting date t, and let N_t^{E1} be the mass of new exporters in date t. The evolution of the mass of exporters is given by $N_{t+1}^1 = \zeta_t^{X1} N_t^1 + N_t^{E1}$, where N_t^{E1} evolves according to $N_t^{E1} = \zeta_t^{E1}(1 - N_t^1)$.

3.4.2 Multinational production

As with the export participation decisions described above, producing in the foreign market involves a sunk entry cost η^{MN} (for a new multinational) and a per-period fixed continuation cost ξ^{MN} (for an incumbent multinational), which are paid as additional foreign labor hired in the destination market. In this case, firms carry over their own firm-level productivity levels, but use labor, capital, intermediate inputs and aggregate productivity available in the destination market.

The value of multinational production for a non-incumbent firm (i.e., potential multinational firm) entering this period with z after choosing $p_t^{MN1}(z)$ is

$$V_t^{ME1}(z) = \max\left\{ Q_t \left(\frac{p_t^{MN1}(z)}{P_{2,t}} \right) y_t^{MN1}(z) - Q_t \frac{MC_{2,t}}{e^z} y_t^{MN1}(z) - Q_t \eta^{MN} w_{2,t} + \beta E_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{t+1}^{MN1}(z_{t+1}), \right.$$
$$\left. \beta E_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} V_{t+1}^{ME1}(z_{t+1}) \right\}. \quad (15)$$

Once a firm becomes a multinational, the value of multinational production for an incumbent

multinational with current firm-level productivity z, after choosing $p_t^{MN1}(z)$, is

$$V_t^{MN1}(z) = \max\left\{Q_t\left(\frac{p_t^{MN1}(z)}{P_{2,t}}\right)y_t^{MN1}(z) - Q_t\frac{MC_{2,t}}{e^z}y_t^{MN1}(z) - Q_t\xi^{MN}w_{2,t} + \beta E_t\frac{\lambda_{1,t+1}}{\lambda_{1,t}}V_{t+1}^{MN1}(z_{t+1}),\right.$$
$$\left.\beta E_t\frac{\lambda_{1,t+1}}{\lambda_{1,t}}V_{t+1}^{ME1}(z_{t+1})\right\}. \quad (16)$$

Using equations (15) and (16), we can define the threshold productivity levels, z_t^{ME1} and z_t^{MN1} for entry and continuation of multinational production, and their respective probabilities of entry and continuation, $\zeta_t^{ME1} = 1 - G\left(z_t^{ME1}\right)$ and $\zeta_t^{MN1} = 1 - G\left(z_t^{MN1}\right)$. Let N_t^{MN1} denote the mass of country 1 multinationals operating in country 2 at the beginning of period t, and N_t^{ME1} be the mass of new country 1 multinationals starting to produce in country 2 in period t. The evolution of the mass of multinationals is given by $N_{t+1}^{MN1} = \zeta_t^{MN1}N_t^{MN1} + N_t^{ME1}$, where N_t^{ME1} evolves according to $N_t^{ME1} = \zeta_t^{ME1}(1 - N_t^{MN1})$.

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 that is proportional to the relative marginal utility of consumption

between the two countries[5]: $Q_t = e_0 \frac{\lambda_{1,t=0}}{\lambda_{2,t=0}} \frac{P_{2,t=0}}{P_{1,t=0}} \frac{\lambda_{2,t}}{\lambda_{1,t}}$

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 good, 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 good. 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 β is set to 0.99 to imply an annual nominal interest rate of 4 percent. The weight on leisure in the household utility χ is 1.902 so that households work one-third of their time. The capital depreciation rate δ is set equal to 0.25 so that the annual depreciation rate is 10 percent, and the capital adjustment cost parameter κ is set equal to 4.5 so that the volatility of investment relative to output is 2.91 in line with data.[6]

I assume that the elasticity of substitution between domestically produced goods and imported goods (ρ for the consumption composite and ϕ 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 goods produced in the same country γ, I follow Ghironi and Melitz (2005) and set it equal to 3.8. The share of capital in the value-added production α 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. Table 1 summarizes the parameter values.

I assume that the idiosyncratic firm-level productivity z is normally distributed: $G(z) = N(0, \sigma_z)$. With this assumption, the remaining nine parameters ((i) the share of value-added in the production function σ, (ii) the home bias in consumer goods ω, (iii) the weight on imports in consumer goods ψ, (iv) the home bias in the intermediate-input composite θ, (v) the steady-state value of entry cost shocks $\bar{\eta}^X$, (vi) the steady state value of continuation cost shocks $\bar{\xi}^X$, (vii) the standard deviation of idiosyncratic firm-level productivity shocks σ_z, (viii) sunk cost of starting as

[5] 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.

[6] 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 1000 times, each with 100 periods.

Table 1: Parameter values

A: Common parameters

Subjective discount factor	β	0.99
Capital depreciation rate	δ	0.025
Capital adjustment cost	κ	4.5
Armington elasticity		
in consumption composite	ρ	1.5
in intermediate composite	ϕ	1.5
Elasticity of substitution	γ	3.8
Share of capital in value-added production	α	0.4
Steady state iceberg cost	$\bar{\tau}$	1.3
Country-specific productivity	A	1

B: Parameters for matching empirical targets

		Baseline model	No multinational
Weight on leisure in utility	χ	1.902	1.257
Share of value-added in production	σ	0.616	0.411
Home bias			
in consumption composite	ω	0.33	0.8144
in intermediate composite	θ	0.798	0.799
Weight on imports in consumption composite	ψ	0.167	0.1856
Steady-state cost of export entry	$\bar{\eta}^X$	0.1852	0.266
Steady-state cost of export continuation	$\bar{\xi}^X$	0.037623	0.0539
Cost of multinational entry	η^{MN}	9.35	–
Cost of multinational continuation	ξ^{MN}	0.91545	–
Standard deviation of firm-level productivity	σ_z	0.36	0.362

Table 2: Target statistics and model moments

	Data	Baseline model	
Total imports/GDP	0.152	0.152	U.S. data (1947Q1-2016Q4)
Total intermediate inputs/total output value	0.434	0.434	Input-Output Table (2000-2014)
Imported intermediate inputs/total intermediate inputs	0.093	0.093	Input-Output Table (2000-2014)
Entry rate	0.037	0.037	Bernard & Jensen (2004)
Continuation rate	0.967	0.966	Bernard & Jensen (2004)
Productivity relative to non-exporters	1.12-1.18	1.12	Bernard & Jensen (1999)
Multinationals' employment share	0.26	0.25	Antràs & Yeaple (2014)
No. of multinationals/total no. of firms	0.02	0.05	Antràs & Yeaple (2014)
No. of multinational entry/no. of exporter entry	0.188	0.186	Deseatnicov & Kucheryavyy (2017)

a multinational η^{MN}, and (ix) continuation cost of operating as a multinational ξ^{MN}) 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 are 0.152, in line with the average value for the United States between 1947Q1 and 2016Q4. The value of intermediate inputs as a share of total output value is 0.434, and the value of imported intermediate inputs as a fraction of total intermediate inputs is 0.093, 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 96.6 percent and that of exporter entry is 3.7 at the quarterly frequency, based on the U.S. manufacturing establishments between 1984 and 1992 (Bernard and Jensen, 2004). 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, 18.8 percent of that of exporter entry for Japanese firms between 1995 and 2013. The number of multinationals as a share of total number of local firms is 2 percent, and multinationals employ 26 percent of total labor in France in 2007 (Antràs and Yeaple, 2014). In my model, the number of multinationals as a share of total number of local firms is 5 percent. The calibration targets and model-implied moments are summarized 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, τ_t^{y1}; (ii) tariffs on country 2's imports of intermediate goods from country 1, τ_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. 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 respective initial steady-state levels, for each trade policy change.

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-good tariffs leading to a larger fall in country 1, while market-access barriers result 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 0.81 to 1.08 percent in country 2, while it falls by 0.16 to 0.33 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). Since households derive utility from having more product variety, the consumption loss is larger for country 2 households. The long-run trade balance improves for the policy-imposing country (country 2) in all three cases, varying from 0.17 to 0.51 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 0.51 percent and 0.46 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 is more than twice as large in the case of intermediate-input tariffs than with market-access barriers, and the GDP loss for country 2 is

Table 3: Long-run effects of trade policy

	Tariffs on final goods	Tariffs on intermediate goods	Barriers to market access
A: GDP			
Country 1	-0.78	-0.88	-0.36
Country 2	-0.26	-0.61	-0.68
B: Consumption			
Country 1	-0.16	-0.33	-0.16
Country 2	-0.81	-1.08	-0.88
C: Investment			
Country 1	-0.78	-0.88	-0.36
Country 2	-0.62	-0.98	-0.68
D: Trade balance (as % of GDP)			
Country 1	-0.51	-0.46	-0.16
Country 2	0.51	0.46	0.17
E: Exporter mass			
Country 1	-5.61	-5.45	-18.62
Country 2	-0.63	-1.02	-0.48
F: Multinational mass			
Country 1	0.58	0.10	0.48
Country 2	-0.18	-0.08	-0.01

Notes: The reported 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. 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.

more than twice as large 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 goods 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 (-18.62 percent), which substantially increase the costs of exporter entry and continuation. On the other hand, the most productive firms from country 1 find it profitable to locate production in country 2 as multinationals, with the mass of country 1 firms that produce in country 2 increasing by 0.10 to 0.58 percent in the long run. Because country 2 faces a recession, its real wages are now lower, which reduces labor costs and the entry and continuation costs of multinational production for country 1 firms. Further, 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 (potential) market share for multinational firms is increased, thereby increasing 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 (0.10 percent) relative to the other two cases. Tariffs on intermediate imports increase the purchasing price of intermediate goods in country 2, and this partially offsets the downward pressure on the marginal cost of production due to the declining costs of labor and capital. In the long run, the fall in real wages and the rental rate of capital dominate the increase in the price of imported intermediate inputs, and we see a slight 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 (-0.26 percent) in the case of final-good tariffs relative to the other two policies (-0.61 percent for intermediate-good tariffs, and -0.68 percent for market-access barriers). In response to final-good tariffs, the country's imports of final goods fall substantially (-6.31 percent). This generates (imperfect) expenditure switching toward domestically produced final goods, and we see a substantially smaller fall in the domestic production of final goods by local firms (-0.14 percent) relative to the other two cases and a slight increase in the final-good production by multinationals (0.02 percent) that are absent in the other two cases. 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.

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	-0.26	-0.61	-0.68
Domestic production			
(i) Final goods			
by local firms	-0.14	-1.00	-0.34
by country 1 multinationals	0.02	-0.97	-0.21
(ii) Intermediate goods	-0.15	-0.45	-0.19
Imports			
(i) Final goods	-6.31	-1.67	-5.27
(ii) Intermediate goods	-1.70	-16.13	-5.12
Real wage	-0.81	-1.08	-0.88
Intermediates price	-0.33	0.93	-0.03

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.

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 goods fall substantially (-16.13 percent). However, this does not lead to an expenditure switching to domestically produced intermediate products. In fact, the fall in the production of intermediate goods is largest in the case of intermediate-good tariffs (-0.45 percent), compared with the other two cases (-0.15 percent for final-good tariffs, and -0.19 percent for market-access barriers). With intermediate-input tariffs, the increase in the purchasing price of imported intermediate inputs immediately raises the marginal cost of production for firms that rely on these imports in production. This places an upward pressure on the price of intermediates, and we see a substantial increase in the price of intermediate goods (0.93 percent) relative to the other two cases in which the changes are negative or negligible (-0.33 percent for final-goods tariffs, and -0.03 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 (-0.36 percent) relative to final-good tariffs and intermediate-

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	-0.78	-0.88	-0.36
Consumption	-0.16	-0.33	-0.16
Real export sales	-3.93	-4.00	-1.57
Relative producer price of exports	0.61	0.40	2.95

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 P_1 in country 1.

input tariffs (-0.78 percent and -0.88 percent, respectively). In country 1, the recessionary effects of trade policy arise mainly from a contraction of the export sector rather than a contraction in consumption, and the fall in real export sales (in units of country 1 consumer goods) is substantially smaller in the case of market-access barriers (-1.57 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 are attributed primarily to 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 (2.95 percent) compared with the two tariff cases (0.61 percent for final-good tariffs, and 0.40 percent for intermediate-input tariffs). With market-access barriers, there is a sizable contraction in the export participation among country 1 firms (-18.62 percent in Table 3). As shown in the literature of product variety and firm entry and exit, fewer varieties lead to an increase in the producer price index of exports (Feenstra, 1994; Ghironi and Melitz, 2005).[7]

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 only marginal effects on aggregate labor, we see a reallocation of labor away from the export sector toward domestic production (by

[7]The effects of trade policy on various GDP components in the two countries are summarized in Table B1 in Appendix B.

Table 6: Labor reallocation

	Tariffs on final goods	Tariffs on intermediate goods	Barriers to market access
A: Country 1			
Aggregate labor	-0.76	-0.69	-0.47
Labor for domestic production	-0.33	-0.26	-0.08
Labor for multinational production	-0.10	-0.04	0.00
Labor for export production	-3.78	-3.67	-1.40
B: Country 2			
Aggregate labor	0.18	0.04	0.18
Labor for domestic production	0.24	0.30	0.28
Labor for multinational production	0.30	0.05	0.25
Labor for export production	-0.43	-0.69	-0.32

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 in the respective market. "Labor for multinational production" refers to local labor used for production by multinational firms producing and selling in the respective host country. "Labor for export production" refers to labor used by local firms to produce exported products.

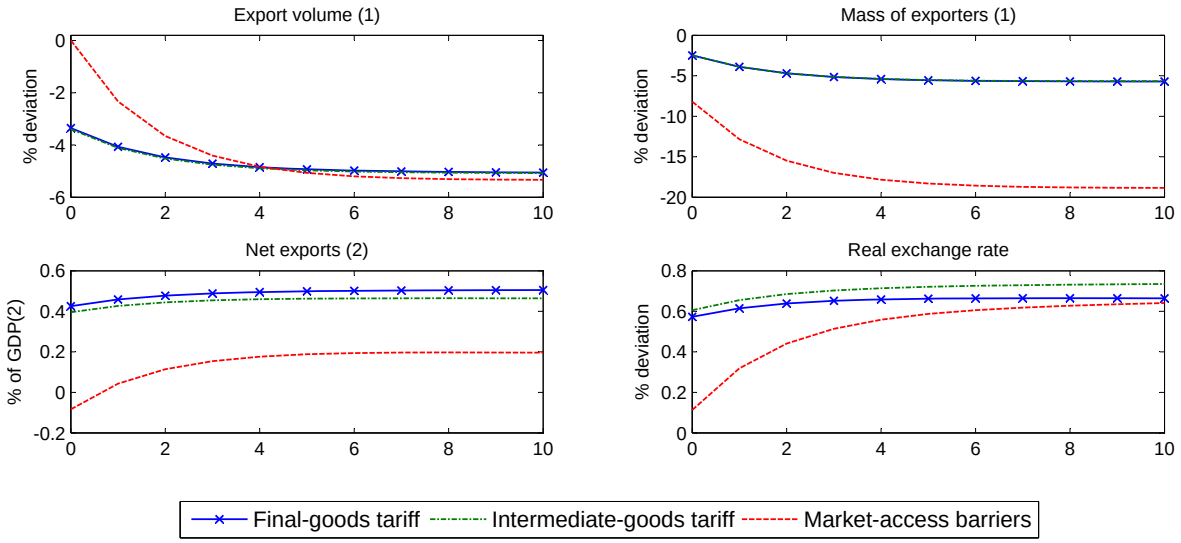
both domestic firms and multinational firms). In the long run, labor used to produce goods sold domestically increases by 0.24 to 0.30 percent and labor employed by multinational firms increases by 0.05 to 0.30 percent, while labor used to produce exports falls by 0.32 to 0.69 percent.

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 2 presents the impulse responses of the volume of country 1 exports, the mass of country 1 exporters, the trade balance of country 2, and the real exchange rate, following each of the three trade policy changes under consideration. We see that market-access barriers (red dotted lines) have significantly more gradual effects on trade flows relative to the other two policies during the first few periods. This is attributed to the hysteresis in exporter dynamics.

Figure 2: Impulse responses to trade barriers



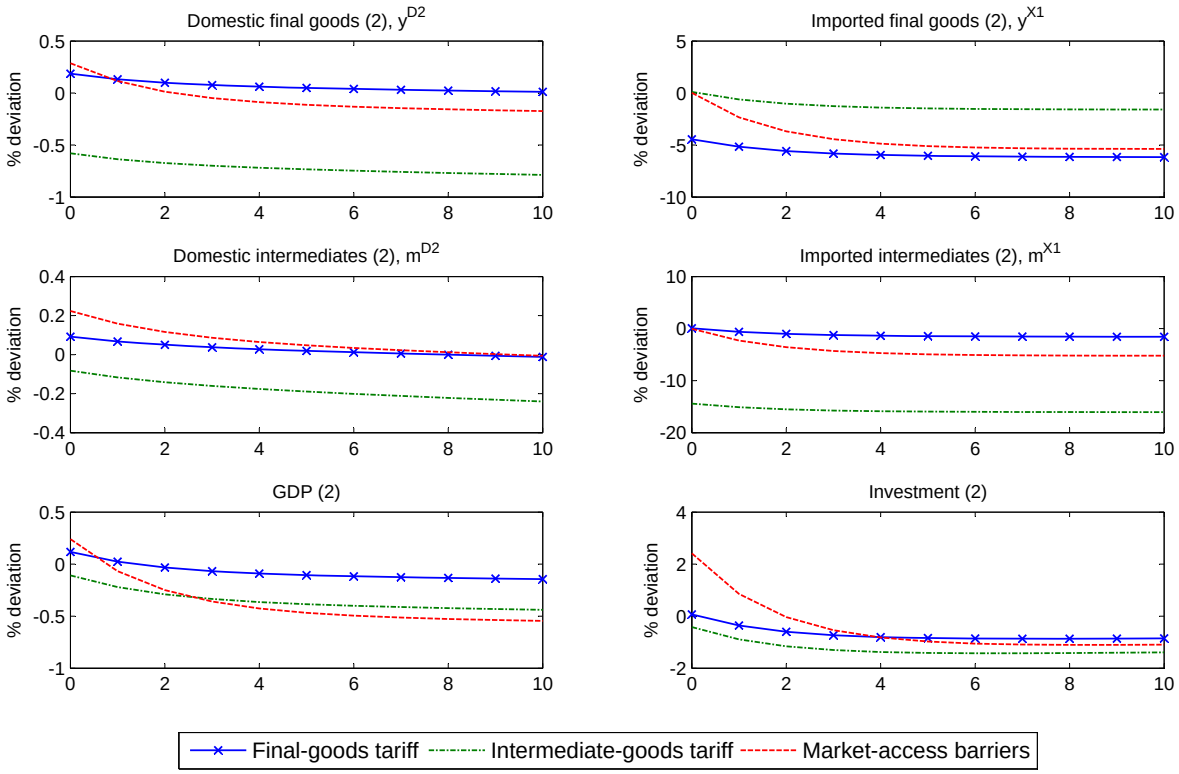
Notes: Impulse responses to a permanent change in (i) tariffs on final goods, (ii) tariffs on intermediate inputs, and (iii) market-access barriers. The magnitude of each shock is chosen so that the volume of exports from country 1 to country 2 falls by 5 percent cumulatively over the first 40 periods following the shock. A positive response of the real exchange rate represents a real depreciation for country 1.

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). Therefore, we see more gradual responses to this policy change.

This slow adjustment of country 1 exports translates to a temporary, small trade deficit 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 first as demand in country 1 starts contracting, while imports of country 2 experience a more gradual fall, and we see a brief worsening of the trade balance 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 3 presents the dynamic responses of aggregate variables in country 2 (where imports are restricted). When country 2 imposes tariffs on imports of final goods from country 1 (dark blue lines with x's), the higher price of imported final goods induces expenditure switching to domestically produced

Figure 3: Impulse responses to various trade barriers (country 2)

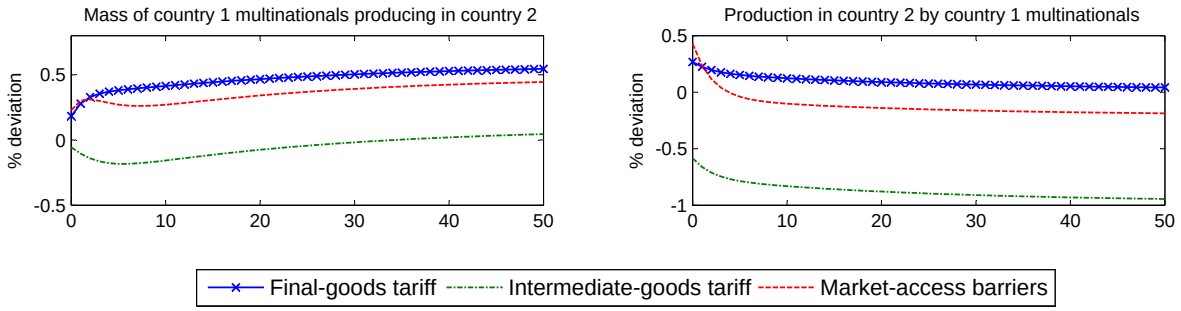


Notes: Impulse responses of country 2 to a permanent change in (i) tariffs on final goods, (ii) tariffs on intermediate goods, and (iii) barriers to market access. The magnitude of each shock is chosen so that the export volume for country 1 falls by 5 percent cumulatively over the first 10 years following the shock. Analogous figures for country 1 are presented in Appendix C.

final goods. In the short run, this leads to a slight but persistent increase in the demand for country 2 final goods, y^{D2}. The increased production of final goods in country 2 in turn entails an increase in the production of intermediate goods there, and we see a marginal increase in m^{D2} 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. Expecting lower 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 dotted lines), the responses are substantially more gradual relative to the other two policies, as discussed above (Figure 2). 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 domestically produced final goods y^{D2} and producers shift

Figure 4: Multinational firms



Notes: Impulse responses of the mass of country 1 multinational firms and their production in country 2 to a permanent change in (i) tariffs on final goods, (ii) tariffs on intermediate goods, and (iii) market-access barriers. 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.

to domestic intermediate inputs m^{D2}. Notice here that the short-run increase in investment is significantly larger in the case of market-access barriers (red dotted lines) than in the case of final-good tariffs (dark blue lines with x's), even though both policies lead to expenditure switching to domestically produced products (y^{D2} and m^{D2}). An important difference is that market-access barriers have larger expenditure switching of intermediate inputs than final-good tariffs do. This suggests that domestic investment is more closely linked to the production of intermediate inputs, highlighting its importance as a contributing factor to aggregate income.

In contrast to the above two policies, intermediate-input tariffs (green dotted lines) lead to an immediate fall in the production of both final goods y^{D2} and 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 sizable falls in production and consumption in country 2.

The short-run boom in country 2 in response to final-good tariffs and market-access barriers is also supported by an immediate increase in the number of country 1 multinational firms operating in country 2 and an increase in their production. Figure 4 presents the impulse responses of the mass of country 1 multinational firms operating in country 2, and their production. With final-good tariffs and market-access barriers, the expenditure switching away from imports to domestically produced varieties in country 2 and the resulting temporary boom in country 2 discussed above lead to an increase in the mass of firms from country 1 producing in country 2 immediately following the policy changes. The level of their production increases immediately, and remains above the initial steady-state level persistently in the case of final-good tariffs.

In contrast, following the introduction of intermediate-input tariffs, we see that the mass of country 1 multinational firms producing in country 2 falls initially, and then turns to a level slightly above the initial steady state after about 30 periods. My assumption of the immediate complete pass-through of tariffs to prices implies that the price of imported inputs increases immediately after the tariff is imposed. This raises the cost of production in country 2 immediately, making it less profitable to produce in country 2, and we see more exit of multinational firms from country 2. Over time, however, as real wages and the rental rate of capital continue to decline toward their long-run levels in country 2, their declines eventually dominate the increase in the price of intermediate inputs, and the marginal cost of production falls below the initial steady state. At the same time, the continued fall in real wages in country 2 reduces the entry and continuation costs facing the multinational firms. Together, we see a slight increase in the mass of country 1 multinationals, despite the increase in the price of intermediate goods due to the tariffs.

6 The role of multinational firms

One distinct feature of my model economy is the endogenous entry and exit of multinational firms that may produce and sell final goods in the foreign market. Because multinational firms are the most productive firms in the economy, their decisions on entry/exit and production can affect the aggregate economy in a nontrivial way. In particular, when trade policy changes reduce the inflow of imported products, the presence of multinationals allows households to reallocate their expenditure to a wider variety of output produced with the same level of productivity as exporters or higher. In the absence of multinationals, however, 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 consider an alternative version of my model in which there is no multinational production. I recalibrate this alternative model so that its steady-state characteristics are identical to those of my baseline model as described in Table 2, except for the last three target moments related to multinational firms (multinational's employment share, the number of multinationals as a share of total number of firms, and the number of multinational entry relative to the number of exporter entry), which are absent in this alternative model. The recalibrated parameter values are reported in panel B of Table 1.

Table 7 compares the effects of trade policy changes from my baseline model with those from the alternative model without multinational production. 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 of production in the policy-imposing country (country 2).

The baseline calibration of my model economy implies that the average costs of entry/continuation are higher for multinational production than 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

Table 7: The role of multinational firms

	Baseline model			No multinational firms		
	Tariffs on final goods	Tariffs on intermediates	Barriers to market access	Tariffs on final goods	Tariffs on intermediates	Barriers to market access
A: Country 1						
GDP	-0.78	-0.88	-0.36	-0.76	-0.92	-0.44
Production						
(i) Final goods						
by local firms	-0.17	-0.23	-0.10	-0.21	-0.35	-0.21
by multinationals	-0.22	-0.25	-0.10	–	–	–
(ii) Intermediate goods	-0.69	-0.70	-0.27	-0.69	-0.77	-0.34
B: Country 2						
GDP	-0.26	-0.61	-0.68	-0.42	-0.82	-0.94
Production						
(i) Final goods						
by local firms	-0.14	-1.00	-0.34	-0.26	-1.20	-0.70
by multinationals	0.02	-0.97	-0.21	–	–	–
(ii) Intermediate goods	-0.15	-0.45	-0.19	-0.30	-0.90	-0.55

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 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 real wages dominates the increasing costs of imported intermediate goods. 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 of multinationals helps to dampen the negative 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 and market-access barriers because these policies generate expenditure switching away from imported products toward domestically produced goods, which induces a larger expansion of multinational production in country 2 (Figure 4). The effects are less obvious in the case of intermediate-good tariffs, since the resulting costs of production in country 2 in this case do not

translate to an expenditure switching toward domestically produced goods and, hence, production by multinational firms.

7 Sensitivity analysis

7.1 Home bias in intermediate inputs

In this subsection, I examine the sensitivity of my main results to the degree of home bias 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 hence 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 5 compares the responses from my baseline model (red lines) with those from the model with θ set equal to 1 (blue lines). In Figure 5a, we see that increasing the value of θ 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 5.61 percent in the long run in my baseline model, whereas the fall is much larger (8.81 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.

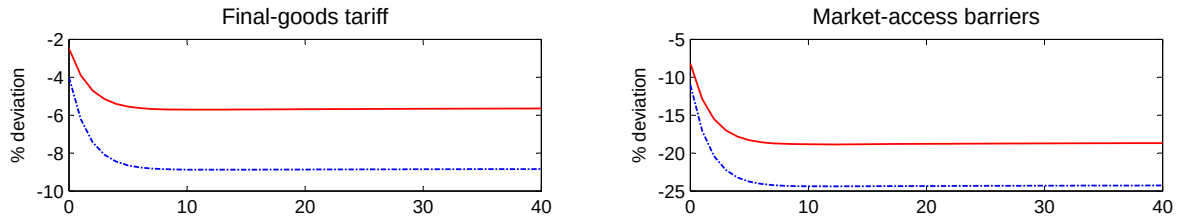
In contrast, the effects of the presence of imported production inputs on the response of the export volume depend on the type of policy changes (Figure 5b). Relative to my baseline model, the fall in the export volume is larger in response to final-good tariffs in the absence of input trade, while the 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 6.31 percent, larger than the 5 percent target for total imports, because the fall in intermediate imports is much smaller (1.70 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 cases 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 few effects on the volume of final good trade, as we see in Figure 5b.

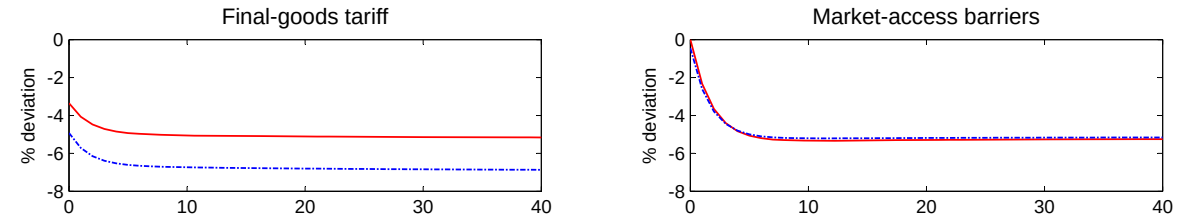
In contrast, we see in Figures 5c and 5d that increasing the value of θ dampens the responses

Figure 5: Home bias in intermediate inputs

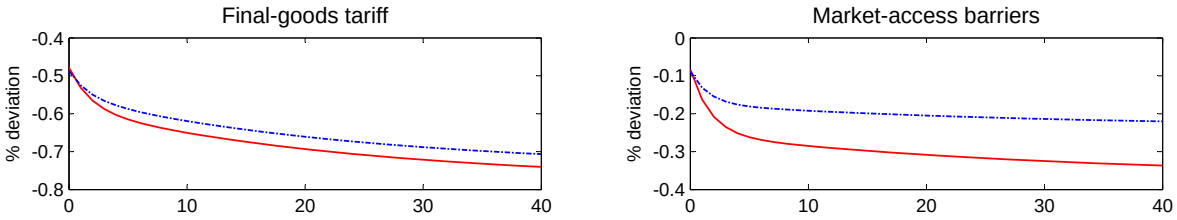
(a) Number of exporters (country 1)



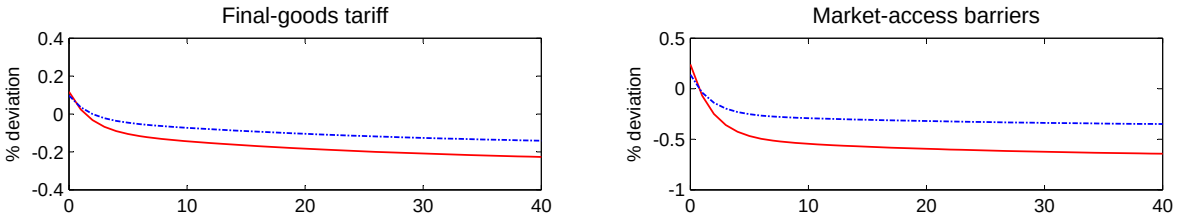
(b) Export volume (country 1)

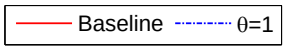


(c) GDP (country 1)



(d) GDP (country 2)





Notes: Impulse responses of the number of exporters (panel a), export volume from country 1 (panel b), GDP in country 1 (panel c), and GDP in country 2 (panel d) to a permanent change in (i) tariffs on final goods and (ii) market-access barriers, from my baseline model (red lines) and from an alternative model without international trade in intermediate goods ($\theta = 1$) (blue lines). The magnitude of each shock is the same as that used in my baseline analysis.

of the aggregate economy to trade policy changes in both countries. When θ is increased to 1 and international trade in intermediate inputs is eliminated, a country's imports as a steady-state share of GDP decline from 15.2 percent in my baseline model to 11 percent. With a smaller share of imports, the aggregate effects of trade policy also become dampened.[8]

7.2 Product substitutability

As described in section 3, my model assumes Armington aggregators for combining domestic and imported consumption goods (equation 1) and combining domestic and imported intermediate goods (equation 9), with exogenously given levels of the elasticity of substitution (ρ and ϕ, respectively). Therefore, it abstracts from production specialization as in Ricardian trade models. In this setting, the degree of product substitutability (between domestic and imported products) plays an important role in the quantitative effects of trade policy. In this subsection, I vary the two elasticities of substitution in my model - one for the composite of consumption goods ρ and the other for the composite of intermediate inputs ϕ, and analyze their aggregate effects in response to trade policy changes.

Figure 6 shows the long-run effects of each trade policy on GDP in country 2 for different combinations of ρ and ϕ. As expected, the long-run effects of final-good tariffs are more sensitive to the product substitutability of final goods faced by households, while the effects of intermediate-input tariffs are more sensitive to the productivity substitutability of intermediate inputs faced by producers. When the effects of these tariffs are compared against each other, we see that the product substitutability of intermediate inputs ϕ has significantly stronger effects than that of final goods for the same degree of variation in substitutability. This result holds for market-access barriers where the product substitutability in intermediate inputs plays a more important role.[9]

8 Comparison with iceberg trade costs

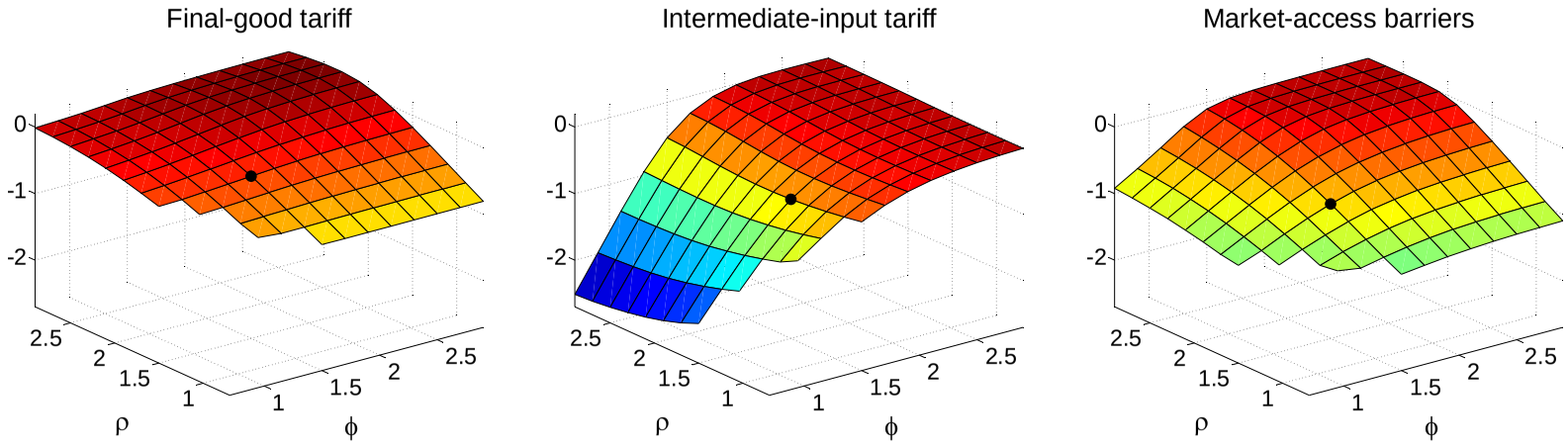
Existing studies on trade policy often consider changes in iceberg trade costs as a trade policy tool. In this section, I compare my baseline results to the effects of changes in iceberg trade costs and show that the long-run effects of changes in iceberg trade costs are similar to those from changes 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 barriers that generate exporter hysteresis.

Figure 7 compares the impulse responses to market-access barriers and iceberg trade costs, for the same set of variables as in Figure 2. We see that the dynamic paths are quite different during the first few periods following the policy changes because the responses to market-access barriers

[8]The same patterns are seen for the responses of consumption in the two countries. The figures are presented in Appendix D.

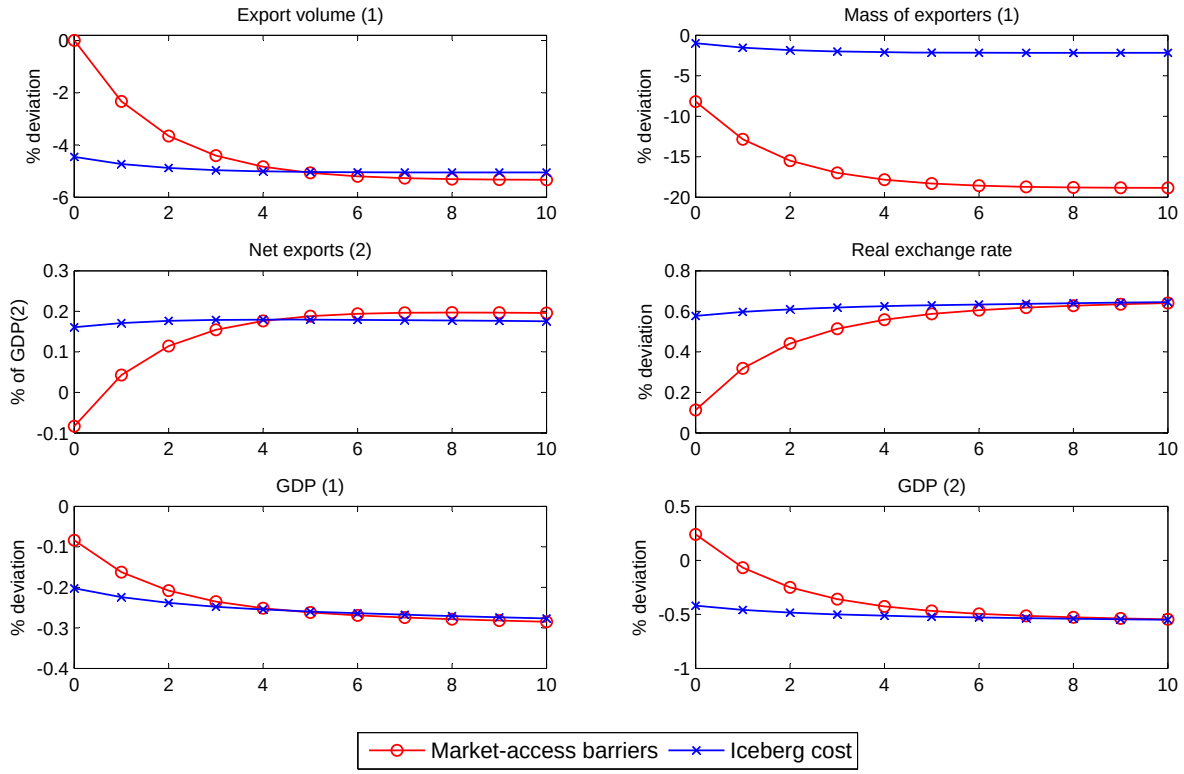
[9]Similar patterns are seen for the effects on country 1 GDP. The figures are presented in Appendix E.

Figure 6: Product substitutability and long-run effects of trade policy: Country 2 GDP



Notes: Long-run responses of GDP in country 2 to a permanent increase in trade policy, for various combinations of the elasticity of substitution for the consumption-good composite (ρ) and the elasticity of substitution for the intermediate-input composite (ϕ). The black dots indicate the benchmark calibration ($\rho = \phi = 1.5$). The magnitude of each shock is the same as that used in my baseline analysis.

Figure 7: Comparison to iceberg costs



Notes: Impulse responses to a permanent change in (i) market-access barriers and (ii) iceberg costs. 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.

are substantially delayed. Relative to the market-access barriers, the short-run responses to iceberg costs reach their long-run levels within the first few periods following the policy change. When the extensive margin adjustment to the market-access barriers becomes near complete, however, the two policies yield very similar quantitative effects in the long run, except for the response of the mass of country 1 exporters that experience a large exit under market-access barriers.

These two policies yield similar quantitative effects on the aggregate economy because they affect the flows of final-goods trade and intermediate-good trade in a similar way in my model. As seen in Table 3, market-access barriers reduce country 1's exports of final goods and its exports of intermediate goods by roughly 5 percent 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 in the long run.

9 Conclusion

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

I show that, in the long run, 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. At the firm level, these trade policies lead less productive exporters to exit from the export destination market, but the most productive few find it profitable to expand production in the foreign market as multinationals due to the falling costs of labor and capital. Therefore, those multinationals are able to partially recover the loss from exporting by locating production in the destination market, even when tariffs are imposed on intermediate inputs.

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.

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, 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. Importantly, 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 Profits from exporting and multinational production

The export profit is given by:

$$\Pi_t^{X1}(z) = \begin{cases} Q_t \frac{p_t^{X1}(z)}{P_{2,t}} \left(y_t^{X1}(z) + \int_0^1 m_t^{X1}(z,z')dz' \right) - \frac{MC_{1,t}}{e^z} \tau_{1,t} \left(y_t^{X1}(z) + \int_0^1 m_t^{X1}(z,z')dz' \right) - \xi_{1,t}^X w_{1,t} & \\ \qquad \text{if incumbent exporter} \\ Q_t \frac{p_t^{X1}(z)}{P_{2,t}} \left(y_t^{X1}(z) + \int_0^1 m_t^{X1}(z,z')dz' \right) - \frac{MC_{1,t}}{e^z} \tau_{1,t} \left(y_t^{X1}(z) + \int_0^1 m_t^{X1}(z,z')dz' \right) - \eta_{1,t}^X w_{1,t} & \\ \qquad \text{if entrant exporter} \\ 0 \qquad \text{if non-exporter} \end{cases}$$

The profit from multinational operation is given by:

$$\Pi_t^{MN1}(z) = \begin{cases} \frac{p_t^{MN1}(z)}{P_{2,t}} y_t^{MN1}(z) - \frac{MC_{2,t}}{e^z} y_t^{MN1}(z) - \xi^{MN} w_{2,t} & \text{if incumbent multinational} \\ \frac{p_t^{MN1}(z)}{P_{2,t}} y_t^{MN1}(z) - \frac{MC_{2,t}}{e^z} y_t^{MN1}(z) - \eta^{MN} w_{2,t} & \text{if entrant multinational} \\ 0 & \text{if non-multinational} \end{cases}$$

A.2 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

$$\begin{aligned} \frac{p_t^{X1}}{P_{2,t}} &= \left[\int_{z \in \Theta_{1,t}} \left(\frac{p_t^{X1}(z)}{P_{2,t}} \right)^{1-\gamma} dz \right]^{\frac{1}{1-\gamma}} \\ &= \left[\frac{N_t^{E1}}{1 - G(z_t^{E1})} \int_{z_t^{E1}} \left(\frac{p_t^{X1}(z)}{P_{2,t}} \right)^{1-\gamma} dG(z) + \frac{\zeta_t^{X1} N_t^1}{1 - G(z_t^{X1})} \int_{z_t^{X1}} \left(\frac{p_t^{X1}(z)}{P_{2,t}} \right)^{1-\gamma} dG(z) \right]^{\frac{1}{1-\gamma}} \end{aligned}$$

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

$$\begin{aligned} \frac{p_t^{MN1}}{P_{2,t}} &= \left[\int_{z \in \Omega_{1,t}} \left(\frac{p_t^{MN1}(z)}{P_{2,t}} \right)^{1-\gamma} dz \right]^{\frac{1}{1-\gamma}} \\ &= \left[\frac{N_t^{ME1}}{1 - G(z_t^{ME1})} \int_{z_t^{ME1}} \left(\frac{p_t^{MN1}(z)}{P_{2,t}} \right)^{1-\gamma} dG(z) + \frac{\zeta_t^{MN1} N_t^{MN1}}{1 - G(z_t^{MN1})} \int_{z_t^{MN1}} \left(\frac{p_t^{MN1}(z)}{P_{2,t}} \right)^{1-\gamma} dG(z) \right]^{\frac{1}{1-\gamma}} \end{aligned}$$

A.3 Total intermediate inputs

The total volume of domestically produced intermediate inputs is given by

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

Similarly, the total volume of country 1's exports of intermediate inputs is given by

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

A.4 Labor demand

Aggregate labor demand in country 1 is a sum of labor used for domestic production, labor used for export production (by entrants and incumbents), labor used by country 2 multinationals actively producing in country 1, export entry/continuation costs paid by country 1 exporters, and multinational entry/continuation costs paid by country 2 multinationals:

$$L_{1,t} = \int_0^1 L_{1,t}^D(z) dz + \int_{z \in \Theta_{1,t}} L_{1,t}^X(z) dz + \int_{z \in \Omega_{2,t}} L_{2,t}^{MN}(z) dz + N_t^{E1} \eta_{1,t} + \zeta_t^{X1} N_t^1 \xi_{1,t} + N_t^{ME2} \eta^{MN} + \zeta_t^{MN2} N_t^{MN2} \xi^{MN}$$

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

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

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

and

$$L_{2,t}^{MN}(z) = \sigma(1-\alpha) \frac{MC_{1,t}}{e^z w_{1,t}} y_t^{MN2}(z)$$

B Long-run effects of trade policies

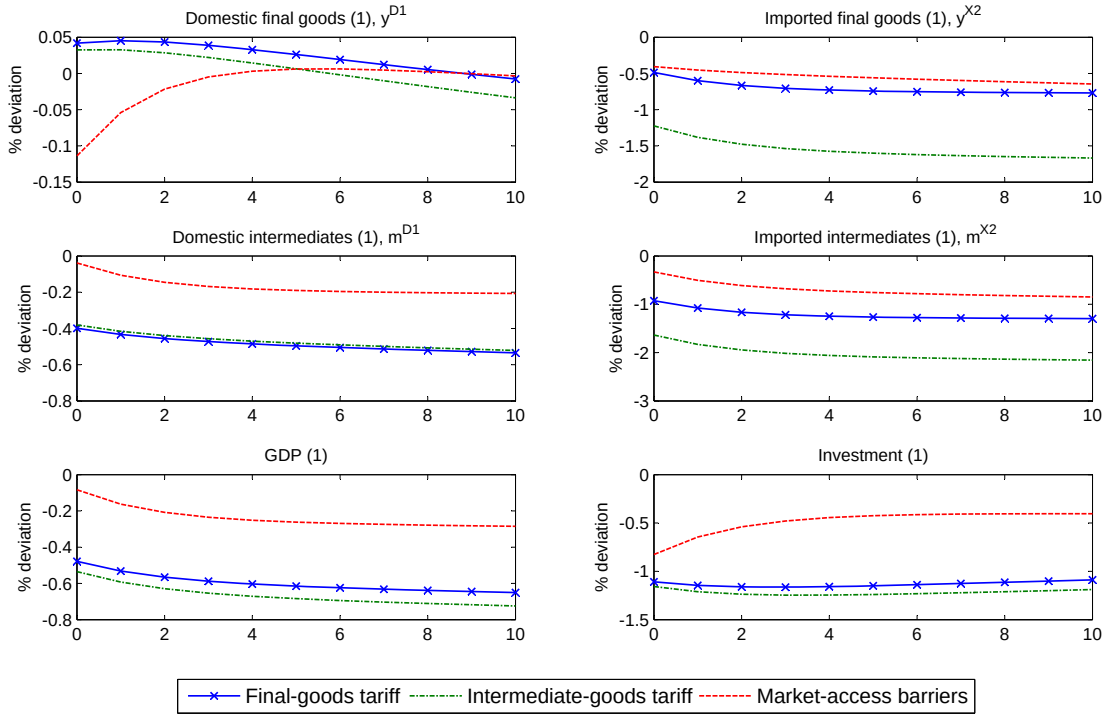
Table B1: Long-run effects

	Tariffs on final goods	Tariffs on intermediate goods	Barriers to market access
A: Country 1			
GDP	-0.78	-0.88	-0.36
Consumption	-0.16	-0.33	-0.16
Investment	-0.78	-0.88	-0.36
Real exports (in units of C_1)	-3.93	-4.00	-1.57
Production for domestic use			
(i) Final goods			
by domestic firms	-0.17	-0.23	-0.10
by country 2 multinationals	-0.22	-0.25	-0.10
(ii) Intermediate goods	-0.69	-0.70	-0.27
Production for exporting			
(i) Final goods	-6.31	-1.67	-5.27
(ii) Intermediate goods	-1.70	-16.13	-5.12
B: Country 2			
GDP	-0.26	-0.61	-0.68
Consumption	-0.81	-1.08	-0.88
Investment	-0.62	-0.98	-0.68
Real exports (in units of C_2)	-1.23	-1.77	-1.21
Production for domestic use			
(i) Final goods			
by domestic firms	-0.14	-1.00	-0.34
by country 1 multinationals	0.02	-0.97	-0.21
(ii) Intermediate goods	-0.15	-0.45	-0.19
Production for exporting			
(i) Final goods	-0.83	-1.86	-0.94
(ii) Intermediate goods	-1.36	-2.33	-1.11

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)

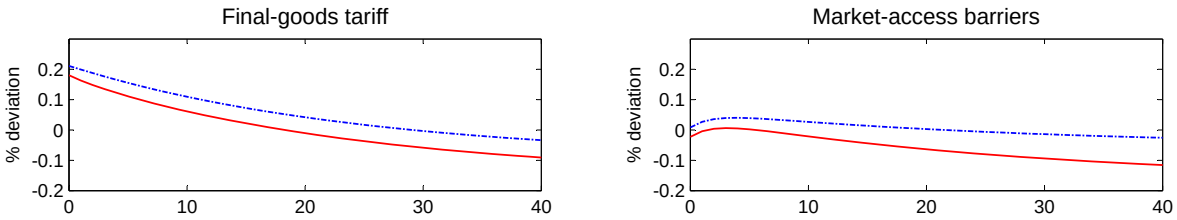


Notes: Impulse responses of country 1 to a permanent change in (i) tariffs on final goods, (ii) tariffs on intermediate goods, and (iii) barriers to market access. The magnitude of each shock is chosen so that the export volume for country 1 falls by 5 percent cumulatively over the first 10 years following the shock.

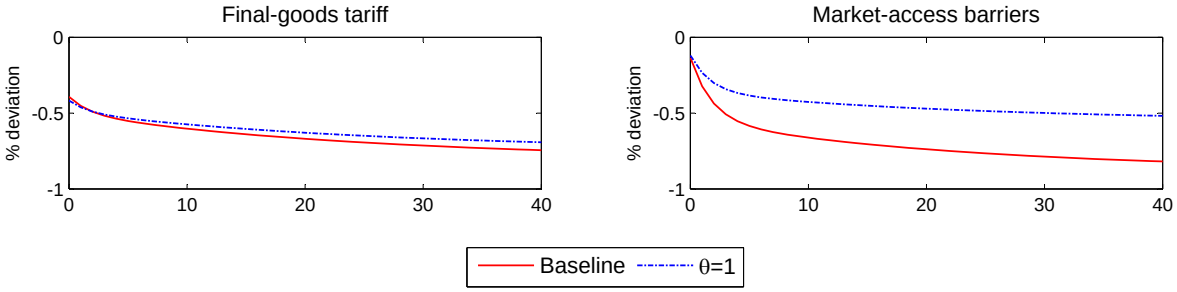
D Sensitivity to home bias in intermediate inputs

Figure D2: Home bias in intermediate inputs: Consumption responses

(a) Consumption (country 1)



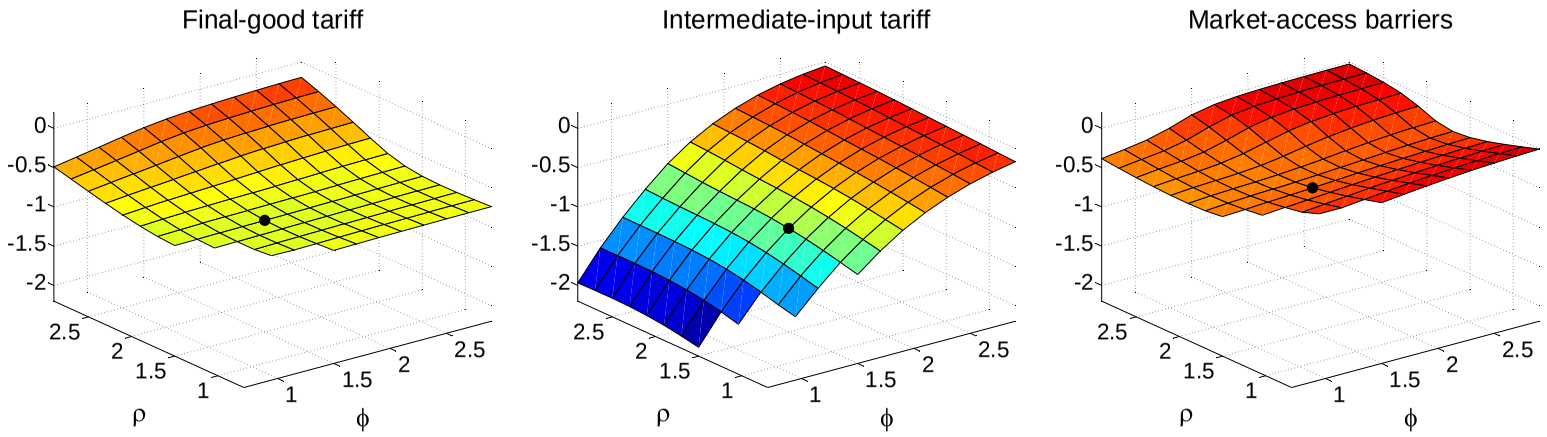
(b) Consumption (country 2)



Notes: Impulse responses of consumption to a permanent change in (i) tariffs on final goods and (ii) barriers to market access, from my baseline model and from an alternative model without international trade in intermediate goods ($\theta = 1$). Panel (a): Consumption responses in country 1. Panel (b): Consumption responses in country 2. The magnitude of each shock is the same as that used in my baseline analysis.

E Product substitutability

Figure E3: Product substitutability and long-run effects of trade policy: Country 1 GDP



Notes: Long-run responses of GDP in country 1 to a permanent increase in trade policy, for various combinations of the elasticity of substitution for the consumption-good composite (ρ) and the elasticity of substitution for the intermediate-input composite (ϕ). The black dots indicate the benchmark calibration ($\rho = \phi = 1.5$). The magnitude of each shock is the same as that used in my baseline analysis.