Essays on International Trade and Macroeconomics

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Abstract

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In this dissertation, I focus on studying three questions about international trade including the interactions between trade and immigration, how trade liberalization influences skill upgrading decisions and the linkages between health investment and trade openness.

In the first chapter, I develop a two-country dynamic stochastic general equilibrium model featuring endogenous firm entry, heterogeneous firms and endogenous labor migration to study whether trade and immigration are substitutes or complements and investigate the macroeconomic consequences of low barriers to labor mobility with emphasizing the roles of the extensive margins of production and trade in shaping immigration dynamics. First, the model predicts that trade and immigration potentially act as substitutes, which is consistent with the derivation from the Heckscher-Ohlin model of trade. Second, high-skilled labor migration makes the labor-sending country worse off due to less output and firm entry, and changes in migration costs create asymmetric welfare effects on high-skilled and low-skilled households. Third, the firm entry channel provides new insights into immigration dynamics: (i) more firm establishments demand more immigrants, and (ii) inflows of immigrants induce firm entry and result in higher labor costs in the long run.

The second chapter is a joint work with Castiel Chen Zhuang[1] and Qiliang Chen[2]. We

[1]Castiel Chen Zhuang was my Ph.D classmate in the Department of Economics at the University of Washington at the time of our collaboration and he will join the School of Economics in Peking University as an assistant professor in September 2022. Email: zogcee@gmail.com.

[2]Qiliang Chen is a Ph.D. student in the Department of Economics at the University of Washington.

observe that India's average applied effective tariff declines by about 15 percentage points and exports to the Indian market by Chinese manufacturing firms increase a lot from 2004 to 2007, but the change in the average tariff in the rest of the world is nearly zero during the same period. Motivated by this fact, we examine the impact of an Asian trade agreement, APTA, on skill upgrading by Chinese manufacturers. First, we develop a general equilibrium model of trade with heterogeneous firms and endogenous export and employee training decisions to explain firm performance following trade liberalization. Second, we test the theoretical model based on general difference-in-differences estimations, showing that firms facing higher reductions in India's tariffs increase investment in on-the-job training faster. The effects of trade openness on export participation and training spending of firms are the largest in the middle range of productivity, which is consistent to our model prediction.

In the third chapter, my co-author, Qiliang Chen, and I study the interactive effects of trade openness and health investment. There is a positive correlation between trade and health outcomes, and increased exports or imports encourage more healthcare spending. However, there are only few theoretical studies addressing the questions that if trade integration is good for health and if health improvement encourages more trade. We develop a two-country dynamic stochastic general equilibrium model with heterogeneous firms, health capital accumulation and endogenous firm entry and labor supply to analyze what channels affect the interconnection between trade and health. Three main results emerge. First, there is positive association between trade openness and health investment. An increase in health investment boosts both the number of exporters and export values as health improvement stimulates economic growth and increases income. Trade openness increases healthcare spending and the stock of health capital because of the income and product variety effects. Second, the dynamic impacts of changes in aggregate productivity on key variables could be underestimated if workers' health status and health investment decisions are neglected. Third, health investment could crowd out physical capital investment and new firm entrants.

Email: qlchen@uw.edu. For this joint work, the co-authors equally contribute to the direction of this project, data colloection, theoretical analysis and empirical studies.

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Chapter 1

INTERNATIONAL TRADE, IMMIGRATION AND MACROECONOMIC DYNAMICS

1.1 Introduction

Immigration has increased substantially in the last decades. In particular, Figure 1.1 shows that the number of immigrants in the United States has been growing steadily from 2007 to 2020, and it was up to 43 million (13.4% of the total U.S. population) in 2019.[1] Many studies examine the impacts of low-skilled immigration on labor market, remittance, offshoring, productivity and CPI in the United States.[2] However, the number of high-skilled U.S. immigrants grows rapidly in recent years. Figure 1.2 indicates that high-skilled immigrants as a percentage of the total U.S. population 25 years and over was more than the percentage of low-skilled immigrants after 2017. There is empirical evidence that high-skilled immigrants contribute to higher total factor productivity, greater innovation and more firm establishments.[3] Additionally, some empirical findings demonstrate that the impact of high-skilled immigrants on trade is more significant compared to those of low-skilled immigrants.[4] Thus, this paper focuses on studying high-skilled immigration due to its significance and growth in the United States.

First, this paper studies how international trade and high-skilled immigration interact with each other in a dynamic stochastic general equilibrium (DSGE) framework. International trade and labor migration are two important dimensions of globalization. Trade contributes to much of the development and prosperity, and immigration also helps boost economic

[1]In this study, I do not distinguish immigrants from foreign born population. The foreign born population includes naturalized U.S. citizens, lawful permanent residents (immigrants), temporary migrants (foreign students), humanitarian migrants (refugees and asylees), and unauthorized migrants.

[2]Please see Ottaviano et al. (2013), Mandelman and Zlate (2012), Ottaviano and Peri (2012), Peri and Sparber (2009), Peri (2012), Cortes (2008).

[3]Please see Kerr and Lincoln (2010), Hunt (2011), Gray et al. (2020) and Waugh (2017).

[4]Empirical estimations and results are presented in Appendix A.3.

growth. There exists a large number of empirical studies linking cross-country labor flows with international trade.[5] Do international trade and labor migration act as substitutes or complements? Some empirical results show that immigration has a positive effect on trade, while traditional trade theories including the Heckscher-Ohlin model or the specific factor model, derive that international trade and immigration act as substitutes.[6] Trade and immigration could act as complements if some assumptions of the Heckscher-Ohlin model are relaxed according to Markusen (1983) and Wong (1986). Nevertheless, the short run and long run linkages between trade and immigration cannot be distinguished with a static model or regression analysis. Meanwhile, the two margins of trade (intensive and extensive) could have different interactions with immigration. To the best of my knowledge, there is no existing dynamic framework in studying the interactions between two margins of trade and immigration. To examine their dynamic linkages, I quantitatively analyze how cross-country labor flows respond to the reduction in trade costs and whether firms change their export decisions or the intensive margin of exports following lower barriers to labor mobility.

Second, what are macroeconomic consequences of low migration barriers for economic activity in the labor-sending and labor-receiving economies? Countries can integrate into the world economy further through implementing trade liberalization and immigration-friendly policies. Many papers study the macroeconomic consequences of trade integration or protectionism such as Cacciatore (2014) and Barattieri et al. (2021), but the business cycle implications of immigration are less well understood. Mandelman and Zlate (2012) is an exceptional paper that examines the business cycle fluctuations of low-skilled labor migration and remittance flows. With a reduction in migration barriers, the increased cross-country labor flows create different economic impacts on the countries of origin and destination. Who is the winner and who is the loser? This paper focuses on the macroeconomic effects of high-skilled labor migration on each country in terms of changes in outputs, wages, skill premium, firm entrants and trade values, and it also documents the households welfare implications of cross-country labor flows.

[5] For instance, Gould (1994), Head and Ries (1998), Rauch and Trindade (2002), Bandyopadhyay et al. (2008) and Peri and Requena-Silvente (2010).

[6] Please see Mundell (1957), chapter 5 of Krugman et al. (2017).

Third, this paper highlights the roles of the extensive margins of production and trade in shaping immigration dynamics. In the recent trade studies, some features such as monopolistic competition, firm heterogeneity, endogenous firm entry and export participation hold a center stage. Empirical studies illustrate that exporters are larger, more productive, more skill-and capital-intensive, and are able to pay higher wages and create more jobs compared to non-exporters as discussed in Bernard et al. (2007).[7] Hence, it is important to feature firm heterogeneity as firms make an endogenous export decision and exporters have a productivity advantage. Meanwhile, the firm entry channel acts as an important endogenous propagation mechanism of macroeconomic shocks and enhances the trade-induced output co-movement.[8] Overall, previous literature has demonstrated that these mechanisms have successfully replicated both the key macro and micro features in the area of international trade. Motivated by previous research, this paper incorporates firm heterogeneity and endogenous firm entry to analyze the linkages between trade and labor migration.

In terms of immigration studies, the firm entry channel could provide new insights into economic outcomes from changes in immigration policies. The number of firms and high-skilled immigration are strongly and positively correlated as shown in Figure 1.3.[9] Some theoretical papers, such as Di Giovanni et al. (2015), Aubry et al. (2016) and Waugh (2017), point out that inflows of immigrants increase the domestic market size and range of varieties and induce more entrepreneurs, so labor-receiving countries gain from immigration due to greater product variety and more new firm entrants. Therefore, the consideration of firm entry and export decisions in response to changes in immigration policies is essential to investigate the macroeconomic effects of cross-country labor movement. Different from previous studies using a static framework, this paper emphasizes how the extensive margin

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[7] Bernard et al. (1995) also show that exporters have a productivity advantage and exhibit "better" performance characteristics than non-exporters. Bernard and Jensen (2004) highlight the significance of entry costs for U.S. plants and find that plant heterogeneity is important in the export decision.

[8] For instance, Bilbiie et al. (2012) argue that firm entry propagates productivity shocks. Liao and Santacreu (2015) prove that the extensive margin of production and trade can explain the trade-induced output co-movement empirically and theoretically. Other papers, including Ghironi and Melitz (2005), Alessandria and Choi (2007) and Jaef and Lopez (2014), also discuss the mechanism of firm entry.

[9] Olney (2013) points out that a 10 percent increase in the share of immigrants leads to a 2 percent increase in the number of firm establishments.

of production shapes immigration dynamics in a DSGE framework.

To address these questions of interest, I develop a two-country dynamic stochastic general equilibrium model featuring endogenous labor migration, heterogeneous firms and endogenous firm entry to study the interaction between high-skilled immigration and trade in intermediate goods, investigate the macroeconomic effects of low barriers to labor mobility on the labor-sending and labor-receiving countries and explore the roles of the extensive margins of production and trade in shaping immigration dynamics. The model of trade in this paper builds on Ghironi and Melitz (2005) and Liao and Santacreu (2015). In every period, firm entry and exit happens under the intermediate good sector. Firms producing intermediate goods are differentiated by their productivity, and they act under monopolistic competition and make an endogenous export decision. The intermediate good sector is skill intensive, which demands high-skilled natives and immigrants for production. I assume there is a one identification between a producer, a product and a firm in this paper as in Bilbiie et al. (2012). This assumption leads to the fact that firm entry and exit is equivalent to product creation and destruction. Following Mandelman and Zlate (2012), this paper features one direction labor migration across countries. I treat the home country as a developed country like the United States and the foreign country as a brunch of developing countries including China, India, Mexico and so on. The foreign high-skilled labor migrates to the home country subject to an emigration sunk cost. The incentive for labor movement depends on several key channels: the stock of home firms, aggregate productivity, export productivity cutoffs, trade costs and the high-skilled labor costs. This paper attempts to bridge an existing gap between international trade literature and immigration theory. Labor is immobile across countries in the heterogeneous-firm trade model, and the dynamic effects of immigration on trade flows, firm entry and trade in the existing immigration model are neglected.

The key model mechanisms and findings are shown as follows. First, trade and immigration potentially act as substitutes. An increase in bilateral trade following trade integration leads to a reduction in the wage difference between countries and a larger increase in foreign output compared to home output,[10] so foreign high-skilled workers have a lower incentive

[10]The labor sending country is less developed, and it is more integrated in trade. Ben-David (1996) and Waugh (2010) study the relationship between international trade and income convergence across countries,

to emigrate. In the other case, an increase in immigrants because of lower barriers to labor mobility induces more firm entry and raises high-skilled native wages in the labor-sending country in the long run.[11] Then, greater high-skilled labor costs reduce the export profitability, reflecting an increase in the export productivity cutoff and a decline in bilateral trade. On average, the negative impact of the export productivity cutoff dominates the positive effect of firm entry, so the number of exporters (the extensive margin of export) falls as well as the total export values.[12] Second, the extensive and intensive margins of trade have different interactions with cross-country labor migration. Inflows of new immigrants lead to a reduction in the extensive margin of export, but a greater number of exporters employ more high-skilled immigrants. In terms of imports, labor inflows in the home country create a promotion effect of the intensive margin of imports due to greater demand for foreign varieties, while there is an inverse effect on the extensive margin of imports. Third, changes in migration costs create distinct macroeconomic consequences for the labor-sending and labor-receiving countries and asymmetric welfare effects on high-skilled and low-skilled households. The model implies that labor outflows make the labor-sending country worse off to some extent: the output level is lower; the number of firms and exporters falls; high-skilled foreign workers lose welfare due to lower wages. However, immigration has inverse economic effects on the labor-receiving country in terms of changes in final output and firm entry. In addition, high-skilled natives receive welfare gains due to firm creation and higher wage levels in the long run. As a whole, cross-country labor flows have a larger impact on the business cycle implications of the labor-sending country compared to the labor-receiving country.

The model predictions also demonstrate that the firm entry channel plays an important role in propagating productivity, trade and migration shocks, which in line with the literature. When the firm entry channel is shut down, an existing home productivity shock has no effects on labor immigrant entry. Meanwhile, a shock on emigration sunk costs causes no

showing that trade liberalization plays an important role in the convergence process.

[11] This wage effect is consistent with the empirical findings in Ottaviano and Peri (2012) that immigration has a positive effect on native wages in the Unites States.

[12] Entry of new firms pushes the number of home exporters upward, but higher export productivity cutoff drops out relatively less productive home exporters.

deviations of aggregate variables from their steady-state values if the number of firms is constant. However, the impacts of macroeconomic shocks on immigration can be amplified under the specification that the export productivity cutoff is fixed. In addition, this paper reproduces one result that the presence of endogenous firm entry and export participation can help explain the trade-induced output co-movement.[13] On the contrary, cross-country labor migration weakens the business cycle synchronization because labor migration positively affects home output, but it has a negative correlation with foreign output. Another departure from the literature is that the extensive margin of production also provides new insights into immigration dynamics with the falling in migration costs: more firm establishments demand more immigrants; new inflows of immigrants induce firm entry, result in higher labor costs and reduce the export profitability in the labor-receiving country in the long run.

The rest of this paper is organized as the follows. Section 1.2 reviews some related literature. Section 1.3 lays out the model. Section 1.4 presents model calibration. Section 1.5 discusses the model results, including impulse responses, business cycle statistics, welfare implications of immigration and the output co-movement of two economies. Section 1.6 makes a conclusion.

1.2 Related Literature

This paper is related to four lines of research. The first line of research is about the trade and factor mobility. Mundell (1957) is the pioneer work to study the relationship of trade and factor mobility. According to the Heckscher-Ohlin-Vanek model of trade, factor mobility is motivated by the differences in factor prices. When returns to the factors of production become equalized, the incentives for migration reduce as trade increases (Mundell (1957)). Markusen (1983) and Wong (1986) show that factor movements and commodity trade could act as complements if some Hecksher-Ohlin assumptions are relaxed.[14] Additionally, Rauch

[13]The output co-movement puzzle in Kose and Yi (2001) refers that the standard international business cycles fails to match the fact that pairs of countries have more trade tend to have more correlated business cycles. Many recent trade studies attempt to solve this puzzle.

[14]Assumptions such as identity of production function, prefect competition or constant return to scale are relaxed in Markusen (1983). Wong (1986) develops necessary and sufficient conditions to see when substitution or complementarity will obtain.

(1991) reconciles the patterns of migration and trade within a Hecksher-Ohlin model and Iranzo and Peri (2009) propose a two-country, two-sector model with heterogeneous workers, technological differences, monopolistic competition and love of variety to explain the pattern of immigration and trade following trade integration and easy labor migration. This paper uses a dynamic framework rather than a static and comparative-static analysis in previous studies to analyze the interaction between trade and immigration and examine the business cycle implications of changes in trade and immigration costs in both countries

This paper is related to the literature that examines the roles of the extensive margins of production and exports in studying international macroeconomic dynamics. Ghironi and Melitz (2005) model trade with monopolistic competition, endogenous firm entry and exporting and heterogeneous firms, which indicates macroeconomic dynamics feed back into firm-level decisions and capture many features in international business cycles. Some papers based on this framework propose a specification of entry costs with endogenous labor supply (Jaef and Lopez (2014)), prove that the extensive margin of exports enhances output co-movement theoretically and empirically (Liao and Santacreu (2015)), and examine the role of the extensive margin on offshoring (Zlate (2016)). In contrast to these papers, my work focuses on firm entry and export decisions in response to changes in trade and immigration costs and the role of the extensive margin in shaping immigration dynamics.

This paper also adds to the literature on exploring macroeconomic consequences of immigration. Furlanetto and Ørjan Robstad (2019) use a empirical model (structural vector autoregression) to explore the macroeconomic effects of immigration on variables such as unemployment, public finances, house prices, credit, exchange rate and productivity in Norway, showing that there is a small positive effect on prices and public finance, but a negative effect on productivity. Weiske (2019) studies the impacts of U.S. immigration with a VAR analysis and concludes that the overall effect of immigration on U.S. business cycles is less important compared to technology shocks. Other recent contributions propose a DSGE model to analyze the business cycle implications of migration shocks (changes in immigration policies). For example, Mandelman and Zlate (2012) examine the macroeconomic dynamics of low-skilled labor migration in the United States and remittance flows from the United States to Mexico. Smith and Thoenissen (2019), Bandeira et al. (2018) and Lozej (2019) also develop a DSGE framework to investigate the macroeconomic effects of immigration in New Zealand, Greece and Ireland. My work is more related to Mandelman and Zlate (2012), but I focus on dynamic effects of high-skilled immigration on trade and firm entry.

Lastly, the paper is related to the existing literature on business cycle synchronization. Backus et al. (1992) start to study an international version of real business cycle model to examine the domestic and international co-movements. In Kose and Yi (2001), the standard international business cycles fails to match the fact that pairs of countries have more trade tend to have more correlated business cycles. This is known as the trade co-movement puzzle.[15] There exists many studies of business cycle co-movement with alternative mechanisms, such as product sharing, offshoring and the extensive margins of production and exports. For instance, Drozd et al. (2021) propose three natural candidate resolutions: financial market frictions, GHH preferences and a dynamic trade elasticity. Burstein et al. (2008), Arkolakis and Ramanarayanan (2009) and Johnson (2014) emphasize the roles of input trade and vertical linkages in synchronizing business cycle across countries with extending the IRBC model.[16] In terms of the extensive margin of production and trade mechanism, Liao and Santacreu (2015) show that trade more at the extensive margin have more correlated aggregate productivity growth and output growth empirically and theoretically; Zlate (2016) generates a positive output correlation with featuring the extensive margin of offshoring; Cacciatore (2014) finds that the joint presence of endogenous firm entry and labor market friction is able to explain the business cycle synchronization. My work contributes to this literature through re-examining the output correlation of two economies with incorporating the firm entry and labor mobility channels.

1.3 The Model

I build a two-country DSGE model to investigate the dynamic effects of trade and immigration. There are two types of representative households, supplying units of low-skilled and high-

[15] Kose and Yi (2006) double this puzzle and modify the model in Backus et al. (1994) to replicate empirical results of bilateral trade and output co-movement. However, model-implied correlation falls far short of the empirical findings.

[16] Di Giovanni and Levchenko (2010) provide empirical findings that vertical linkages account for 30 percent of the trade-induced business cycle correlation.

skilled labor and purchasing two types of financial assets, risk-free bonds and mutual funds of firms. The home country, as the labor receiving country, attracts high-skilled immigrants from the foreign country because of the wage differences between countries. A continuum of monopolistically competitive firms with heterogeneous labor productivity employs high-skilled natives and immigrants to produce intermediate goods.[17] Firm entry takes place every period under the intermediate good sector, and each intermediate good producers makes an endogenous export decision. They enter the export market only if it is profitable. Skilled-intensive good is a C.E.S. combination of domestic and imported inputs. Low-skilled labor is the production factor for unskilled goods. Perfectly competitive final good producers aggregate skill-intensive and unskilled goods to produce non-tradable final goods. Figure 1.4 displays the model overview.

1.3.1 Household's Problem

Home Households

The home economy consists of a continuum of two types of infinitely lived households, supplying units of high-skilled and low-skilled labor, with relative size γ and $1-\gamma$.

$$\max_{(c_{j,t},j_t,b_{j,t+1},\varphi_{j,t+1})} E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t}\{lnc_{j,\tau} - \frac{\chi_j}{1+\mu} j_{\tau}^{1+\mu}\}$$

where $\beta \in (0,1)$ is the subjective discount factor, $j \in (h,l)$ denotes the household type, χ_j is the weight on the disutility from labor, and $1/\mu \geq 0$ is the Frisch elasticity of labor supply. The household budget constraint is:

$$\begin{aligned} w_{j,t}j_t + (1+r_t)b_{j,t} + (1+r_t^*)Q_t b_{*j,t} + (\tilde{v}_t + \tilde{\pi}_t)N_{d,t}\varphi_{j,t} + T_{j,t} = \\ c_{j,t} + \tilde{v}_t(N_{d,t}+N_{e,t})\varphi_{j,t+1} + b_{j,t+1} + Q_t b_{*j,t+1} + \frac{\zeta}{2}(b_{j,t+1})^2 + \frac{\zeta}{2}Q_t(b_{*j,t+1})^2 \quad (1.1) \end{aligned}$$

In every period, the household earns wage incomes by supplying labor units elastically, and purchases the risk-free, country specific real bonds from the home and foreign countries,

[17]This model focuses on trade in intermediate goods as intermediate inputs account for about 60% of international trade. Moreover, previous studies prove that input trade generate more comovement in gross output than real value added (Johnson (2014)). I assume only firms who produce intermediate goods are able to employ high-skilled natives and immigrants for production, and endogenously choose to become an exporter.

$b_{j,t}$ and $b_{*j,t}$. Real return rates of home and foreign bonds are r_t and r_t^* respectively. I follow Turnovsky (1985) to assume quadratic costs of adjusting bond holdings, $\frac{\zeta}{2}(b_{j,t+1})^2$ and $\frac{\zeta}{2}Q_t(b^*_{j,t+1})^2$, which are rebated to the households as T.[18] The real exchange rate Q_t plays a role in converting the holding of foreign bonds into units of the home basket.[19] The household entering period t holds shares $\varphi_{j,t}$ in a mutual fund of $N_{d,t}$ firms whose average market value is $\tilde{v}_t$, and receives dividends equal to the total profits of firms $N_{d,t}\tilde{\pi}_t$. During period t, the household purchases shares $\varphi_{j,t+1}$ in a mutual fund of $N_{d,t}+N_{e,t}$ firms, although only $(1-\delta_e)$ of these firms enter market and pay dividends in $t+1$.

The aggregate levels of consumption, labor supply and bond holdings of each type of households are: $C_{h,t} = \gamma c_{h,t}, C_{l,t} = (1-\gamma)c_{l,t}; H_t = \gamma h_t, L_t = (1-\gamma)l_t; B_{h,t} = \gamma b_{h,t}, B_{*h,t} = \gamma b_{*h,t}, B_{l,t} = (1-\gamma)b_{l,t}, B_{*l,t} = (1-\gamma)b_{*l,t}$.

The first order conditions of labor supply for each type of household j:

$$\frac{w_{j,t}}{c_{j,t}} = \chi_j(j_t)^{\mu} \tag{1.2}$$

The Euler equation for home and foreign bonds are:

$$\begin{aligned} 1+\zeta b_{j,t+1} &= \beta(1+r_{t+1})E_t\left[\frac{c_{j,t}}{c_{j,t+1}}\right] \\ 1+\zeta b_{*j,t+1} &= \beta(1+r^*_{t+1})E_t\left[\frac{Q_{t+1}c_{j,t}}{Q_t c_{j,t+1}}\right] \end{aligned} \tag{1.3}$$

The Euler equation for share holdings for each type of household j:

$$\tilde{v}_t = \beta(1-\delta_e)E_t\left[\frac{c_{j,t}}{c_{j,t+1}}(\tilde{v}_{t+1}+\tilde{\pi}_{t+1})\right] \tag{1.4}$$

where δ_e is the exogenous exit shock for firms.

Foreign Households

The foreign economy also consists of a continuum of two types of infinitely lived households, supplying units of high-skilled and low-skilled labor indexed by $j_t^* \in (h_t^*, l_t^*)$, with relative

[18] The assumption of quadratic costs of adjusting bond holdings induces stationary and determinacy of the steady state.

[19] Q_t is the consumption-based real exchange rate (units of home consumption per unit of foreign consumption).

size $\gamma*$ and $1-\gamma*$. Following Mandelman and Zlate (2012), I model endogenous labor immigration. The high-skilled wage is higher in home, so high-skilled foreign labor has an incentive to migrate from foreign to home. The remaining foreign high-skilled in a household are $\xi_t^* = h_t^* - m_t$ as only some household members m_t choose to work abroad.[20] With an exogenous return shock with probability δ_m and the time-to-build assumption of m_t, the law of motion for the stock of high-skilled immigrant labor is $m_t = (1-\delta_m)(m_{t-1} + m_{e,t-1})$.

The foreign household maximizes lifetime utility by choosing how much to consume $c_{j,t}^*$, work j_t^*, invest in migration $m_{e,t}$, and invest in two type of financial assets $b_{*j,t+1}^*$ and $\varphi_{j,t+1}^*$.[21] The budget constraint of the foreign high-skilled household is

$$w_{h,t}^*(h_t^* - m_t) + w_{m,t}Q_t^{-1}m_t + (\tilde{v}_t^* + \tilde{\pi}_t^*)N_{d,t}^*\varphi_{h,t}^* + (1+r_t^*)b_{*h,t}^* + (1+r_t)Q_t^{-1}b_{h,t}^* + T_{h,t}^* =$$
$$c_{h,t}^* + f_{m,t}m_{e,t} + \tilde{v}_t^*(N_{d,t}^* + N_{e,t}^*)\varphi_{h,t+1}^* + Q_t^{-1}b_{h,t+1}^* + b_{*h,t+1}^* + \frac{\zeta}{2}(b_{*h,t+1}^*)^2 + \frac{\zeta}{2}Q_t^{-1}(b_{h,t+1}^*)^2 \tag{1.5}$$

where $w_{h,t}^*(h_t^* - m_t)$ is wage income earned by high-skilled non-emigrants in the foreign country, and $w_{m,t}Q_t^{-1}m_t$ is high-skilled emigrant wage income expressed in units of the foreign final good. A sunk emigration cost for high-skilled labor is defined as $f_{m,t}$ units of the foreign final good. Changes in immigration policies are reflected by shocks $\varepsilon_t^{f_m}$ to the level of the sunk emigration cost f_m, so that $f_{m,t} = \varepsilon_t^{f_m} f_m$.

The first order condition with respect to new high-skilled emigrants $m_{e,t}$:

$$f_{m,t} = \sum_{\tau=t+1}^{\infty} [\beta(1-\delta_m)]^{\tau-t} E_t \left[\frac{c_{h,t}^*}{c_{h,\tau}^*} d_{m,\tau} \right] \tag{1.6}$$

where $d_{m,t} = w_{m,t}Q_t^{-1} - w_{h,t}^*$ is defined as the wage difference between the immigrant wage in home and the high-skilled wage in foreign expressed in units of the foreign final good. The right hand side of Eq.(1.6) is the expected stream of future wage gains adjusted for the stochastic discount factor and the probability of return to the original country. In equilibrium, the sunk emigration cost equals the emigration benefit.

[20]Following Mandelman and Zlate (2012), I assume the demand for the foreign intermediate good is always positive, and foreign high-skilled labor is always required to produce foreign intermediate good ($\xi_t^* > 0$). The population is assumed to be unbounded.

[21]Emigrants and non-emigrants are treated as the same entities as the foreign household maximizes utility as a single agent.

Like in home, the aggregate levels of consumption, labor supply and bond holdings of each type of household can be expressed as: $C^*_{h,t} = \gamma^* c^*_{h,t}, C^*_{l,t} = (1-\gamma^*)c^*_{l,t}; H^*_t = \gamma^* h^*_t, L^*_t = (1-\gamma^*)l^*_t; B^*_{h,t} = \gamma^* b^*_{h,t}, B^*_{*h,t} = \gamma^* b^*_{*h,t}, B^*_{l,t} = (1-\gamma^*)b^*_{l,t}, B^*_{*l,t} = (1-\gamma^*)b^*_{*l,t}$.

1.3.2 Producer of Final Goods

The representative final good producer under perfect competition combines the sectoral basket of skill-intensive goods $Y_{s,t}$ and unskilled goods $Y_{u,t}$ to produce final goods Y_t.

$$Y_t = \left[(1-\alpha)^{\frac{1}{\rho}}(Y_{s,t})^{\frac{\rho-1}{\rho}} + \alpha^{\frac{1}{\rho}}(Y_{u,t})^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \tag{1.7}$$

where $\alpha \in (0,1]$ is the share of unskilled goods and $\rho > 1$ is the elasticity of substitution. Let P_t be the price of home final good, and let $P_{s,t}$ and $P_{u,t}$ denote the price of home skilled and unskilled goods respectively. The problem of the producer of final goods is given by:

$$\max_{Y_{s,t},Y_{u,t}} P_t Y_t - P_{s,t}Y_{s,t} - P_{u,t}Y_{u,t}$$

subject to the technology in Eq.(1.7). The solution to the profit maximization problem gives the following demand functions of skill-intensive good $Y_{s,t}$ and unskilled good $Y_{u,t}$, and the aggregate price function P_t.

$$Y_{s,t} = (1-\alpha)\left[\frac{P_{s,t}}{P_t}\right]^{-\rho} Y_t = (1-\alpha)\rho_{s,t}^{-\rho} Y_t \tag{1.8}$$

$$Y_{u,t} = \alpha\left[\frac{P_{u,t}}{P_t}\right]^{-\rho} Y_t = \alpha\rho_{u,t}^{-\rho} Y_t \tag{1.9}$$

$$P_t = \left[(1-\alpha)(P_{s,t})^{1-\rho} + \alpha(P_{u,t})^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{1.10}$$

where real prices of skill-intensive and unskilled goods relative to the aggregate price index in the home country are $\rho_{s,t} = \frac{P_{s,t}}{P_t}$ and $\rho_{u,t} = \frac{P_{u,t}}{P_t}$. The aggregate price index in the home country is a C.E.S. combination of price indexes of skill-intensive and unskilled goods.

1.3.3 Producer of Unskilled Goods

The unskilled good producer in the perfectly competitive market has the following production function:

$$Y_{u,t} = Z_t L_t \tag{1.11}$$

where Z_t is the aggregate productivity in the home country and L_t is the low-skilled labor employed by the representative firm. The problem of the producer of unskilled goods is given by:

$$\max_{L_t} \rho_{u,t} Y_{u,t} - w_{l,t} L_t$$

Thus, the relative price of unskilled goods is pinned down as:

$$\rho_{u,t} = w_{l,t}/Z_t \tag{1.12}$$

1.3.4 Producer of Skill-intensive Goods

In every period, there exists a set of domestically produced intermediate goods $\Omega_{d,t}$ and a set of imported varieties $\Omega^*_{x,t}$. The skill-intensive good in the home country aggregates domestic and imported inputs in Armington form:

$$Y_{s,t} = \left[\underbrace{\int_{z_{min}}^{z_x} y_{d,t}(z)^{\frac{\theta-1}{\theta}} dz}_{z \in \Omega_{d,t}} + \underbrace{\int_{z^*_x}^{\infty} y^*_{x,t}(z)^{\frac{\theta-1}{\theta}} dz}_{z \in \Omega^*_{x,t}} \right]^{\frac{\theta}{\theta-1}} \tag{1.13}$$

where $\theta > 1$ denotes the elasticity of substitution. The demand for the domestic variety z is denoted by $y_{d,t}(z)$, while imports of the home country are referred to as $y^*_{x,t}(z)$. An identical technology is assumed for the foreign country.

Let $P_{d,t}(z)$ and $P^*_{x,t}(z)$ denote the price of a domestic and a foreign variety z. The problem of the producer of skilled-intensive goods is given by:

$$\max_{y_{d,t}(z), y^*_{x,t}(z)} P_{s,t} Y_{s,t} - \int_{z \in \Omega_{d,t}} P_{d,t}(z) y_{d,t}(z) \mathrm{d}z - \int_{z \in \Omega^*_{x,t}} P^*_{x,t}(z) y^*_{x,t}(z) \mathrm{d}z$$

subject to the technology in Eq.(1.13). The solution to the profit maximization problem gives the following demand functions of domestic variety $y_{d,t}(z)$ and imported variety $y^*_{x,t}(z)$, and the price function of skill-intensive goods $P_{s,t}$.

$$\begin{aligned} y_{d,t}(z) &= \left[\frac{P_{d,t}(z)}{P_{s,t}}\right]^{-\theta} Y_{s,t} = (1-\alpha)\left[\frac{P_{d,t}(z)}{P_{s,t}}\right]^{-\theta}\left[\frac{P_{s,t}}{P_t}\right]^{-\rho} Y_t \\ &= (1-\alpha)\rho_{d,t}(z)^{-\theta}\rho_{s,t}^{\theta-\rho} Y_t \end{aligned} \tag{1.14}$$

$$\begin{aligned} y^*_{x,t}(z) &= \left[\frac{P^*_{x,t}(z)}{P_{s,t}}\right]^{-\theta} Y_{s,t} = (1-\alpha)\left[\frac{P^*_{x,t}(z)}{P_{s,t}}\right]^{-\theta}\left[\frac{P_{s,t}}{P_t}\right]^{-\rho} Y_t \\ &= (1-\alpha)\rho^*_{x,t}(z)^{-\theta}\rho_{s,t}^{\theta-\rho} Y_t \end{aligned} \tag{1.15}$$

$$P_{s,t} = \left[(P_{d,t})^{1-\theta} + (P^*_{x,t})^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{1.16}$$

where $P_{d,t} = \left[\int_{z_{min}}^{z_x} P_{d,t}(z)^{1-\theta}dz\right]^{1/(1-\theta)}$, $P^*_{x,t} = \left[\int_{z_x^*}^{\infty} P^*_{x,t}(z)^{1-\theta}dz\right]^{1/(1-\theta)}$. Real prices of domestic and imported varieties relative to the aggregate price index in the home country are $\frac{P_{d,t}(z)}{P_t} = \rho_{d,t}(z)$ and $\frac{P^*_{x,t}(z)}{P_t} = \rho^*_{x,t}(z)$.

1.3.5 Producers of Intermediate Goods

Under the intermediate good sector, a continuum of monopolistically competitive firms endogenously choose to enter the domestic and export markets.

Production and exporting decisions

Firms producing intermediate goods are differentiated by their productivity z, and the production function is defined as a nested C.E.S. combination of high-skilled natives $h_t(z)$ and immigrants $m_t(z)$.

$$\begin{aligned} y_{s,t}(z) &= Z_t z\left[\lambda m_t(z)^{(\sigma-1)/\sigma} + (1-\lambda)h_t(z)^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)} \\ &= y_{d,t}(z) + x_t\tau_t y_{x,t}(z) \end{aligned} \tag{1.17}$$

where $\sigma > 1$ captures the imperfect substitutability between skilled natives and immigrants.[22] λ is the weight of high-skilled immigrants, which reflects the importance of high-skilled immigrants for production of intermediate goods.

[22] Ottaviano and Peri (2012) estimate the elasticity of substitution between immigrant and native workers within the same education and experience group, and their preferred estimate is 20 with constraining the native–immigrant elasticity to be the same for all education groups.

Let $y_{x,t}(z)$ be the variety produced in the domestic market and sold abroad. The term $x(t)$ is an indicator function that captures the export status, being 1 when it exports and 0 otherwise. Exporting is costly and requires a payment of an iceberg cost $\tau_t > 1$ for each unit of intermediate goods sold abroad.

Given the production function, the optimal combination of high-skilled immigrants and natives is chosen by each firm to minimize the labor cost.

$$\min_{h_t(z),m_t(z)} w_{h,t}h_t(z) + w_{m,t}m_t(z)$$

subject to $y_{s,t}(z) = Z_t z \left[\lambda m_t(z)^{(\sigma-1)/\sigma} + (1-\lambda)h_t(z)^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)}$

The firm's relative demand for high-skilled immigrants and natives is

$$\frac{m_t(z)}{h_t(z)} = \left(\frac{\lambda}{1-\lambda}\right)^{\sigma} \left(\frac{w_{m,t}}{w_{h,t}}\right)^{-\sigma}$$

The demand for natives relative to immigrants is inversely related to the relative real wage with the elasticity substitution between high-skilled natives and immigrants σ. Thus, within-firm share of high-skilled immigrants and natives can be expressed as

$$\phi_{m,t} = \frac{\lambda^{\sigma} w_{m,t}^{-\sigma}}{\lambda^{\sigma} {w_{m,t}}^{-\sigma} + (1-\lambda)^{\sigma} {w_{h,t}}^{-\sigma}} \tag{1.18}$$

$$\phi_{h,t} = \frac{(1-\lambda)^{\sigma} w_{h,t}^{-\sigma}}{\lambda^{\sigma} {w_{m,t}}^{-\sigma} + (1-\lambda)^{\sigma} {w_{h,t}}^{-\sigma}} \tag{1.19}$$

Since λ does not vary with idiosyncratic productivity z, all firms under the intermediate good sector will employ the same share of high-skilled natives and immigrants. The optimal mix of high-skilled workers from home and foreign is denoted as Φ_t, which is a C.E.S. aggregate of the share of high-skilled natives and immigrants:

$$\Phi_t = \left[\lambda \phi_{m,t}^{(\sigma-1)/\sigma} + (1-\lambda)\phi_{h,t}^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)} \tag{1.20}$$

Let the firm's total high-skilled labor demand be $\xi_t(z)$. Given the within-firm share of high-skilled immigrants and natives, the employment amounts of high-skilled immigrants and natives are $\phi_{m,t}\xi_t(z)$ and $\phi_{h,t}\xi_t(z)$ respectively. Besides iceberg trade costs τ_t, exporting involves a per-period fixed cost $f_{x,t}$. To pay for it, every exporting firm needs to purchase a bundle of final goods. The profit maximization problem for a domestic producer to produce intermediate goods is expressed as

$$\max_{\xi_t(z),\rho_{d,t}(z),\rho_{x,t}(z)} \rho_{d,t}(z)y_{d,t}(z) + x_t Q_t \rho_{x,t}(z)y_{x,t}(z) \\ - (w_{h,t}\phi_{h,t} + w_{m,t}\phi_{m,t})\xi_t(z) - x_t f_{x,t}$$

subject to

$$y_{d,t}(z) + x_t\tau_t y_{x,t}(z) = Z_t z\Phi_t\xi_t(z)$$
$$y_{d,t}(z) = (1-\alpha)\rho_{d,t}(z)^{-\theta}\rho_{s,t}^{\theta-\rho}Y_t$$
$$y_{x,t}(z) = (1-\alpha^*)\rho_{x,t}(z)^{-\theta}{\rho_{s,t}^*}^{(\theta-\rho)}Y_t^*$$

Each firm under monopolistic competition chooses output prices and total high-skilled labor units to maximize period profits. Prices are expressed in units of the final good at destination, and export prices are assumed to be denominated in the currency of the export market. Hence, the nominal prices set by a domestic producer for its sales in the home country $\rho_{d,t}(z)$ and the foreign market $\rho_{x,t}(z)$ are derived as[23]

$$\rho_{d,t}(z) = \frac{P_{d,t}(z)}{P_t} = \frac{\theta}{\theta-1}mc_t(z) \tag{1.21}$$

$$\rho_{x,t}(z) = \frac{P_{x,t}(z)}{P_t^*} = Q_t^{-1}\frac{\theta}{\theta-1}\tau_t mc_t(z) = Q_t^{-1}\tau_t\rho_{d,t}(z) \tag{1.22}$$

Let $mc_t(z)$ denotes the marginal cost of intermediate good production, equal to $\frac{w_{h,t}\phi_{h,t}+w_{m,t}\phi_{m,t}}{zZ_t\Phi_t}$. Period profits from domestic sales $\pi_{d,t}$ and from foreign sales $\pi_{x,t}$ are expressed as

$$\pi_{d,t}(z) = \frac{1-\alpha}{\theta}[\rho_{d,t}(z)]^{(1-\theta)}\rho_{s,t}^{(\theta-\rho)}Y_t \tag{1.23}$$

$$\pi_{x,t}(z) = \frac{(1-\alpha^*)Q_t}{\theta}[\rho_{x,t}(z)]^{(1-\theta)}{\rho_{s,t}^*}^{(\theta-\rho)}Y_t^* - f_{x,t} \tag{1.24}$$

Demand for high-skilled labor units is

$$\xi_t(z) = \frac{(1-\alpha)(\rho_{d,t})^{-\theta}(\rho_{s,t})^{\theta-\rho}Y_t}{z_{d,t}\Phi_t Z_t} + \frac{(1-\alpha^*)\tau_t(\rho_{x,t})^{-\theta}(\rho_{s,t}^*)^{\theta-\rho}Y_t^*}{z_{x,t}\Phi_t Z_t} \tag{1.25}$$

[23]With the law of one price, $\rho_{x,t}(z) = \tau_t e_t \rho_{d,t}(z)$, where e_t is the nominal exchange rate (units of home currency per unit of foreign). The real exchange rate is defined as $Q_t \equiv e_t P_t^*/P_t$. For foreign firms, $\rho_{x,t}^*(z) = Q_t\tau_t^*\rho_{d,t}^*(z)$

A exporter faces a per-period fixed export cost $f_{x,t}$ units of the final good, so it chooses to export if and only if there is a positive profit. Hence, the export productivity cutoff is $z_{X,t} = inf\{z : \pi_{x,t} > 0\}$. A firm with an idiosyncratic productivity ($z < z_{x,t}$) produces intermediate goods sold in the domestic market only. There always exits a subset of firms that decide not to export, which endogenously determines a non-traded sector of intermediate goods. Meanwhile, the number of exporters differs across countries and changes over time in response to aggregate productivity, migration or trade shocks.

Firm Entry and Exit

There is a mass of $N_{d,t}$ domestic firms under the intermediate good sector in the home country. Following the mechanism in Ghironi and Melitz (2005), firm entry takes place in every period. After paying sunk entry costs of $f_{e,t}$ in units of the final good, each firm is randomly assigned an idiosyncratic productivity z from a common distribution $G(z)$ with the support interval $[z_{min}, \infty)$. There are $N_{e,t}$ new entrants in every period t, and new firms start production at $t+1$. All firms are subject to an exogenous "death" shock, which occurs with probability δ_e. Thus, the law of motion for the total number of firms in each sector is $N_{d,t+1} = (1 - \delta_e)(N_{d,t} + N_{e,t})$.[24] The expected post-entry value of new firms $\tilde{v}_t$ depends on the expected stream of future profits, the stochastic discount factor and the exogenous probability of exit every period, which is expressed as

$$\tilde{v}_t = E_t \left[\sum_{\tau=t+1}^{\infty} (\beta(1-\delta_e))^{\tau-t} \left(\frac{c_{j,t}}{c_{j,\tau}} \right) \tilde{\pi}_\tau \right] \tag{1.26}$$

In equilibrium, firm entry occurs until the expected value of the average firm equals to the sunk entry costs ($\tilde{v}_t = f_{e,t}$).

Average Productivity, Prices and Profits

Every period, there are $N_{d,t}$ firms with average productivity $\tilde{z}_{d,t}$ in the home market. There are also $N_{x,t}$ firms above the productivity cutoff $z > z_{x,t}$ that choose to export. As in

[24] As discussed in Ghironi and Melitz (2005), $N_{d,t}$ is a state variable with sunk costs and time-to-build assumption, and it acts like a capital stock. $N_{e,t}$ represents the investment of home consumers.

Ghironi and Melitz (2005), the firm-specific labor productivity draws z that are Pareto-distributed with C.D.F $G(z) = 1 - (z_{min}/z)^{\kappa}$ and P.D.F. $g(z) = \kappa z_{min}^{\kappa}/z^{\kappa+1}$, so the two average productivity levels are

$$\tilde{z}_{d,t} = \left(\int_{z_{min}}^{\infty} z^{\theta-1} dG(z) \right)^{\frac{1}{\theta-1}} = \nu z_{min}$$
$$\tilde{z}_{x,t} = \frac{1}{1-G(z_{x,t})} \left(\int_{z_{x,t}}^{\infty} z^{\theta-1} dG(z) \right)^{\frac{1}{\theta-1}} = \nu z_{x,t}$$

where parameters $\nu \equiv \left(\frac{\kappa}{\kappa-(\theta-1)} \right)^{1/(\theta-1)}$ and $\kappa > \theta - 1$.

According to Eq.(1.10), the aggregate price index of final goods can be expressed as $1 = (1-\alpha)(\rho_{s,t})^{1-\rho} + \alpha(\rho_{u,t})^{1-\rho}$. Using the aggregation properties of the model, the price indexes can be written as the product of average prices and product variety: $P_{s,t} = N_{s,t}^{\frac{1}{1-\theta}} \tilde{P}_{s,t}$, $P_{d,t} = N_{d,t}^{\frac{1}{1-\theta}} \tilde{P}_{d,t}$ and $P_{x,t} = N_{x,t}^{\frac{1}{1-\theta}} \tilde{P}_{x,t}$, where $N_{s,t} \equiv N_{d,t} + N_{x,t}$. The relative price level of skill-intensive goods (Eq.(1.16)) can be expressed as $(P_{s,t})^{1-\theta} = N_{d,t}(\tilde{P}_{d,t})^{1-\theta} + N_{x,t}^{*}(\tilde{P}_{x,t}^{*})^{1-\theta}$. This is equivalent to $(\rho_{s,t})^{1-\theta} = N_{d,t}(\tilde{\rho}_{d,t})^{1-\theta} + N_{x,t}^{*}(\tilde{\rho}_{x,t}^{*})^{1-\theta}$.[25]

The average total profits of firms producing intermediate inputs in the home country can be decomposed into two parts, the average total domestic profits and the average total exporting profits, equal to $N_{d,t}\tilde{\pi}_t = N_{d,t}\tilde{\pi}_{d,t} + N_{x,t}\tilde{\pi}_{x,t}$.[26] Since the firm's idiosyncratic productivity is distributed according to $G(z)$ and $z_{x,t}$ denotes as the export productivity cutoff, the mass of exporting firms is $N_{x,t} = [1 - G(z_{x,t})]N_{d,t}$. Therefore, the share of exporting firms can be derived as $\frac{N_{x,t}}{N_{d,t}} = \left(\frac{z_{min}}{z_{x,t}} \right)^{\kappa}$.

Foreign Firms

Similarly, a foreign producer with an idiosyncratic productivity z produces intermediate goods under monopolistic competition according to the following production function.

$$y_{s,t}^{*}(z) = Z_t^{*} z \xi_t^{*}(z) = y_{d,t}^{*}(z) + x_t^{*} \tau_t^{*} y_{x,t}^{*}(z)$$

[25] The average real price of home firms in the domestic market is $\tilde{\rho}_{d,t} = \rho_{d,t}(\tilde{z}_{d,t})$ while the average real price of home exporters in the export market is $\tilde{\rho}_{x,t} = \rho_{x,t}(\tilde{z}_{x,t})$.

[26] The average domestic profit and the average exporting profit can be respectively written as $\tilde{\pi}_{d,t} = \pi_{d,t}(\tilde{z}_{d,t})$ and $\tilde{\pi}_{x,t} = \pi_{x,t}(\tilde{z}_{x,t})$.

where $\xi_t^*(z)$ denotes as labor demand for high-skilled non-emigrants in the foreign country.

The profit maximization problem pins down the relative prices and labor demand for high-skilled non-emigrants:

$$\rho_{d,t}^*(z) = \frac{P_{d,t}^*(z)}{P_t^*} = \frac{\theta}{\theta - 1} mc_t^*(z)$$

$$\rho_{x,t}^*(z) = \frac{P_{x,t}^*(z)}{P_t} = \frac{\theta}{\theta - 1} \tau_t^* Q_t mc_t^*(z)$$

$$\xi_t^*(z) = \frac{(1-\alpha^*)(\rho_{d,t}^*)^{-\theta}(\rho_{s,t}^*)^{\theta-\rho} Y_t^*}{z_{d,t}^* Z_t^*} + \frac{(1-\alpha)\tau_t^*(\rho_{x,t}^*)^{-\theta}(\rho_{s,t})^{\theta-\rho} Y_t}{z_{x,t}^* Z_t^*}$$

where $mc_t^*(z) = \frac{w_{h,t}^*}{z Z_t^*}$. Period profits for products sold in the foreign market $\tilde{\pi}_{d,t}^*$ and exported to the home country $\tilde{\pi}_{x,t}^*$ are

$$\tilde{\pi}_{d,t}^* = \frac{1-\alpha^*}{\theta}(\tilde{\rho}_d^*)^{1-\theta}(\rho_{s,t}^*)^{\theta-\rho} Y_t^*$$

$$\tilde{\pi}_{x,t}^* = \frac{1-\alpha}{\theta}(\tilde{\rho}_x^*)^{1-\theta}(\rho_{s,t})^{\theta-\rho} Y_t Q_t^{-1} - f_{x,t}^*$$

1.3.6 Equilibrium

The resource constraint in the home country takes into account not only the consumption of natives, but also the consumption of immigrants. The home final good also can be used for investments in firm entry and export participation. In equilibrium, the final good clearing condition in home is

$$Y_t = C_{h,t} + C_{l,t} + C_{m,t} + N_{e,t} f_{e,t} + N_{x,t} f_{x,t} \tag{1.27}$$

The foreign final good can be consumed by the non-emigrant foreign labor and invested in firm entry, export participation and emigration. Therefore, the foreign resource constraint is

$$Y_t^* = C_{h,t}^* + C_{l,t}^* - Q_t^{-1} C_{m,t} + N_{e,t}^* f_{e,t}^* + N_{x,t}^* f_{x,t}^* + f_{m,t} M_{e,t} \tag{1.28}$$

The real wage rates adjust so that supply equals demand in both high-skilled and low-skilled labor markets. The home high-skilled labor market clearing condition is

$$\begin{aligned}\Xi_t =&\gamma h_t + \gamma^* m_t \\ =&\frac{(1-\alpha)(\tilde{\rho}_{d,t})^{-\theta}(\rho_{s,t})^{\theta-\rho}Y_t N_{d,t}}{\tilde{z}_{d,t}\Phi_t Z_t} + \frac{(1-\alpha^*)\tau(\tilde{\rho}_{x,t})^{-\theta}(\rho^*_{s,t})^{\theta-\rho}Y^*_t N_{x,t}}{\tilde{z}_{x,t}\Phi_t Z_t}\end{aligned} \tag{1.29}$$

The aggregate levels of high-skilled natives and immigrants can be expressed as: $H_t = \gamma h_t = \phi_{h,t}\Xi_t$ and $M_t = \gamma^* m_t = \phi_{m,t}\Xi_t$ respectively. Similar to home, the foreign high-skilled labor market clearing condition is given as

$$\begin{aligned}\Xi^*_t =& \gamma^*(h^*_t - m_t) \\ =&\frac{(1-\alpha^*)(\tilde{\rho}^*_{d,t})^{-\theta}(\rho^*_{s,t})^{\theta-\rho}Y^*_t N^*_{d,t}}{\tilde{z}^*_{d,t}Z^*_t} + \frac{(1-\alpha)\tau^*(\tilde{\rho}^*_{x,t})^{-\theta}(\rho_{s,t})^{\theta-\rho}Y_t N^*_{x,t}}{\tilde{z}^*_{x,t}Z^*_t}\end{aligned} \tag{1.30}$$

Low-skilled labor market clearing conditions in home and foreign are: $L_t = (1-\gamma)l_t = \alpha\rho_{u,t}^{-\rho}Y_t/Z_t$ and $L^*_t = (1-\gamma^*)l^*_t = \alpha{\rho^*_{u,t}}^{-\rho}Y^*_t/Z^*_t$ respectively.

Bonds are in zero net supply, which implies the bond market clearing conditions $B_{h,t} + B_{l,t} + B^*_{h,t} + B^*_{l,t} = B_t + B^*_t = 0$ and $B^*_{*h,t} + B^*_{*l,t} + B_{*h,t} + B_{*l,t} = B^*_{*t} + B_{*t} = 0$. Finally, the balance of international payments indicates that the trade balance and income from bond investments (the current account) equal to the changes in bond holdings:

$$TB_t + r^b_t B_t + r^{b^*}_t Q_t B_{*,t} = (B_{t+1} - B_t) + Q_t(B_{*,t+1} - B_{*,t}) \tag{1.31}$$

where $TB_t \equiv N_{x,t}(1-\alpha^*)(\tilde{\rho}_x)^{1-\theta}(\rho^*_{s,t})^{\theta-\rho}Y^*_t Q_t - N^*_{x,t}(1-\alpha)(\tilde{\rho}^*_x)^{1-\theta}(\rho_{s,t})^{\theta-\rho}Y_t$ is the trade balance.

In this framework, aggregate output in home and foreign are: $GDP_t = Y_t + TB_t$ and $GDP^*_t = Y^*_t + TB^*_t$ respectively. Table 1.1 summaries the key equilibrium conditions of the model.

1.3.7 Analytical Solution and Intuition

Combining the high-skilled labor market clearing condition, zero-cutoff profit condition, the share of exporters and the expression for average prices, demand for high-skilled immigrants can be derived as

$$\begin{aligned} M_t =&\phi_{m,t}\left(\frac{(1-\alpha)(\tilde{\rho}_{d,t})^{-\theta}(\rho_{s,t})^{\theta-\rho}Y_t N_{d,t}}{Z_t\tilde{z}_{d,t}\Phi_t}+\frac{(1-\alpha^*)\tau_t(\tilde{\rho}_{xt})^{-\theta}(\rho^*_{st})^{\theta-\rho}Y^*_t N_{x,t}}{Z_t\tilde{z}_{x,t}\Phi_t}\right) \\ =&\phi_{m,t}B_t N_{d,t}\left(\Psi_t A_t\left(\frac{Z_t}{Z^*_t\tilde{z}^*_{x,t}}\right)^{\theta-1}+\left(\frac{1}{\tilde{z}_{x,t}}\right)^{\kappa}\right) \end{aligned} \tag{1.32}$$

where $\nu \equiv \left(\frac{\kappa}{\kappa-(\theta-1)}\right)^{1/(\theta-1)}$, $A_t \equiv \left(\frac{w^*_{h,t}\Phi_t}{\phi_{h,t}w_{h,t}+\phi_{m,t}w_{m,t}}\right)^{\theta-1}$, $\Psi_t \equiv ((\nu)^{\theta-1-\kappa}Q_t)\frac{f^*_{x,t}\tau_t^{\theta-1}}{f_{x,t}}$ and $B_t \equiv \frac{(\theta-1)\nu^{\theta-1+\kappa}}{\phi_{h,t}w_{h,t}+\phi_{m,t}w_{m,t}}$.

The aggregate productivity Z_t and Z^*_t, and the trade policy variables $f_{x,t}, f^*_{x,t}, \tau_t, \tau^*_t$ are exogenous variables. Eq.(1.32) implies that the stock of immigrants is determined by aggregate productivity, average export productivity cutoffs, trade costs, wages and the share of immigrants. Log-linearization is a way to interpret important channels for changes in immigrant stock. Using sans-serif fronts to denote percentages deviations from this steady state, log-linearizing (1.32) derives

$$\begin{aligned} \mathsf{M_t} =& \underbrace{\phi_{\mathsf{m,t}}}_{\text{Immigrant share}} + \underbrace{\mathsf{N_{d,t}}}_{\text{The stock of home firms}} + \underbrace{\frac{(\theta-1)C}{D}(\mathsf{Z_t}-\mathsf{Z^*_t})}_{\text{Difference of aggregate productivity}} \\ &- \underbrace{\left(\frac{(\theta-1)C\tilde{\mathsf{z}}^*_{\mathsf{x,t}}}{D}+\frac{\kappa\tilde{\mathsf{z}}^{-\kappa}_{\mathsf{x,t}}}{D}\right)}_{\text{Average export productivity cutoffs}} + \underbrace{\frac{C(\mathsf{Q_t}+\mathsf{f^*_{x,t}}-\mathsf{f_{x,t}}+(\theta-1)\tau_\mathsf{t})}{D}}_{\text{Trade costs}} \\ &- \underbrace{\left(\frac{(\theta-1)C+D}{D}\right)\Lambda_\mathsf{t}+\frac{(\theta-1)C(\mathsf{w^*_{h,t}}+\Phi_\mathsf{t})}{D}}_{\text{High-skilled labor costs in home and foreign}} \end{aligned} \tag{1.33}$$

where $C \equiv \Psi A\left(\frac{Z}{Z^*\tilde{z}^*_x}\right)^{\theta-1}$ and $D \equiv \left(\Psi A\left(\frac{Z}{Z^*\tilde{z}^*_x}\right)^{\theta-1}+\left(\frac{1}{\tilde{z}_x}\right)^{\kappa}\right)$. Let $\Lambda_t \equiv \phi_{h,t}w_{h,t}+\phi_{m,t}w_{m,t}$ as the weighted average high-skilled labor wages in home. I drop time subscripts to denote a variable's level in steady state.[27]

Eq.(1.33) highlights several channels for changes in the stock of immigrants as follows. 1) The employment share of immigrants determined by high-skilled wage levels of natives and immigrants directly affects $\mathsf{M_t}$. 2) A greater number of home firms leads to higher labor

[27] Please see Appendix A.2 for more details about the model steady state.

demand and increases the immigrant stock. 3) An increase in home aggregate productivity makes the home market more attractive compare to the foreign market, inducing more home firm entrants and new inflows of immigrants. 4) Higher export productivity cutoffs reduce the number of exporters as the export profitability declines. This reduces high-skilled labor demand for exporting production; thus, there is a negative impact on immigrant stock. 5) Immigrant stock is decreasing in exporting costs $f_{x,t}$, but increasing in iceberg trade costs τ_t. For instance, an increase in bilateral trade due to lower trade costs reduces the number of immigrants in the home country, which pin downs that bilateral trade is substitutes for cross-country labor flows. However, a reduction in fixed exporting costs creates more exporters, increasing the labor demand for immigrant in the home country.[28] 6) Changes in high-skilled labor costs also affect the incentives for immigration. It is intuitive that firms demand more labor and increase production if labor costs is relatively lower.

1.4 Calibration

The model is calibrated to the home (U.S. as a labor receiving country) and foreign economy (a bunch of main labor sending countries) during the period 2004-2018. High-skilled U.S. immigrants mainly come from several developing countries, including Mexico, China, India, Philippines and Vietnam. Moreover, some of them are also U.S. major trading partners.[29] Thus, I construct an aggregate of these five countries as a foreign economy. Periods are interpreted as years. Parameter values shown in Table 1.2 are chosen from the literature and to match features of macroeconomic data of these two economies.

The discount factor is set to 0.96, corresponding to an annual real interest rate of 4% as in the literature. Following Ghironi and Melitz (2005), I set the elasticity of substitution across varieties for the intermediate good sector θ equal to 3.8, the Pareto distribution parameter κ equal to 3.4 and the probability of firm exit the market δ_e equal to 0.025. z_{min} is normalized to 1. The quadratic adjustment cost parameter for bond holdings is $\zeta = 0.0025$. The elasticity of substitution across skill-intensive and unskilled goods is equal to 0.5, consistent

[28] On the other hand, an increase in inflows of new immigrants does not necessarily boost the extensive margin of exports in the home country.

[29] See Appendix A.1 for more stylized facts.

with the estimates in Mendoza (1991). To match the annual separation rate of foreign workers, the probability of immigrants back to original countries δ_m is chosen to 0.1. The sunk emigration cost f_m is 2.25, targeting the high-skilled immigrants as a percentage of the U.S. population (25 years and over) at 7.5% on average. The share of unskilled goods in home is calibrated by measuring the skill intensity of all private industries in the U.S., reflecting $\alpha = 0.79$. For the foreign economy, the average share of unskilled goods α^* is 0.85.[30]

Some recent papers have estimated the native-immigrant elasticity of substitution.[31] I choose the elasticity of substitution between high-skilled natives and immigrants σ to 20 following Ottaviano and Peri (2012). Based on the statistics from Kerr et al. (2015), the employment of high-skilled immigrants λ is set to 0.185 regardless of firm's productivity level. According to the post-secondary data from the World Bank, the percentages of high-skilled workers in home γ and foreign γ^* are 46% and 16% respectively.[32] The elasticity of labor supply is $1/\mu = 1$ as in Farhat (2009). The weight on disutility is set as $\chi_h = 0.42$ for high-skilled labor and $\chi_l = 0.50$ for low-skilled labor so that the U.S. skill premium of 1.81 is targeted. Similarly, I set $\chi_h^* = 0.45$ and $\chi_l^* = 0.55$ to obtain the average foreign skill premium equal to 2.43 in steady state.[33]

The iceberg trade costs τ is calibrated so that the total trade over GDP is equal to 28% in steady state, implying $\tau = 1.3$. The fixed costs of exporting in two economies (f_x and f_x^*) are set to 0.04 and 0.025 to match the export and import shares of GDP in U.S. as 12% and 16% respectively. As in Zlate (2016), the sunk entry cost in the less developed economy

[30]Following Bustos (2011b), I calculate the skill intensity (the ratio of non-production to production workers to obtain the shares of unskilled and skill-intensive goods. Data is collected from U.S. Bureau of Labor Statistics and World Development Indicators, the World Bank.

[31]See Docquier and Rapoport (2004), Card (2009), Raphael and Smolensky (2009).

[32]Skill levels are defined according to the educational attainment. Workers over 25 years old are denoted as high-skilled labor if they earn a college degree or higher, and they are low-skilled labor otherwise. γ^* is the average high-skilled labor size of the main labor-sending countries.

[33]The skill premium is defined as the ratio of the average wage of skilled workers to unskilled workers. The skill premium of US is calculated with data (2004-2018) of earnings by educational attainment from U.S. Bureau of Labor Statistics. The skill premium of Mexico is calculated with OECD data. The skill premium of China is ratio of average earning of skilled industries to unskilled industries. Data sources are from National Bureau of Statistics of China. Data of other countries' skill premium is from Cruz et al. (2018).

is set to be larger so the sunk entry costs in home and foreign are $f_e = 1$ and $f_e^* = 4$.

1.5 Results

The section introduces alternative models, presents the impulse responses of key variables, compare the model with data, and discusses welfare implications of immigration and trade-induced output comovment under different scenarios.

1.5.1 Alternative Models

This section introduces three counterfactual scenarios in order to emphasize the roles of immigration and the extensive margin of production and exports (firm entry and cutoffs for exporting) in explaining business cycle dynamics.

Cross-country Labor Immobility

In this case without labor migration from foreign to home, there are only two types of labor supply in the home country, low-skilled and high-skilled labor. Labor is immobile across countries, so home firms under the intermediate good sector employ only high-skilled natives for production. To model labor immobility, two variables, the stock of immigrants and the number of immigrant entry, are eliminated.

Fixed Export Productivity Cutoff

Following Jaef and Lopez (2014), the fixed exporting cost can be defined as

$$f_{x,t} = f_x + \eta_x[exp(z_{x,t} - \bar{z}_x) - 1]$$

It is convex in the deviation of the cutoff from its steady-state value $\bar{z}_x$. η_x is equal to 0 in the baseline model, so the fixed exporting cost is constant along the cycle. The extensive margin of exports is shut down with a large η_x (i.e., $\eta_x = 10,000$), and the export productivity cutoff is fixed.

Fixed Entry

The baseline model features a fixed number of producers within each period and a fully flexible number of firms in the long run. To model a constant number of firms in every period, the firm entry costs is defined using the following expression:

$$f_{e,t} = f_e + \eta_e[exp(N_{e,t} - \bar{N_e}) - 1]$$

Similarly, the sunk entry cost is convex in the deviation of firm entry from its steady-state value $\bar{N_e}$. The number of new firms is fixed by setting parameter η_e large enough as η_e governs the volatility of firm entry directly. To entirely shunt down the extensive margins, both firm entry and the cutoff for exporting are held fixed.

1.5.2 Impulse Responses

This section analyzes the impulse responses of model variables to temporary shocks of aggregate productivity, iceberg trade costs and sunk emigration costs, and compares the effects on the macroeconomy between the baseline model and three alternative models.[34]

Positive Aggregate Productivity Shock in Home

In the baseline mode (blue lines in Figure 1.5), a temporary 1% increase in aggregate productivity in home encourages more firm entry N_e since the home country becomes more attractive, which leads to a boost in the stock of firms N_d and higher labor demand for high-skilled workers. This illustrates that there is a gradual increase in the stock of high-skilled immigration M. Entry of new firms also pushes the number of home exporters N_x upward, but the intensive margin of exports in home (export values per firm) drops below its steady state slightly since the increase in regular export values is not enough to offset the growth in the extensive margin of exports N_x. The overall labor costs for production in home go up in response to an increase in home aggregate productivity. Hence, the export profitability of home firms falls due to the relative higher labor costs of home exporters, reflecting an increase in the productivity cutoff for home exporters z_x but a decrease in

[34] The impulse responses of another scenario, fixed extensive margins, displays in Appendix A.1.

those of foreign exporters z_x^*. Although higher z_x drops out relatively less productive home exporters, the net result is that N_x deviates positively from its steady state since the firm entry effect generating a greater number of home firms N_d dominates the opposite effect of z_x. Due to the demand-supply spillover effect, foreign output and the number of foreign firm entrants and exporters increase as well but at smaller levels. Additionally, a positive home aggregate productivity shock also creates a higher skill premium in both countries as high-skilled workers are more affected by a productivity shock compared to low skilled workers.

The alternative model in which firm entry is fixed (red lines in Figure 1.5) illustrates that no firm entrants occur in the home and foreign countries when there is a positive aggregate productivity shock. A temporary 1% increase in home aggregate productivity generates smaller steady-state deviations in output, the number of exporters and export values per firm in the case without the firm entry channel. Moreover, home high-skilled labor costs are relatively lower, leading to a decline in home export productivity cutoff. Home skill premium has no deviations from its steady state, but there is still an increase in foreign skill premium. This results from the fact that the increased demand for foreign varieties in the home market leads to excess demand for foreign high-skilled labors. In terms of immigration dynamics, the stock of immigrants and the number of immigrant entry have no deviations from their steady state values with a constant number of home firms. The comparison between the baseline model and the counterfactual case with shutting down the extensive margin of production indicates that firm entry acts as an important endogenous propagation mechanism of a productivity shock as discussed in the literature, such as Bilbiie et al. (2012). This also displays how firm entry shapes immigration dynamics.

In the other case with fixed exporting cutoffs (red lines in Figure 1.6), z_x and z_x^* stay constant. New firm entrants in home with an idiosyncratic productivity above the current fixed cutoff enter the export market and the number of home exporters increases gradually, mirroring the build-up in the stock of home firms. As there are no changes in export productivity cutoffs, the dynamic effects on N_x and N_x^* only come from the firm entry channel. Compared to the benchmark model, changes in the number of home exporters is larger while there is a smaller adjustment in the number of foreign exporters in the years after the shock. Moreover, this gradual increase in the number of home exporters results in a larger amount of immigrants and a greater reduction in the intensive margin of exports in home over time. In the foreign country, the increase in foreign output is smaller with fixed export productivity cutoffs, which is consistent to the other findings that there exists less foreign firm entrants and exporters, but a larger amount of high-skilled labor outflows from foreign.

Immigration has little impact on business cycles of the home country as impulse responses to a productivity shock in the alternative model in which labor is immobile across countries (red lines in Figure 1.7) and the baseline model are very similar. This model implication is in line with the empirical results in Weiske (2019).[35] Although the dynamic effects of immigration on most aggregate variables are not obvious, changes in the extensive and intensive margins of exports are relative smaller with labor immobility across countries. In fact, the foreign country is better off without labor emigration in terms of foreign outputs and firm entrants. When the emigration channel is shut down, the foreign country is able to maintain a larger market size and foreign high-skilled workers are able to benefit from higher wage and consumption levels. Therefore, foreign high-skilled non-emigrants lose welfare with labor outflows to the home country. However, labor migration has an inverse effect on foreign low skilled workers.[36] The labor movement reduces the skill premium in the foreign country. Overall, the model predicts that cross-country labor flows have greater macroeconomic consequences in the labor-sending country compared to the labor-receiving country.

Negative Shock to Sunk Emigration Costs

As discussed in section 1.3.1, changes in immigration policies in home are reflected by shocks to sunk emigration costs (migration shocks). Figure 1.8 displays the impulse responses to a transitory 1% decline in sunk emigration costs. Although the percentage deviations of

[35]Weiske's paper implements a VAR analysis of the macroeconomic effects of U.S. immigration and concludes that immigration has been of little importance for U.S. business cycles.

[36]Remittance, which is not discussed in this paper, could be an important mechanism to study welfare gain or lose of labor immigration.

aggregate variables from their steady states are slight, the directions and adjustments of macroeconomic dynamics still can be observed. A lower migration barrier across countries boosts the stock of immigrants in home gradually. Inflows of immigrants results in a negative influence on firm entrants initially, but the deviations of N_e from its steady state becomes positive after several years of the sunk emigration cost shock, mirroring the range of varieties available as intermediate inputs increases in the long run. The home market size becomes larger, and home output goes up. Inversely, labor emigration creates a negative impact on foreign output, firm entrants and the number of exporters. There is also a welfare loss of foreign high-skilled workers following labor outflows.

Since the model features a small but significant degree of imperfect substitutability between high-skilled natives and immigrants, immigrants already in the home country suffer much larger wage loses than the high-skilled natives when there are more new immigrants. The deviation of immigrant wages is below its steady state, but the high-skilled wage in home increases above its steady state after several years of the shock. This finding is in line with the empirical study in Ottaviano and Peri (2012), which shows that there is a small positive effect of U.S. immigration on native wages but a substantial negative effect on wages of previous immigrants in the long term. Inflows of new immigrants induce more firm entrants in home over time, which leads to more demand for high-skilled workers. Eventually, there is a positive impact of immigration on native wages in the longer term. Since the share of immigrant employment is still much smaller compared to the labor demand of natives, the negative effect on immigrant wages still exists after many years.

Within one or two years of the sunk emigration cost shock, inflows of new immigrants pin down a greater number of exporters and larger total export values in home. However, the export profitability declines gradually with higher export productivity cutoffs, so the number of home exporters goes down, as well as the home export values per firm. This indicate that there is a substitution effect between immigration and exports (the extensive and intensive margins) in the longer run. On the other hand, an increase in home output induces more demand for foreign varieties, so foreign exports per firm goes up. Therefore, there is a promotion effect of immigration on the intensive margin of imports.

Figure 1.9 displays the effects of a decrease in emigration costs on two counterfactual scenarios, fixed cutoffs and fixed entry. First, in the special case with fixed cutoffs (red lines), the impacts of the shock on aggregate variables are enhanced compared to the baseline model. One key difference is the result of the number of home exporters. In the benchmark model, the negative influence of z_x on N_x dominates the positive firm entry effect so N_x deviates negatively from its steady state. When the cutoff stays constant, there is an upward trend of N_x. Second, all variables have no deviations from their steady state values when the firm entry channel is shut down. Firm entry also propagates the effects of a migration shock. Because firm dynamics are slow, the influences of entry on macroeconomic variables are highly persistent.[37]

Negative Shock to Trade Costs

The model assumes a symmetric iceberg trade cost τ in two countries, and the impulse responses to a negative trade cost shock in the baseline model are shown in Figure 1.10. First, a transitory 1% decrease in trade costs boosts output and encourages more firm entrants in both economies. Second, lower trade barriers increases the profitability of exports and reduces the export productivity cutoffs, so the number of exporters increases. Regular exports of both countries go up as well though changes in intensive margins of trade are relatively smaller. Third, the foreign (less developed) country is more integrated in trade and benefits more from trade integration. The increase in foreign output is larger compared to home output, demonstrating that the foreign market becomes relatively more attractive for entrepreneurs and skilled workers. Meanwhile, the wage difference between countries falls with a reduction in trade costs, reducing incentives for labor migration as well. This finding is consistent with previous research about trade and convergence. For instance, the Heckscher-Ohlin-Samuelson model indicates that the factor price tends to be equal with free trade. In term of empirical studies, Ben-David (1996) quantitatively shows that trade is associated with a reduction in income gaps across counties. Waugh (2010) also studies the role of trade costs in reducing income difference with emphasizing the importance of the systematic asymmetry in trade frictions. Therefore, an increase in bilateral trade could be

[37] Gourio et al. (2016) provide a state-level analysis to argue that firm entry acts as a propagation mechanism.

substituted for labor migration due to the wage convergence effect.

The special case with fixed export productivity cutoffs (red lines in Figure 1.11) pins down a similar positive effect on regular exports and imports but a much smaller impact on the extensive margin of exports and a larger deviation of the intensive margin of exports. Meanwhile, the reduction on immigrant labor stock and entry is greater. The impacts of trade shocks on the intensive margin of exports, the stock of immigrants and inflows of immigrants are enhanced with fixed cutoffs. There is a stronger substitution effect of immigration and the intensive margin of exports in this scenario. Surprisingly, the influence on the intensive margin of imports is contrary. Next, when the firm entry channel is shut down, changes in the number of exporters are close to the benchmark model but there is only little impact on export values per firm (green lines in Figure 1.11). There are no deviations of immigrant stock and entry from their steady state levels at all. The adjustments in home and foreign outputs are similar, so the incentives for labor migration may not be affected.

1.5.3 Moments

I assume the percentage deviations of Z_t and Z_t^* from the steady state follow the bivariate autoregressive process:

$$\begin{bmatrix} Z_t \\ Z_t^* \end{bmatrix} = \begin{bmatrix} \rho_z & \rho_{zz^*} \\ \rho_{z^*z} & \rho_{z^*} \end{bmatrix} \begin{bmatrix} Z_{t-1} \\ Z_{t-1}^* \end{bmatrix} \begin{bmatrix} u_t \\ u_t^* \end{bmatrix}$$

where the persistent parameters ρ_z and ρ_z^* are in the unit interval, the spillover parameters ρ_{zz^*} and ρ_{z^*z} are non-negative, and technology shocks u_t and u_t^* are normally distributed with zero mean.

I use the persistence and spillover parameters, as well as the variance-covariance matrix in Zlate (2016) which calibrates that the productivity process is more persistent in the Unites States than Mexico and the spillovers from the US to Mexico is larger than Mexico-to-U.S. spillovers. Since Mexico is one of the main labor-sending country and it is less developed than the home country, I use the following asymmetric estimate of the bivariate productivity as in Zlate (2016):

$$\begin{bmatrix} \rho_z & \rho_{zz^*} \\ \rho_{z^*z} & \rho_{z^*} \end{bmatrix} = \begin{bmatrix} 0.996 & 0.003 \\ 0.049 & 0.951 \end{bmatrix}$$

Table 1.3 presents the moments from model simulations and data. The baseline model generates volatilities for home output and consumption that are close to the data, but the volatilities of foreign output and consumption are less than the data. In the model setting, N_d acts like capital stock and N_e represents the investment in firm entrants. Consistent with the finding in Backus et al. (1992), investment (the number of firm entrants) is more volatile compared to output and consumption. Meanwhile, the benchmark model underestimates volatilities of labor migration, exports and imports. Three alternative models also deliver similar results, but the volatility of labor migration is higher under the special case with fixed cutoffs.

Regarding domestic variables, all scenarios deliver positive co-movement of the following variables with output as in previous studies: consumption, export, import and the extensive margins of exports and imports. In the meantime, this paper produces that the numbers of firms, new entrants and immigrants are also pro-cyclical, which is consistent with the data. However, the number of exporters is much less pro-cyclical under the special cases with fixed cutoffs. Additionally, the counterfactual case with fixed entry fails to generate a strong and positive correlation between output and the number of firm entrants. Interestingly, these correlations under labor immobility are very close to those values of the baseline model. This indicates that business cycle implications of immigration is relatively less significant compared to the other two specifications.

Regarding the international correlation, cross-country correlations of consumption and output are positive. These findings are relevant to the standard demand and supply spillover effects across countries. The output-consumption anomaly is presented under all models as the output correlation of two economies is close to consumption correlation, but it is in contrast to the data. Firm entry has a direct effect on the dynamics of output, so the model predicts that cross-country firm establishment and the number of exporters are also positively correlated.

Labor migration is positively correlated with home output while there is a negative correlation with foreign output in the data and every specification. Moreover, each model specification delivers the pro-cyclical pattern between labor migration and home aggregate consumption, but the linkage between migration and foreign aggregate consumption is negative. These results also indicate that economic outcomes of the foreign country are worse off due to labor outflows, and cross-country labor flows weaken the business cycle synchronization. There also exists a positive correlation between immigrant stock and the number of firms, reflecting that inflows of new immigrants could induce more firm entrants, and a greater number of domestic firms increase immigrant labor demand as well.

To check the robustness, I also use the symmetric estimate of the bivariate productivity for the United States and the rest of the world from Heathcote and Perri (2002).[38] The symmetric estimate of the bivariate productivity is

$$\begin{bmatrix} \rho_z & \rho_{zz^*} \\ \rho_{z^*z} & \rho_{z^*} \end{bmatrix} = \begin{bmatrix} 0.970 & 0.025 \\ 0.025 & 0.970 \end{bmatrix}$$

The productivity spillover across countries are small and positive. Standard deviations of innovations to home and foreign productivity are 0.0073 and 0.0044 respectively, and the correlation is set to 0.290. The model implications hold with this symmetric bivariate TFP process.

1.5.4 Welfare Implications of Immigration

Following Schmitt-Grohé and Uribe (2004), I apply the second-order approximation to the policy functions to evaluate welfare effects with a smaller sunk emigration cost f_m. The long-run welfare gain or loss of each type of households in two countries from a 50% decrease in sunk emigration costs (loosening the immigration policy) is computed as the percentage change (Δ) in the steady-state consumption under the baseline model, so that households are indifferent in the immigration policies between the benchmark model and the case with a 50% reduction in sunk emigration costs. Therefore, Δ solves:

$$\frac{1}{1-\beta}U[(1+0.01\Delta)c_j, j] = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} U(c_{j,t}, j_t), \quad \forall j \in \{h, l\}$$

Table 1.4 displays that a loose immigration policy leads to a 0.0277% increase in native high-skilled welfare under the benchmark model as new inflows of immigrants induce firm

[38] The rest of the world is an aggregate of Canada, Japan and 15 European countries in Heathcote and Perri (2002).

entry and result in higher high-skilled wages in home. However, there is a 0.0194% fall in native low-skilled welfare due to the decline in the price level of unskilled goods and domestic consumption demand of low-skilled workers. Foreign high-skilled households lose welfare by -0.0294% because the market size of the foreign intermediate good sector falls. More generally, foreign labor outflows create a negative impact on firm entry, export participation and output in the foreign country. However, foreign low-skilled households still benefit from high-skilled labor emigration with welfare gains at 0.0323%. This results from a rise in the price level of the unskilled sector, as well as low-skilled wages following high-skilled labor outflows in foreign.

Under the counterfactual case with fixed cutoffs, the welfare gains or loses are amplified as shown in Table 1.4. A reduction in sunk emigration costs leads to larger changes on output, firm entry, export participation, trade and wages when the export productivity cutoffs are constant. Nevertheless, the model implies that deviations from steady-states values of these aggregate variables are close to zero without the firm entry channel, so there are nearly no changes in households' welfare following a reduction in migration costs if the number of firms is fixed.

1.5.5 Trade Integration and Output Co-movement

The empirical literature identifies that business cycles become more synchronized when trade linkages are stronger.[39] For instance, estimating a cross-country regression of business cycle correlation, Baxter and Kouparitsas (2003) find that the estimated slope coefficients of bilateral trade normalized by total trade and total trade normalized by GDP are 3.4991 and 0.1136 respectively. Meanwhile, they use the base regressions for different bilateral trade variables to test the relationship of trade and output co-movement (Table 1.5, Panel B). There is a positive, significant relationship between trade and business-cycle correlation.

However, the standard international-business-cycle model fails to generate business cycle synchronization following trade integration (Kose and Yi (2001)). This is called the trade-comovement puzzle. The standard IRBC model predicts that lower transportation costs lead

[39] See Frankel and Rose (1998), Clark and Wincoop (2001), Baxter and Kouparitsas (2003), Calderon et al. (2007).

to more "expenditure switching " since production is reallocated toward a more productive country. The domestic shocks create too small and short-lasting effects on foreign output dynamics, so the demand-supply spillover effect is too weak to explain trade-induced output co-movement. Furthermore, the standard trade theory illustrates that trade openness leads to increased specialization; thus, business cycle correlations are reduced as discussed in Frankel and Rose (1998). On the other hand, intra-industry trade specialization may result in more highly correlated business cycles.

The extensive margin of production and trade channel is able to solve the trade-comovement puzzle. For example, Liao and Santacreu (2015) argue that business cycles are more strongly correlated between countries that trade a wider variety of goods since they find empirical and theoretical supports that the extensive margin of trade explains most of the trade-productivity and trade-output co-movement, and the international transmission of shocks through trade in varieties is a plausible explanation for the output correlation between countries.[40]

As shown in Table 1.5, Panel A, the baseline model predicts that when the bilateral trade as a fraction of aggregate output in two economies increases by 50%, cross-country GDP correlation increases by 0.1008, and the output comovment is about 37.07% higher relative to the pre-integration scenario. Converted into a model-implied slope coefficient, the corresponding value is 3.95. To some extent, the model-implied coefficient is relatively close to the regression results with the explanatory variable expressed as 1995 values of bilateral trade normalized by GDP presented in column 3 of Table 1.5, Panel B.

The alternative model with no labor migration generates stronger output co-movement, which is in line with the previous impulse response result that the foreign country loses welfare from immigration due to lower final output and investment in new firms. In fact, labor movement across countries weakens the business cycle synchronization as the inverse effect from labor flows on the foreign economy dominates the traditional demand-supply spillover effect.

[40] Cacciatore (2014) also find that the joint presence of endogenous firm entry and labor market friction can explain the observed trade-induced business cycle synchronization. Zlate (2016) generates a positive output correlation with featuring the extensive margin of offshoring.

If the export productivity cutoff is constant, the trade-induced co-movement of output is greater than that of the baseline model. The specification with fixed cutoffs enlarges the macroeconomic effects following a shock, as well as the output correlation of two countries. However, when the firm entry channel is shut down, the estimated slope coefficient becomes 3.06, lower than the value in the baseline model. This finding supports the hypothesis that endogenous firm entry and the extensive margin of trade can enhance the correlation of GDP between two economies as discussed in the literature.

1.6 Conclusion

This paper contributes to the heterogeneous-firm trade literature, which abstracts cross-country labor flows, and the immigration literature by studying the interaction between trade and immigration in a DSGE framework, investigating the macroeconomic consequences of easy labor migration and exploring the role of the extensive margins of production and trade in shaping immigration dynamics.

The model predicts that bilateral trade and high-skilled labor migration are inversely related in the model, which differs from the empirical findings to some extent but is consistent with the derivation from the Heckscher-Ohlin model of trade. There are two main mechanisms of this finding. First, the labor-sending country is more integrated into trade and the wage difference between countries narrows down following trade integration, so an increase in bilateral trade reduces incentives for high-skilled foreign labor to emigrate. Second, incorporating the firm entry channel, this paper shows that inflows of new immigrants due to the reduction in immigration barriers induce more firm entry and result in higher labor costs in the labor sending country in the long term. Consequently, the profitability of home exporters declines, indicating a fall in the intensive and extensive margins of exports. However, labor inflows in the home country creates a promotion effect of the intensive margin of imports due to greater demand for foreign varieties.

Consistent with previous studies, the firm entry channel plays an important role in propagating aggregate productivity, trade and migration shocks and enhances the trade-induced output co-movement even though cross-country labor flows weaken the business cycle synchronization. Additionally, it provides new insights in shaping immigration dynamics, reflecting the interaction between firm establishment and immigration.

An increase in labor movement because of lower barriers to immigration creates different economic consequences for each country and asymmetric welfare effects on high-skilled and low-skilled households. Overall, the dynamic effects of labor flows on the home country are relatively less significant compared to the foreign country. Moreover, the model generates a pro-cyclical pattern of high-skilled immigration and home output, while labor outflows and foreign output are negatively correlated. The foreign economy may lose welfare from a reduction in migration barriers, but benefits more following trade integration than the home economy. Hence, immigration and trade policies that are flexible to adjust may be beneficial for both economies.

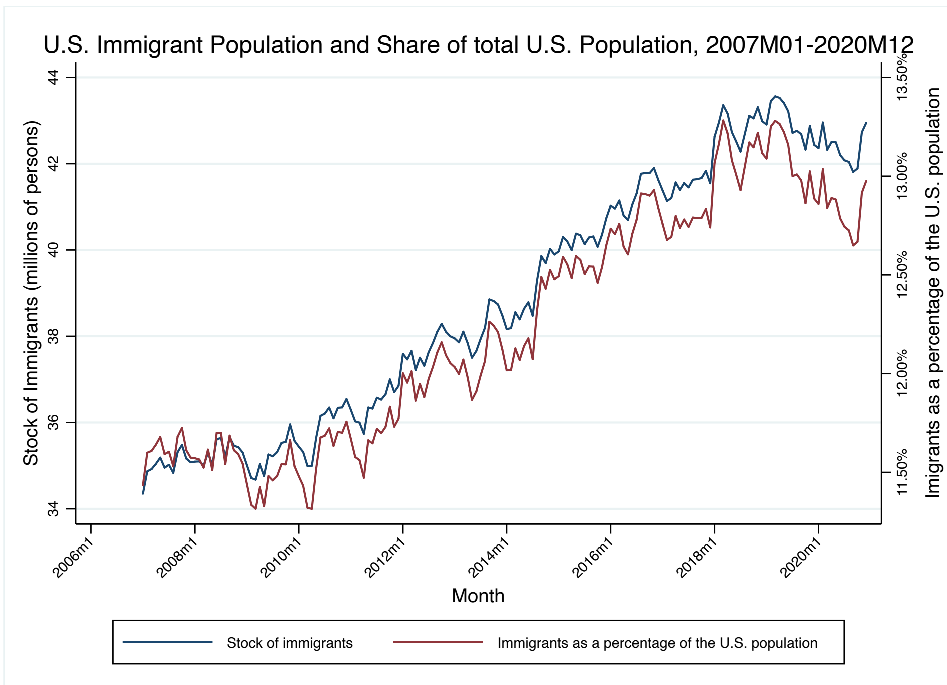

Figure 1.1: U.S. immigrant population and its share of total U.S. population.

Source: U.S. Bureau of Labor Statistics, Population Level - Foreign Born and U.S. Bureau of Economic Analysis, Population, retrieved from FRED.

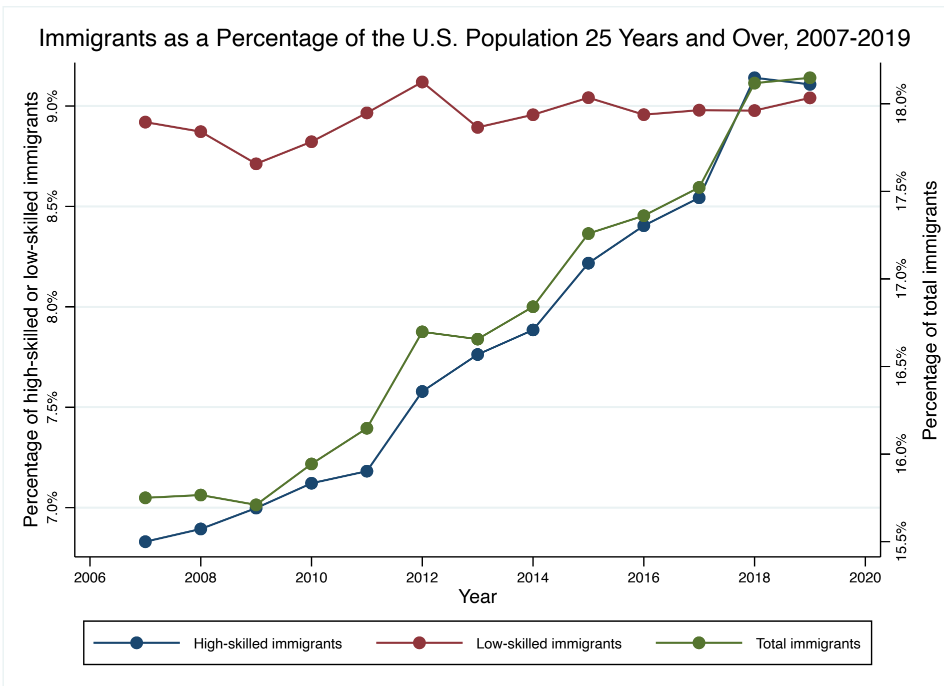

Figure 1.2: Immigrants as a percentage of the U.S. population 25 years and over, 2007-2019

Source: U.S. Census Bureau, Current Population Survey, Annual Social and Economic Supplement.

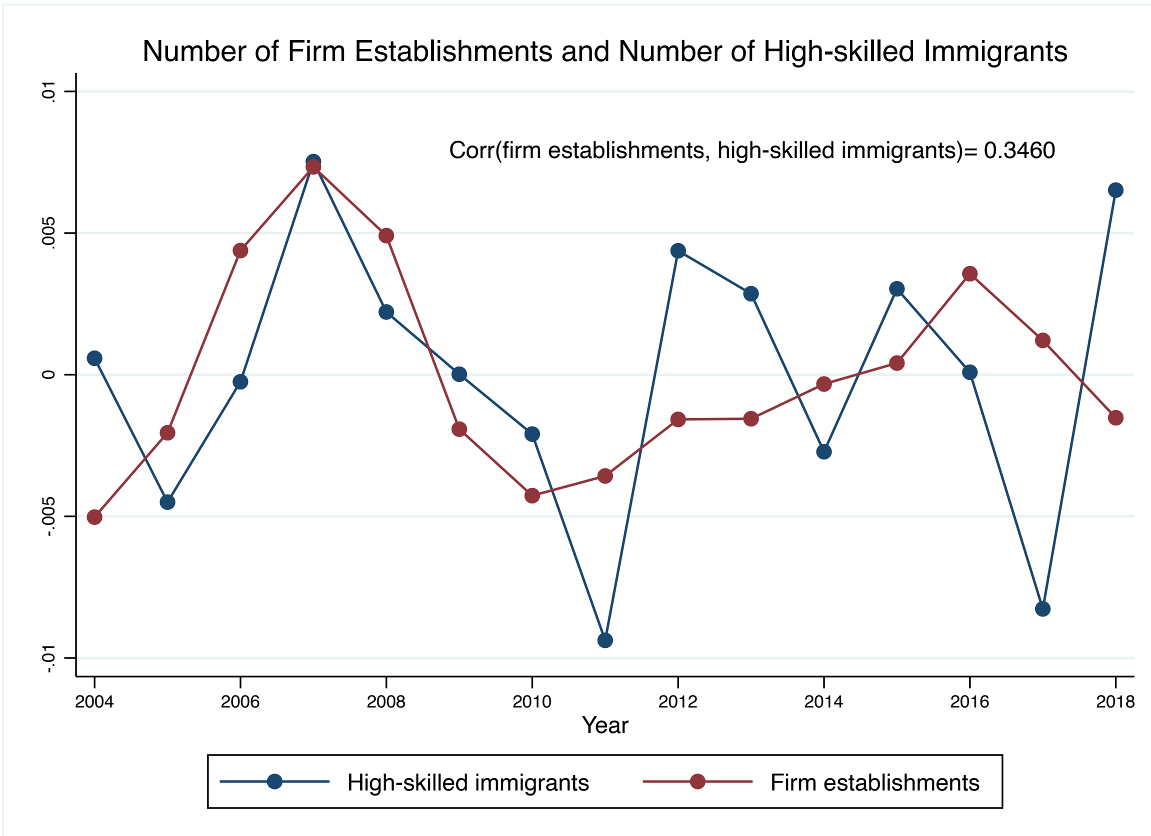

Figure 1.3: The correlation of the number of firm establishments and the number of high-skilled immigrants

Note: The series are converted in natural logs and expressed in deviations from a Hodrick-Prescott trend. Following Ravn and Uhlig (2002), I set the HP smoothing parameter to be 6.25 for annual data. Source: U.S. Census Bureau, Current Population Survey and Annual Economic Surveys, Business Dynamics Statistics.

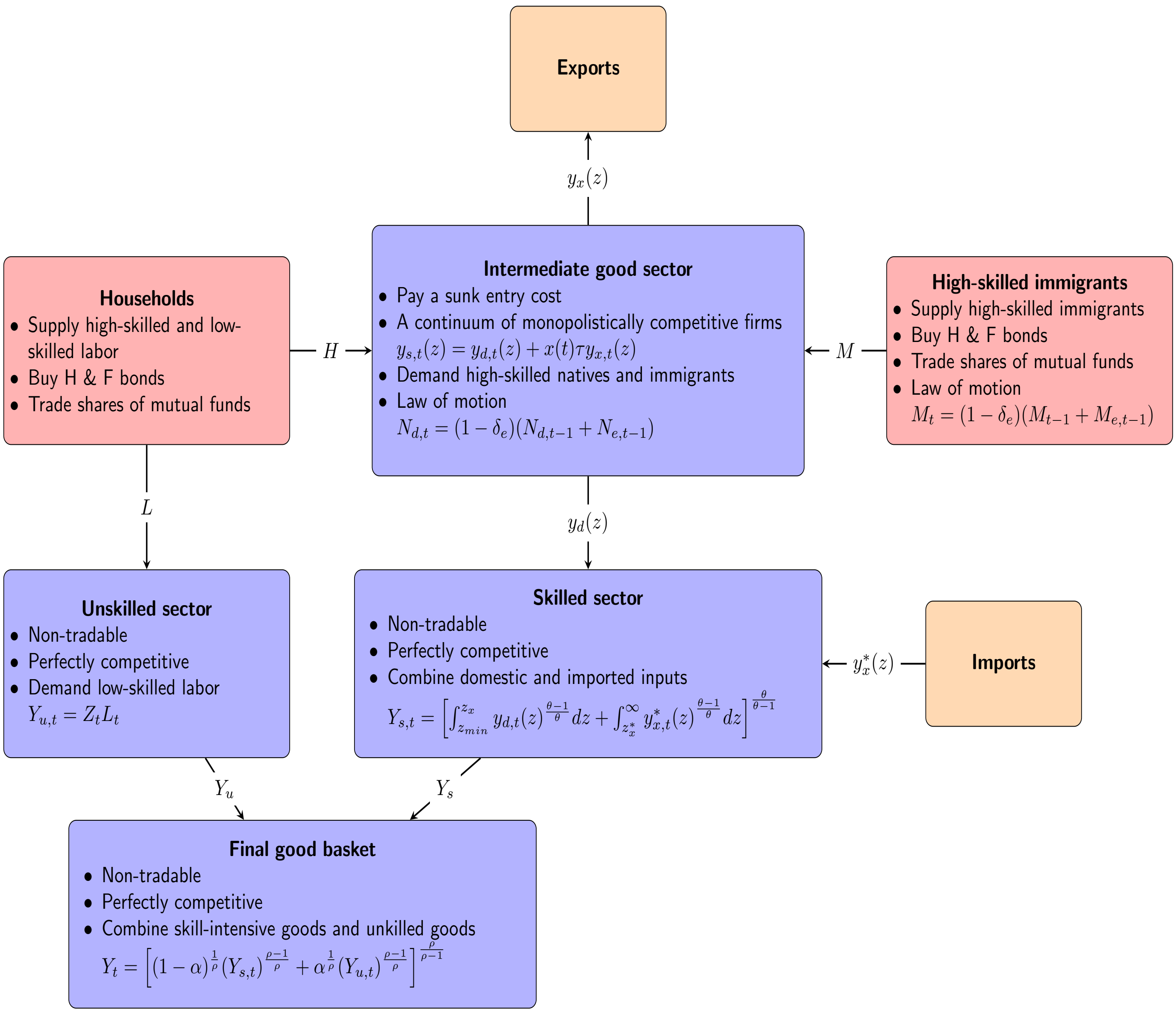

Figure 1.4: Model overview

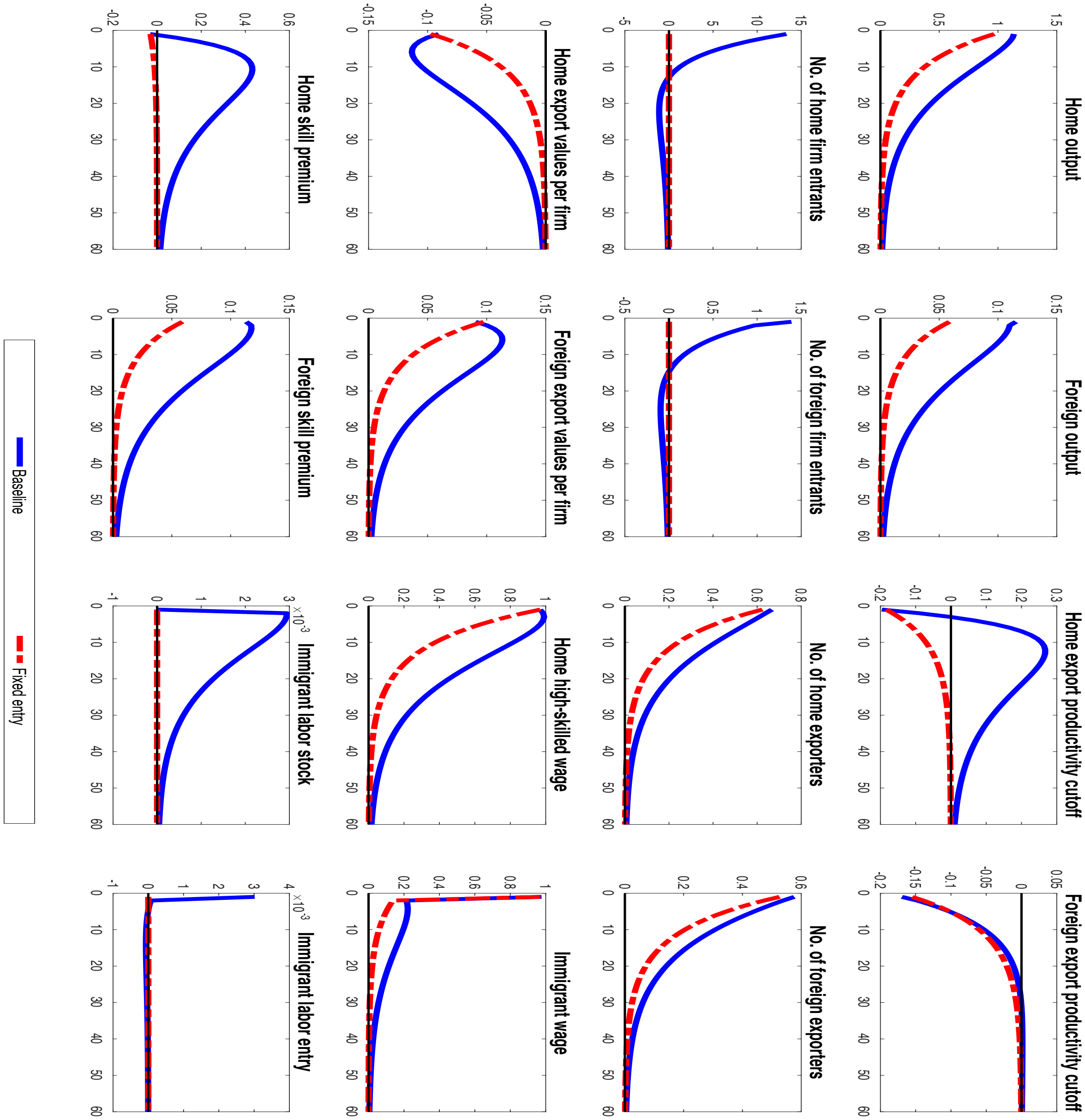

Figure 1.5: Impulse responses to a positive aggregate productivity shock in home, baseline model vs. model with fixed firm entry.

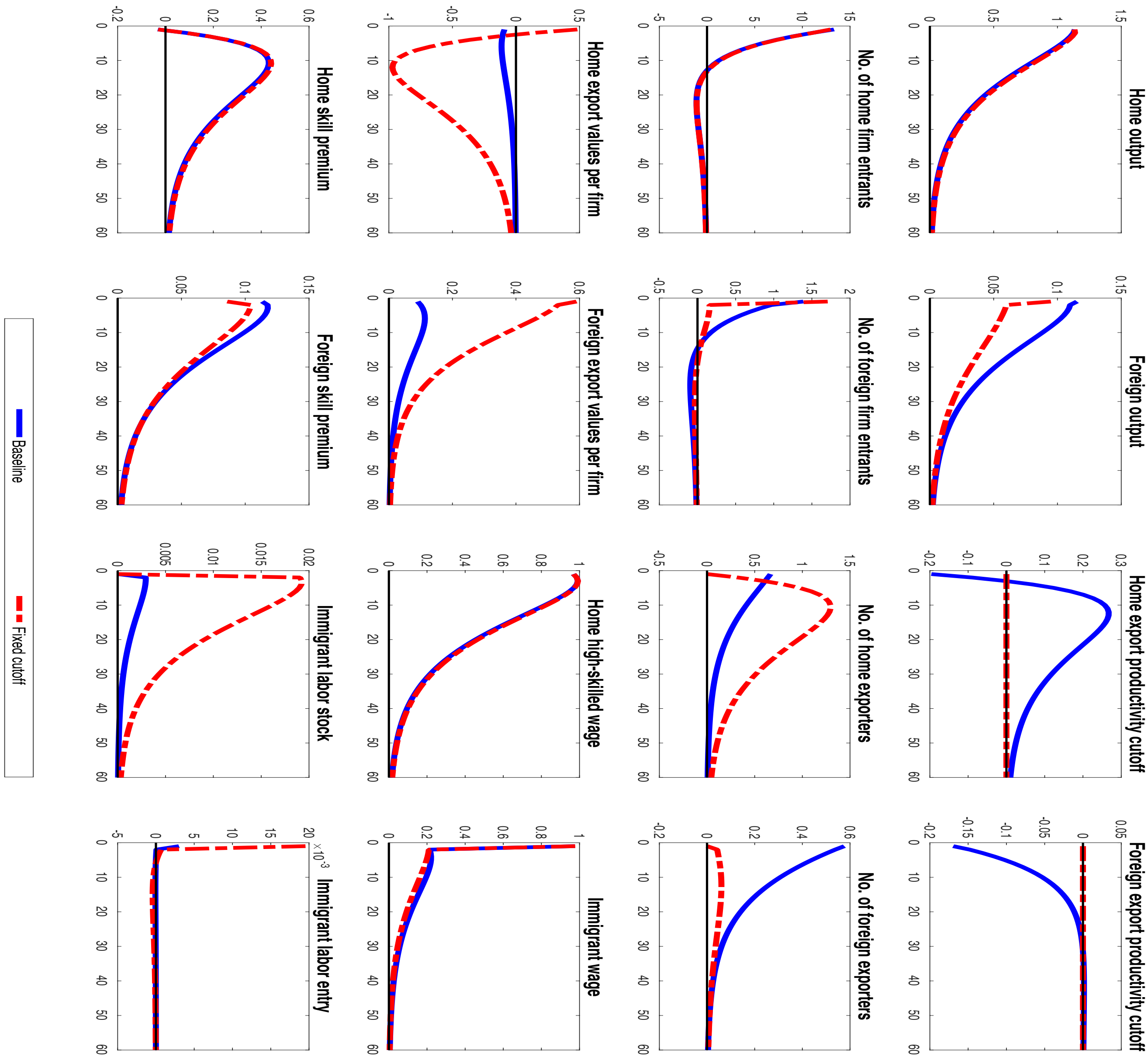

Figure 1.6: Impulse responses to a positive aggregate productivity shock in home, baseline model vs. model with fixed export productivity cutoffs.

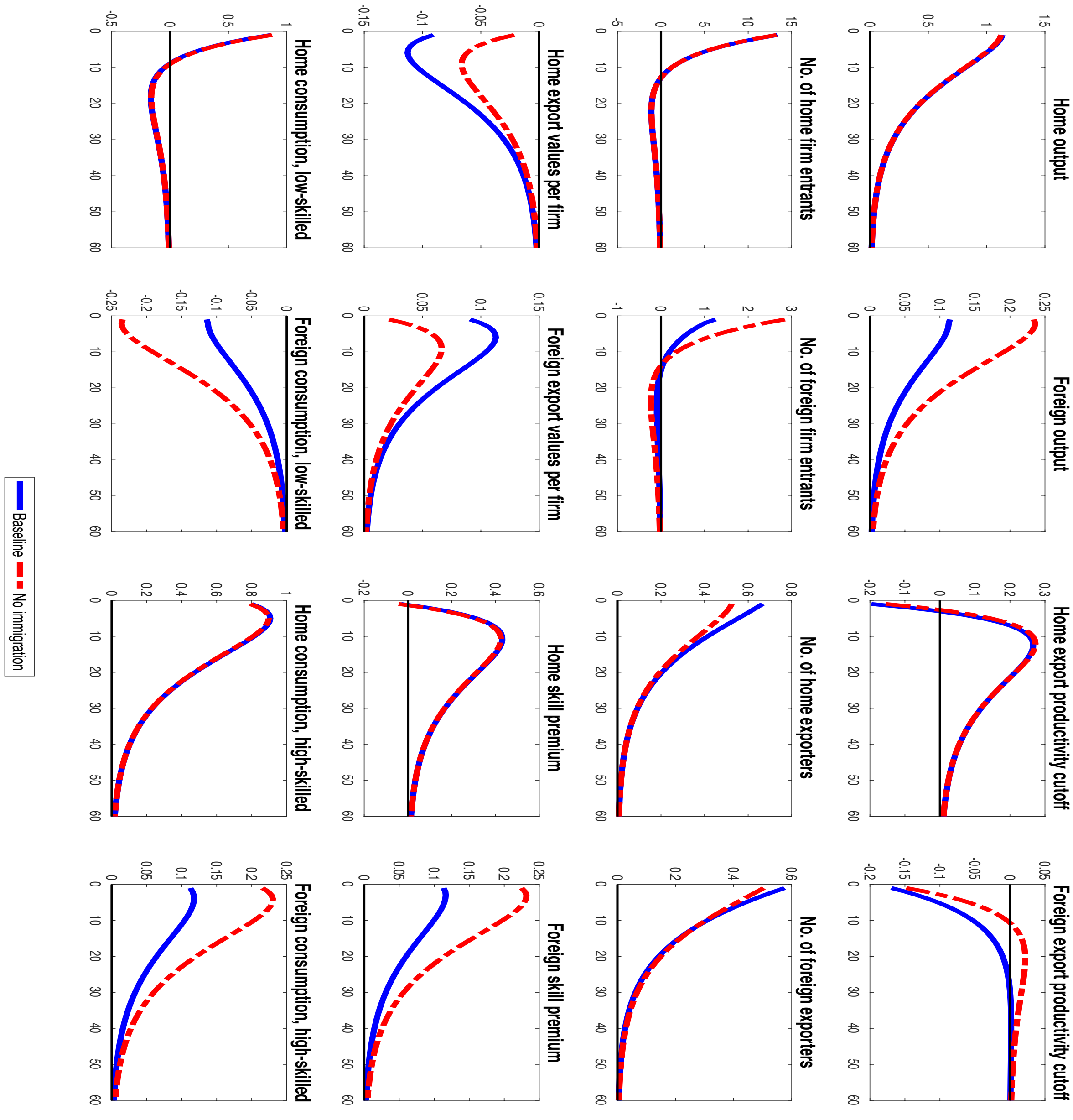

Figure 1.7: Impulse responses to a positive aggregate productivity shock in home, baseline model vs. model with no immigration.

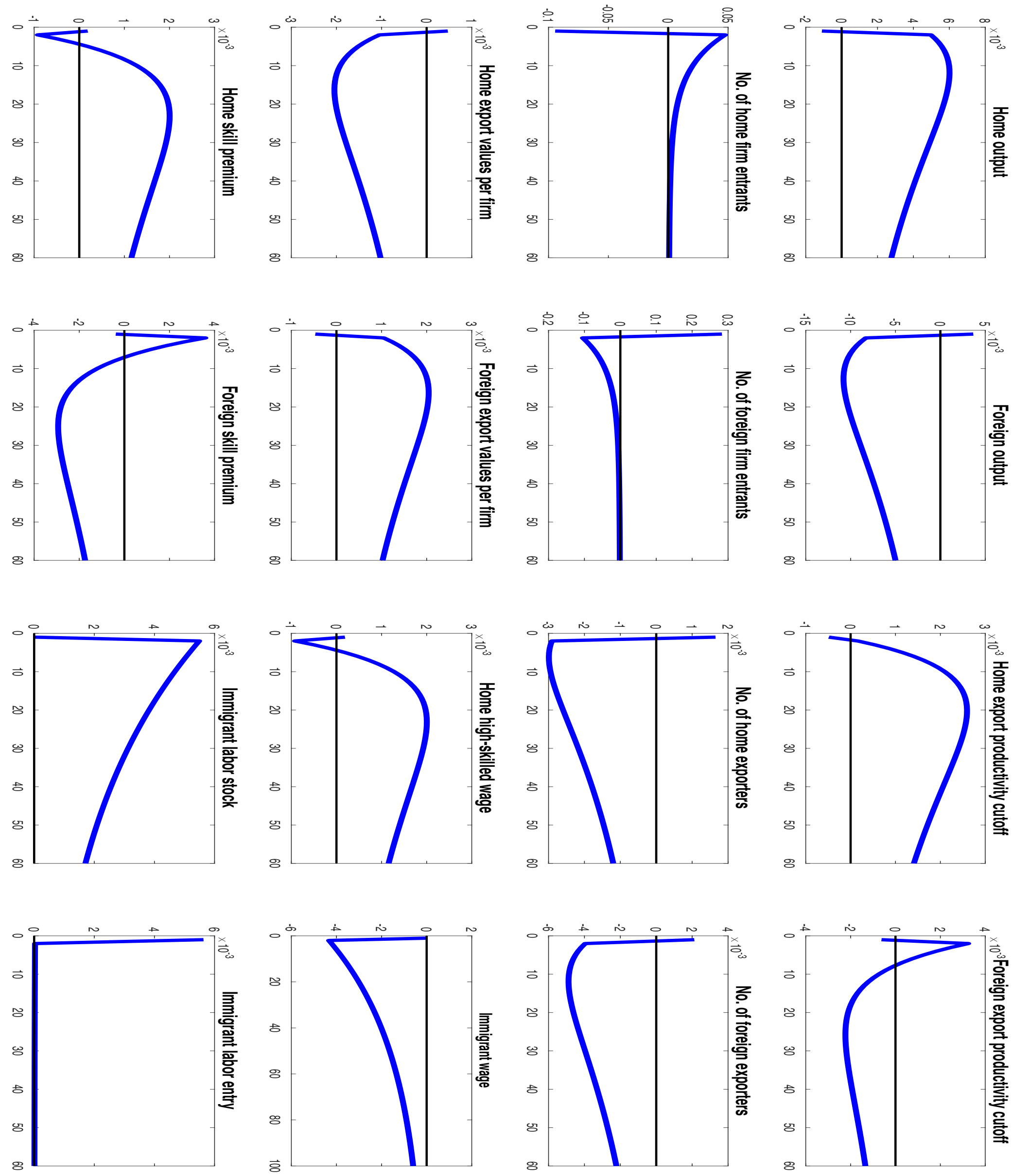

Figure 1.8: Impulse responses to a decrease in sunk emigration costs, baseline model.

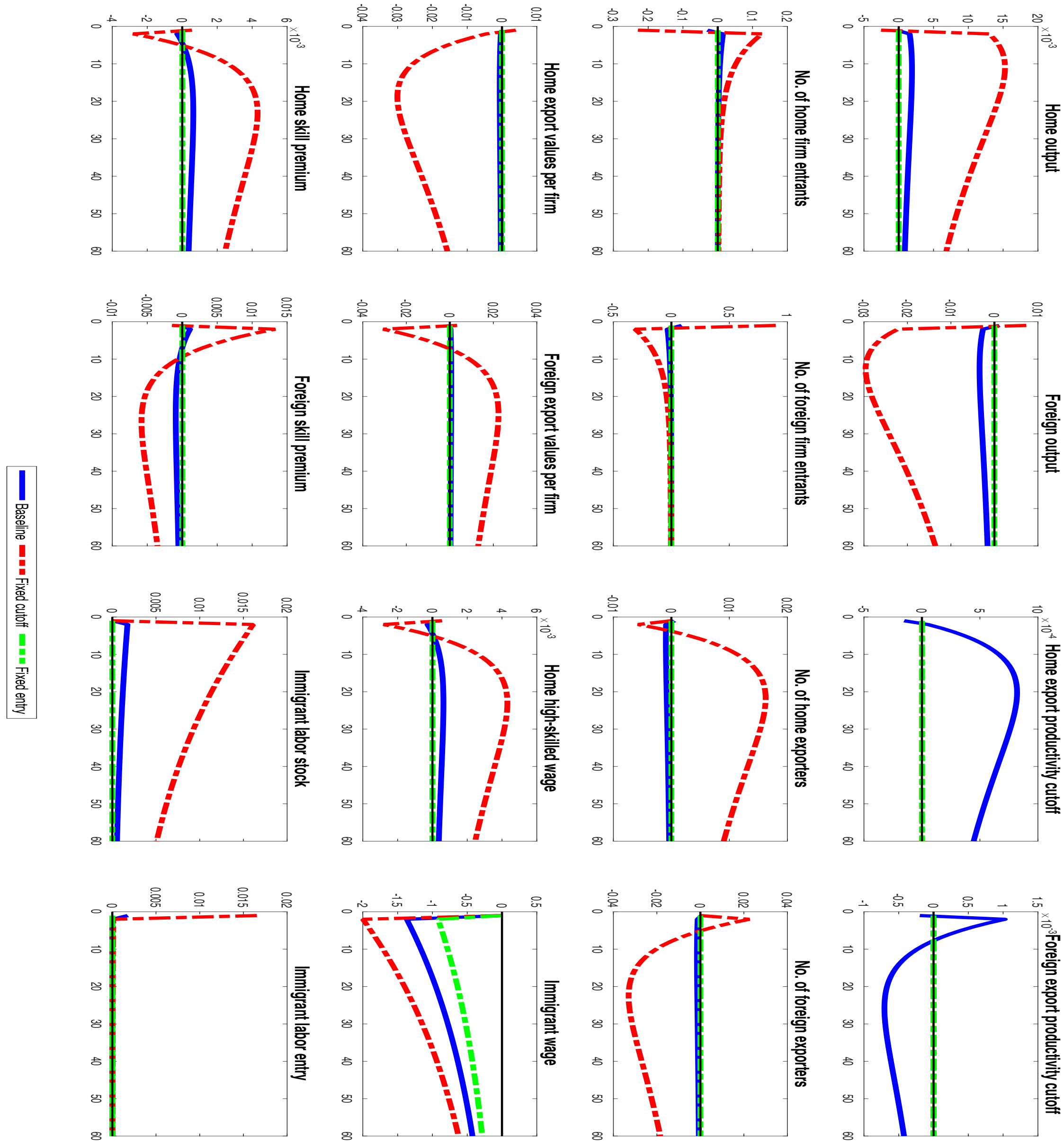

Figure 1.9: Impulse responses to a decrease in sunk emigration costs, baseline model vs. models with fixed firm entry and fixed export productivity cutoffs.

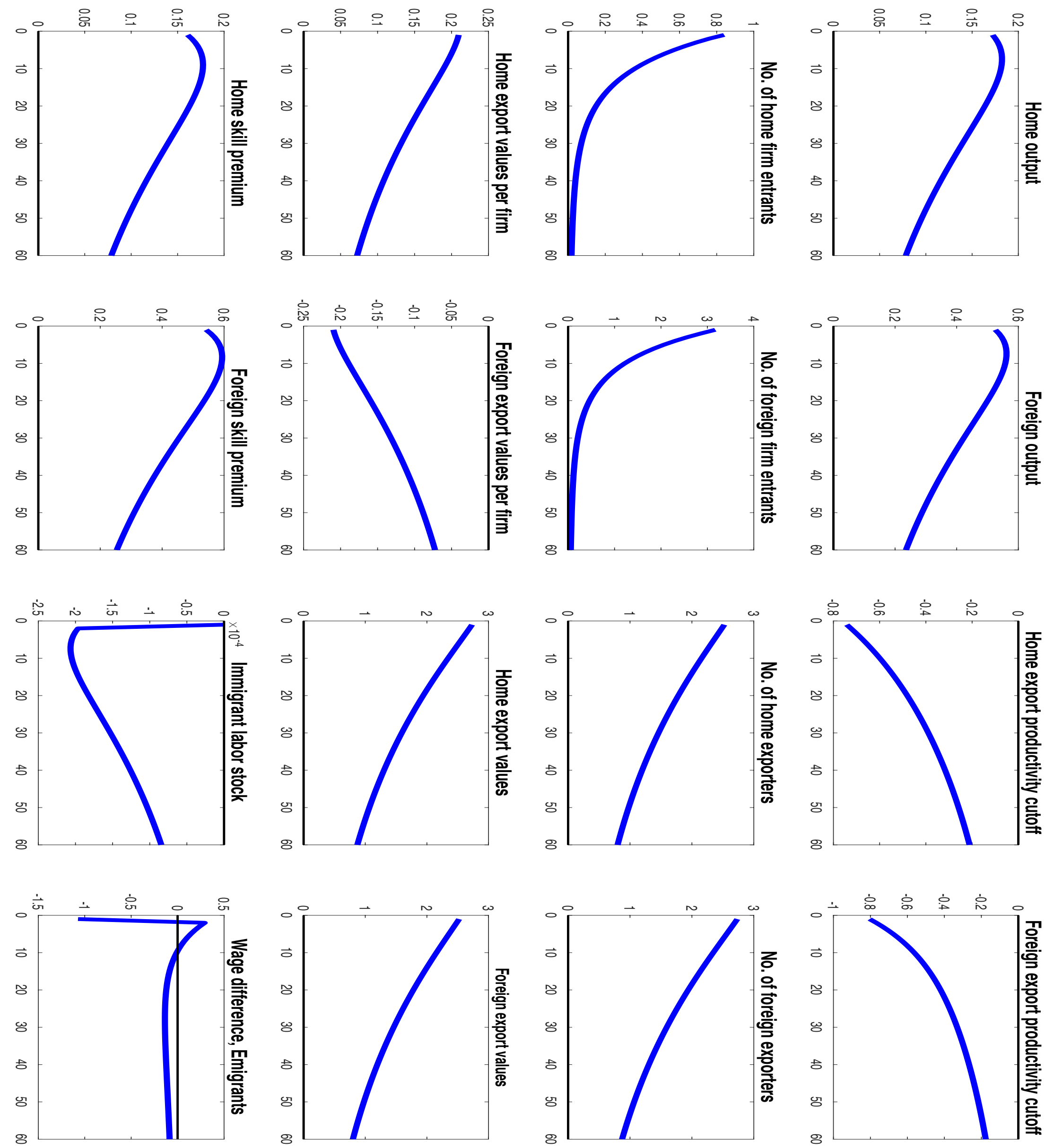

Figure 1.10: Impulse responses to a decrease in iceberg trade costs, baseline model.

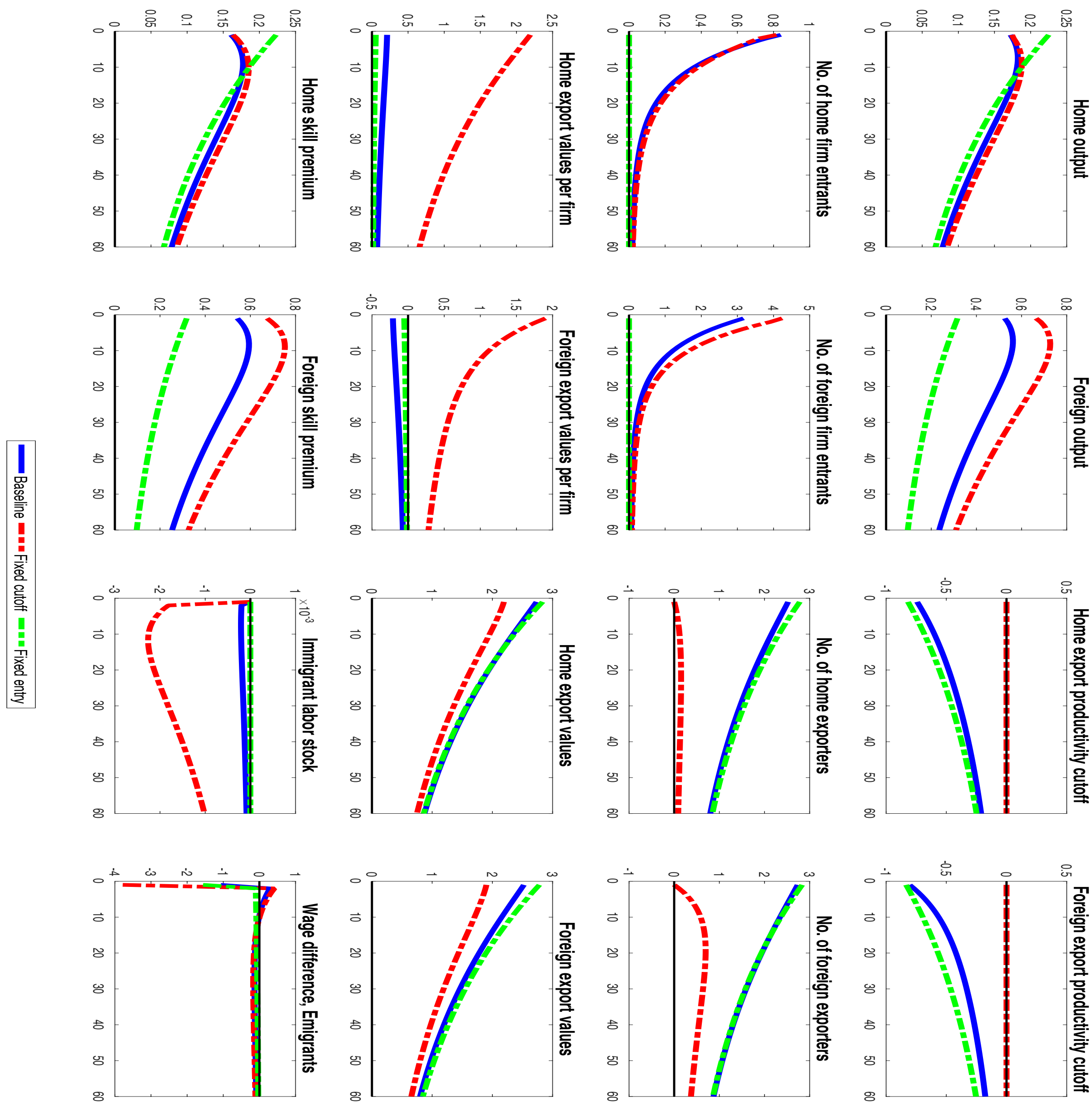

Figure 1.11: Impulse responses to a decrease in iceberg trade costs, baseline model vs. models with fixed firm entry and fixed export productivity cutoffs.

Table 1.1: Baseline model summary

Economic variables	Equilibrium equations
Euler equation, bonds	$1+\zeta b_{j,t+1} = \beta(1+r_{t+1})E_t\left[\frac{c_{j,t}}{c_{j,t+1}}\right]$ $1+\zeta b_{*j,t+1} = \beta(1+r^*_{t+1})E_t\left[\frac{Q_{t+1}c_{j,t}}{Q_t c_{j,t+1}}\right]$ $1+\zeta b^*_{j,t+1} = \beta^*(1+r_{t+1})E_t\left[\frac{Q_t c_{j^*,t}}{Q_{t+1}c_{j^*,t+1}}\right]$ $1+\zeta b^*_{*j,t+1} = \beta^*(1+r^*_{t+1})E_t\left[\frac{c_{j^*,t}}{c_{j^*,t+1}}\right]$
Bond market clearing	$B_{h,t}+B_{l,t}+B^*_{h,t}+B^*_{l,t} = B_t+B^*_t = 0$ $B^*_{*h,t}+B^*_{*l,t}+B_{*h,t}+B_{*l,t} = B^*_{*t}+B_{*t} = 0$
Euler equation, stocks	$\tilde{v}_t = \beta(1-\delta_e)E_t\left[\frac{c_{j,t}}{c_{j,t+1}}(\tilde{v}_{t+1}+\tilde{\pi}_{t+1})\right]$ $\tilde{v}^*_t = \beta(1-\delta^*_e)E_t\left[\frac{c^*_{j,t}}{c^*_{j,t+1}}(\tilde{v}_{t+1}+\tilde{\pi}^*_{t+1})\right]$
Labor supply	$\frac{w_{j,t}}{c_{j,t}} = \chi_j(j_t)^\mu$ $\frac{w^*_{j,t}}{c^*_{j,t}} = \chi_j(j^*_t)^\mu$
Emigration condition	$f_{m,t} = \sum_{\tau=t+1}^{\infty}[\beta(1-\delta_m)]^{\tau-t}\, E_t\left[\frac{c^*_{h,t}}{c^*_{h,\tau}}(w_{m,\tau}Q_\tau^{-1}-w^*_{h,\tau})\right]$
Law of motion, immigration	$m_{t+1} =(1-\delta_m)(m_t+m_{e,t})$
Immigrant consumption	$w_{m,t}m_t = c_{m,t}$
Law of motion, firms	$N_{d,t+1} = (1-\delta_e)(N_{d,t}+N_{e,t})$ $N^*_{d,t+1} = (1-\delta^*_e)(N^*_{d,t}+N^*_{e,t})$
Free entry	$\tilde{v}_t = f_{e,t}$ $\tilde{v}^*_t = f^*_{e,t}$

Baseline model summary continued

Price index	$1 = (1-\alpha)(\rho_{s,t})^{1-\rho} + \alpha(\rho_{u,t})^{1-\rho}$ $1 = (1-\alpha^*)(\rho^*_{s,t})^{1-\rho} + \alpha^*(\rho^*_{u,t})^{1-\rho}$ $(\rho_{s,t})^{1-\theta} = N_{d,t}(\tilde{\rho}_{d,t})^{1-\theta} + N^*_{x,t}(\tilde{\rho}^*_{x,t})^{1-\theta}$ $(\rho^*_{s,t})^{1-\theta} = N^*_{d,t}(\tilde{\rho}^*_{d,t})^{1-\theta} + N_{x,t}(\tilde{\rho}_{x,t})^{1-\theta}$ $\rho_{u,t} = w_{l,t}/Z_t$ $\rho^*_{u,t} = w^*_{l,t}/Z^*_t$ $\tilde{\rho}_{d,t} = \frac{\theta}{\theta-1}\frac{w_{h,t}\phi_{h,t} + w_{m,t}\phi_{m,t}}{\tilde{z}_{d,t}Z_t\Phi_t}$ $\tilde{\rho}^*_{d,t} = \frac{\theta}{\theta-1}\frac{w^*_{h,t}}{\tilde{z}^*_{d,t}Z^*_t}$ $\tilde{\rho}_{x,t} = \frac{\theta}{\theta-1}\frac{\tau(w_{h,t}\phi_{h,t} + w_{m,t}\phi_{m,t})Q^{-1}}{\tilde{z}_{x,t}Z_t\Phi_t}$ $\tilde{\rho}^*_{x,t} = \frac{\theta}{\theta-1}\frac{\tau w^*_{h,t}Q}{\tilde{z}^*_{x,t}Z^*_t}$
Average productivity	$\tilde{z}_{d,t} = \nu z_{min}$ $\tilde{z}^*_{d,t} = \nu z^*_{min}$ $\tilde{z}_{x,t} = \nu z_{x,t}$ $\tilde{z}^*_{x,t} = \nu z^*_{x,t}$
Share of exported firms	$\frac{N_{x,t}}{N_{d,t}} = \left(\frac{z_{min}}{z_{x,t}}\right)^{\kappa}$ $\frac{N^*_{x,t}}{N^*_{d,t}} = \left(\frac{z^*_{min}}{z^*_{x,t}}\right)^{\kappa}$
Average profits	$\tilde{\pi}_{d,t} = \frac{1-\alpha}{\theta}(\tilde{\rho}_{d,t})^{1-\theta}(\rho_{s,t})^{\theta-\rho}Y_t$ $\tilde{\pi}^*_{d,t} = \frac{1-\alpha^*}{\theta}(\tilde{\rho}^*_{d})^{1-\theta}(\rho^*_{s,t})^{\theta-\rho}Y^*_t$ $\tilde{\pi}_{x,t} = \frac{1-\alpha^*}{\theta}(\tilde{\rho}_{x})^{1-\theta}(\rho^*_{s,t})^{\theta-\rho}Y^*_tQ_t - f_{x,t} = (\nu^{\theta-1}-1)f_{x,t}$ $\tilde{\pi}^*_{x,t} = \frac{1-\alpha}{\theta}(\tilde{\rho}^*_{x})^{1-\theta}(\rho_{s,t})^{\theta-\rho}Y_tQ^{-1}_t - f^*_{x,t} = (\nu^{\theta-1}-1)f^*_{x,t}$
Total profits	$\tilde{\pi}_t = \tilde{\pi}_{d,t} + \frac{N_{x,t}}{N_{d,t}}\tilde{\pi}_{x,t}$ $\tilde{\pi}^*_t = \tilde{\pi}^*_{d,t} + \frac{N^*_{x,t}}{N^*_{d,t}}\tilde{\pi}^*_{x,t}$

Baseline model summary continued

High-skill index	$\Phi_t = \left[\lambda\phi_{m,t}^{(\sigma-1)/\sigma} + (1-\lambda)\phi_{h,t}^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)}$
Share of high-skilled labor	$\phi_{m,t} = \frac{\lambda^{\sigma} w_{m,t}^{-\sigma}}{\lambda^{\sigma} w_{m,t}^{-\sigma} + (1-\lambda)^{\sigma} w_{h,t}^{-\sigma}}$ $\phi_{h,t} = \frac{(1-\lambda)^{\sigma} w_{h,t}^{-\sigma}}{\lambda^{\sigma} w_{m,t}^{-\sigma} + (1-\lambda)^{\sigma} w_{h,t}^{-\sigma}}$
Low-skilled Labor market clearing	$Z_t L_t = Z_t(1-\gamma) l_t$ $= \alpha \rho_{u,t}^{-\rho} Y_t$ $Z_t^* L_t^* = Z_t^*(1-\gamma^*) l_t^*$ $= \alpha^* \rho_{u,t}^{*}{}^{-\rho} Y_t^*$
High-skilled labor market clearing	$\Xi_t = \frac{(1-\alpha)(\tilde{\rho}_{d,t})^{-\theta}(\rho_{s,t})^{\theta-\rho} Y_t N_{d,t}}{\tilde{z}_{d,t}\Phi_t Z_t}$ $+ \frac{(1-\alpha^*)\tau(\tilde{\rho}_{x,t})^{-\theta}(\rho_{s,t}^*)^{\theta-\rho} Y_t^* N_{x,t}}{\tilde{z}_{x,t}\Phi_t Z_t}$ $\Xi_t^* = \frac{(1-\alpha^*)(\tilde{\rho}_{d,t}^*)^{-\theta}(\rho_{s,t}^*)^{\theta-\rho} Y_t^* N_{d,t}^*}{\tilde{z}_{d,t}^* Z_t^*}$ $+ \frac{(1-\alpha)\tau^*(\tilde{\rho}_{x,t}^*)^{-\theta}(\rho_{s,t})^{\theta-\rho} Y_t N_{x,t}^*}{\tilde{z}_{x,t}^* Z_t^*}$
Sectoral basket demand	$Y_{s,t} = (1-\alpha)\rho_{s,t}^{-\rho} Y_t$ $Y_{s,t}^* = (1-\alpha^*)\rho_{s,t}^{*}{}^{-\rho} Y_t^*$ $Y_{u,t} = \alpha \rho_{u,t}^{-\rho} Y_t$ $Y_{u,t}^* = \alpha^* \rho_{u,t}^{*}{}^{-\rho} Y_t^*$
Production function of final good	$Y_t = \left[(1-\alpha)^{\frac{1}{\rho}}(Y_{s,t})^{\frac{\rho-1}{\rho}} + \alpha^{\frac{1}{\rho}}(Y_{u,t})^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}$ $Y_t^* = \left[(1-\alpha^*)^{\frac{1}{\rho}}(Y_{s,t}^*)^{\frac{\rho-1}{\rho}} + \alpha^{\frac{1}{\rho}}(Y_{u,t}^*)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}$
Final good market clearing condition	$Y_t = C_{h,t} + C_{l,t} + C_{m,t} + N_{e,t} f_{e,t} + N_{x,t} f_{x,t}$ $Y_t^* = C_{h,t}^* + C_{l,t}^* - Q_t^{-1} C_{m,t} + N_{e,t}^* f_{e,t}^* + N_{x,t}^* f_{x,t}^*$ $+ f_{m,t} M_{e,t}$
Balance of international payment	$N_{x,t}(1-\alpha^*)(\tilde{\rho}_x)^{1-\theta}(\rho_{s,t}^*)^{\theta-\rho} Y_t^* Q_t - N_{x,t}^*(1-\alpha)(\tilde{\rho}_x^*)^{1-\theta}(\rho_{s,t})^{\theta-\rho} Y_t$ $= (B_{t+1} - B_t) + Q_t(B_{*,t+1} - B_{*,t}) - r_t^b B_t - r_t^{b^*} Q_t B_{*t}$

Table 1.2: Calibration parameters

Parameters	Values	Sources or targets
Discount factor	$\beta = 0.96$	Literature, 4 % interest rate
Elasticity of substitution across input varieties	$\theta = 3.8$	Ghironi and Melitz (2005)
Elasticity of substitution across skill-intensive and unskilled goods	$\rho = 0.5$	Mendoza (1991)
Pareto distribution	$\kappa = 3.4$	Ghironi and Melitz (2005)
Probability of firm exit	$\delta_e = 0.025$	Ghironi and Melitz (2005)
Probability of immigrant return	$\delta_m = 0.1$	Center for Immigration Studies (2011)
Elasticity of substitution between high-skilled natives and immigrants	$\sigma = 20$	Ottaviano and Peri (2012)
Weight of high-skilled immigrants	$\lambda = 0.185$	LEHD, Kerr et al. (2015)
Share of unskilled goods in home	$\alpha = 0.79$	U.S. Bureau of Labor Statistics
Share of unskilled goods in foreign	$\alpha^* = 0.85$	The World Bank and other sources
Size of high-skilled labor in home	$\gamma = 0.46$	The World Bank
Size of high-skilled labor in foreign	$\gamma^* = 0.16$	The World Bank
Disutility from high-skilled labor in home	$\chi_h = 0.42$	Skill premium 1.81 (US)
Disutility from low-skilled labor in home	$\chi_l = 0.50$	Skill premium 1.81 (US)
Disutility from high-skilled labor in foreign	$\chi_h^* = 0.45$	Skill premium 2.43 (foreign economies)
Disutility from low-skilled labor in foreign	$\chi_l^* = 0.55$	Skill premium 2.43 (foreign economies)
Elasticity of labor supply	$1/\mu = 1$	Farhat (2009)
Quadratic adjustment cost	$\zeta = 0.0025$	Stationary bond holding
Iceberg trade cost	$\tau = 1.3$	The World Bank, trade share 28% of GDP
Fixed cost of exporting in home	$f_x = 0.04$	The World Bank, U.S. export share 12% of GDP
Fixed cost of exporting in foreign	$f_x = 0.025$	The World Bank, U.S. import share 16% of GDP
Sunk entry cost in home	$f_e = 1$	Zlate (2016)
Sunk entry cost in foreign	$f_e = 4$	Zlate (2016)
Sunk emigration cost	$f_m = 2.25$	Share of high-skilled immigrants, 7.5%

Table 1.3: Business cycle statistics

	Data	Baseline	No labor migration	Fixed cutoff	Fixed entry
St. dev (%)					
Y	1.59	1.53	1.52	1.50	1.22
C	0.97	1.19	1.17	1.17	1.22
EX	4.30	1.28	1.29	1.14	1.10
IM	4.88	1.27	1.42	1.13	1.10
N_x	0.56	1.27	1.22	1.24	1.10
N_e	4.94	6.67	6.56	6.37	0
N_d	0.89	1.26	1.25	1.24	0
M	0.80	0.17	n/a	1.08	0
Y^*	2.71	1.39	1.35	1.31	1.19
C^*	2.64	1.20	1.17	1.15	1.19
N_x^*	1.21	1.28	1.29	1.24	1.10
Corr with Y					
C	0.68	0.98	0.98	0.98	0.99
EX	0.69	0.69	0.64	0.69	0.72
IM	0.61	0.79	0.69	0 .75	0.82
N_x	0.65	0.76	0.68	0.37	0.82
N_x^*	0.64	0.65	0.64	0.09	0 .72
N_d	0.44	0.37	0.37	0.37	-0.07
N_e	0.54	0.89	0.89	0.89	n/a
M	0.24	0.46	n/a	0.45	0.44
International correlations					
Y	0.28	0.27	0.40	0.31	0.24
C	0.43	0.27	0.40	0.32	0.23
N_d	n/a	0.24	0.35	0.23	0.22
N_e	n/a	0.24	0.35	0.24	0.21
N_x	n/a	0.99	0.99	0.24	0.99
Corr with M					
Y	0.24	0.46	n/a	0.45	0.44
Y^*	-0.27	-0.39	n/a	-0.38	-0.37
C	0.22	0.51	n/a	0.49	0.44
C^*	-0.19	-0.41	n/a	-0.40	-0.37
N_d	0.24	0.46	n/a	0.45	0.16
N_e	0.43	0.28	n/a	0.27	n/a

Note: For the data, variables are converted in natural logs and expressed in deviations from a Hodrick-Prescott trend. Following Ravn and Uhlig (2002), I set the HP smoothing parameter to be 6.25 for annual data. $N_X(N_x^*)$ refers to the number of (exported) (imported) HS6 digit products to (from) the foreign country (China) in the data, while is denoted as the number of exporters (importers) in the model. Data period is from 2004 to 2018.

Table 1.4: Welfare gain or lose from a loose immigration policy

	Home, high-skilled	Home, low-skilled	Foreign, high-skilled	Foreign, low-skilled
Baseline	0.0277	-0.0194	-0.0294	0.0323
Fixed cutoff	0.0344	-0.0244	-0.0708	0.0423

Note: The long-run welfare gain or loss of each type of households in two countries is calculated from a 50% decrease in the sunk emigration cost. Values are in percent. Under the special case with fixed entry, the values of Δ are close to zero so there are no welfare gains or loses of all types of households.

Table 1.5: Trade integration – Output co-movement

Panel A: Model					
	Baseline	No labor migration	Fixed cutoff	Fixed entry	Fixed extensive margin
Δ corr(Y, Y^*)	0.1008	0.1015	0.0969	0.0704	0.0701
Coefficient	3.9456	4.8558	4.2395	3.0623	2.8976
Panel B: Data (Baxter and Kouparitsas, 2005)					
	Bilateral trade % of total trade	Bilateral Trade % of GDP,1970	Bilateral trade % of GDP, 1995		
Coefficient	2.42	9.27	5.07		

Note: In Panel A, the coefficient of bilateral trade as a fraction of aggregate GDP in two countries are shown under the baseline and alternative models. The coefficient is defined as the ratio between the change in correlation and the change in the log of trade share. In Panel B, these empirical results are from Table 3 (Robustness tests with no "always-included" variables) in Baxter and Kouparitsas (2005).

Chapter 2

TRADE LIBERALIZATION AND SKILL UPGRADING: EVIDENCE ON THE IMPACT OF APTA ON CHINESE MANUFACTURERS

2.1 Introduction

China's performance in economic growth is remarkable, and one of the significant contributors is trade openness. After joining the World Trade Organization (WTO) in 2001, China engages further in international trade and attracted more foreign direct investments (FDI). It benefits greatly from trade integration through acting as a leading country of exports, inducing capital inflows and promoting economic growth. Besides the WTO accession, regional trade liberalization such as the Asian Pacific trade agreement (APTA) and Regional Comprehensive Economic Partnership (RCEP) also foster economic development in China. In the meantime, human capital accumulation has improved sharply in China in the past twenty years. For instance, its tertiary school enrollment rate has increased from 7.69% in 2000 to 53.77% in 2018 according to the World Bank. Workers upgrade their skill levels through education or on-the-job training. Our firm level data show a pattern that Chinese new exporters have greater incentives in providing labor training than non-exporters. This indicates that there is a relationship between exports and human capital investment, but is not enough to explain whether expanded export opportunities encourages firms to invest more in human capital for innovation or vice versa. In this paper, we intend to study the effect of trade liberalization (APTA) on export and skill upgrading decisions of Chinese manufacturers theoretically and empirically.

The heterogeneous-firm trade model in Melitz (2003) and Bernard et al. (2003) emphasizes that trade integration reallocates market shares towards exporters who are larger, more productive and more skill- and capital-intensive than non-exporters. In our benchmark model, following the literature, more productive firms find it profitable to pay for the fixed costs of entering the export market, and those with even higher productivity choose to invest in human capital with fixed skill-upgrading costs because firms receiving larger sales are able to provide labor training, which is also consistent with our data pattern. A reduction in trade cost increases export sales and encourages more new entrants in the export market, and then it also induces more firms to invest in human capital and produce skill-intensive products.

Figure 2.1 (green solid line) reflects that a reduction in India's tariff leads to a boost in exports to the Indian market by Chinese firms. India's average applied effective tariff declines by about 15 percentage points from 2004 to 2007, but the change in the average tariff in the rest of the world (Figure 2.1's red dashed line) is nearly zero during the same period. Based on this fact, we extend our model to distinguish export destinations—the "main" trading countries with lower and stable trade barriers (the rest of the world) and the less preferential trading partners such as India who impose relatively higher (but declining) tariffs—and then analyze the impacts of trade liberalization on firms' export participation and investment in on-the-job training in the home country (China). Regional trade liberalization policies are expected to boost regional trade and investment, facilitate technology and skill upgrading, and stimulate economic growth. We test the model in the context of a regional trade liberalization episode, APTA, through estimating the impact of the reduction in India's tariffs on firm entry in the export market and labor training provided by firms between 2004 and 2007.

We start our empirical analysis by exploring data patterns. In the first check, we investigate whether the sorting pattern predicted by the benchmark model is consistent with the observed differences between exporters and non-exporters. The model implies that productivity differences produce a sorting of firms in four groups: the least productive firms exit the market (not in data), the low productivity group employs low-skilled workers and serve the domestic market only, the middle group exports but still produces unskilled goods with demand for low-skilled workers, and the most productive firms both export and produce skilled goods through upgrading labor skill levels. Indeed, the data confirm that exporters provide more labor training than non-exporters in 2004. Moreover, new exporters increase investment in human capital faster than continuing exporters during the 2004–2007 liberalization period. It is plausible that new exporters produce more skill-intensive products in order to become more competitive in the foreign market.

In the second data check, we investigate whether the sorting pattern predicted by the extended model is consistent with the observed differences between exporters to main trading partners and exporters to less preferential trading partners. In the extended model, the least productive firms exit the market; the lower-middle group exports unskilled goods to main trading countries; the upper-middle group exports unskilled goods to less preferential trading partners; the high productivity group upgrades labor skills, and only exports skilled goods to main trading countries; the most productive firms are able to both provide labor training and export skilled goods to less preferential trading countries. The extended model assumes that some firms find it more profitable to export skilled goods to main countries than to export unskilled goods to other countries who impose higher trade barriers. This assumption comes directly from the data pattern, as we notice that switching exporters from India to the rest of the world increase training spending per worker faster during 2004–2007. The data pattern also shows that exporters to less preferential trading countries such as India invest more in on-the-job training than those exporting to main countries (the rest of the world) in 2004, except for those who switch destination countries in 2007. In particular, both new and switching exporters to India increase labor training slightly more than continuing, exiting, and never exporters during the regional trade liberalization period.

The data patterns describe above show that there is a coincidence between export participation and skill upgrading but do not address the question of whether trade liberalization induces firms to invest in human capital and produce skill-intensive goods instead of unskilled goods. Thus, we attempt to establish causality by linking exporting and skill upgrading directly to the reduction in India's tariffs for imports from China. This is a direct test of the model where firm decisions to enter the export markets and provide labor training are endogenous. In the meantime, we compare two export destinations imposing different trade costs, and analyze whether exporters switch to another export market following trade liberalization.

First, the benchmark model predicts that the productivity cutoffs to enter the export market and to upgrade labor skills fall more when tariffs fall more. Firms find it easier and more profitable to participate in foreign markets and provide labor training following trade integration. Thus, we estimate the change in the probability that a firm enters the export market as a function of the change in India's tariffs. The average reduction in tariffs (15 percentage pints) increases the probability of entering the export market by 1.55 to 1.88 percentage points from 2004 to 2007. Then, we estimate the change in spending on labor training as a function of the change in tariffs. The average reduction in tariffs increases spending on labor training by 0.11 to 0.13 log points during the same period. The above empirical results are from a sample of selected sectors. In the other sectors, we find that the effect of trade liberalization on export participation is positive but insignificant, and the lower trade costs even decrease spending on training. The different results between selected sectors and other sectors are due to sector heterogeneity in productivity and policy in China. Therefore, some of our empirical findings can go beyond the benchmark model predictions, which indicates a need for model extension.

Next, the extended model predicts that the reduction in tariffs of less preferential trading partners (country o) increases the probability of entering the export markets of both main trading partners (country m) and less preferential trading partners (country o). Meanwhile, lower trade costs induce more spending on labor training provided by exporters to country o, but discourages skill upgrading of exporters to country m as predicted by the extended model. The extended estimation of selected sectors shows that the reduction in India's tariffs induce more export entry in the Indian market and increase spending on labor training provided by new exporters to India. Consistent with model prediction, new exporters have a larger likelihood to enter the Indian market and new exporters to India induce more investment in on-the-job training following the reduction in India's tariffs.

This paper contributes to the theoretical literature that studies the mechanism of how trade openness affects firms' investment training. The theoretical model in this paper builds on Melitz (2003) and Bustos (2011b).[1] The heterogeneous-firm model offers new insights into the causes and consequences of international trade.[2] There are model specifications

[1] Bustos (2011a) points out that firms upgrading skills also upgrade technology, and analyze skill upgrading in the context of the employment share of skilled workers. In this paper, firms make skill upgrading decisions through increasing spending in labor training.

[2] Recent literature also incorporates firm dynamics in models of international trade. Burstein and Melitz (2013) generate substantial aggregate-transition dynamics from endogenous shifts in firm-size distribution

that study trade-induced economic outcomes.[3] In the context of human capital adjustment, however, Falvey et al. (2010) build a traditional two-sector Heckscher-Ohlin trade model with skilled and unskilled labor to address when and whether unskilled workers opt for skill upgrading in response to trade liberalization in a skill-abundant country; Van Long et al. (2007) develop a model of firm-specific human capital accumulation, and focus on the decision of workers to accumulate firm-specific skills following trade liberalization. The major differences between our paper and theirs are that 1) we apply the "new" trade theory (heterogeneous-firm model) and 2) we focus on the decision of firms. In terms of studies on China's economy, some papers associate China's economic growth with its human capital accumulation. China has been sustaining the fastest growth for a long period of time after it started economic reform and engaged in global economy. Li et al. (2017) point out that human capital is also an important source and prospect for the future economic growth in China as higher per capita income is positively associated with higher levels of human capital. This paper focuses on the impact of a regional trade liberalization policy, APTA, on export participation, as well as labor training decisions by Chinese manufacturing firms. Firms' investment in on-the-job training is an important way for skill enhancement, human capital adjustment and product quality improvement in China.

The empirical work presented herein is related to the fields of trade liberalization and manufacturing firms' performance. A wide range of studies have investigated the impacts of trade integration on export market entry, technology adaption, skill upgrading, productivity, wage inequality and other economic outcomes. For instance, Bustos (2011b) empirically analyzes the impact of free trade on export participation and technology upgrading of Argentinian firms. Bas (2012) extends the previous work by also considering skill upgrading with plant-level data from Chile's manufacturing sector. There, however, can be heterogeneity in the trade effect on skill upgrading by export destinations. For example, Yamashita (2008) finds that fragmentation trade with high income countries has a skill downgrading effect, in

in response to trade liberalization and find that the responses of trade volumes, innovation, and aggregate output depends on the assumption for firm dynamics, endogenous innovation, and the expected time path of trade liberalization.

[3] For instance, Helpman et al. (2004) highlight the important role of within-sector firm productivity differences in explaining the structure of international trade and FDI with heterogeneous firms.

contrast to skill upgrading among firms with developing East Asian countries, based on a panel dataset covering 52 Japanese manufacturing industries. There are empirical studies about trade adjustment and human capital development of less developed countries, such as India (Edmonds et al., 2010),[4] and Indonesia (Bazzi et al., 2016).[5] Wang (2007) uses data from manufacturing industries in 25 developing countries to study the role of human capital in trade-related technology spillovers. Regarding trade liberalization in China, Brandt et al. (2017) focus on how the WTO accession influences markups and productivity of Chinese manufacturing firms. Our research is closely related to Bustos (2011b). The departure of this paper from the literature is that we introduce two different export markets to discuss firms' export decisions in response to the reduction in one destination's tariffs, and examine how a regional trade liberalization (APTA) affects investment in on-the-job training of Chinese manufacturers.[6]

The rest of the paper is organized as follows. Section 2.2 presents the benchmark model. Section 2.3 derives the extended model in which we distinguish two distinct export markets. Section 2.4 describes trade policies and data sets. Section 2.5 provides an empirical framework to exam the effects of trade liberalization on export participation and skill upgrading and test the predictions of the baseline and extended models; in particular, section 2.5.5 makes a discussion about selected and other sectors. Section 2.6 concludes the whole paper.

2.2 The Benchmark Model

The model is built on Melitz (2003) and Bustos (2011b) to study the impact of trade liberalization on firms' human capital investment decisions. There are two identical countries,

[4] They examine the impact of India's 1991 trade reform on schooling and child labor. They find that rural India experiences an increase in schooling and decline in child labor, but the rural districts with employment subject to larger changes in final product protection have a relative rise in poverty and smaller improvements in schooling.

[5] They study the role of location-specific human capital and skill transferability in shaping productivity in Indonesia.

[6] In the context of labor training, Liu and Lu (2016) and Huang and Zhuang (2021) apply a large panel data of manufacturing firms in China to investigate the effects of on-the-job training on firm productivity and wages.

and each country has two sectors, the skill-intensive sector s and the unskilled sector u. We consider a monopolistically competitive setup with heterogeneous firm productivity, endogenous skill upgrading decision and endogenous export participation. The least productive firms have to exit the market due to negative profits. Some firms in the middle range of productivity can export to the foreign country even though they are not productive enough to invest in labor training. The most productive firms are able to export and invest in labor training. Precisely, they employ high-skilled labor and produce skill-intensive products.

2.2.1 Preferences

In each country, there are two sectors, indexed by $i \in (s, u)$, the skill-intensive sector s and unskilled sector u. The preferences of a representative consumer in the home country is give by the following CES function combing skilled and unskilled goods:

$$\max_{y_{s,t}(\omega), y_{u,t}(\omega)} \left[\left(\int_{\omega \in \Omega_u} y_{u,t}(\omega)^{\frac{\theta-1}{\theta}} d\omega \right)^{\frac{\theta}{\theta-1}\frac{\rho-1}{\rho}} + \left(\int_{\omega \in \Omega_s} y_{s,t}(\omega)^{\frac{\theta-1}{\theta}} d\omega \right)^{\frac{\theta}{\theta-1}\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}$$

subject to

$$\int_{\omega \in \Omega_u} p_{u,t}(\omega) y_{u,t}(\omega) d\omega + \int_{\omega \in \Omega_s} p_{s,t}(\omega) y_{s,t}(\omega) d\omega = E$$

where Ω_i is the mass of varieties available in sector i coming from home and foreign countries, E is the aggregate level of spending, $y_i(\omega)$ and $p_i(\omega)$ are the consumption of good ω and the price of this good respectively, θ is the elasticity of substitution within sector varieties and ρ is the elasticity of substitution between sector varieties.

These preferences generate demand functions in sector u and s, and they are

$$y_u(\omega) = \left(\frac{p_u(\omega)}{P_u} \right)^{-\theta} \frac{P}{P_u} Y = \rho_u(\omega)^{-\theta} \rho_1^{\theta-\rho} Y$$
$$y_s(\omega) = \left(\frac{p_s(\omega)}{P_s} \right)^{-\theta} \frac{P}{P_s} Y = \rho_s(\omega)^{-\theta} \rho_2^{\theta-\rho} Y$$

where the relative prices are defined as $\frac{p_u(\omega)}{P} = \rho_u(\omega)$, $\frac{p_s(\omega)}{P} = \rho_s(\omega)$, $\frac{P_u}{P} = \rho_1$, $\frac{P_s}{P} = \rho_2$ and aggregate consumption good defined as $Y \equiv U$ (utility) and $PY = E$.

The aggregate price index is denoted as

$$P = \left[P_u^{1-\rho} + P_s^{1-\rho} \right]^{\frac{1}{1-\rho}}$$

where $P_u = \left(\int_{\omega\in\Omega} p_u(\omega)^{1-\theta} d\omega\right)^{\frac{1}{1-\theta}}$ and $P_s = \left(\int_{\omega\in\Omega} p_s(\omega)^{1-\theta} d\omega\right)^{\frac{1}{1-\theta}}$ are the prices of unskilled and skilled goods respectively.

2.2.2 Firm Entry

Firms under monopolistic competition are heterogeneous in their productivity z, and pay a sunk entry cost f_e in units of aggregate consumption good. Following Ghironi and Melitz (2005), the firm entrant draws its productivity z with a Pareto distribution $G(z) = 1 - z^{-\kappa}$ after entering the market. Then, firms can make decisions for exporting and human capital investment. Human capital investment in this paper refers to how much training spending firms are able to provide workers with for skill upgrading.

2.2.3 Production

There is a continuum of firms with heterogeneous productivity z. Let $z \in \Omega$ be a particular variety. Firms endogenously choose to produce unskilled or skilled goods. Firm technology is represented by a total cost function, and the total cost under the unskilled sector is

$$TC_u(z) = f_u + \frac{w_l}{z} y_u(z)$$

where f_u is fixed production costs of the unskilled sector measured in units of aggregate consumption goods, and w_l is the real wage of low-skilled workers. More productive firms can hire high-skilled workers to produce skill-intensive goods with paying higher fixed costs $f_s > f_u$, and deliver lower marginal production costs with $\gamma > 1$ and $\beta \in (0, 1)$. w_h is the real wage of high-skilled workers. The total cost of skill-intensive goods is

$$TC_s(z) = f_s + \frac{w_h^{\beta} w_l^{1-\beta}}{\gamma z} y_s(z)$$

The profit maximization of these two sectors yields the following pricing rules of domestic sales:

$$\rho_u^d(z) = \frac{\theta}{\theta - 1} \frac{w_l}{z}$$
$$\rho_s^d(z) = \frac{\theta}{\theta - 1} \frac{w_h^{\beta} w_l^{1-\beta}}{\gamma z}$$

The two pricing rules of exporting are $\rho_s^x(z) = \tau\rho_s^d(z)$, $\rho_u^x(z) = \tau\rho_u^d(z)$. Hence, $\rho_s^d(z) = \rho_u^d(z)/\lambda$ where $\lambda \equiv \gamma\left(\frac{w_l}{w_h}\right)^{\beta}$.

Profits if producing unskilled goods and only serving the domestic market:

$$\begin{aligned}\pi_u^d(z) &= \frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_l}{z}\right)^{1-\theta}\rho_1^{\theta-\rho}Y - f_u \\ &= \frac{r_u^d(z)}{\theta} - f_u\end{aligned}$$

where firm revenue $r_u^d(z) = \left(\frac{\theta}{\theta-1}\frac{w_l}{z}\right)^{1-\theta}\rho_1^{\theta-\rho}Y$.

Profits if producing unskilled goods and exporting:

$$\begin{aligned}\pi_u^x(z) &= (1+\tau^{1-\theta})\frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_l}{z}\right)^{1-\theta}\rho_1^{\theta-\rho}Y - f_u - f_x \\ &= (1+\tau^{1-\theta})\frac{r_u^d(z)}{\theta} - f_u - f_x\end{aligned}$$

Exporting is costly, incurring iceberg trade costs τ and fixed exporting costs, f_x, measured in units of aggregate consumption goods.

Profits if producing skill-intensive goods and only serving the domestic market:

$$\begin{aligned}\pi_s^d(z) &= \frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_h^{\beta}w_l^{1-\beta}}{\gamma z}\right)^{1-\theta}\rho_2^{\theta-\rho}Y - f_s \\ &= \lambda^{\theta-1}\frac{r_u^d(z)}{\theta}\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - \phi f_u\end{aligned}$$

Profits if producing skill-intensive goods and exporting:

$$\begin{aligned}\pi_s^x(z) &= (1+\tau^{1-\theta})\frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_h^{\beta}w_l^{1-\beta}}{\gamma z}\right)^{1-\theta}\rho_2^{\theta-\rho}Y - f_s - f_x \\ &= \lambda^{\theta-1}(1+\tau^{1-\theta})\frac{r_u^d(z)}{\theta}\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - \phi f_u - f_x\end{aligned}$$

where $\phi > 1$ and $f_s > f_u$. High productivity firms find it profitable to export skilled goods with incurring higher fixed production costs, ϕf_u.

After learning the idiosyncratic productivity z, firms endogenously choose to produce unskilled or skilled goods. The least productive firms must exit the market if the domestic sales profit is negative, so the exit cutoff z_e is defined as:

$$z_e = \{z | \pi_u^d(z) = 0\}$$

z_x denotes the productivity level above which firms producing unskilled goods and finding export profitable, so

$$z_x = \{z|\pi_u^d(z) = \pi_u^x(z)\}$$

Thus, z_x can be expressed as a function of z_e with the zero profit condition for marginal exporters:

$$z_x = \tau z_e \left(\frac{f_x}{f_u}\right)^{\frac{1}{\theta-1}} \tag{2.1}$$

This condition shows that $z_x > z_e$ as long as $\tau \left(\frac{f_x}{f_u}\right)^{\frac{1}{\theta-1}} > 1$.

More productive firms are able to provide training to upgrade workers' skill levels, so they can enter the skill-intensive sector. The productivity cutoff z_s is the cutoff level where firms obtain equal profits from producing unskilled and skilled goods:

$$z_s = \{z|\pi_s^x(z) = \pi_u^x(z)\}$$

The zero profit condition for the marginal firm to produce skill-intensive goods gives the following expression of z_s as a function of z_e:

$$z_s = z_e \left[\frac{\phi - 1}{(1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - 1)}\right]^{\frac{1}{\theta-1}} \tag{2.2}$$

The restriction required for $z_s > z_e$ is $\phi - 1 > (1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - 1)$. Given $\tau \left(\frac{f_x}{f_u}\right)^{\frac{1}{\theta-1}} > 1$, the ratio of z_s and z_x is larger than one:

$$\frac{z_s}{z_x} = \left[\frac{\tau^{1-\theta}(\phi-1)f_u}{(1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - 1)f_x}\right]^{\frac{1}{\theta-1}} > 1$$

In equilibrium, there are four groups of firms. The least productive firms $z < z_e$ exit the market, the low productivity firms $z_e < z < z_x$ are not able to investment in labor training and they only serve the domestic market, the moderate productivity firms $z_x < z < z_s$ also cannot invest in human capital but can export to the foreign market, and the most productive firms $z > z_s$ are able to both export and upgrade skill levels of their workers. The productivity cutoffs in the model $z_s > z_x$ are consistent with the data since some firms find it profitable to export, but not profitable to provide labor training and produce skilled goods.

2.2.4 Equilibrium

labor Market

The aggregate demand for low-skilled workers under both the unskilled and skill-intensive sectors is:

$$\begin{aligned} L &= L_u + L_s \\ &= \int_{z_e}^{z_x} l_u^d(z)dz + \int_{z_x}^{z_s} l_u^x(z)dz + \int_{z_s}^{\infty} l_s^x(z)dz \end{aligned}$$

The aggregate demand for high-skilled workers under the skill-intensive sector is

$$H = \int_{z_s}^{\infty} h_s^x(z)dz$$

Free Entry

The present value of the average profit flows $\tilde{v} = \sum_{t=0}^{\infty}(1-\delta)^t\tilde{\pi} = \frac{\tilde{\pi}}{\delta}$ and the net value of entry is $v_e = \frac{1}{1-G(z_e)}\tilde{v} - f_e$, so the free entry condition is

$$f_e = (1 - G(z_e))\frac{\tilde{\pi}}{\delta} \tag{2.3}$$

The average profit is $\tilde{\pi} = \tilde{\pi}_u^d + n_x\tilde{\pi}_u^x + n_s\tilde{\pi}_s^x$, where $\tilde{\pi}_u^d$ is the average profit for firms that produce unskilled goods and serve the domestic market only, $n_x \equiv \frac{1-G(z_x)}{1-G(z_e)} = \left(\frac{z_x}{z_e}\right)^{-\kappa}$ is the fraction of firms that export but employ low-skilled labor and produce unskilled goods, $\tilde{\pi}_u^x$ is the average profits for exporters producing unskilled goods, and $n_s \equiv \frac{1-G(z_s)}{1-G(z_e)} = \left(\frac{z_s}{z_e}\right)^{-\kappa}$ is the fraction of exporters providing labor training and produce skilled goods, and $\tilde{\pi}_s^x$ is their average profits.

In Appendix B.2, we derive the average revenues of surviving firms is

$$\tilde{r} = \theta f_u \left(\frac{\tilde{z}_e}{z_e}\right)^{\theta-1} + n_x\theta f_x \left(\frac{\tilde{z}_x}{z_x}\right)^{\theta-1} + n_s\theta f_u(\phi-1)\left(\frac{\tilde{z}_s}{z_s}\right)^{\theta-1}.$$

After substituting $\tilde{r}$ into the free entry condition, we obtain

$$z_e = \left(\frac{1}{f_e\delta}\frac{\theta-1}{\kappa-(\theta-1)}\right)^{\frac{1}{\kappa}} [f_u + n_x f_x + n_s f_u(\phi-1)]^{\frac{1}{\kappa}} \tag{2.4}$$

where $n_x = \left(\frac{z_x}{z_e}\right)^{-\kappa} = \tau\left(\frac{f_x}{f_u}\right)^{\frac{-\kappa}{\theta-1}}$ and $n_s = \left(\frac{z_s}{z_e}\right)^{-\kappa} = \left[\frac{\phi-1}{(1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right]^{\frac{-\kappa}{\theta-1}}$

Substituting n_x and n_s into equation (2.4), we get

$$z_e = \Lambda\Phi \tag{2.5}$$

where $\Lambda \equiv \left(\frac{f_u}{f_e\delta}\frac{\theta-1}{\kappa-(\theta-1)}\right)^{\frac{1}{\kappa}}$ and

$\Phi \equiv \left[1 + \frac{f_x}{f_u}\left(\frac{f_x}{f_u}\right)^{\frac{-\kappa}{\theta-1}}\tau^{-\kappa} + (\phi-1)\left(\frac{\phi-1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right)^{\frac{-\kappa}{\theta-1}}(1+\tau^{1-\theta})^{\frac{\kappa}{\theta-1}}\right]^{\frac{1}{\kappa}}$.

By substituting the solution for the exit cutoff, we can get a solution for the export and skill upgrading cutoffs below.

$$z_x = \tau\Lambda\Phi \tag{2.6}$$

$$z_s = \Lambda\Phi\left[\frac{\phi-1}{(1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right]^{\frac{1}{\theta-1}} \tag{2.7}$$

2.2.5 Trade Liberalization

In this section, we analyze the impact of trade liberalization on export participation and skill upgrading. We find that the reduction in iceberg trade costs increases export profits, inducing more firm to enter the export market and encourage exporters to provide more labor training and produce skilled goods.

Proposition 1. A reduction in iceberg trade costs (τ):

a. increases the equilibrium skill premium, $\frac{\partial\frac{w_h}{w_l}}{\tau} < 0$

b. increases the average profit, $\frac{\partial\tilde{\pi}}{\tau} < 0$

c. increases the exit productivity cutoff, $\frac{\partial z_e}{\tau} < 0$

d. reduces the export productivity cutoff, $\frac{\partial z_x}{\tau} > 0$

e. reduces the skill upgrading cutoff, $\frac{\partial z_s}{\tau} > 0$

Proof: see Appendix B.2.1.

There is an asymmetric effect of trade liberalization since firms are heterogeneous. Market shares are reallocated from the firms producing unskilled goods to the firms providing skilled goods with a reduction in trade costs, which increases the relative demand for skilled labor. This leads to an increase in the skill premium. We also can conclude that trade integration increases firms' revenues, encourages more firms in the middle range of productivity levels to enter the export market, and makes labor training more profitable for productive exporters.

2.3 The Extended Model

2.3.1 Production

Different from the benchmark model, we assume that the foreign country can be either a main trading partner of the home country, denoted as country m, or a less preferential trading partner of the home country, denoted as country o. The home country and its main trading partner are assumed to impose the most-favored-nation (MFN) tariff, which is the lowest possible tariff a country can assess from another country. The less preferential trading partner imposes larger tariffs. In this section, two export productivity cutoffs are considered to distinguish if the firm can export to only the main country m or both countries o and m. In section 2.5.5, we regard India as a representative country o because empirically India impose higher tariffs on Chinese products compared to the rest of the world during our study period 2004–2007.

There are two types of iceberg trade costs, $\tau_m < \tau_o$, and fixed export costs, $f_{mx} < f_{ox}$, since trade barriers are lower if the home firms export to country m. Four pricing rules of export are $\rho_s^{mx}(z) = \tau_m \rho_s^d(z)$, $\rho_s^{ox}(z) = \tau_o \rho_s^d(z)$, $\rho_u^{mx}(z) = \tau_m \rho_u^d(z)$ and $\rho_u^{ox}(z) = \tau_o \rho_u^d(z)$.

Profits if producing unskilled goods and only serving the domestic market:

$$\begin{aligned}\pi_u^d(z) &= \frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_l}{z}\right)^{1-\theta}\rho_1^{\theta-\rho}Y - f_u \\ &= \frac{r_u^d(z)}{\theta} - f_u\end{aligned}$$

Profits if producing unskilled goods and exporting to country m:

$$\begin{aligned}\pi_u^{mx}(z) &= (1+\tau_m^{1-\theta})\frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_l}{z}\right)^{1-\theta}\rho_1^{\theta-\rho}Y - f_u - f_{mx} \\ &= (1+\tau_m^{1-\theta})\frac{r_u^d(z)}{\theta} - f_u - f_{mx}\end{aligned}$$

Profits if producing unskilled goods and exporting to country o:

$$\pi_u^{ox}(z) = (1+\tau_o^{1-\theta})\frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_l}{\gamma_u z}\right)^{1-\theta}\rho_1^{\theta-\rho}Y - f_u - f_{ox}$$
$$= (1+\tau_o^{1-\theta})\frac{r_u^d(z)}{\theta}\gamma_u^{\theta-1} - f_u - f_{ox}$$

Profits if producing skill-intensive goods and exporting to country m:

$$\pi_s^{mx}(z) = (1+\tau_m^{1-\theta})\frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_h^{\beta}w_l^{1-\beta}}{\gamma_m z}\right)^{1-\theta}\rho_2^{\theta-\rho}Y - f_{ms} - f_{mx}$$
$$= \lambda_m^{\theta-1}(1+\tau_m^{1-\theta})\frac{r_u^d(z)}{\theta}\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - \phi_m f_u - f_{mx}$$

Profits if producing skill-intensive goods and exporting to country o:

$$\pi_s^{ox}(z) = (1+\tau_o^{1-\theta})\frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_h^{\alpha}w_l^{1-\alpha}}{\gamma_o z}\right)^{1-\theta}\rho_2^{\theta-\rho}Y - f_{os} - f_{ox}$$
$$= \lambda_o^{\theta-1}(1+\tau_o^{1-\theta})\frac{r_u^d(z)}{\theta}\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - \phi_o f_u - f_{ox}$$

where $f_{ox} > f_{mx}$, $f_{os} > f_{ms} > f_u$, $\alpha > \beta$, $\gamma_o > \gamma_m > \gamma_u > 1$ and $\phi_o > \phi_m > 1$.

Firms with productivity above z_{mx} export to country m (the main trading partner) while they can export to country o if their productivity is above z_{ox}. Thus, these two export productivity cutoffs are

$$z_{mx} = \{z|\pi_u^d(z) = \pi_u^{mx}(z)\} \qquad z_{ox} = \{z|\pi_u^{mx}(z) = \pi_u^{ox}(z)\}$$

The productivity cutoff of producing skill-intensive goods (skill upgrading) is also different from the one in the benchmark model. The highly productive firms find it profitable to provide labor training when trading with country m, and the most productive firms are able to export to country o and invest in human capital; thus the two productivity cutoffs of skill upgrading are

$$z_{ms} = \{z|\pi_u^{ox}(z) = \pi_s^{mx}(z)\} \qquad z_{os} = \{z|\pi_s^{mx}(z) = \pi_s^{ox}(z)\}$$

In equilibrium, firms sort into six different groups: the least productive firms ($z < z_e^{'}$) exit the market, the low productivity firms ($z_e^{'} < z < z_{mx}$) employ low-skilled labor and serve only the home country, the lower-middle productivity firms ($z_{mx} < z < z_{ox}$) employ low-skilled labor and export to country m; the upper-middle productivity firms ($z_{ox} < z < z_{ms}$) export unskilled goods to country o; the high productivity firms ($z_{ms} < z < z_{os}$) export to country m but is able to employ skilled labor, the most productive firms ($z > z_{os}$) can export to country o and provide labor training.

$$z_{mx} = z_e^{'}\tau_m \left(\frac{f_{mx}}{f_u}\right)^{\frac{1}{\theta-1}} \tag{2.8}$$

$$z_{ox} = z_e^{'}\left(\frac{f_{ox} - f_{mx}}{((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - \tau_m^{1-\theta} - 1)f_u}\right)^{\frac{1}{\theta-1}} \tag{2.9}$$

$$z_{ms} = z_e^{'}\left[\frac{(\phi_m - 1)f_u + f_{mx} - f_{ox}}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)f_u}\right]^{\frac{1}{\theta-1}} \tag{2.10}$$

$$z_{os} = z_e^{'}\left[\frac{f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u}{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta}) - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}f_u}\right]^{\frac{1}{\theta-1}} \tag{2.11}$$

2.3.2 Equilibrium

Labor Market

The aggregate demand for low-skilled workers in both the unskilled and skill intensive sectors is

$$\begin{aligned} L^{'} &= L_u^{'} + L_s^{'} \\ &= \int_{z_e^{'}}^{z_{mx}} l_u^d(z)dz + \int_{z_{mx}}^{z_{ox}} l_u^{mx}(z)dz + \int_{z_{ox}}^{z_{ms}} l_u^{ox}(z)dz + \int_{z_{ms}}^{z_{os}} l_s^{mx}(z)dz + \int_{z_{os}}^{\infty} l_s^{ox}(z)dz \end{aligned}$$

while the aggregate demand for high-skilled workers in the skill-intensive sector is

$$H^{'} = \int_{z_{ox}}^{z_{ms}} h_s^{mx}(z)dz + \int_{z_{os}}^{\infty} h_s^{ox}(z)dz$$

Free Entry

The numbers of firms exporting unskilled or skilled goods to country m and country o can be derived as: $n_{mx} = \left(\frac{z_{mx}}{z_e^{'}}\right)^{-\kappa}$, $n_{ox} = \left(\frac{z_{ox}}{z_e^{'}}\right)^{-\kappa}$, $n_{ms} = \left(\frac{z_{ms}}{z_e^{'}}\right)^{-\kappa}$ and $n_{os} = \left(\frac{z_{os}}{z_e^{'}}\right)^{-\kappa}$. The average profit is $\tilde{\pi} = \tilde{\pi}_u^d + n_{mx}\tilde{\pi}_u^{mx} + n_{ox}\tilde{\pi}_u^{ox} + n_{ms}\tilde{\pi}_s^{mx} + n_{os}\tilde{\pi}_s^{ox}$, and it can be described in this way:

$$\tilde{\pi}' = \frac{\tilde{r}'}{\theta} - f_u - n_{mx}f_{mx} - n_{ox}(f_{ox} - f_{mx}) - n_{ms}((\phi_m - 1)f_u + f_{mx} - f_{ox}) - n_{os}((\phi_o - \phi_m)f_u + f_{ox} - f_{mx})$$

Similar to the benchmark model, we can derive the average revenues $\tilde{r}'$ expressed as the productivity cutoffs:

$$\tilde{r} = \theta f_u \left(\frac{\tilde{z}_e'}{z_e'}\right)^{\theta-1} + n_{mx}\theta f_{mx}\left(\frac{\tilde{z}_{mx}}{z_{mx}}\right)^{\theta-1} + n_{ox}\theta(f_{ox} - f_{mx})\left(\frac{\tilde{z}_{ox}}{z_{ox}}\right)^{\theta-1} + n_{ms}\theta(f_u(\phi_m - 1) + f_{mx} - f_{ox})\left(\frac{\tilde{z}_{ms}}{z_{ms}}\right)^{\theta-1} + n_{os}\theta(f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u)\left(\frac{\tilde{z}_{os}}{z_{os}}\right)^{\theta-1}$$

After substituting $\tilde{r}'$ into the free entry condition, we obtain

$$z_e' = \left(\frac{\theta - 1}{\kappa - (\theta - 1)}\frac{1}{\delta f_e}\Psi\right)^{1/\kappa} \tag{2.12}$$

where $\Psi^\kappa = f_u + n_{mx}f_{mx} + n_{ox}(f_{ox} - f_{mx}) + n_{ms}(f_u(\phi_m - 1) + f_{mx} - f_{ox}) + n_{os}(f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u)$.

2.3.3 Trade Liberalization

We have two additional propositions below.

Proposition 2. A reduction in iceberg trade costs of country m (τ_m):

a. increases the average profit, $\frac{\partial \tilde{\pi}'}{\tau_m} < 0$

b. increases the exit productivity cutoff, $\frac{\partial z_e'}{\tau_m} < 0$

c. reduces the productivity cutoff of exporting to country m, $\frac{\partial z_{mx}}{\tau_m} > 0$

d. reduces the skill-upgrading cutoff of exporters to country m, $\frac{\partial z_{ms}}{\tau_m} > 0$

Proof: Please see Appendix B.2.2. Part d is established only when certain conditions are met.

Proposition 3. A reduction in iceberg trade costs of country o (τ_o):

a. increases the average profit, $\frac{\partial \tilde{\pi}'}{\tau_o} < 0$

b. increases the exit productivity cutoff, $\frac{\partial z_e'}{\tau_o} < 0$

c. reduces the productivity cutoff of exporting to country m, $\frac{\partial z_{mx}}{\tau_o} > 0$

d. reduces the productivity cutoff of exporting to country o, $\frac{\partial z_{ox}}{\tau_o} > 0$

e. increases the skill-upgrading productivity cutoff of exporters to country m, $\frac{\partial z_{ms}}{\tau_o} < 0$

f. reduces the skill-upgrading productivity cutoff of exporters to country o, $\frac{\partial z_{os}}{\tau_o} > 0$

Proof: Please see Appendix B.2.2. Parts c and d are established only when certain conditions are met.

2.4 Trade Policies and Data

2.4.1 Post-WTO Accession Trade Liberalization in China

Trade liberalization policies undertaken in China after WTO accession are described in this session. First, China joined WTO in 2001 and continued trade liberalization from 2001-2005. For instance, China bounded all tariff lines and the average applied most-favored nation (MFN) rate dropped from 15.6% in 2001 to 9.7% in 2005, with the manufactured goods rate declining from 14.3% to 8.9%, and agricultural products rate decreasing from 23.2% to 14.6% during the same period (Bin, 2015). This indicates that China made a great achievement of import liberalization. Meanwhile, China's industrial goods conquered the global markets after it joined the WTO in 2001. China doubled its share of trade in manufactured goods from 7.9% in 2000 to 17.7% in 2012 (Hilpert, 2014). According to UNCTADStat, its share of global export goods was 3.9% in 2000, and went up to 14.7% in 2020. FDI in China was less restricted after WTO accession, so China became the most important global investment destination. According to the World Bank, the net inflows FDI in China started with 42.1 billion dollars in 2000 and achieved a peak level at 290.9 billion dollars in 2013. Furthermore, China overtook US as the world's leading destination for FDI in 2020.

Next, we describe an important regional trade liberalization—Asian Pacific Trade Agreement (APTA). APTA, previously the Bangkok Agreement, was signed in 1975 and renamed in 2005. Bangladesh, China, India, Lao PDR, Mongolia, Republic of Korea, and Sri Lanka are the current parties. APTA promotes intra-regional trade and contributes to economic development of the seven developing countries through trade and investment liberalization. China acceded APTA in 2001 and endorsed a preferential trade arrangement among developing Asian countries. In 2005, the first Ministerial Council was held in Beijing, China and the third round of negotiation results was implemented in 2006. Trade and tariff data from World Integrated Trade Solution (WITS) between 2004 and 2007 (see Figure 2.1) shows that India became the most preferential trading partner of China. This paper emphasizes the impact of APTA on exports and human capital investment of Chinese manufactured firms theoretically and empirically. India is selected as a representative country, which imposed much higher tariffs than the rest of the world in 2004, but also reduced trade barriers with China more significantly from 2004 to 2007. More trade agreements among APTA members were made after 2007,[7] which will not be our focus.

2.4.2 Firm-Level Data

We resort to two data sources to construct a balanced panel of manufacturing firms in China. First of all, we obtain data from the Chinese Industrial Enterprises Database (CIED). The CIED is constructed by China's National Bureau of Statistics (CNBS) mainly based on the annual or quarterly reports submitted to local bureau of statistics. The database contains all industrial enterprises that are non-state-owned and "large-scale"[8] or state-owned. In the

[7] A new Asia-Pacific trade deal was created in November 2020. It is a new overarching Regional Comprehensive Economic Partnership (RCEP) Free Trade Agreement (FTA) between 15 Asia-Pacific countries. Its signatories are the 10 members of the Association of Southeast Asian Nations (ASEAN) countries and Japan, Korea, China, Australia and New Zealand. The signing of the RCEP aims to facilitate regional or even world trade and investment further. RCEP connects about 30% of the world's population and output, makes the Asian economies more efficient, and improves technology and solidifies global value chains. China continues to benefit from trade openness.

[8] That is, the main business income of an enterprise was larger than 5 million RMB, and this standard was revised to 20 million RMB in 2011.

database, approximately 90% of the enterprises are manufacturing firms, which will be what we focus on in this research. Although the database spans from 1998 to 2013, information about on-the-job training spending (TS), which is our main measure of skill upgrading in the empirical analysis, is only available in 2004–2007, which is exactly the regional trade liberalization period we emphasize. This database has been exploited by economists such as Hsieh and Klenow (2009), Song et al. (2011), Brandt et al. (2017), as well as Huang and Zhuang (2021), who provide more details about this database. From CIED, we also learn about each firm's total sales (which include both domestic and export sales) and number of employees, other than TS.

Second, we collect dis-aggregated information from the China Customs Database (CCD). It provides the data of exports by firm, 8-digit HS product, and destination country. We merge the information from CCD to the CIED according to the firms' names, postal codes, or telephone numbers, following Ruiqin et al. (2019).[9] We then aggregate export data at the 4-digit CIC industry level for each firm-destination country pair (some firms operate in multiple industries domestically and/or globally).

Next, we select the firms in the sectors that are covered by India's consolidated list of concessions of the first 3 rounds of negotiations to APTA member countries and in the 4-digit CIC industries with information on India's tariffs. We ended up with a balanced panel of 110,632 manufacturing firms (operating in 131,460 4-digit CIC industries) in each year from 2004 to 2007. The sample is representative of firms owning establishments with more than 10 employees that can potentially be affected by APTA.

By merging the CIED and CCD data, we can calculate the total sales per employee for each firm, which will be one of our firm-level controls. Moreover, domestic sales can be calculated by subtracting the export sales from total sales. One special feature of the data is that we know each firm's export sales to each destination country, including India—we can therefore learn about whether a firm exports to India or not.

Table B.1 in Appendix B.3 contains summary statistics by export status for the main variables of interest for the initial year, 2004.

[9] The numbers of merged manufacturing enterprises are 52,046 in 2004, 51,026 in 2005, 60,345 in 2006, and 61,749 in 2007. These correspond to 38.1%, 37.7%, 27.8%, and 28.9% of the enterprises in CCD.

2.4.3 Industry-Level Data

In the empirical section we use controls for 4-digit CIC industry characteristics that might be correlated with changes in tariffs. We first obtain average capital and skill intensity in the industry in the United States in the 1980s from the National Bureau of Economic Research (NBER) productivity database (see Appendix B.3 for details). We also use the import demand elasticity and export supply elasticity as estimated by Broda and Weinstein (2006) and Broda et al. (2008).

2.5 Empirics

In this section we test the theoretical predictions developed in Sections 2.2 and 2.3. First, we check whether the sorting pattern of firms into exporting and training predicted by the model is consistent with the observed characteristics of exporters to different countries and non-exporters operating in the same four-digit CIC industry. Second, we test the main predictions of our model: a reduction in export tariffs encourages firm entry in the export market and induces skill upgrading. We focus on the regional trade liberalization (APTA) effect, as we select the sectors covered by India's consolidated list of concessions of the first 3 rounds of negotiations to APTA member countries.

2.5.1 Within-Industry Patterns in the Data

In the benchmark model, underlying productivity differences produce a sorting of firms into four groups: the least productive firms exit the market (not in data), the low productivity firms produce unskilled goods and serve the domestic market only, the middle ones still produce unskilled goods but also export, and the most productive firms both export and provide labor training for skilled goods production. In this setting, a reduction in trade costs τ increases export profits, inducing more firms in the middle range of the productivity distribution to enter the export market and upgrade workers' skill levels. Figure 2.2 indicates the effects of trade liberalization for firms in each range of the productivity distribution through reflecting the changes in productivity cutoffs from 2004 to 2007. Precisely speaking, firms with intermediate productivity find it easier to start exporting and the more productive firms also have greater incentives to provide labor training.

In the extended model, we distinguish the trade effects of two export destinations, countries m and o. Country m refers to a main trading partner of the home country, while country o is a less preferential trading partner since it imposes a higher tariff ($\tau_o > \tau_m$). This paper refers to India as a representative country o. In this case, firms sort into six groups: the least productive firms exit the market, the low productivity firms produce unskilled goods and serve the domestic market only, the lower-middle ones still produce unskilled goods but also export to country m, the upper-middle ones export unskilled goods to country o, the high productivity firms are able to provide labor training but export skilled goods to country m, and the most productive firms can export skilled goods to country o. Figure 2.3 also displays the effect of trade liberalization for firms in each part of the productivity distribution. In particular, as shown by the shaded areas, firms switching export markets from country m to o could continue producing unskilled goods, start skill downgrading, or begin skill upgrading.[10]

To check whether the sorting patterns depicted in Figures 2.2 and 2.3, and the parameter restrictions required to obtain the model are consistent with the data, we follow Bustos (2011b) to divide firms into four groups: continuing exporters, new exporters, exiting exporters and firms serving the domestic market only (never exporters), and compute the differences in characteristics, including sales, employment and training spending per worker, for firms operating within the same four-digit CIC industry.

First, Table 2.1 indicates that, based on the basic model, all types of exporters have higher sales, employment, and training spending per worker than never exporters in 2004 on average, which mirrors the fact that (potential) exporters are larger, more productive and more skill-intensive. Second, although sales and employment of new exporters are relatively lower than incumbent exporters in 2004, their per capita training spending is higher than continuing exporters on average, preparing them to enter the skill-intensive sector and employ more high-skilled workers. Third, the increase in training spending per worker for continuing exporters are almost zero from 2004 to 2007 (trade liberalization period), but

[10] The extended model does not reflect trade-induced switching from country o to m. There should be an exogenous shock that leads to this switching.

exiting exporters that later serve the domestic market only reduce labor training.[11] On the contrary, new exporters have the largest average increases in sales, employment, and training spending per worker compared to never exporters. These results indicate that new exporters benefit more from trade liberalization and has greater incentives in human capital investment. It is intuitive that new exporters might demand more high-skilled workers in order to become more competitive in the foreign market.

In terms of the extended model, we distinguish two export markets, country m and o. Exporters to India have higher sales, employment, and training spending per worker in 2004 than those exporting to non-Indian countries (except for those who switch destinations) as shown in Table 2.1, which is consistent with the model setting that firms exporting to India are more productive, conditional on skill level. Moreover, firms switching from non-India to Indian markets in 2004 have slightly higher training spending per worker than those doing the converse, which shows that more of them started to produce high-skilled products earlier. From 2004 to 2007, there is a larger decline in India's tariffs and a greater increase in exports to India compared to those of other countries (Figure 2.1). Therefore, new exporters targeting Indian markets have even larger average increases in sales and employment than those targeting non-Indian markets. However, interestingly, new exporters targeting India have a slightly less significant average increase in training spending per worker than those targeting non-Indian countries. This is probably due to the fact that they have already spent more in training their workers in 2004 before changes in trade costs τ_o, or there could be sector heterogeneity. Moreover, continuing exporters targeting non-Indian markets had even lower average increases in sales and employment than those targeting India, although their increases in average per capita training spending were almost the same. Additionally, there are firms switching export destinations during the same period. Table 2.1 shows that the trade liberalization period coincides with a slightly higher increase in training pending per worker among firms who switch export markets from country o to m, which supports our model assumption that some firms could find it more profitable to export skilled goods to

[11] Based on the number of industry-level observations and the number of distinct firms, we can see that only continuing exporters operate in multiple industries, while exiting and new exporters both operated in a single industry.

country m than to export unskilled goods to country o who imposes higher (but declining) trade barriers. For firms who switch destinations from m to o, the increase in per capita training is not so significant. This result is actually also in line with the model in some way, as two shading areas in Figure 2.3 imply that these firms either start skill downgrading or continue producing unskilled goods. Thus, the average effect of labor training could be ambiguous.

The pattern in the Table 2.1 shows that there is coincidence between entry in the export market and skill upgrading, and the performance of exporters targeting the Indian market differs from other firms, but we cannot establish whether it is better export opportunities that induce human capital investment or vice versa, or whether both are caused by a third factor. The next empirical exercise is to establish causality by linking exporting and skill upgrading directly to the reduction in India's tariffs for imports from China.

2.5.2 The Impact of the APTA: Identification Strategy

After China joined APTA in 2001, a reduction in India's tariffs for imports from China across four-digit CIC industries leads to changes in Chinese firms' entry in the export market and skill upgrading. There are two features of the source of identification that make it exogenous with respect to these two outcomes of interest. First, the tariff reductions were constantly adjusted and negotiated among APTA members during 2004 and 2007. In our data, the average tariff facing manufacturing firms in the sectors covered by APTA decreases from about 28.59 percentage points in 2004 to 13.43 percentage points in 2007. These tariff reductions are not likely to be determined by any individual firm in a specific country. Second, the 2004 simple average effectively applied (AHS) import tariff of India for China was close to those of the rest of the world.[12] Import tariffs of India are unlikely to be targeted to industry characteristics particular to China. Share of India's imports from China was 6.11% in 2004, but rose to 11.24% in 2007, since India's average tariff declined by more than a half during the same period.

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[12] According to WITS, the simple average AHS tariffs of India for China and the world are 28.78 and 28.57 percentage points respectively in 2004. In terms of the simple average MFN tariff, the 2004 tariff rates of India are 28.78 percentage points for China and 29.51 percentage points for the world.

The reverse causality problem may not be a concern, but India's initial tariff structure is surely not random. India's trade policy is correlated with some industry characteristics, so omitting them could lead to a source of bias. Hence, we estimate all the equations in first differences to eliminate constant industry characteristics. Still, India's tariffs could capture some omitted industry-level time-varying variable if industries with different initial characteristics are on different trends. In order to further address this issue, we include in the first-differenced equations sector dummies to control for unobserved sector trends, and also include four-digit CIC level controls for industry characteristics such as import demand elasticity, export supply elasticity, and capital and skill intensity.

We use the India's tariffs to measure the effect of increased export opportunities on export participation and skill upgrading, but these influences might be correlated with changes in China's tariffs. Thus, we control for the changes in China's tariffs with respect to the world between 2004 and 2007, as well as the changes in China's tariffs with respect to India.[13]

Under the benchmark model, the reduction in India's tariffs induces entry in the export market and skill upgrading for firms in the middle range of the productivity distribution rather than affects the least and most productive groups. The extended model also predicts that firms in the middle or upper-middle range have a higher likelihood of exporting, switching export destinations and starting skill downgrading or upgrading following trade integration. To study these heterogeneous effects of firm productivity, we use firm size relative to the four-digit CIC industry mean in 2004 as a proxy for initial productivity and divide firms into quartiles. In the next section, we discuss the empirical results of how the reduction in India's tariffs affects each quartile of the firm size distribution through emphasizing export entry and skill upgrading decisions, and compare them with our theoretical findings.

2.5.3 Export Markets Entry Decision

In this section, we intend to recover the signs of the partial derivatives of interest in the model of the export markets entry choices described by equations (2.6), as well as (2.8) and

[13] Both final goods and intermediate inputs tariffs are controlled.

(2.9). To do so, we estimate a linearized version of the entry models and access the economic significance of the estimated coefficients. We first describe estimation of the average effect of a reduction in India's tariffs on entry in the export market for all firms. Next, we distinguish the export markets, comparing non-Indian countries with India.

Consistent with the benchmark model, we empirically analyze the export entry decision using an index model:

$$EX_{ijst}^{k} = \begin{cases} 1 & \text{if } \beta_{\tau^{ex}}^{k}\tau_{jt}^{ex} + \alpha_{st}^{k} + \mu_{i}^{k} + \epsilon_{ijst}^{k} > 0 \\ 0 & \text{otherwise} \end{cases} \tag{2.13}$$

where i indexes firms; j indexes four-digit CIC industries; s indexes sectors; t indexes years from 2004 to 2007; τ_{jt}^{ex} are India's tariffs that vary across four-digit CIC industries and time; α_{st}^{k} are sector dummies that capture time-varying sector features; μ_{i}^{k} are firm fixed effects capturing unobserved constant heterogeneity including firm heterogeneity z defined in the model and other characteristics affecting productivity cutoffs; EX_{ijst}^{k} is a dummy that captures firms' export decisions to any partner or India. When $k = 0$, firms can either be exporters or non-exporters; EX_{ijst}^{0} takes the value of 1 if a firm exports to any country in the world in year t and 0 otherwise. If $k = 1$, the firm is an exporter; $EX_{ijst}^{1} = 1$ when the firm exports to India (and potentially other counrties at the same time), and $EX_{ijst}^{1} = 0$ if the firm exports only to non-Indian countries.

First-Differenced Specification

We take first differences to eliminate time-invariant plant and sector heterogeneity, and obtain

$$\Delta EX_{ijst}^{0} = \beta_{\tau^{ex}}^{0}\Delta\tau_{jt}^{ex} + \Delta\alpha_{st}^{0} + \Delta\epsilon_{ijst}^{0} \tag{2.14}$$

In the meantime, we control for changes in China's import tariffs for both outputs and inputs with respect to the world and India ($\Delta\tau_{jt}^{im}$), the firm characteristics in the initial year (2004) such as the number of workers and sales per worker (z_{ij2004}), and four-digit industry characteristics like the import demand and export supply elasticities, skill and capital intensity in the United States (c_j).[14] Hence, we have the following equation:

$$\Delta EX^0_{ijst} = \beta^0_{\tau^{ex}} \Delta\tau^{ex}_{jt} + \beta^0_{\tau^{im}} \Delta\tau^{im}_{jt} + \beta^0_z Z_{ij2004} + \beta^0_c c_j + \Delta\alpha^0_{st} + \Delta\epsilon^0_{ijst} \tag{2.15}$$

Estimation of equation (2.14) is reported in column 1 of Table 2.1, and the regression coefficients including other controls (equation 2.15) are shown in columns 2 to 8. From panel A of Table 2.2, we find that a reduction in India's tariffs increases the likelihood of entry in the export market for the sample of selected sectors. For instance, columns 5 and 8 indicate that the probability of firm entry in the export market increases by 1.55 percentage points when the average reduction in India's tariffs is around 15 percentage points from 2004 to 2007. This empirical result is consistent with the model prediction that a reduction in trade costs increases firm profit and encourages export participation. Interestingly, only certain sectors show a significant relationship between trade openness and export participation by Chinese firms, and the coefficients are not statistically significant for other sectors as shown in panel B of Table 2.2. Due to sector heterogeneity, there are some limitations of the model, which may not be able to distinguish firm performance (in particular, export decisions) in different sectors after trade liberalization. The different results in panels A and B imply that diverse trade policies could be necessary to further encourage exports because of the heterogeneous features across sectors.

Lagged-Dependent Variable

To check for robustness, we implement two more exercises. First, current export decisions might be influenced by lagged export status because of sunk export costs. Therefore, we control the export status in the previous year and estimate the equation in levels with the following regression:

$$EX^0_{ijst} = \beta^0_{\tau^{ex}} \Delta\tau^{ex}_{jt} + \gamma^0 EX^0_{ijs,t-1} + \alpha^0_{st} + \epsilon^0_{ijst} \tag{2.16}$$

The second check is to create a sample of baseline non-exporters under selected sectors and estimate the equation (2.16) that is restricted to non-exporters in 2004. This estimation

[14] We calculate elasticities sand intensity following Broda and Weinstein (2006) and Broda et al. (2008).

highlights the effects of changing tariffs on initial non-exporters as we notice that trade liberalization between 2004 and 2007 has a greater positive impact on sales, employment and labor training of new exporters in Table 2.1. The estimates in panels C and D of Table 2.2 are very close to the coefficients of changes in India's tariffs in panel A. This implies that our estimated results of the export entry decision are fairly robust.

Export Decision by Quartile of the Firm Size Distribution

The benchmark model predicts that lower trade costs induce entry in the export market for firms with intermediate productivity levels since a reduction in trade costs decreases the export productivity cutoff z_x. More precisely, as depicted by Figure 2.2, the export productivity cutoff in 2007 (z_x^1) is much lower than the initial cutoff (z_x^0). Firms with productivity in the range $z_x^1 < z < z_x^0$ become exporters following trade liberalization. The less productive firms still stay out of the market or serve domestic market only and the most productive firms continue exporting. Empirically, we estimate the impact of the change in India's tariffs on each quartile of the initial firm size distribution with the following equation:

$$\Delta EX_{ijst}^0 = \sum_{n=1}^{4} \beta_{\tau^{ex},n}^0 (\Delta\tau_{jt}^{ex} \times Q_{ij,n}) + \sum_{n=1}^{4} \delta_n^0 Q_{ij,n} + \beta_{\tau^{im}}^0 \Delta\tau_{jt}^{im} + \Delta\alpha_{st}^0 + \Delta\epsilon_{ijst}^0 \qquad (2.17)$$

where n is each of the four quartiles of the firm size distribution and $Q_{ij,n}$ are dummy variables being 1 when firm i belongs to quartile n. Columns 1 to 9 of Table 2.3 show that the effect of the reduction in India's tariffs on firm entry in the export market is significant in the last three quartiles of the firm size distribution, while firms in the fourth quartile ($\beta_{\tau^{ex},4} = -0.17$) actually receive larger influences from changing in tariffs than those in the second ($\beta_{\tau^{ex},2} = -0.11$) and third quartiles ($\beta_{\tau^{ex},3} = -0.13$) within the selected sectors. Columns 4 to 6 present estimation of the above equation in levels controlling for lagged export status. The point estimates of $\beta_{\tau^{ex},n}$ are a bit larger, but still have the same pattern. Additionally, the estimated results of the sample of non-exporters in 2004 are smaller than those of the full sample, and the impacts of trade costs on the third and fourth quartiles are more significant compared to the first and second quartiles. In particular, the point estimates of $\beta_{\tau^{ex},3}$ in columns 4 and 7 imply that the the average decline in India's tariffs

(15 percentage points) increases the probability to participate in the export market by 2.13 percentage points for all firms in the selected sectors and 1.64 percentage points for the sample of non-exporters in 2004.

All coefficients ($\beta_{\tau^{ex},n}$) are negative within the selected sectors (columns 1 to 9) though some firms in the first quartile are not always statistically significant. This suggests that some firms in the first quartile are less likely to be induced to export with a reduction in India's tariffs, which is consistent with the model prediction. Nevertheless, the firm size distribution may not be a good measure of firm productivity and the export productivity cutoffs could differ across industries, which explains the significance of the fourth quartile.

Overall, most of firms in the first quartile are still below the productivity threshold of exports after liberalization, while firms in the middle range (second and third quartiles) of the size distribution are more likely to be induced to enter in the export market. However, the empirical findings show that firms in the fourth quartile have the largest incentive to enter the export market as the absolute value of $\beta_{\tau^{ex},4}$ is the biggest in each column of selected sectors. This result is not in line with the model prediction that the most productive firms would always export regardless of tariffs. Besides the initial firm size not being a perfect measure, some relevant policies in China could help explain this finding. Former Chinese leader Hu Jintao encouraged large-scale enterprises to participate the export market and implemented the the Eleventh Five-Year Plan in 2006. In particular, the chapter 11 of the Eleventh Five-Year Plan includes goals to revitalize manufacturing of major technical equipment, strengthen the shipbuilding industry and improve the performance of the automotive industry. Therefore, this policy can explain why more firms in the fourth quartiles enter the export market during the trade-integration period.

Even though the impact of trade liberalization on other sectors is not significant on average as shown in panel B of Table 2.2, the export decision of the fourth quartile of the firm size distribution is significantly and negatively affected by trade costs with point estimates around -0.05 presented in columns 10–12 of Table 2.3. This suggests that the 15 percentage point decline in India's tariffs also increases the probability of firms in the fourth quartile to enter in the export market by 0.75 percentage points in other sectors from 2004 to 2007. Thus, trade liberalization induces more entry in the export market for moderately productive firms (consistent with the benchmark model) only within certain specific sectors.

2.5.4 Skill Upgrading Decision

In this section, we focus on the skill upgrading decisions made by firms. The decision of providing labor training is described in equations (2.7), (2.10) and (2.11). Following the estimation of equation (2.15), in addition to India's tariffs, we control for China's import tariffs regarding outputs and inputs, four-digit CIC industry characteristics, sector dummies and plant fixed effects; thus, the level of investment in on-the-job training can be expressed as:

$$\log TS_{ijst} = \beta_{\tau^{ex}} \tau_{jt}^{ex} + \beta_{\tau^{im}} \tau_{jt}^{im} + \alpha_{st} + \mu_i + \epsilon_{ijst} \tag{2.18}$$

where TS denotes a firm's spending of labor training; τ_{jt}^{im} are China's import tariffs, which also affect firm revenues and skill upgrading decisions.

First-Differenced Estimation

Similarly, we estimate equation (2.18) in first differences to eliminate constant plant and sector heterogeneity:

$$\Delta \log TS_{ijst} = \beta_{\tau^{ex}} \Delta\tau_{jt}^{ex} + \beta_{\tau^{im}} \Delta\tau_{jt}^{im} + \Delta\alpha_{st} + \Delta\epsilon_{ijst} \tag{2.19}$$

Panel A of Table 2.4 indicates that trade liberalization between 2004 and 2007 induces more investment in on-the-job training by manufacturing firms in selected sectors. In particular, columns 5 and 8 of panel A with inclusion of additional controls shows that the 15 percentage point decline in India's tariffs increases labor training provided by firms by about 0.11 to 0.13 log points. When trade costs become lower, the productive firms earn greater revenues, so they have higher incentives to increase human capital investment and produce skill-intensive products more.

Nevertheless, there are reverse findings in other sectors from panel B of Table 2.4 with average point estimates around 0.15 (a 0.02 log point reduction in training spending occurs when India's tariffs drop by 15 percentage points). In these sectors, firms reduce labor training even though trade barriers decline. There could be several reasons. First, the productivity (not directly observed) of more firms in these sectors may fall between z_{ms}^0 and z_{ms}^1 in Figure 2.3, so the reduction in India's tariffs may not affect their export participation (not specific to any country) as shown by Table 2.2, but can cause skill downgrading. Second, the local government may finance labor training when trade barriers are high, but reduce fiscal support when trade barriers become lower. Findings from panels A and B imply that sector heterogeneity in productivity and policy plays a role in affecting skill upgrading decisions following trade integration. The theoretical model explains trade-induced investment in on-the-job training within some sectors, while providing a possibility of skill downgrading in other sectors where firms are around the cutoff of switching destination countries due to an increase in skill upgrading productivity cutoff in country m.

In terms of the sample of non-exporters in 2004 in selected sectors, the estimation in panel C of Table 2.4 implies that skill upgrading in response to a reduction in India's tariff is still positive but less precise. The estimated coefficients for the sample of exporters in 2004 in selected sectors are also insignificant as presented in panel D. One possible explanation is that some continuing exporters switch to the Indian market due to an increase in skill upgrading productivity cutoff in non-Indian countries and no longer produce high-skill products, and some exiting exporters no longer demand high-skill workers when serving the domestic market only.[15]

Skill Upgrading Decision by Quartile of the Firm Size Distribution

The benchmark model predicts that lower trade costs encourage firms operating in the range $z_s^1 < z < z_s^0$ to provide more labor training, since a reduction in trade costs decreases the skill upgrading productivity cutoff z_s. As shown in Figure 2.2, these firms are in the middle range of the productivity distribution, and they invest more in human capital following trade liberalization. The least and the most productive firms wouldn't change their decisions of labor skill upgrading in response to trade openness. Empirically, we estimate the impact of the change in India's tariffs on each quartile of the initial firm size distribution with the

[15]Although not shown in Table 2.2, the effect of trade liberalization on entry in the export market is less statistically significant (although larger) in the sample of baseline exporters.

following equation:

$$\Delta \log TS_{ijst} = \sum_{n=1}^{4} \beta_{\tau^{ex},n}(\Delta\tau_{jt}^{ex} \times Q_{ij,n}) + \sum_{n=1}^{4} \delta_n Q_{ij,n} + \beta_{\tau^{im}}\Delta\tau_{jt}^{im} + \Delta\alpha_{st} + \Delta\epsilon_{ijst} \quad (2.20)$$

where n is each of the four quartiles of the firm size distribution and $Q_{ij,n}$ are dummy variables being 1 when firm i belongs to quartile n. Columns 1–3 of Table 2.5 show that the effect of the reduction in India's tariffs on investment in on-the-job training is significant in the first three quartiles of the firm size distribution for the full sample of selected sectors. Trade liberalization has a relatively larger impact on the skill upgrading decision of firms in the second quartile. For instance, the 15 percentage point reduction in India's tariffs from 2004 to 2007 increases spending on training of firms in the second quartile by 0.18 log points, while firms in the first and third quartiles increase labor training by only about 0.14 log points. As the model predicts that firms with productivity in the middle range are sensitive to changes in trade costs, so the reduction in the tariffs positively affects skill upgrading decisions of firms in the second and third quartiles.

One question is: why firms in the low or lower-middle range of the size distribution choose to increase human capital investment after liberalization? The benchmark model cannot match this empirical result. One possible reason is that Chinese local governments protect some smaller domestic firms and state-owned enterprises. The less productive firms could receive subsidies from governments or benefit from new regulations, so that they can follow their high productive competitors to provide more labor training and employ more high-skilled workers during the liberalization period, especially among those who are encouraged to "go out" (a famous slogan from the Chinese government during that period).

In terms of the sample of initial non-exporters and the sample of initial exporters in 2004, the trade-integration effect on labor training by firms in the first quartile is very similar to the findings in panels C and D of Table 2.4. Regardless of the initial export status, the effect of the reduction in tariffs on the fourth quartile is less precisely estimated. It is consistent with the model prediction that the most productive firms ($z > z_s$) still find it profitable to provide labor training even when the India's tariffs are lower.

The point estimates in other sectors are positive but not significant for the first and third quartiles as shown in columns 10–12 of Table 2.5. The reduction in tariffs induces a statistically significant reduction in spending on labor training in the fourth quartile of the firm size distribution. Precisely, the 15 percentage point decline in India's tariffs from 2004 to 2007 reduces spending on training by about 0.07 log points for firms in the fourth quartile. Some of these large firms may actually be in the range $z^1_{mx} < z < z^1_{ms}$ in Figure 2.3, as initial firm size may not be a perfect measure of productivity. As a result, trade liberalization may both encourage the large firms to export and downgrade skill level on average. Interestingly, trade liberalization induces more labor training of firms in the second quartile in these other sectors with $\beta_{\tau^{ex},2}$ equal to about -0.09.

From the findings in Table 2.3 and Table 2.5, trade liberalization induces a significant increase in both the probability of export participation and spending on labor training by firms in the second and third quartiles in selected sectors, which is consistent with the benchmark model prediction. Results based on other sectors and for other quartiles are partially explained by our extended model. In the next section, we attempt to extend our empirical analysis to focus more on the extended model, and make some further discussions including sector characteristics and specific policies or regulations in China to understand those empirical results.

2.5.5 Extension

Recall that the data pattern shows that India's tariffs are much higher than those of other countries, but the reduction in India's tariffs is much more drastic between 2004 and 2007. Thus, we build the extended model that distinguishes two different export destinations, countries m and o in order to highlight the effect of trade liberalization on exporters to the Indian market or other foreign markets. Next, we estimate two similar first-differenced models as in subsections 2.5.3 and 2.5.4, but analyze the export destination decisions of new exporters and the skill upgrading decisions of new exporters to the Indian market.

Rewriting equation (2.13) when $k = 1$ yields:

$$EX^1_{ijst} = \begin{cases} 1 & \text{if exporting to India} \\ 0 & \text{if exporting to non-Indian countries} \end{cases}$$

Figure 2.3 shows that more continuing exporters switch to India and new exporters are more likely to enter the Indian market after India's tariffs are reduced. Meanwhile, within-industry patterns in the data (Table 2.1) shows that new exporters have the largest increase in sales and training per worker from 2004 to 2007. Hence, to estimate the equation (2.21), we select the sample of firms who do not export in 2004 but become exporters in 2007.

$$\Delta EX^1_{ijst} = \sum_{n=1}^{4} \beta^1_{\tau^{ex},n}(\Delta\tau^{ex}_{jt} \times Q_{ij,n}) + \sum_{n=1}^{4} \delta^1_n Q_{ij,n} + \beta^1_{\tau^{im}}\Delta\tau^{im}_{jt} + \Delta\alpha^1_{st} + \Delta\epsilon^1_{ijst} \qquad (2.21)$$

Columns 1–3 of Table 2.6 present the estimated results of equation (2.21). Coefficients in each quartile of size distribution are statistically significant. In particular, the 15 percentage point decline in India's tariffs increases the probability of entering the Indian market for new exporters in the high productivity group (fourth quartile) by 24.23 percentage points. Furthermore, the empirical results of exporting to India in Table 2.6 are consistent with the extended model prediction as there are three shaded areas located in different ranges of productivity levels in Figure 2.3, representing that firms in each range of productivity levels could find it more profitable to export to India.

Next, recall that some firms switch export destinations from country m to o and start to produce unskilled or skilled goods after trade liberalization (Figure 2.3). To investigate the skill upgrading decisions made by new exporters to India, we estimate equation (2.20) again with the sample of non-exporters in 2004 and exporters to India in 2007.

In column 5 of Table 2.6, trade liberalization is shown to have significantly positive effects on skill upgrading of new exporters targeting India in the last three quartiles. Although firm size may not be a perfect measure of productivity, this reflects that new exporters targeting India with a size above the medium level actually start to increase investment in on-the-job training when trade costs are lower. The absolute value of the coefficient of the fourth quartile is the largest potentially due to the fact that the most productive new exporters to India are more capable of increasing labor training. Precisely, column 5 of Table 2.6 presents that a 15 percentage point reduction in trade costs from 2004 to 2007 leads to a 3.54 log point increase in labor training provided by the new exporters to India in the fourth quartile. The absolute value of the coefficient of second quartile is smaller, but still larger than that of the third quartile. These results are in line with the pattern in Figure 2.3 as some firms in the middle range of productivity levels continue to produce unskilled products or reduce spending on labor training.

2.5.6 Mechanism

Empirically, the reduction in the tariffs induces more firm entry in the export market and increase spending on labor training in the second and third quartiles of the firm size distribution (in selected sectors) based on the previous tables, which indicates that firms in the middle range of the productivity distribution greatly benefit from trade liberalization. The model mechanism implies that firms gain higher revenues when trade costs are lower, so they find it more profitable to export and have greater incentives in skill upgrading, mirroring the reduction in productivity cutoffs of export and skill upgrading. In this section, we provide evidence that how trade integration between China and India affect China's export sales to India and domestic sales.

Export Sales to India

We select the sample of firms who do not export in 2004 but become new exporters to India in 2007. We find that the reduction in India's tariffs increases China's export sales to India as reported by columns 1–3 of Table 2.7 following the previous estimation method. When we control for the change of China's import tariffs with respect to India, the 15 percentage point reduction in India's tariffs leads to an increase in export sales to India by about 6.18 log points. This exercise produces consistent results, and mainly reflects changes of export sales of new exporters to India. The coefficients are large in magnitude because we analyze the export sales at the firm level instead of the industry level. The firm level data can help emphasize how a small group of firms respond to changes in trade costs.

Domestic Sales

Our theoretical model also shows that the reduction in trade costs leads to a decline in domestic sales and causes more low productivity firms to exit the market. However, trade costs are symmetric for two countries in the model, which cannot be easily matched to the data. In fact, India's tariffs differ from China's tariffs. The empirical evidence under columns

4–6 of Table 2.7 suggests that the decline in China's tariffs with respect to India could result in lower domestic sales with point estimates from 0.30–0.52. However, these results are not significant. This is probably due to the fact that China as a developing country has a rapid growth rate, as well as a large population. For instance, GDP annual growth rate in China increased from 10% in 2004 to 14% in 2007.[16] Chinese firms increase export sales a lot following trade openness, and also can maintain a great amount of domestic sales even if there are more imported varieties.

2.5.7 Discussion

In this section, we attempt to understand why firms in certain sectors would enter in the export markets and invest more in on-the-job training following trade liberalization, while others would not. The theoretical benchmark model can only explain some empirical findings, while others can result from special sector characteristics or policies targeting certain industries. Due to sector heterogeneity in productivity and policy, trade liberalization has positive impacts on firms' decisions of export entry and skill upgrading in only some selected sectors, including manufacturers of "ship and floating devices".

First, some large-scale manufacturing companies in China such as pharmaceutical, home appliances and electronics manufacturers, have their own universities for labor training, so their labor training procedures are canonical and their training decision might not be sensitive to changes in trade costs. Second, industry characteristics and certain policies could determine whether some industries have comparative advantage or sustainable competition in the foreign market. We pick the shipbuilding industry from selected sectors and the textile industry from other sectors to understand their different responses to the regional trade liberalization.

Textile Industry. According to an investigation report from the CNBS[17], the labor-intensive textile industry used to have a strong advantage in terms of labor costs, but it is offset by low labor productivity. Compared with China's main competitors in Asia,

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[16]Data source: World Bank national accounts data, and OECD National Accounts data files.

[17]The first China Industrial Security Forum was held in 2006. It reported the domestic environment of China's textile industry from 1997 to 2005.

its labor costs gradually lose the advantage. In 2002, the average wage level in China's textile industry reached 1.12 times that of India. Moreover, the production technology of spinning machinery is relatively mature, while the production technology of weaving and sewing machinery is relatively backward. Due to low productivity levels and less advanced technologies, some firms in the textile industry are less competitive in the export market, and find it not profitable to participate in exports or increase labor training even if trade costs are very low. This explains why they are not sensitive to changes in tariffs. Instead, they could have a higher investment in on-the-job training when tariffs are high and when they could receive protection or subsidies from the government.

Shipbuilding Industry. China engages in foreign trade further after joining the WTO and APTA in 2001. In particular, China's total volume of imports and exports increased by 23.2% and the export of mechanical and electrical products and high-tech products increased by 32.0% and 31.8% respectively, from 2004 to 2005.[18] Meanwhile, the Eleventh Five-Year-Plan was announced in 2006, which encourages large-scale enterprises such as shipbuilding or auto-car firms to enter the export market. In 2020, China was still the world's largest shipbuilding market, accounting for 43.08% of total shipbuilding volume in the world. Shipbuilding industry is one of the selected sectors in the empirical studies. Shipbuilding firms are more productive and likely to fall in the second or the third quartiles of the firm size distribution. They should be sensitive to changes in trade costs. Besides, they actually receive supports in the export market after the government implements the Eleventh Five-Year-Plan. Thus, the reduction in tariffs still have significantly positive impacts on their export entry decisions.

2.6 Conclusion

The evidence from selected sectors reported in this paper suggests that a reduction of trade costs can help reduce the export productivity cutoff and increases profits for exporters, resulting in more export participation and more spending in labor training. According to the model implication and empirical results, the positive impact of trade liberalization on firms in the middle range of productivity levels is the largest. Due to sector heterogeneity and

[18]These data were reported at the Fourth Session of China's Tenth National Congress in 2006.

specific policies targeting to some other sectors, the empirical findings in other sectors revert. As expanded export opportunities positively affect firm performance in selected sectors, it is important to implement trade policies targeting to certain industries, including regional or multilateral trade liberalizations. More export participation leads to more investment in on-the-job training, which increases labor skill levels and improves product quality in the long term.

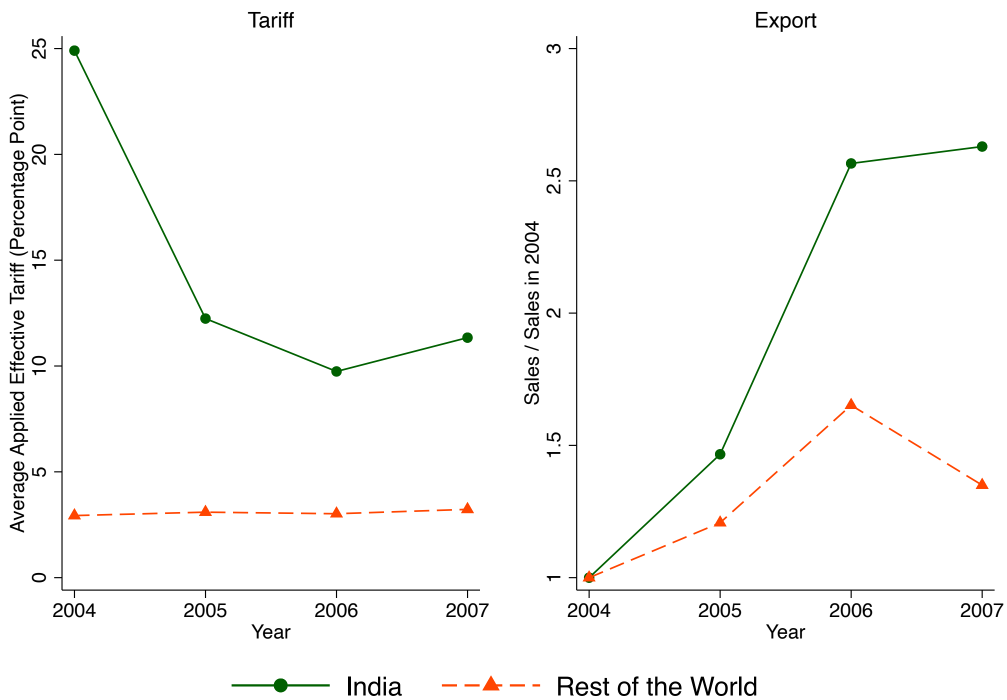

Figure 2.1: Trends of tariffs and China's export sales (2004–2007)

Notes: The left panel shows the average applied effective tariff China faces when exporting goods to India and the rest of the world; the average for the rest of the world is weighted by the export sales from China to each country. The right panel depicts China's total export sales in each year relative to 2004.

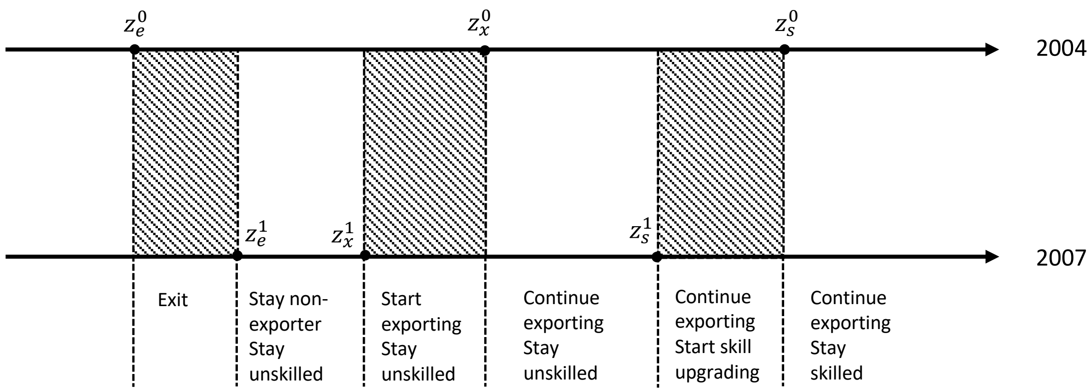

Figure 2.2: Effect of lowering variable trade Costs: Benchmark model

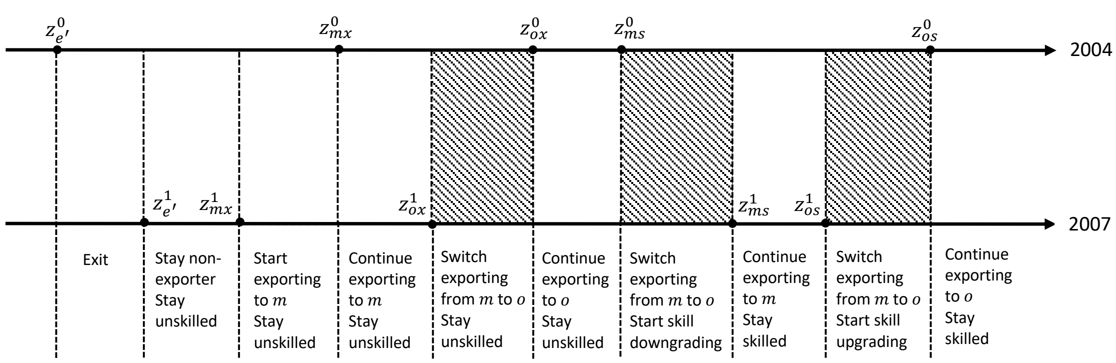

Figure 2.3: Effect of lowering variable trade costs: Extended model

Table 2.1: Differences between different types of exporters and non-exporters in APTA sectors

	Levels in 2004			Changes 2004–2007			Size	
Firm characteristic	Sales	Employment	Training per worker	Sales	Employment	Training per worker	Observations	Firms
Basic model								
New exporters	0.596***	0.505***	0.412***	0.176***	0.146***	0.129***	3,957	3,957
	(0.020)	(0.017)	(0.041)	(0.014)	(0.010)	(0.048)		
Continuing exporters	1.240***	1.027***	0.150***	-0.095***	0.058***	0.011	40,873	20,045
	(0.009)	(0.008)	(0.017)	(0.006)	(0.004)	(0.019)		
Exiting exporters	1.086***	0.852***	0.438***	-0.130***	-0.035***	-0.087*	3,919	3,919
	(0.021)	(0.018)	(0.040)	(0.015)	(0.010)	(0.046)		
Extended model								
New exporters to non-Indian	0.532***	0.462***	0.329***	0.152***	0.132***	0.129**	3,203	3,203
countries (m)	(0.021)	(0.018)	(0.045)	(0.015)	(0.011)	(0.052)		
New exporters to India (o)	0.876***	0.691***	0.769***	0.278***	0.205***	0.128	754	754
	(0.049)	(0.042)	(0.091)	(0.027)	(0.021)	(0.111)		
Continuing exporters to m	1.160***	0.997***	0.047***	-0.113***	0.046***	-0.001	34,448	17,227
	(0.010)	(0.008)	(0.018)	(0.006)	(0.004)	(0.020)		
Continuing exporters to o	1.751***	1.234***	0.813***	-0.024*	0.102***	0.015	2,200	1,831
	(0.032)	(0.026)	(0.058)	(0.014)	(0.011)	(0.063)		
Switching exporters from m to o	1.562***	1.131***	0.594***	0.061***	0.163***	0.080	2,971	2,379
	(0.029)	(0.024)	(0.049)	(0.012)	(0.010)	(0.054)		
Switching exporters from o to m	1.545***	1.157***	0.435***	-0.165***	0.014	0.140*	1,254	1,082
	(0.042)	(0.034)	(0.071)	(0.020)	(0.016)	(0.078)		
Exiting exporters to m	0.997***	0.794***	0.338***	-0.140***	-0.044***	-0.080	3,348	3,348
	(0.022)	(0.019)	(0.043)	(0.016)	(0.011)	(0.049)		
Exiting exporters to o	1.618***	1.194***	1.032***	-0.072**	0.015	-0.129	571	571
	(0.053)	(0.045)	(0.104)	(0.031)	(0.023)	(0.124)		
Observations	131,460	131,460	131,460	131,460	131,460	131,460		
Firms	110,632	110,632	110,632	110,632	110,632	110,632		

Notes: (1) Robust standard errors are in parentheses. (2) Exporter premia are estimated from a regression of the form $\ln Y_{ij} = \alpha_1 \text{Type } 1_{ij} + \alpha_2 \text{Type } 2_{ij} + ... + I_j + \varepsilon_{ij}$ where i indexes firms, and j indexes four-digit CIC industries; the reference category relative to which differences are estimated is non-exporters; I are industry dummies, and Y is the firm characteristic for which the differences are estimated. (3) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (4) Some continuing and switching exporters operated in multiple industries.

Table 2.2: Entry in the export markets stratified by sector group

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Sample of selected sectors. Dependent variable: year-over-year change in export status								
ΔIndia's tariffs	-0.124***	-0.125***	-0.120***	-0.104***	-0.103**	-0.112***	-0.104***	-0.103***
	(0.032)	(0.031)	(0.034)	(0.038)	(0.040)	(0.031)	(0.032)	(0.033)
ΔChina's tariffs w.r.t. world								
Outputs			yes	yes	yes			
Inputs				yes	yes			
ΔChina's tariffs w.r.t. India								
Outputs						yes	yes	yes
Inputs							yes	yes
Sector FE	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes	yes
Firm-level controls		yes	yes	yes	yes	yes	yes	yes
Industry controls					yes			yes
Observations	91,869	91,869	91,869	91,869	91,869	91,869	91,869	91,869
R^2	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Panel B: Sample of other sectors. Dependent variable: year-over-year change in export status								
ΔIndia's tariffs	-0.014	-0.014	-0.011	-0.016	-0.016	-0.012	-0.015	-0.015
	(0.015)	(0.015)	(0.017)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
Observations	302,511	302,511	302,511	302,511	302,511	302,511	302,511	302,511
R^2	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Panel C: Sample of selected sectors. Dependent variable: export status in the current year								
ΔIndia's tariffs	-0.147***	-0.147***	-0.143***	-0.127***	-0.116***	-0.135***	-0.128***	-0.116***
	(0.036)	(0.036)	(0.038)	(0.042)	(0.043)	(0.036)	(0.036)	(0.036)
Export status in the	0.933***	0.932***	0.932***	0.932***	0.931***	0.932***	0.932***	0.931***
previous year	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
R^2	0.884	0.884	0.884	0.884	0.884	0.884	0.884	0.884
Panel D: Sample of baseline non-exporters in selected sectors. Dependent variable: export status in the current year								
ΔIndia's tariffs	-0.128***	-0.126***	-0.122***	-0.121***	-0.090**	-0.127***	-0.120***	-0.092***
	(0.038)	(0.039)	(0.039)	(0.043)	(0.035)	(0.039)	(0.038)	(0.031)
Export status in the	0.729***	0.726***	0.726***	0.726***	0.725***	0.726***	0.726***	0.725***
previous year	(0.021)	(0.021)	(0.021)	(0.021)	(0.020)	(0.021)	(0.021)	(0.020)
Observations	60,273	60,273	60,273	60,273	60,273	60,273	60,273	60,273
R^2	0.317	0.318	0.318	0.318	0.319	0.318	0.318	0.319

Notes: (1) Standard errors are clustered at the 4-digit CIC industry level. (2) Δ denotes the year-over-year change in a variable during the period 2004–2007. (3) Firm-level controls include number of employees and sales per worker, all measured in the initial year (2004). (4) Industry controls include import demand elasticity, export supply elasticity, skill intensity, and capital intensity in the United States. (5) In panels B and D, remaining controls are the same as in the corresponding column in panel A. (6) In panel C, controls and number of observations are the same as in the corresponding column in panel A. (7) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (8) Selected sectors include 14 manufacturing sectors as follows: "wood processing and wood, bamboo, rattan, palm and grass products" (No. 32), "coatings, inks, pigments and similar products" (No. 42), "daily chemical products" (No. 45), "rubber products" (No. 48), "plastic products" (No. 49), "brick, stone and other building materials" (No. 52), "boilers and prime movers" (No. 64), "metal processing machines" (No. 65), "mining, metallurgy, and special equipment for construction" (No. 69), "special machines for agriculture, forestry, animal husbandry and fishery" (No. 71), "ship and floating devices" (No. 75), "household electric and non-electric appliances" (No. 80), "instrumentation" (No. 88), and "cultural and office machines" (No. 89).

Table 2.3: Entry in the export market by quantile of the firm size distribution and sector group

Sample	Selected sectors									Other sectors		
	Full sample						Baseline non-exporters			Full sample		
Dependent variable	Change in status			Status in the current year			Status in the current year			Change in status		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
ΔIndia's tariffs												
× first size quartile	-0.070*	-0.054	-0.050	-0.079**	-0.064	-0.060	-0.060*	-0.059	-0.060*	0.016	0.015	0.014
	(0.036)	(0.042)	(0.036)	(0.039)	(0.046)	(0.040)	(0.036)	(0.040)	(0.036)	(0.016)	(0.015)	(0.014)
× second size quartile	-0.113***	-0.095**	-0.095**	-0.124***	-0.107**	-0.107**	-0.084**	-0.082**	-0.083**	0.001	-0.001	-0.001
	(0.035)	(0.041)	(0.037)	(0.039)	(0.047)	(0.042)	(0.038)	(0.041)	(0.038)	(0.015)	(0.016)	(0.015)
× third size quartile	-0.126***	-0.107***	-0.107***	-0.142***	-0.124***	-0.124***	-0.109***	-0.107***	-0.107***	-0.016	-0.018	-0.016
	(0.033)	(0.041)	(0.034)	(0.037)	(0.044)	(0.038)	(0.034)	(0.039)	(0.035)	(0.019)	(0.020)	(0.020)
× fourth size quartile	-0.169***	-0.150***	-0.149***	-0.194***	-0.176***	-0.175***	-0.162***	-0.160***	-0.160***	-0.051**	-0.054**	-0.051**
	(0.040)	(0.048)	(0.038)	(0.041)	(0.048)	(0.039)	(0.041)	(0.047)	(0.041)	(0.021)	(0.022)	(0.022)
ΔChina's tariffs w.r.t. world		yes			yes			yes			yes	
ΔChina's tariffs w.r.t. India			yes			yes			yes			yes
Sector FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
Year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
Firm-level controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
Industry controls		yes	yes		yes	yes		yes	yes		yes	yes
Observations	91,869	91,869	91,869	91,869	91,869	91,869	60,273	60,273	60,273	302,511	302,511	302,511
R^2	0.004	0.004	0.005	0.884	0.884	0.884	0.320	0.320	0.320	0.005	0.005	0.005

Notes: (1) Standard errors are clustered at the 4-digit CIC industry level. (2) Δ denotes the year-over-year change in a variable during the period 2004–2007. (3) Firm-level controls include dummies for the second, third, and fourth quartile of the firm-size distribution in the initial year (2004). (4) Industry controls include import demand elasticity, export supply elasticity, skill intensity, and capital intensity in the United States. (5) Controls for changes in China's tariffs with respect to the world and India include both output and input tariffs. (6) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (7) Selected sectors include 14 manufacturing sectors mentioned in Table 2.2.

Table 2.4: Investment in on-the-job training stratified by sector group and initial export status

Dependent variable: year-over-year change in log(training spending)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Sample of selected sectors.								
ΔIndia's tariffs	-0.854***	-0.854***	-0.903***	-0.796**	-0.753*	-0.859***	-0.883***	-0.842***
	(0.304)	(0.304)	(0.325)	(0.397)	(0.409)	(0.316)	(0.311)	(0.320)
ΔChina's tariffs w.r.t. world								
Outputs			yes	yes	yes			
Inputs				yes	yes			
ΔChina's tariffs w.r.t. India								
Outputs						yes	yes	yes
Inputs							yes	yes
Sector FE	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes	yes
Firm-level controls		yes	yes	yes	yes	yes	yes	yes
Industry controls					yes			yes
Observations	91,869	91,869	91,869	91,869	91,869	91,869	91,869	91,869
R^2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Panel B: Sample of other sectors.								
ΔIndia's tariffs	0.140*	0.139*	0.144*	0.145*	0.141	0.142*	0.152*	0.148*
	(0.081)	(0.081)	(0.083)	(0.086)	(0.086)	(0.082)	(0.085)	(0.085)
Observations	302,511	302,511	302,511	302,511	302,511	302,511	302,511	302,511
R^2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Panel C: Sample of baseline non-exporters in selected sectors.								
ΔIndia's tariffs	-0.810**	-0.804**	-0.818**	-0.778*	-0.683	-0.820**	-0.908***	-0.824**
	(0.324)	(0.324)	(0.344)	(0.443)	(0.441)	(0.339)	(0.325)	(0.320)
Observations	60,273	60,273	60,273	60,273	60,273	60,273	60,273	60,273
R^2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Panel D: Sample of baseline exporters in selected sectors.								
ΔIndia's tariffs	-0.917	-0.915	-1.018	-0.931	-1.096	-0.878	-0.889	-1.050
	(0.788)	(0.785)	(0.851)	(0.869)	(0.900)	(0.805)	(0.805)	(0.833)
Observations	31,596	31,596	31,596	31,596	31,596	31,596	31,596	31,596
R^2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Notes: (1) Standard errors are clustered at the 4-digit CIC industry level. (2) Δ denotes the year-over-year change in a variable during the period 2004–2007. (3) Firm-level controls include number of employees and sales per worker, all measured in the initial year (2004). (4) Industry controls include import demand elasticity, export supply elasticity, skill intensity, and capital intensity in the United States. (5) In panels B, C, and D, remaining controls are the same as in the corresponding column in panel A. (6) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (7) Selected sectors include 14 manufacturing sectors mentioned in Table 2.2.

Table 2.5: Investment in on-the-job training by quantile of the firm size distribution, sector group, and initial export status

Dependent variable: year-over-year change in log(training spending)												
Sample	Selected sectors									Other sectors		
	Full sample			Baseline non-exporters			Baseline exporters			Full sample		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
ΔIndia's tariffs												
× first size quartile	-0.977***	-0.913**	-0.992***	-1.065***	-0.999**	-1.117***	-0.860	-0.895	-0.845	0.015	0.018	0.022
	(0.338)	(0.416)	(0.344)	(0.330)	(0.419)	(0.330)	(0.904)	(0.981)	(0.919)	(0.126)	(0.129)	(0.129)
× second size quartile	-1.222***	-1.153**	-1.246***	-1.045**	-0.972*	-1.117***	-1.838**	-1.857*	-1.824**	-0.100	-0.092	-0.086
	(0.380)	(0.478)	(0.386)	(0.403)	(0.523)	(0.407)	(0.877)	(0.959)	(0.897)	(0.097)	(0.101)	(0.101)
× third size quartile	-0.924***	-0.854**	-0.953***	-0.650*	-0.573	-0.740**	-1.537*	-1.560*	-1.511*	0.088	0.097	0.104
	(0.332)	(0.427)	(0.335)	(0.352)	(0.469)	(0.351)	(0.846)	(0.938)	(0.875)	(0.116)	(0.122)	(0.120)
× fourth size quartile	-0.168	-0.099	-0.195	0.048	0.124	-0.051	-0.420	-0.432	-0.388	0.476***	0.485***	0.493***
	(0.343)	(0.420)	(0.354)	(0.338)	(0.423)	(0.353)	(0.866)	(0.952)	(0.884)	(0.173)	(0.179)	(0.176)
ΔChina's tariffs w.r.t. world		yes			yes			yes			yes	
ΔChina's tariffs w.r.t. India			yes			yes			yes			yes
Sector FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
Year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
Firm-level controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
Industry controls		yes	yes		yes	yes		yes	yes		yes	yes
Observations	91,869	91,869	91,869	60,273	60,273	60,273	31,596	31,596	31,596	302,511	302,511	302,511
R^2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Notes: (1) Standard errors are clustered at the 4-digit CIC industry level. (2) Δ denotes the year-over-year change in a variable during the period 2004–2007. (3) Firm-level controls include dummies for the second, third, and fourth quartile of the firm-size distribution in the initial year (2004). (4) Industry controls include import demand elasticity, export supply elasticity, skill intensity, and capital intensity in the United States. (5) Controls for changes in China's tariffs with respect to the world and India include both output and input tariffs. (6) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (7) Selected sectors include 14 manufacturing sectors mentioned in Table 2.2.

Table 2.6: Entry in the India export market and investment in on-the-job training

Sample	Selected sectors New exporters			Selected sectors New exporters to India		
Dependent variable	Change in status of exporting to India			log(training spending)		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔIndia's tariffs						
× first size quartile	-1.721***	-1.723***	-1.888***	-8.054	-15.082*	-3.714
	(0.484)	(0.562)	(0.522)	(6.791)	(8.015)	(5.745)
× second size quartile	-1.533***	-1.555***	-1.676***	-13.208*	-20.970**	-10.031
	(0.486)	(0.555)	(0.512)	(7.591)	(8.530)	(6.596)
× third size quartile	-1.450***	-1.471**	-1.522***	-11.187	-18.683**	-7.860
	(0.485)	(0.565)	(0.502)	(7.409)	(8.943)	(5.681)
× fourth size quartile	-1.600***	-1.615***	-1.654***	-15.153	-23.569**	-12.200*
	(0.533)	(0.603)	(0.549)	(9.079)	(10.006)	(7.083)
ΔChina's tariffs w.r.t. world		yes			yes	
ΔChina's tariffs w.r.t. India			yes			yes
Sector FE	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
Firm-level controls	yes	yes	yes	yes	yes	yes
Industry controls		yes	yes		yes	yes
Observations	2,475	2,475	2,475	489	489	489
R^2	0.025	0.026	0.028	0.035	0.061	0.054

Notes: (1) Standard errors are clustered at the 4-digit CIC industry level. (2) Δ denotes the year-over-year change in a variable during the period 2004–2007. (3) Firm-level controls include dummies for the second, third, and fourth quartile of the firm-size distribution in the initial year (2004). (4) Industry controls include import demand elasticity, export supply elasticity, skill intensity, and capital intensity in the United States. (5) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (6) New exporters and new exporters to India are defined in Table 2.1. (7) Selected sectors include 14 manufacturing sectors mentioned in Table 2.2.

Table 2.7: Export sales to India and domestic sales of new exporters to India in selected sectors

Dependent variable	Change in log(export sales to India)			Change in log(domestic sales)		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔIndia's tariffs	-40.851***	-41.207***	-43.108**			0.016
	(13.352)	(13.727)	(17.650)			(1.577)
ΔChina's tariffs w.r.t. India						
Output		yes		0.302	0.521	0.518
				(0.862)	(1.995)	(1.984)
Input		yes			-1.515	-1.517
					(14.819)	(14.862)
ΔChina's tariffs w.r.t. world			yes			
Sector FE	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
Firm-level controls	yes	yes	yes	yes	yes	yes
Industry controls		yes	yes		yes	yes
Observations	489	489	489	489	489	489
R^2	0.141	0.154	0.153	0.063	0.071	0.071

Notes: (1) Standard errors are clustered at the 4-digit CIC industry level. (2) Δ denotes the year-over-year change in a variable during the period 2004–2007. (3) Firm-level controls include number of employees and sales per worker, all measured in the initial year (2004). (4) Industry controls include import demand elasticity, export supply elasticity, skill intensity, and capital intensity in the United States. (5) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (6) New exporters to India are defined in Table 2.1. (7) Selected sectors include 14 manufacturing sectors mentioned in Table 2.2.

Chapter 3

HEALTH INVESTMENT AND TRADE OPENNESS

3.1 Introduction

A lot of researches attempt to understand how healthcare expenditure affects economic performance and what economic indicators influence health directly.[1] Globalization plays an important role in affecting public health, personal healthcare consumption and investment. Increased cross-country flows in goods and services affect population health and health expenditure in many ways, so the linkages between trade and health are complex. Public health practitioners care about the how trade liberalization affects population health, and trade policy-makers investigate how trade openness improve economic performance. Is trade good for health or a challenge for health improvement? Does health investment stimulate more trade? This paper focuses on studying the interactive effects of trade openness and health investment in a dynamic framework with heterogeneous firms.

Many empirical and theoretical studies show that increased trade reduces poverty, boosts economic growth and encourages firm establishments, but there is a lack of evidence regarding how trade liberalization affects population health, health expenditure and health capital investment. According to a report from World Health Organization in 2015, trade will affect health through influencing economic growth and national wealth. In particular, trade could influence growth rate, the distribution and provision of health goods and services and investment in health capital while economic opening also create risk factors including infectious disease and environmental pollution (Smith et al. (2015)). The income effect is one of the key channel linking trade and health investment. In terms of empirical studies of trade and health, Owen and Wu (2007) show that trade openness can improve health outcomes, while better health outcomes may be associated with the knowledge spillovers, technology

[1] Please see Raghupathi and Raghupathi (2020) and Costa (2015)

transfer and domestic economic policies.[2] Their empirical findings mainly indicate there is a positive correlation between trade openness and health outcomes, but the causality may not be established. In most studies, health outcomes are measured by life expectancy and infant mortality rates. At the cross-country level, Figure 3.1 displays a strong and positive correlation between trade and health improvement. Increased exports or imports could increase life expectancy at birth and reduce infant mortality rates.

Figure 3.2 shows that the U.S. healthcare spending is rising very fast in recent years. This could be due to the increased government, compulsory or voluntary health spending.[3] This paper focuses on studying the private healthcare spending since households' health decisions could have significant effects on economic outcomes. There is a rapid growth in the U.S. pharamaceutical spending as shown in Figure 3.3, reflecting that purchasing medical goods and services is an important way for individuals to accumulate more health capital and obtain better health status. As discussed in Atolia et al. (2019), individuals purchase more medical goods and services to improve quality of life, and there is a drastic increase in the fitness and health industry in the advanced economies. Motivated by these stylized facts, this paper incorporates healthcare expenditure and health investment in the model. To accumulate more health capital, individuals need to increase healthcare spending or devote more time to exercise.

More exports or imports are associated with more private health expenditure per capita as displayed in Figure 3.4. Beyond looking at the cross-country analysis correlation of trade and health, the time series patterns of the U.S. trade, GDP and health in Figure 3.5 and Figure 3.6 indicate that: (a) The personal healthcare service consumption is pro-cyclical with the U.S. GDP; (b) it is also positively correlated with the U.S. regular exports and imports with the correlation coefficient around 0.25-0.35. Motivated by the positive correlation of trade and health spending,[4] this paper investigates if trade openness stimulate more health

[2] Herzer (2017) also find that trade openness has a positive long-run effect on health with using time-series data techniques, but the effect differs from the developed and developing countries.

[3] According to the definition from OECD, voluntary health spending includes voluntary health insurance and private funds such as households' out-of-pocket payments, NGOs and private corporations.

[4] Additional empirical evidence is provided in C.1 to motivate this study. We implement a quarterly VAR exercise to see the macroeconomic effect of a health shock on trade and how changes in trade costs

investment and studies the effects of private health expenditure on trade, firm performance and other economic outcomes in a dynamic stochastic general equilibrium framework with firm heterogeneity.

Following analytical studies in health such as Grossman (1972), Hokayem and Ziliak (2014) and Atolia et al. (2019), we treat health as a "consumption commodity" directly entering consumers' utility function and the household is able to accumulate more health capital through spending more in medical services or devoting less time to work. In this setting, the household can also maintain "good health" and increase labor productivity. According to the finding that there might be a positive correlation between trade openness and spending in healthcare, this paper proposes a model of trade and health with two economics, building on the dynamic stochastic general equilibrium framework in Ghironi and Melitz (2005) to analyze what channels affect this relationship. Following their paper, the key model ingredients include firm heterogeneity, endogenous firm entry and export participation. To this framework, we add: (1) endogenous labor supply, which allows varying time allocation to work, leisure or exercise so that workers' health status is not constant; (2) effective labor supply through capturing workers' health status, which indicates that workers with higher health levels are more productive; (3) the stock of health capital and the firm entry channel, which presents the trade-off between investment decisions in health capital, physical capital and new firm entrants; (4) healthcare consumption, which provides the different effects of a reduction in trade barriers on non-medical consumption and medical spending.

The key model implications are as follows. First, the impacts of changing aggregate productivity on key aggregate variables such as consumption, regular exports, the number of exporters, the stock of firms and terms of labor could be underestimated if workers' health status and health investment decisions are neglected in the framework. An increase in aggregate productivity makes the market more attractive, which encourages more firm entrants and more investment in health capital. More health capital formation facilitates economic growth again. Second, there is a positive association between personal income

influence healthcare expenditure.

and healthcare expenditure. A greater stock of health capital improves labor productivity, increases national income, leads to more consumption spending in both non-medical and medical good and stimulates more trade. Third, an increase in health investment results in an increase in the stock of health capital but a decline in the stock of firms in the short term, reflecting a trade-off between investment in health and new firm entrants. Meanwhile, health investment could crowd out physical capital investment, which may harm economic growth if the stock of physical capital is not sufficient. Fourth, there is a positive linkage between trade openness and health investment. An increase in health investment boosts both the number of exporters and export values because health improvement facilitates economic growth, and then affects trade activities indirectly. A reduction in trade barriers creates more healthcare spending and increases the stock of health capital. This finding is in line with the literature that trade causes growth and growth leads to more health consumption and investment.[5] Additionally, lower trade costs create more tradable varieties (the extensive margin of exports) including medical supplies, equipment, drugs and services, which could improve workers' health status, increase labor productivity and accumulate more health capital in the economy.

This paper is related to a recent literature in international trade with firm heterogeneity and firm entry, Melitz (2003), and in international macroeconomics such as Ghironi and Melitz (2005), Jaef and Lopez (2014) and Liao and Santacreu (2015), while our paper differs from their studies in that it captures workers' health status with adding the features of healthcare expenditure and health capital investment to examine trade dynamics and economic performance. This paper also adds to the literature that studies the relationship between globalization and health such as Owen and Wu (2007) and Herzer (2017). Regrading the relationship between tariffs and health, some studies focus on the impacts of either import tariff or export tariffs reduction on health. For instance, Fan et al. (2020) find that input tariff reductions increase working hours, the likelihood of getting illness or injury of Chinese manufacturing workers, while Feng et al. (2021) argue that reduced export tariffs lead to greater health improvements because of increased earnings. The

[5]Please see Frankel and Romer (1999) and Smith et al. (2015)

home and foreign countries are symmetric in our model for simplicity, so import and export tariffs are symmetric as well.[6] Other researches including Woodward et al. (2001) focus on sector-specific intersections between health and trade, such as trade in medicines and health services or investigate the effects of trade policy on food, nutrition and health. In terms of the effects of health on aggregate economic outcomes, Costa (2015) summarizes various health indicators affecting economic outcomes and studies how health interacts with education, productivity and economic growth in the United States from 1750 to the present.[7] Additional health-related research topics focus on the impacts of health issues on growth (Aghion et al. (2010)), the relationship between disease and human capital (Bleakley (2010)) or the connection between inequality and health (Deaton (2003)). Different from the most previous studies, this paper aids to address the concern if trade openness benefits health or is a challenge for health and if health improvement stimulates more trade through modeling effective labor supply with health investment and distinguishing healthcare and non-healthcare consumption. Following Grossman (1972), health capital is different from physical capital and human capital as health is one of "consumption commodity" entering consumers' utility function and an "investment commodity" to reflect individual health status and labor productivity. Atolia et al. (2019) introduce health decisions in a dynamic framework and discuss the government's role in changing health status, productivity, growth and well-being. Our model also incorporate health decision, but focus on the effect of private healthcare spending. Meanwhile, this paper highlights the income effect and physical capital crowding-out effect in changing the relation between health investment and trade.

The rest of this paper is organized as the follows. Section 3.2 lays out the theoretical model. Section 3.3 presents the model calibration. Section 3.4 discusses some numerical results. Section 3.5 makes a conclusion.

[6] It may be necessary to study the case of asymmetric economies in the future work as Jawadi et al. (2018) show that impacts of trade openness on health in developing and developed countries are different.

[7] The environment is also associated with health, and Antweiler et al. (2001) point out that international trade creates relatively small changes in pollution concentrations and free trade is good for the environment surprisingly.

3.2 The Model

Based on Ghironi and Melitz (2005) and Hokayem and Ziliak (2014), we build a two-country DSGE model to investigate the interactions between trade openness and health capital investment. The home and foreign countries are symmetric. We denote foreign variables by an asterisk. There is a unit mass of atomistic households in both economies.

3.2.1 Household's Problem

The representative household maximizes expected lifetime utility:

$$\max_{(C_t, L_{j,t}, M_{j,t}, H_{j,t+1})} E_t \sum_{s=t}^{\infty} \beta^{s-t} \{ \frac{C_s^{1-\gamma}}{1-\gamma} + \psi_h \frac{H_s^{1-\sigma}}{1-\sigma} - \frac{\chi}{1+\psi_l} L_s^{1+\psi_l} \}$$

where $\beta \in (0,1)$ is the subjective discount factor, $\gamma > 0$ and $\sigma > 0$ are the inverses of the inter-temporal elasticity of substitution, ψ_h is the utility weight on health status, χ is the weight on the disutility from labor, and $1/\psi_l \geq 0$ is the Frisch elasticity of labor supply. The budget constraint under financial autarky is:

$$C_t + M_t + \tilde{v}_t(N_{d,t} + N_{e,t})\varphi_{t+1} + B_{t+1} = w_t(L_t H_t) + (\tilde{v}_t + \tilde{\pi}_t)N_{d,t}\varphi_t + (1+r_t)B_t \quad (3.1)$$

The amount of labor supplies is L_t, and H_t captures the health status of labor. The wage rate, w_t, is defined as the rate of return per unit of effective labor, LH. The household starts every period with share holdings φ_t in a mutual fund of $N_{d,t}$ firms whose average market value is $\tilde{v}_t$. The household receives dividends equal to the average profit in proportion with the stock of firms $N_{d,t}$. It also holds risk-free bond B_t with the real return rate r_t .

The non-medical consumption and medical spending are expressed as C_t and M_t. Every period, the household purchases two types of financial assets, the risk free bond B_{t+1} and shares of mutual fund of domestic firms φ_{t+1}. The total number of domestic firms include the incumbent firms $N_{d,t}$ producing in period t and new firms $N_{e,t}$ that enter the market in period t.

Following Hokayem and Ziliak (2014), the household inherits a stock of health that depreciates at rate δ_h, and health can be replenished by purchasing medical goods and devoting work time to leisure and exercise. Therefore, health capital accumulates following the rule below:

$$H_{t+1} = (1-\delta_h)H_t + \epsilon_t^h M_t^{\alpha}(1-L_t)^{1-\alpha} \tag{3.2}$$

Health capital investment is positively related to medical consumption, but negatively related to labor supply. ϵ_t^h is defined as an investment-specific health shock, and it is assumed to follow AR(1) processes with i.i.d normal error terms, $\log \epsilon_t^h = \rho^h \log \epsilon_{t-1}^h + \eta_t^h$ in which $0 < \rho^h < 1$ and $\eta^h \sim \mathcal{N}(0, \sigma^h)$.

Combing the first order conditions for non-medical and medical consumption, labor and health capital, we get the following equations:

$$\chi L_t^{\psi_l} + \frac{(1-\alpha)M_t}{\alpha(1-L_t)C_t^{\gamma}} = \frac{w_t H_t}{C_t^{\gamma}} \tag{3.3}$$

$$\beta E_t \left(\frac{1}{H_{t+1}^{\sigma}} + \frac{w_{t+1}L_{t+1}}{C_{t+1}^{\gamma}} + \frac{(1-\delta_h)}{\alpha\epsilon_{t+1}^h(1-L_{t+1})^{1-\alpha}C_{t+1}^{\gamma}} \right) = \frac{1}{\alpha\epsilon_t^h(1-L_t)^{1-\alpha}M_t^{\alpha-1}C_t^{\gamma}} \tag{3.4}$$

The Euler equations for bond and share holdings are

$$1 = \beta(1+r_{t+1})E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\right] \tag{3.5}$$

$$\tilde{v}_t = \beta(1-\delta_e)E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}(\tilde{v}_{t+1} + \tilde{\pi}_{t+1})\right] \tag{3.6}$$

The home composite good Y_t^c that incorporate a set of domestic varieties $\Omega_{d,t}$ and foreign varieties $\Omega_{x,t}^*$ is used for non-medical consumption and medical spending ($Y_t^c = C_t + M_t$):

$$C_t + M_t = \left[\underbrace{\int_{z_{min}}^{z_x} y_{d,t}(\omega)^{\frac{\theta-1}{\theta}} d\omega}_{\omega\in\Omega_{d,t}} + \underbrace{\int_{z_x^*}^{\infty} y_{x,t}^*(\omega)^{\frac{\theta-1}{\theta}} d\omega}_{\omega\in\Omega_{x,t}^*} \right]^{\frac{\theta}{\theta-1}} \tag{3.7}$$

where $\theta > 1$ denotes the elasticity of substitution. $[z_{min}, \infty]$ is the support interval for the idiosyncratic productivity of firms, and only the more productive firms choose to enter the export market. Let $p_t(\omega)$ be the home nominal price for the good $\omega \in \Omega_t$. The consumption-based price index for the home economy is $P_t = \left(\int_{\omega\in\Omega_t} p_t(\omega)^{1-\theta}\right)^{\frac{1}{1-\theta}}$. $\rho_t(\omega) = \frac{p_t(\omega)}{P_t}$ is the real price for each variety and $\omega \in \Omega_{d,t} \cup \Omega_{x,t}^*$.

The foreign representative household maximizes a similar utility function, and the foreign composite good is also used for foreign non-medical consumption and medical spending. The consumption-based price index for the foreign economy is $P_t^* = \left(\int_{\omega^* \in \Omega_t^*} p_t(\omega)^{*1-\theta^*}\right)^{\frac{1}{1-\theta^*}}$. $\rho_t^*(\omega) = \frac{p_t^*(\omega)}{P_t^*}$ is the real price for each variety and $\omega^* \in \Omega_{d,t}^* \cup \Omega_{x,t}$.

3.2.2 Firm Entry

There is a mass of $N_{d,t}$ domestic firms in the home country. Following the mechanism in Ghironi and Melitz (2005), firm entry takes place in every period. To enter the market, firms pay a sunk entry cost of $f_{e,t}$ measured in units of the effective labor, equal to $w_t f_{e,t}/Z_t$ units of home composite good. Each firm is randomly assigned an idiosyncratic productivity z from a common distribution $G(z)$ with the support interval $[z_{min}, \infty)$. There are $N_{e,t}$ new entrants in every period t, and new firms start production at $t+1$. All firms are subject to an exogenous "death" shock, which occurs with probability δ_e. Thus, the law of motion for the total number of firms is $N_{d,t+1} = (1-\delta_e)(N_{d,t} + N_{e,t})$.[8] The expected post-entry value of new firms $\tilde{v}_t$ depends on the expected stream of future profits π_t, the stochastic discount factor β and the exogenous probability δ_e of exit every period, which is expressed as

$$\tilde{v}_t = E_t\left[\sum_{s=t+1}^{\infty} (\beta(1-\delta_e))^{s-t} \left(\frac{C_s}{C_t}\right)^{-\gamma} \tilde{\pi}_s\right] \tag{3.8}$$

In equilibrium, firm entry occurs until the expected value of the average firm equals to the sunk entry costs ($\tilde{v}_t = f_{e,t}\frac{w_t}{Z_t}$).

3.2.3 Production

Firms can serve both domestic and export markets. Exporting is costly, involving a per-unit melting-iceberg trade cost $\tau_t \geq 1$ and a per-period fixed cost $f_{x,t}$ measured in units of effective labor, which is equal to $w_t\frac{f_{x,t}}{Z_t}$ units of home composite good. Firms choose to enter the export market if and only if the exporting profit is positive; thus the time-varying productivity cutoff for exporters is: $z_{x,t} = \inf\{z|d_x(z) > 0\}$. A firm with an idiosyncratic productivity ($z < z_{x,t}$) produces goods sold in the domestic market only. There always exits

[8] As discussed in Ghironi and Melitz (2005), $N_{d,t}$ is a state variable with sunk costs and time-to-build assumption, and it acts like a capital stock. $N_{e,t}$ represents the investment of home consumers.

a subset of firms that decide not to export, which endogenously determines a non-traded sector. Let $y_{d,t}(z)$ be the variety produced and sold in the domestic market, and $y_{x,t}(z)$ be the variety produced in the domestic market and sold abroad. The term $x(t)$ is an indicator function that captures the export status, being 1 when it exports and 0 otherwise. Q_t is the consumption-based real exchange rate (units of home consumption per unit of foreign consumption)

To maximize the profit, the firm with idiosyncratic productivity z under monopolistic competition chooses relative price levels, $\rho_{d,t}(z)$ and $\rho_{x,t}(z)$, and effective labor demand capturing health status, $l_t(z)h_t(z)$. The profit maximization problem for a domestic producer is given by

$$\max_{\rho_{d,t}(z),\rho_{x,t}(z),l_t(z)h_t(z)} \rho_{d,t}(z)y_{d,t}(z) + x_t Q_t \rho_{x,t}(z)y_{x,t}(z) - w_t(l_t(z)h_t(z)) - x_t f_{x,t}\frac{w_t}{Z_t}$$

subject to

$$y_{d,t}(z) + x_t\tau_t y_{x,t}(z) = Z_t z(l_t(z)h_t(z))$$
$$y_{d,t}(z) = \rho_{d,t}(z)^{-\theta}Y_t^c$$
$$y_{x,t}(z) = \rho_{x,t}(z)^{-\theta}Y_t^{c*}$$

Prices are expressed in units of the final good at destination, and export prices are assumed to be denominated in the currency of the export market. Hence, the nominal prices set by a domestic producer for its sales in the home country $\rho_{d,t}(z)$ and the foreign market $\rho_{x,t}(z)$ are derived as[9]

$$\rho_{d,t}(z) = \frac{P_{d,t}(z)}{P_t} = \frac{\theta}{\theta-1}mc_t(z) \tag{3.9}$$

$$\rho_{x,t}(z) = \frac{P_{x,t}(z)}{P_t^*} = Q_t^{-1}\frac{\theta}{\theta-1}\tau_t mc_t(z) = Q_t^{-1}\tau_t\rho_{d,t}(z) \tag{3.10}$$

Let $mc_t(z)$ denotes the marginal cost, equal to $\frac{w_t}{Z_t z}$. Period profits from domestic sales $\pi_{d,t}$ and from foreign sales $\pi_{x,t}$ are expressed as

$$\pi_{d,t}(z) = \frac{1}{\theta}\rho_{d,t}(z)^{(1-\theta)}Y_t^c \tag{3.11}$$

[9]With the law of one price, $\rho_{x,t}(z) = \tau_t e_t \rho_{d,t}(z)$, where e_t is the nominal exchange rate (units of home currency per unit of foreign). The real exchange rate is defined as $Q_t \equiv e_t P_t^*/P_t$. For foreign firms, $\rho_{x,t}^*(z) = Q_t\tau_t^*\rho_{d,t}^*(z)$

$$\pi_{x,t}(z) = \frac{Q_t}{\theta}\rho_{x,t}(z)^{(1-\theta)}Y_t^{c*} - f_{x,t}\frac{w_t}{Z_t} \tag{3.12}$$

Demand for effective labor units is

$$l_t(z)h_t(z) = \frac{\rho_{d,t}^{-\theta}Y_t^c}{z_{d,t}Z_t} + \frac{\tau_t\rho_{x,t}^{-\theta}Y_t^{c*}}{z_{x,t}Z_t} \tag{3.13}$$

3.2.4 Average Productivity, Prices and Profits

Every period, there are $N_{d,t}$ firms with average productivity $\tilde{z}_{d,t}$ in the home market. There are also $N_{x,t}$ firms above the productivity cutoff $z > z_{x,t}$ that choose to export. As in Ghironi and Melitz (2005), the firm-specific labor productivity draws z that are Pareto-distributed with C.D.F $G(z) = 1 - (z_{min}/z)^{\kappa}$ and P.D.F. $g(z) = \kappa z_{min}^{\kappa}/z^{\kappa+1}$, so the two average productivity levels are

$$\begin{aligned}\tilde{z}_{d,t} =& \left(\int_{z_{min}}^{\infty} z^{\theta-1}dG(z)\right)^{\frac{1}{\theta-1}} = \nu z_{min}\\ \tilde{z}_{x,t} =& \frac{1}{1-G(z_{x,t})}\left(\int_{z_{x,t}}^{\infty} z^{\theta-1}dG(z)\right)^{\frac{1}{\theta-1}} = \nu z_{x,t}\end{aligned}$$

where parameters $\nu \equiv \left(\frac{\kappa}{\kappa-(\theta-1)}\right)^{1/(\theta-1)}$ and $\kappa > \theta - 1$.

Using the aggregation properties of the model, the price indexes can be written as the product of average prices and product variety: $P_{d,t} = N_{d,t}^{\frac{1}{1-\theta}}\tilde{P}_{d,t}$ and $P_{x,t} = N_{x,t}^{\frac{1}{1-\theta}}\tilde{P}_{x,t}$. The aggregate price index in home can be expressed as $P_t = [N_{d,t}(\tilde{P}_{d,t})^{1-\theta} + N_{x,t}^{*}(P_{x,t})^{1-\theta}]^{1/(1-\theta)}$.

The average total profits of firms producing intermediate inputs in the home country can be decomposed into two parts, the average total domestic profits and the average total exporting profits, equal to $N_{d,t}\tilde{\pi}_t = N_{d,t}\tilde{\pi}_{d,t} + N_{x,t}\tilde{\pi}_{x,t}$.[10] Since the firm's idiosyncratic productivity is distributed according to $G(z)$ and $z_{x,t}$ denotes as the export productivity cutoff, the mass of exporting firms is $N_{x,t} = [1 - G(z_{x,t})]N_{d,t}$. Therefore, the share of exporting firms can be derived as $\frac{N_{x,t}}{N_{d,t}} = \left(\frac{z_{min}}{z_{x,t}}\right)^{\kappa}$. We define the terms of labor $TOL_t \equiv$

[10]The average domestic profit and the average exporting profit can be respectively written as $\tilde{\pi}_{d,t} = \pi_{d,t}(\tilde{z}_{d,t})$ and $\tilde{\pi}_{x,t} = \pi_{x,t}(\tilde{z}_{x,t})$.

$\frac{e_t(W_t^*/(Z_t^*H_t^*)}{W_t/(Z_tH_t)}$,[11] which measures the relative cost of effective units of labor. It adjusts for the aggregate productivity level and workers' health status.

3.2.5 Equilibrium

The home equilibrium price index is $1 = N_{d,t}(\tilde{\rho}_{d,t})^{1-\theta} + N_{x,t}^*(\rho_{x,t})^{1-\theta}$.[12] The aggregate effective labor is employed for the production, firm entry and fixed exporting costs. The wage rate adjusts so that effective labor supply equals to effective labor demand:

$$L_tH_t = N_{d,t}\frac{\tilde{\rho}_{d,t}^{-\theta}Y_t^c}{\tilde{z}_dZ_t} + N_{x,t}\frac{\tau_t\tilde{\rho}_{x,t}^{-\theta}Y_t^{c*}}{\tilde{z}_xZ_t} + N_{e,t}\frac{f_{e,t}}{Z_t} + N_{x,t}\frac{f_{x,t}}{Z_t}$$

In equilibrium, we have $\varphi_t = \varphi_{t+1} = 1$ as stocks are not traded across countries, and $B_t = B_{t+1}$ under financial autarky. Thus, the aggregate accounting condition is $C_t + M_t + N_{e,t}\tilde{v}_t = w_t(L_tH_t) + N_{d,t}\tilde{\pi}_t$.[13] The financial autarky condition implies balanced trade: $Q_tN_{x,t}(\tilde{\rho}_{x,t})^{1-\theta}Y_t^{c*} = N_{x,t}^*(\tilde{\rho}_{x,t}^*)^{1-\theta}Y_t^c$.

3.2.6 International Bond Trading

The home household can purchase the risk-free, country specific real bonds from the home and foreign countries, $B_{h,t}$ and $B_{f,t}$. Real return rates of home and foreign bonds are r_t and r_t^* respectively. We follow Turnovsky (1985) to assume quadratic costs of adjusting bond holdings, $\frac{\zeta}{2}(B_{h,t+1})^2$ and $\frac{\zeta}{2}Q_t(B_{f,t+1})^2$, which are rebated to the households as T.[14] The real exchange rate Q_t plays a role in converting the holding of foreign bonds into units of the home basket. The new budget constraint is $C_t+M_t+\tilde{v}_t(N_{d,t}+N_{e,t})\varphi_{t+1}+B_{h,t+1}+Q_tB_{f,t+1}+\frac{\zeta}{2}(B_{h,t+1})^2 + \frac{\zeta}{2}Q_t(B_{f,t+1})^2 = w_t(L_tH_t) + (\tilde{v}_t + \tilde{\pi}_t)N_{d,t}\varphi_t + (1+r_t)B_{h,t} + (1+r_t^*)B_{f,t} + T_t$.

---

[11] e_t is the nominal exchange rate, units of home currency per unit of foreign. The real wage is $w_t \equiv W_t/P_t$.

[12] The average real price of home firms in the domestic market is $\tilde{\rho}_{d,t} = \rho_{d,t}(\tilde{z}_{d,t})$ while the average real price of home exporters in the export market is $\tilde{\rho}_{x,t} = \rho_{x,t}(\tilde{z}_{x,t})$.

[13] The sum of C_t and M_t is total consumption level, and $N_{e,t}\tilde{v}_t$ is the value of home investment in new firms. Thus, consumption plus investment equal to income and dividend hold by the household.

[14] The assumption of quadratic costs of adjusting bond holdings induces stationary and determinacy of the steady state.

The Euler equation for home and foreign bonds are

$$1 + \zeta B_{h,t+1} = \beta(1 + r_{t+1})E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} \right]$$
$$1 + \zeta B_{f,t+1} = \beta(1 + r^*_{t+1})E_t \left[\frac{Q_{t+1}}{Q_t} \left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} \right]$$

Bond holdings of the foreign household are $B^*_{h,t}$ and $B^*_{f,t}$. The bond market clearing conditions in home and foreign countries are

$$B_{h,t} + B^*_{h,t} = 0$$
$$B_{f,t} + B^*_{f,t} = 0$$

The balance of international payment is give by

$$TB_t + r_t B_{h,t} + r^*_t Q_t B_{f,t} = (B_{h,t+1} - B_{h,t}) + Q_t(B_{f,t+1} - B_{f,t})$$

where the trade balance is the difference between total exports and imports (in units of home consumption), which is expressed as $TB_t \equiv Q_t N_{x,t}(\tilde{\rho}_{x,t})^{1-\theta} Y_t^{c*} - N^*_{x,t}(\tilde{\rho}^*_{x,t})^{1-\theta} Y_t^c$.

3.2.7 Physical Capital

In the model with physical capital, r^k_t is the gross rental rate of physical capital owned by the households. Physical capital accumulation follows the rule: $K_{t+1} = (1 - \delta_k)K_t + \epsilon^k_t I_t$, where ϵ^k_t is an investment-specific technology shock,[15] and δ_k is the depreciation rate. ϵ^k_t is assumed to follow AR(1) processes with i.i.d normal error terms, $\log \epsilon^k_t = \rho^k \log \epsilon^k_{t-1} + \eta^k_t$ in which $0 < \rho^k < 1$ and $\eta^k \sim \mathcal{N}(0, \sigma^k)$. The new budget constraint is $C_t + M_t + \tilde{v}_t(N_{d,t} + N_{e,t})\varphi_{t+1} + I_t = w_t(L_t H_t) + (\tilde{v}_t + \tilde{\pi}_t)N_{d,t}\varphi_t + r^k_t K_t$. The first order condition for capital K_{t+1} is

$$\frac{1}{\epsilon^k_t} = \beta E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} \left(r^k_{t+1} + \frac{1}{\epsilon^k_{t+1}}(1 - \delta_k) \right) \right]$$

The composite good Y^c_t is used for non-medical consumption, medical spending and

[15] We follow Mandelman and Zlate (2012) to construct a structural technology shock.

investment in physical capital:

$$C_t + M_t + I_t = \left[\underbrace{\int_{z_{min}}^{z_x} y_{d,t}(\omega)^{\frac{\theta-1}{\theta}} d\omega}_{\omega \in \Omega_{d,t}} + \underbrace{\int_{z_x^*}^{\infty} y_{x,t}^*(\omega)^{\frac{\theta-1}{\theta}} d\omega}_{\omega \in \Omega_{x,t}^*} \right]^{\frac{\theta}{\theta-1}}$$

The production function takes the form $y_t(z) = Z_t z[l_t(z)h_t(z)]^{1-\mu} k_t(z)^{\mu}$. The marginal cost for production is $mc_t(z) = \frac{1}{Z_t z} \left(\frac{w_t}{1-\mu}\right)^{1-\mu} \left(\frac{r_t^k}{\mu}\right)^{\mu}$. The wage rate and the return rate of physical capital are

$$r_t^k = mc_t(z)\mu \frac{y_t(z)}{k_t(z)}$$

$$w_t = mc_t(z)(1-\mu)\frac{y_t(z)}{l_t(z)h_t(z)}$$

The market clearing conditions for effective labor and physical capital are given by

$$L_t H_t = N_{d,t} \left[\frac{r_t^k(1-\mu)}{w_t \mu}\right]^{\mu} \left[\left(\frac{r_t^k}{\mu}\right)^{\mu} \left(\frac{w_t}{1-\mu}\right)^{1-\mu} \frac{\theta}{\theta-1}\right]^{-\theta} Z_t^{\theta-1} \left[(\tilde{z}_{d,t})^{\theta-1} Y_t^c + \frac{N_{x,t}}{N_{d,t}} (\tilde{z}_{x,t})^{\theta-1} \tau^{1-\theta} Q_t^{\theta} Y_t^{c*}\right] + N_{e,t}\frac{f_{e,t}}{Z_t} + N_{x,t}\frac{f_{x,t}}{Z_t}$$

$$K_t = N_{d,t} \left[\frac{w_t \mu}{r_t^k(1-\mu)}\right]^{1-\mu} \left[\left(\frac{r_t^k}{\mu}\right)^{\mu} \left(\frac{w_t}{1-\mu}\right)^{1-\mu} \frac{\theta}{\theta-1}\right]^{-\theta} Z_t^{\theta-1} \left[(\tilde{z}_{d,t})^{\theta-1} Y_t^c + \frac{N_{x,t}}{N_{d,t}} (\tilde{z}_{x,t})^{\theta-1} \tau^{1-\theta} Q_t^{\theta} Y_t^{c*}\right]$$

3.3 Calibration

We choose parameter values to match features of the U.S. economy at a quarterly frequency by setting $\beta = 0.99$ to match an average annual interest rate of 4%. Following the literature Ghironi and Melitz (2005), we calibrate the coefficient of relative risk aversion $\gamma = 2$, the intra-temporal elasticity of substitution $\theta = 3.8$, the probability of firm exit the market $\delta_e = 0.025$, the Pareto distribution parameter $\kappa = 3.4$, the quadratic adjustment cost parameter $\eta = 0.0025$ and the sunk entry cost $f_e = 1$. The lower bound of firm-specific productivity z_{min} is set to 1.

The iceberg trade costs τ is calibrated so that the average U.S. trade over GDP is equal to 25% in the steady state, implying $\tau = 1.56$. The fixed cost of exporting f_x is set to 0.04 to match the average U.S. export shares of GDP as 11%. The utility weight ψ_h is set to 0.32 to match the average personal healthcare expenditure as 13.8% in the United States. The elasticity of labor supply is $1/\mu = 1$ as in Farhat (2009). The weight on disutility χ is calibrated to be 0.32 so that $TOL = 1$ in the steady state. α is set to 0.5 to match the average U.S. health investment of GDP as 0.94%. A summary of the calibrated parameters of the baseline model is presented in Table 3.1.

3.4 Results

The section presents the impulse responses of key model variables to examine the linkage between health investment and trade openness.

3.4.1 Positive Home Aggregate Productivity Shock

Figure 3.7 compares the effect of home aggregate productivity shock in the baseline model and model under financial autarky in Ghironi and Melitz (2005). Similar to their model results, a temporary 1% increase in aggregate productivity in home encourages more firm entry N_e, leading to a boost in the stock of firms N_d. Entry of new firms also pushes the number of home exporters N_x upward. The productivity cutoff for home exporters z_x increases but that of foreign exporters z_x^* decreases because of the relative higher labor costs, reflecting the reduction in terms of labor. The main departure from the literature is that the baseline model considers the health capital accumulation through increasing personal medical expenditure and devoting more work time to leisure or exercise. Without capturing workers' health status and health investment, the impacts of changing in aggregate productivity could be underestimated as there exists a gap between the blue and red lines in Figure 3.7. An increase in home productivity leads to more growth in the non-medical consumption and the number of exporters in the home country, and its positive impacts on the stock of firms and export values last for a longer time compared to the literature. The reason is that health capital plays a role in affecting not only labor productivity but also consumption and investment levels. Following an increase in aggregate productivity in home, the home economy has greater output and higher national income, encouraging more health consumption and investment. Meanwhile, a greater stock of health capital increases output again, stimulates more investment in new firm and boosts trade values.

Our baseline model also predicts that an increase in home aggregate productivity boosts not only non-medical consumption C but also medical spending M due to the income effect. This result is consistent with the empirical finding that there is a positive linkage between healthcare expenditure and personal income. More medical spending indicates greater investment in health capital, so the stock of health capital H deviates from the steady state positively following a positive home aggregate productivity shock.

Compared to the baseline model (financial autarky), a transitory 1% increase in aggregate productivity results in similar dynamic effects on the key variables in the model with international bond trading as displayed in Figure 3.8 (red line). To some extent, incorporating bond trading creates stronger spillover effects in terms of changes in foreign non-medical consumption C^*, health capital H^* and the number of firms N_d^*.

3.4.2 Positive Investment-Specific Health Shock

A positive health shock refers to a transitory 1% increase in health investment of the household. Figure 3.9 indicates that an increase in health capital investment due to more healthcare expenditure leads to a gradual increase in the stock of health capital in home. Better health status of labor results in higher personal income, mirroring an increase in consumption levels. The number of home firm entrants deviates negatively from its steady state within 10 periods following a positive health shock, which predicts that there is a trade-off between health capital and physical capital investment.[16] In the longer term, the stock of home firms increases gradually as the positive income effect becomes stronger. Moreover, to improve health status, the household supplies less labor units so home wage is relatively higher compared to the foreign economy. There is a reduction in terms of labor in the long run because of an increase in firm entrants and a decline in labor supply.

Additionally, an increase in health investment boosts home export values and the number

[16] The number of firms acts like physical capital and the number of firm entrants is treated as the physical capital investment in the model.

of home exporters as well. The main mechanism is that health investment creates a greater stock of health capital, facilitating long-run economic growth and stimulating bilateral trade. The positive effect of health on economic growth comes from more healthcare expenditure, better health status of the household and higher labor productivity levels in the economy.

We also look at the impulse response of a positive investment-specific health shock in the home country under the alternative model with physical capital accumulation as shown in Figure 3.10. The key implication is that health investment crowds out physical capital investment. More investment in medical devices and equipment may reduce the physical capital stock if the change in output is very small or constant. According to the discussion in Gong et al. (2012), health investment may not benefit economic growth if the contribution of health capital to production is not sufficient and the ratio of health capital to physical capital stock is very large.

3.4.3 Positive Investment-Specific Technology Shock

Figure 3.11 shows that the impulse response of a transitory 1% increase in investment in physical capital K in home under the alternative model incorporating physical capital accumulation. More physical capital accumulation results in greater stocks of health capital and the number of firms due to the positive effects on income, growth and welfare. These effects last for a long time as they are back to the steady-state levels in about 100 periods. According to Denison (1980), capital is an important sources of output growth with around 18% of the growth rate of the national income. In addition, there is a positive demand spillover effect in the foreign country. However, an increase in physical capital investment leads to negative changes in regular exports and the number of exporters in the home economy.

3.4.4 Negative Trade Costs Shock

The model assumes a symmetric iceberg trade cost τ in two countries, and the impulse responses to a negative trade cost shock in the baseline model are shown in Figure 3.12. First, a transitory 1% decrease in trade costs boosts consumption and encourages more firm entrants in both economies. Second, lower trade barriers increase the profitability of exports and reduce the export productivity cutoffs, so the number of exporters increases. There is a larger increase in regular exports compared to the extensive margin of exports. Third, trade openness creates more healthcare spending and increases the stock of health capital. Consistent with previous studies, more trade leads to economic growth, contributing higher income and wealth levels in the country. Therefore, there are more medical spending and health investment from the household. In addition, there is one identification of the number of exporters and the number of exported varieties; thus, trade integration could result in more product varieties including medical supplies, drugs and health services. The household benefits from greater health product varieties. In general, trade openness creates a positive income effect, which encourages more investment in health capital, but a decline in the number of firm entrants. This indicates that the household face a trade-off between investment in health capital and new firm entrants.

Table 3.2 displays that a permanent 20% reduction in trade costs creates 25% increase in consumption C, 30% increase in medical expenditure M, 16% increase in health capital H and 12% increase in the number of firm entrants N_e. The household benefits from trade integration because of an increases in consumption levels $(C + M)$. Medical expenditure is relatively more affected by the changes in trade costs, which indicates that it is more income elastic compared to non-medical spending. In terms of investment in capital, the household has relatively greater incentive in accumulating more health capital rather than investing more in new firms.

3.4.5 Sensitivity Analysis

We verify the robustness of results with respect to key parameters whose calibration is relatively challenging. The results of the sensitivity analysis are shown in Table 3.2. Overall, the effects of trade integration on non-medical consumption, healthcare spending, health capital accumulation, the numbers of firm entrants and exporters and export values are less pronounced for smaller values of the share of healthcare spending in health investment α and the utility weight of health capital ψ_h. With a greater depreciation rate of health capital

δ_h, a reduction in trade costs has less influences on these key variables. On the contrary, larger values of α and ψ_h indicate greater positive impacts of trade openness on these key variables. These findings are consistent with the previous results of the impulse responses as health capital plays an important role in enhancing the impacts of trade openness on the economy. Overall, the benchmark calibration is robust to the alternative parameterizations.

3.5 Conclusion

We develop a two-country dynamic stochastic general equilibrium model of macroeconomic dynamics and trade with featuring health investment and capturing workers' health status. This paper contributes to the trade literature through exploring how changes in health capital affect trade and investigating whether a reduction in trade barriers stimulates more health expenditure and investment. It also contributes to the international macroeconomic literature by studying the role of health capital stock in explaining international business cycles.

A key message of the paper is that there is positive association between trade openness and health investment in a dynamic framework, which is in line with some existing empirical findings. Trade is good for health as more trade leads to growth, encouraging more healthcare spending and health capital investment in the economy. In addition, trade openness create more firm entrants and increase the tradable healthcare varieties. The household could benefit from more imported medical goods and services at lower prices following the reduction in trade barriers. Health investment results in a greater stock of health capital, which contributes to economic growth and stimulates more trade. To accumulate more health capital, the household need to give up more investment in new firm establishments and physical capital.

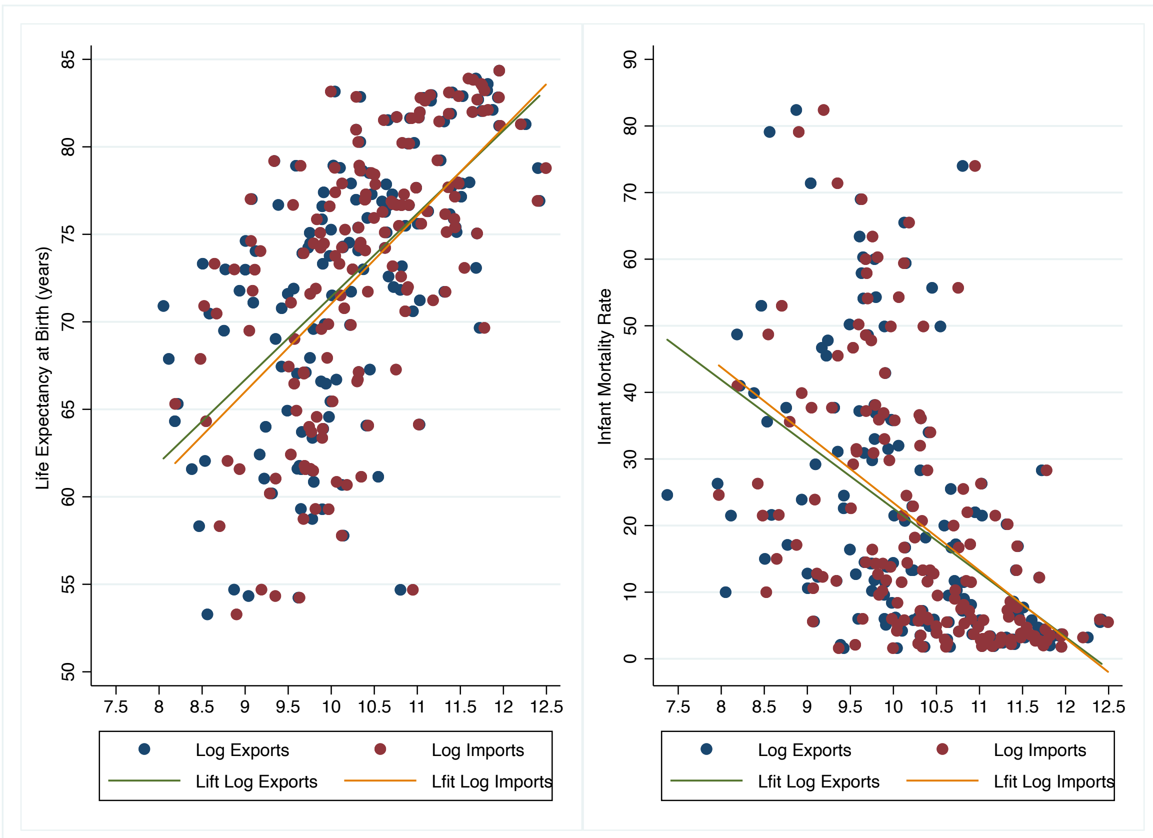

Figure 3.1: Health outcomes and trade

Source: Data are from the World Bank World Development Indicators, 2019. There are 162 countries in total.

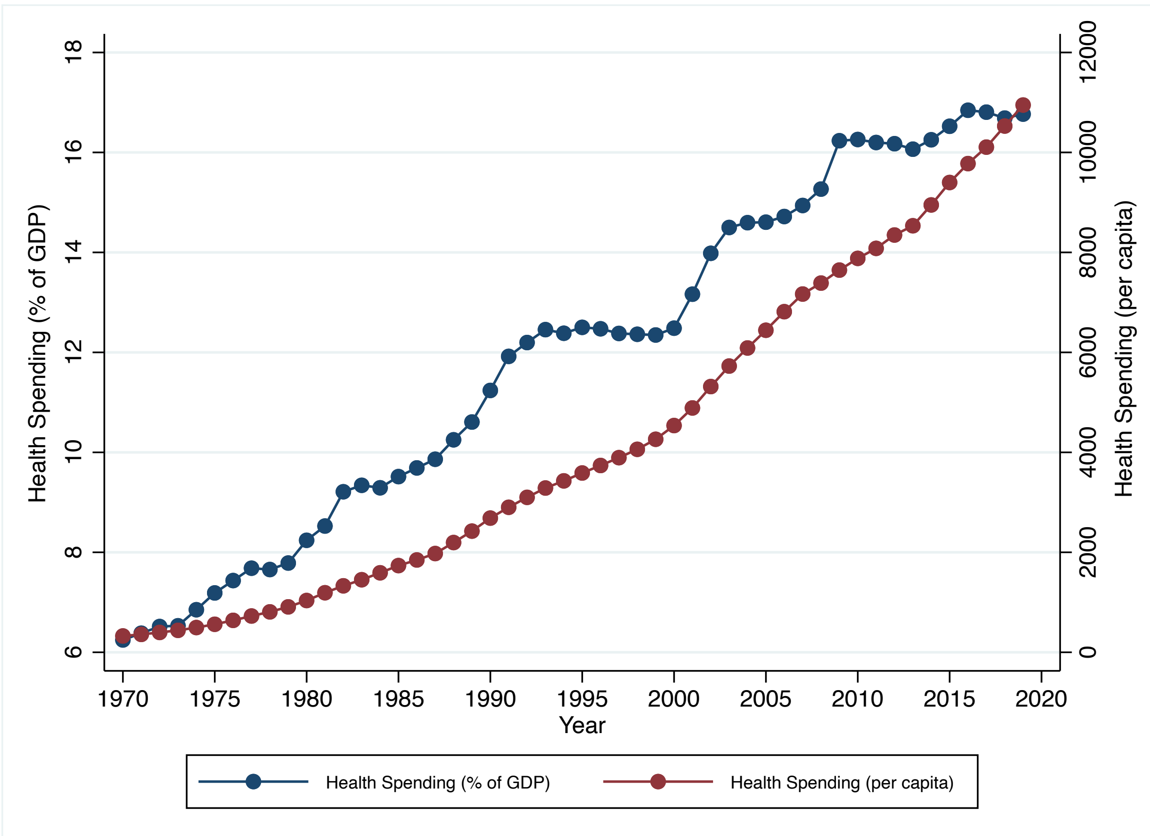

Figure 3.2: Health spending in the United States

Source: OECD (2022), health spending (indicator). Health spending measures the final consumption of healthcare goods and services.

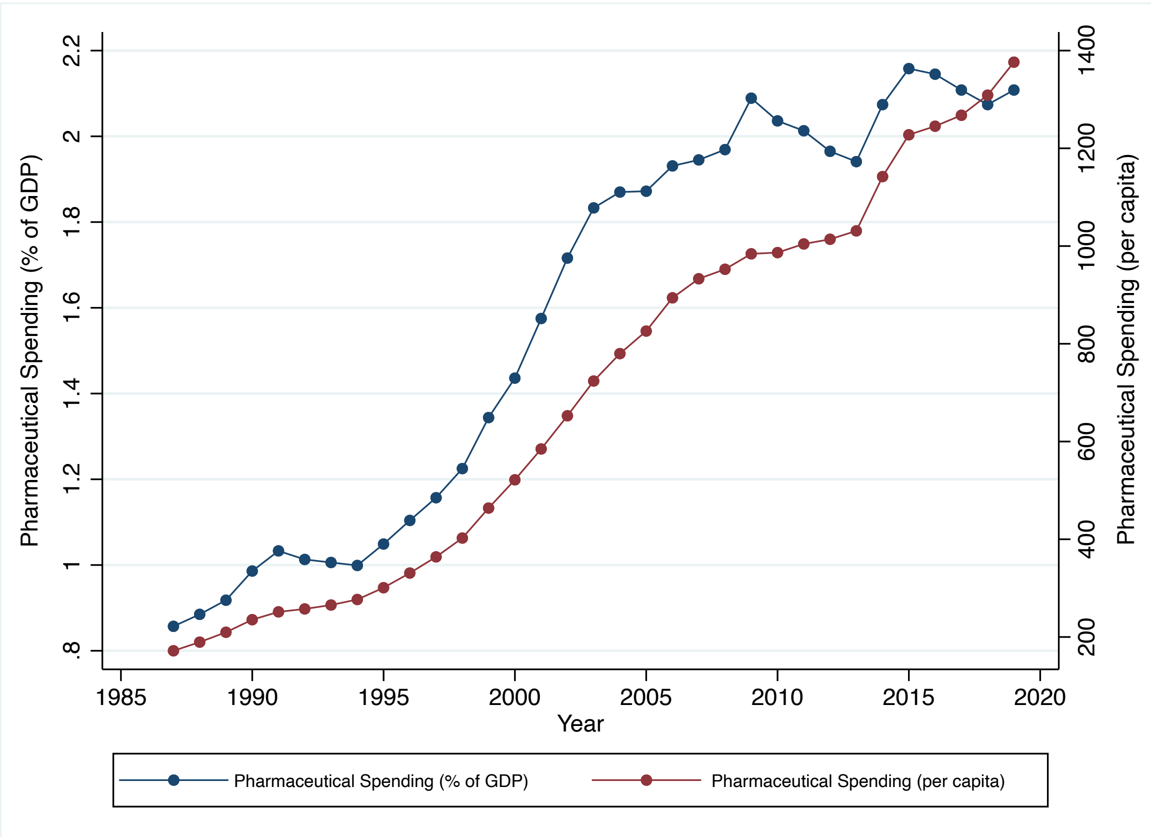

Figure 3.3: Pharmaceutical spending in the United States

Source: OECD (2022), Pharmaceutical spending (indicator). Pharmaceutical spending covers expenditure on prescription medicines and self-medication, often referred to as over-the-counter products.

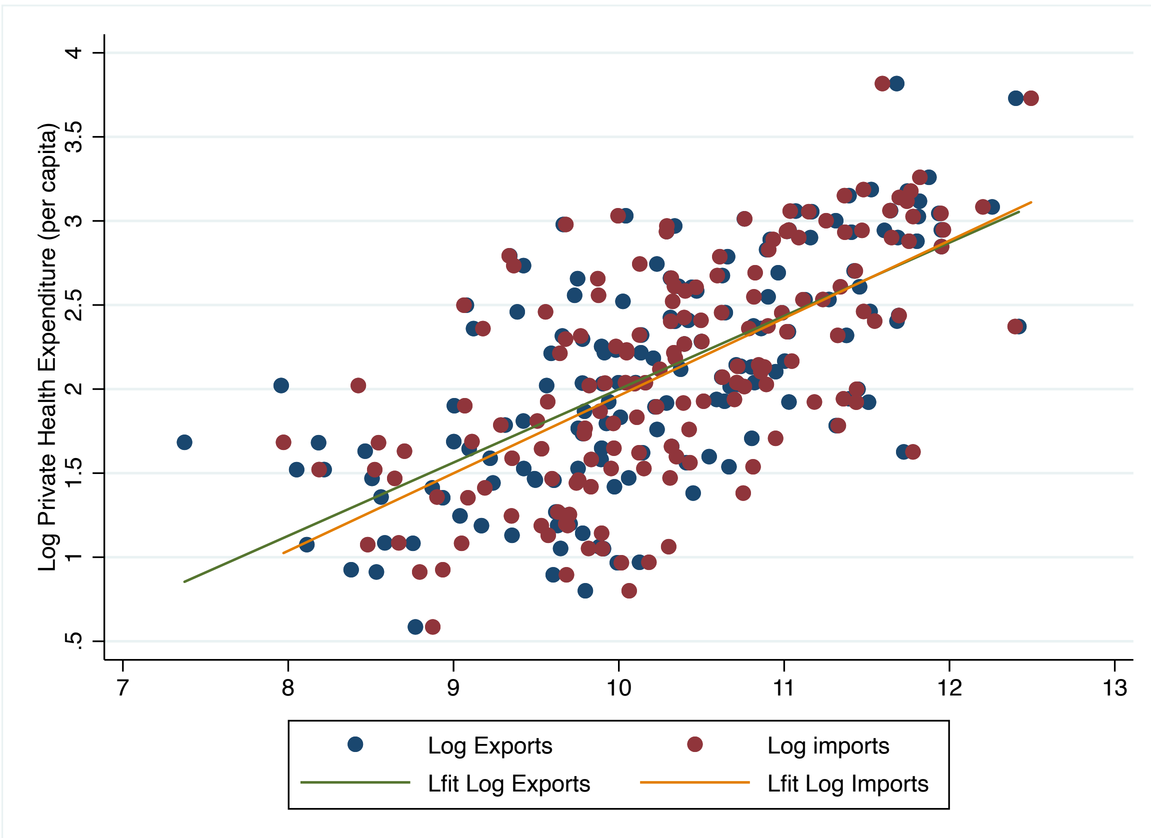

Figure 3.4: Private health expenditure and trade

Source: Data are from the World Bank World Development Indicators, 2019. There are 162 countries in total.

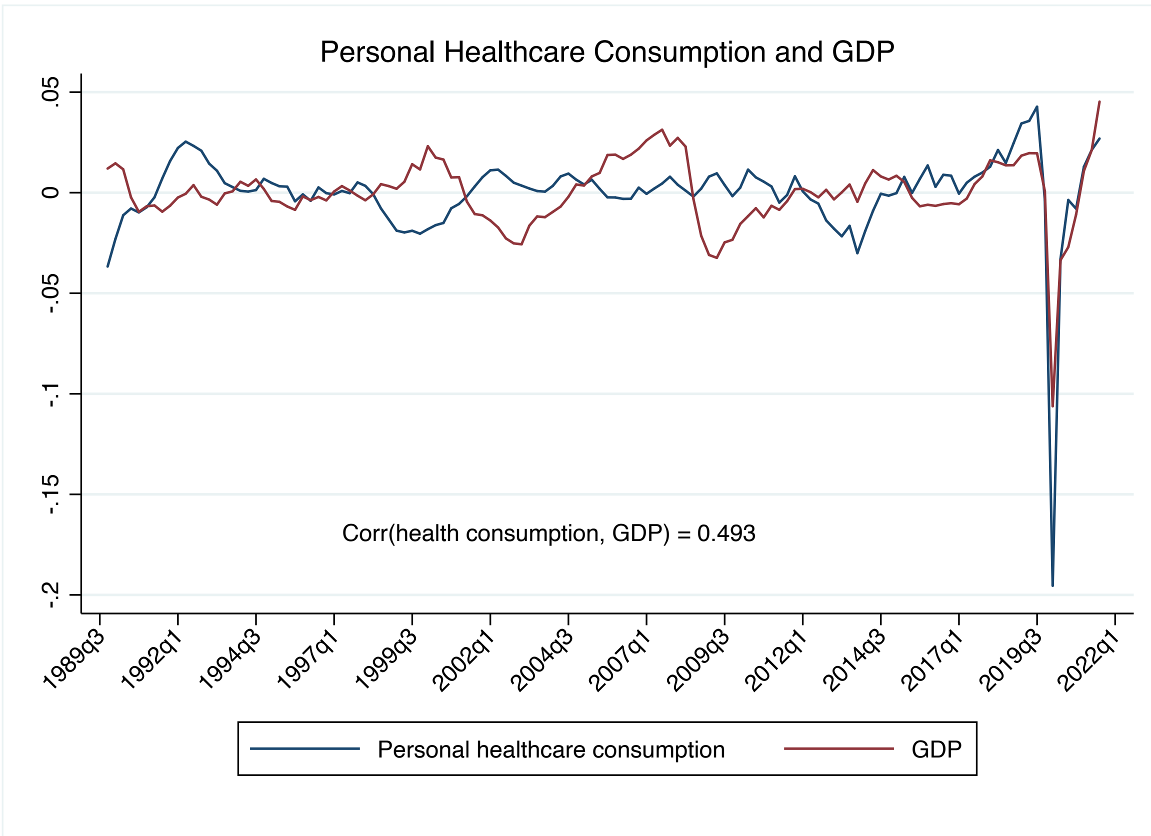

Figure 3.5: Personal healthcare expenditure and GDP in the United States

Note: The data series is from U.S. Bureau of Economic Analysis, Gross Domestic Product [GDP], Personal consumption expenditures: Services: Health care [DHLCRC1Q027SBEA], retrieved from FRED, Federal Reserve Bank of St. Louis. The series are seasonally adjusted, converted in natural logs, and expressed in deviations from a Hodrick-Prescott trend.

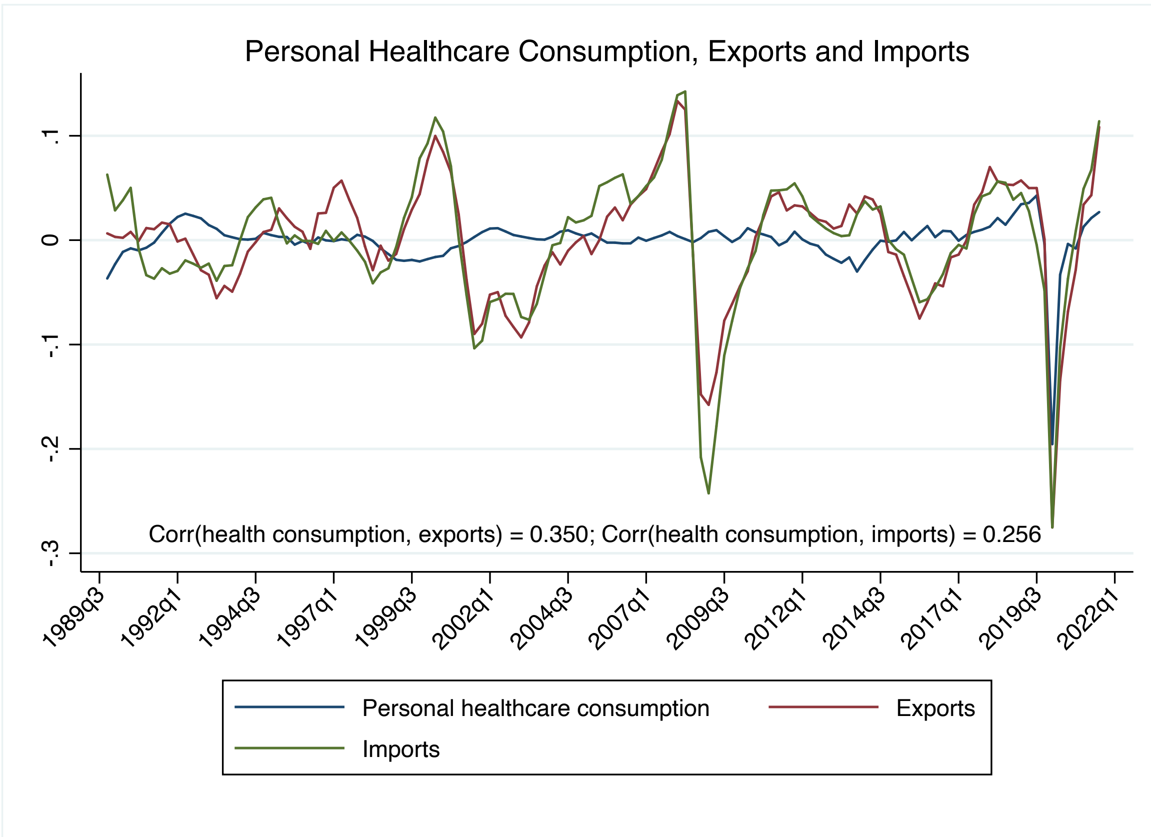

Figure 3.6: Personal healthcare expenditure, exports and imports in the United States

Note: U.S. Bureau of Economic Analysis, Exports of Goods and Services [EXPGS], Imports of Goods and Services [IMPGS], Personal consumption expenditures: Services: Health care [DHLCRC1Q027SBEA], retrieved from FRED, Federal Reserve Bank of St. Louis. The series are seasonally adjusted, converted in natural logs, and expressed in deviations from a Hodrick-Prescott trend.

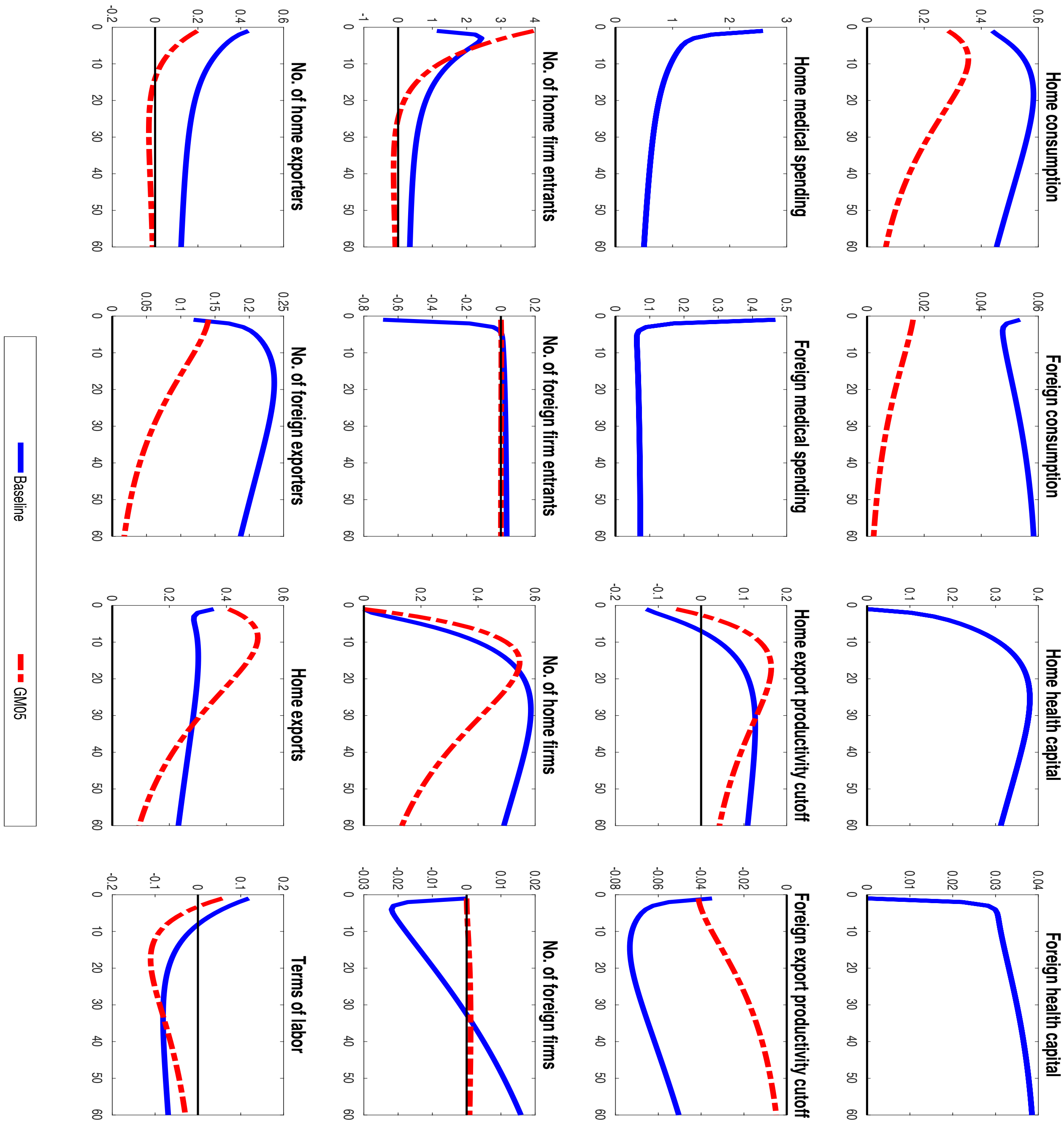

Figure 3.7: Impulse responses to a positive aggregate productivity shock in home, baseline model vs. model in GM(2005)

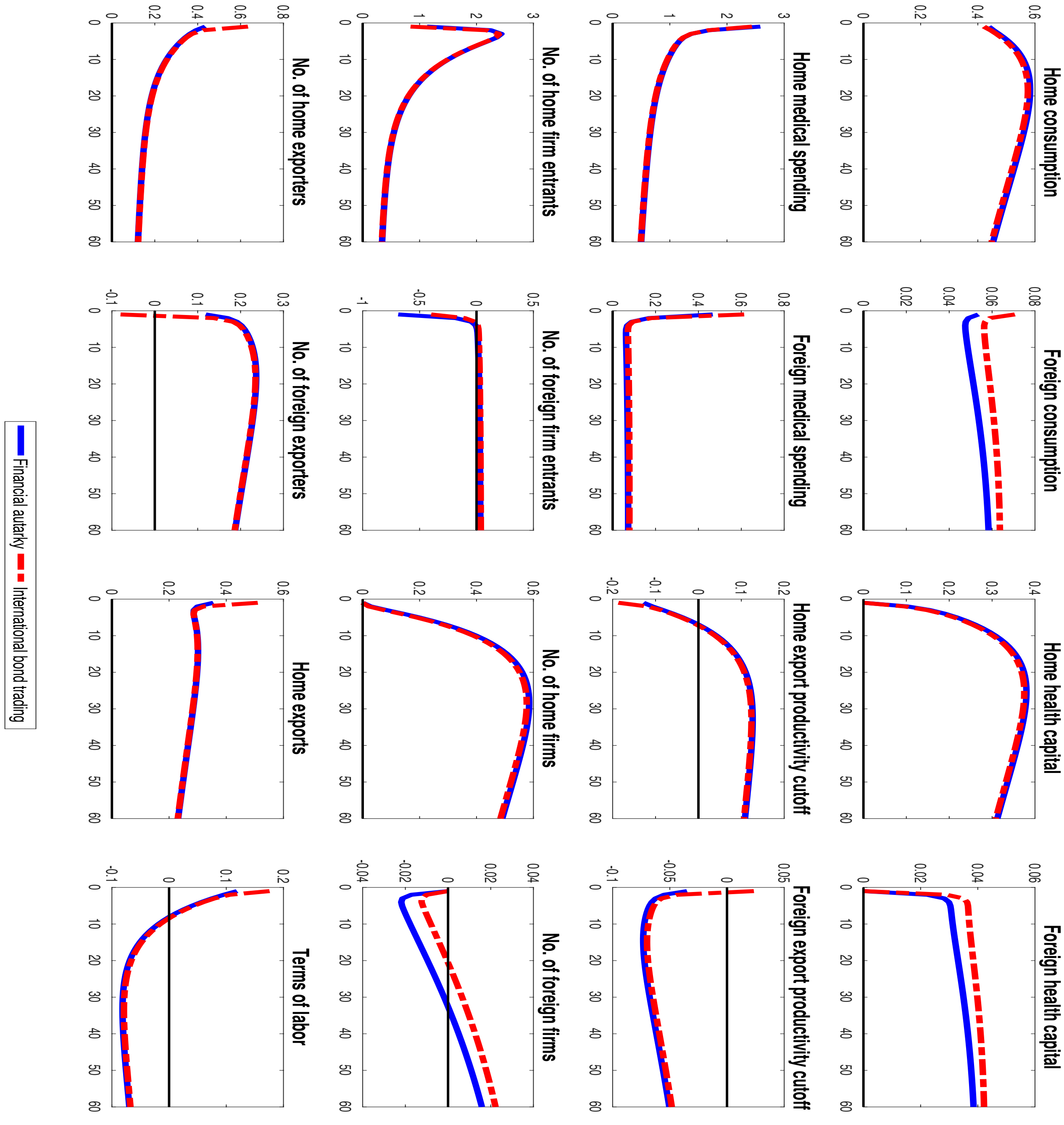

Figure 3.8: Impulse responses to a positive aggregate productivity shock in home, baseline model vs. model with international bond trading

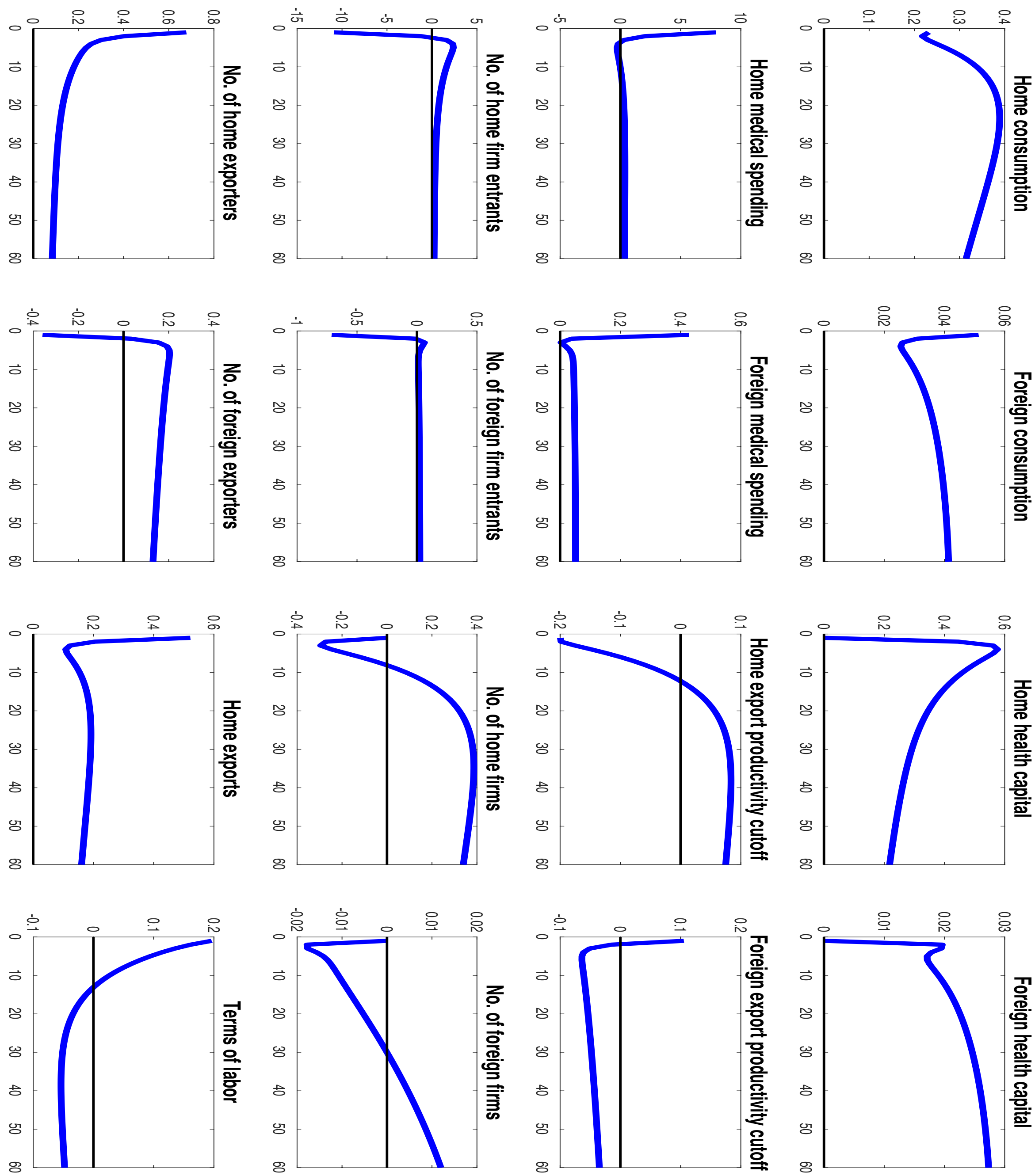

Figure 3.9: Impulse responses to a positive investment-specific health shock in home, baseline model

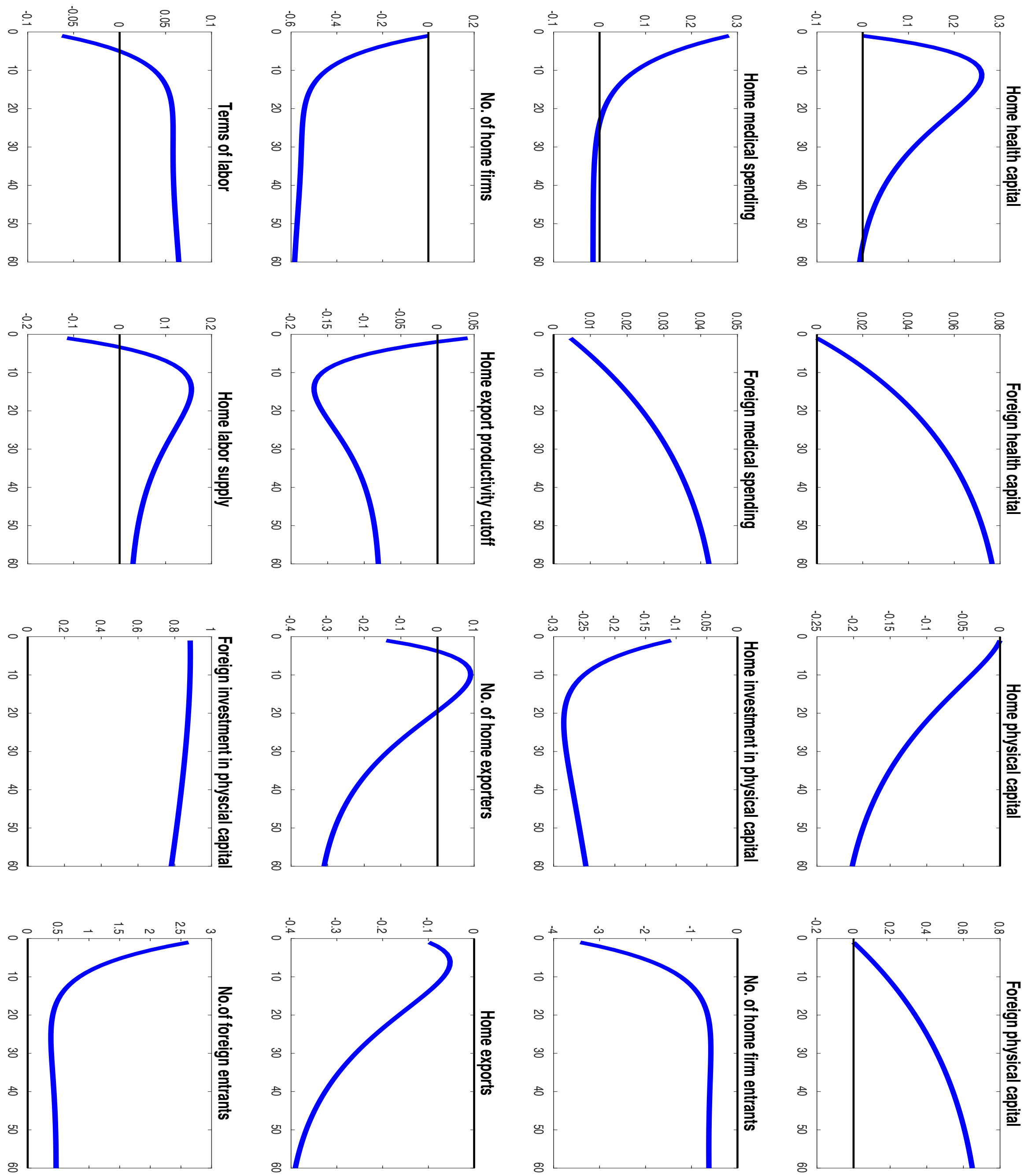

Figure 3.10: Impulse responses to a positive investment-specific health shock in home, model with physical capital

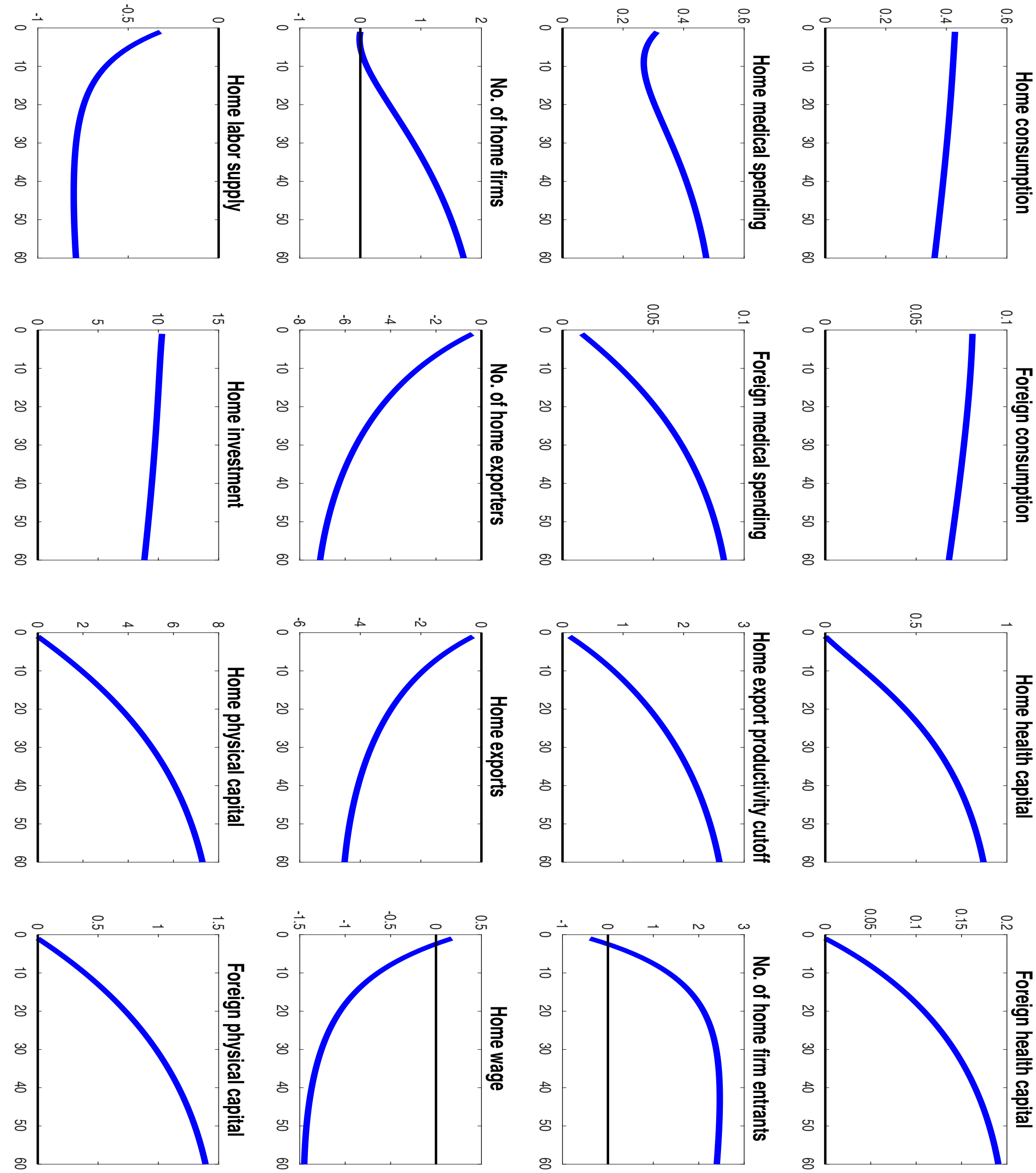

Figure 3.11: Impulse responses to a positive investment-specific technology shock in home

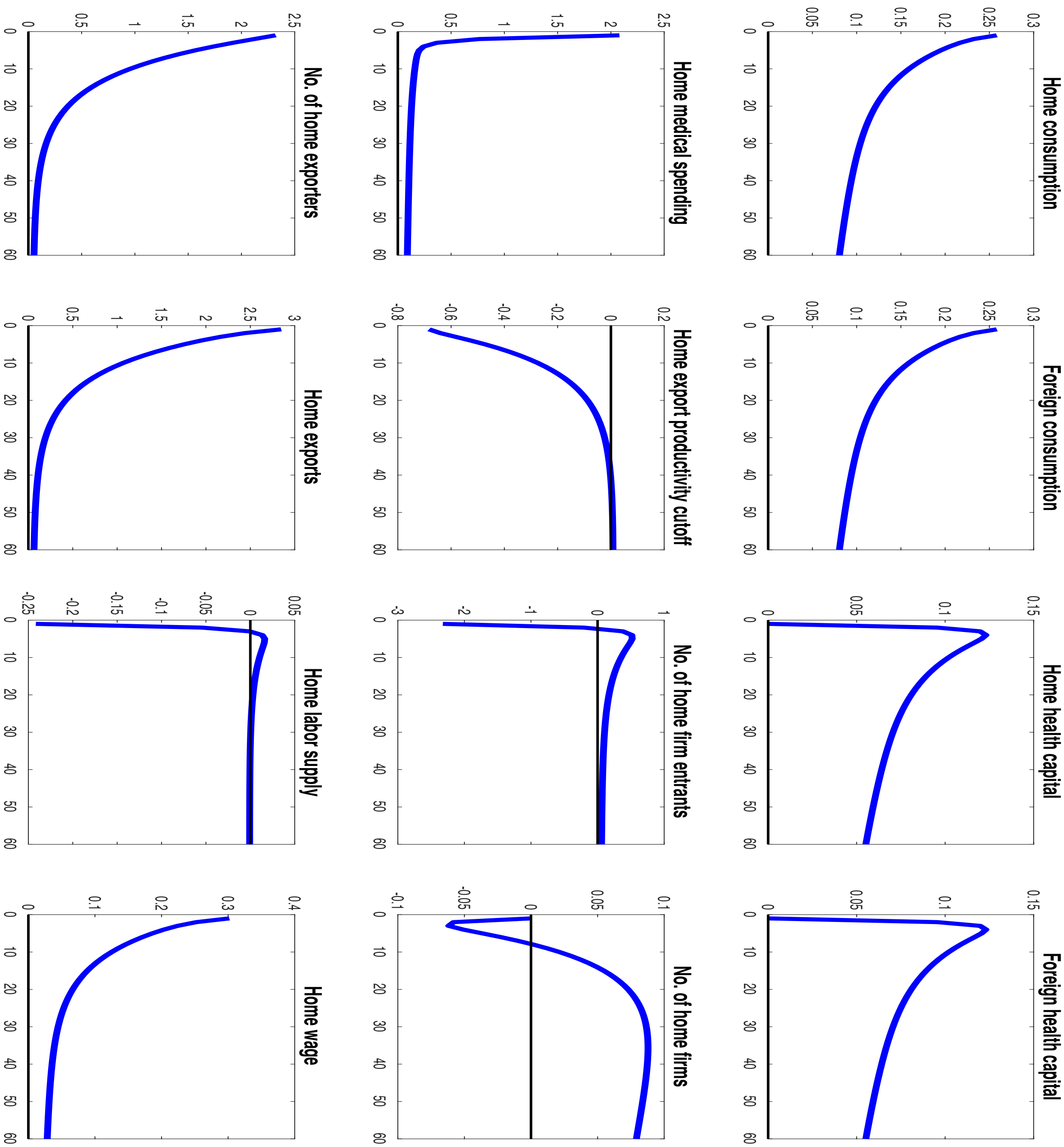

Figure 3.12: Impulse responses to a negative trade costs shock in home

Table 3.1: Calibration parameters

Parameters	Values	Sources or targets
Discount factor	$\beta = 0.99$	Literature, 4 % interest rate
Relative risk aversion	$\gamma = 2$	Literature
Elasticity of substitution	$\theta = 3.8$	Literature
The probability of firm exit	$\delta_e = 0.025$	Literature
Pareto distribution	$\kappa = 3.4$	Literature
Quadratic adjustment cost	$\zeta = 0.0025$	Stationary bond holdings
Sunk entry cost	$f_e = 1$	Literature
Iceberg trade cost	$\tau = 1.56$	U.S. trade share 25% of GDP
Fixed cost of exporting in home	$f_x = 0.04$	U.S. export share 11% of GDP
Elasticity of labor supply	$1/\mu = 1$	Literature
Disutility from labor	$\chi = 0.35$	Terms of labor equal to 1 in the steady state
Utility weight of health capital	$\psi_h = 0.32$	U.S. personal healthcare expenditure 13.8% of GDP
Depreciation rate of health capital	$\delta_h = 0.025$	Literature, capital depreciation rate
Share of medical spending in health investment	$\alpha = 0.5$	U.S. health investment 0.94% of GDP

Table 3.2: Trade openness – Percentage changes of non-stochastic steady state

	% ΔC	% ΔM	% ΔH	% ΔEx	% ΔN_x	% ΔN_e
Baseline	25.3	30.1	16.2	84.2	92.0	12.2
$\delta_h = 0.05$	19.2	22.3	11.9	77.9	85.1	7.97
$\alpha = 0.4$	20.5	28.9	13.55	79.1	87.4	9.51
$\alpha = 0.6$	29.1	33.4	18.9	85.3	94.5	13.1
$\psi_h = 0.2$	17.1	19.2	9.85	75.2	82.0	6.73
$\psi_h = 0.4$	30.7	39.5	22.6	92.6	98.1	20.5

Notes: Trade openness refers to the specification that there is a permanent 20 % reduction in the trade cost τ. The percentage changes in non-statistic steady state of non-medical consumption, healthcare spending, the stock of health capital, the number of firm entrants, the number of exporters and export values are calculated under alternative parameterizations.

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Appendix A

INTERNATIONAL TRADE, IMMIGRATION AND MACROECONOMIC DYNAMICS

A.1 Additional Figures and Tables

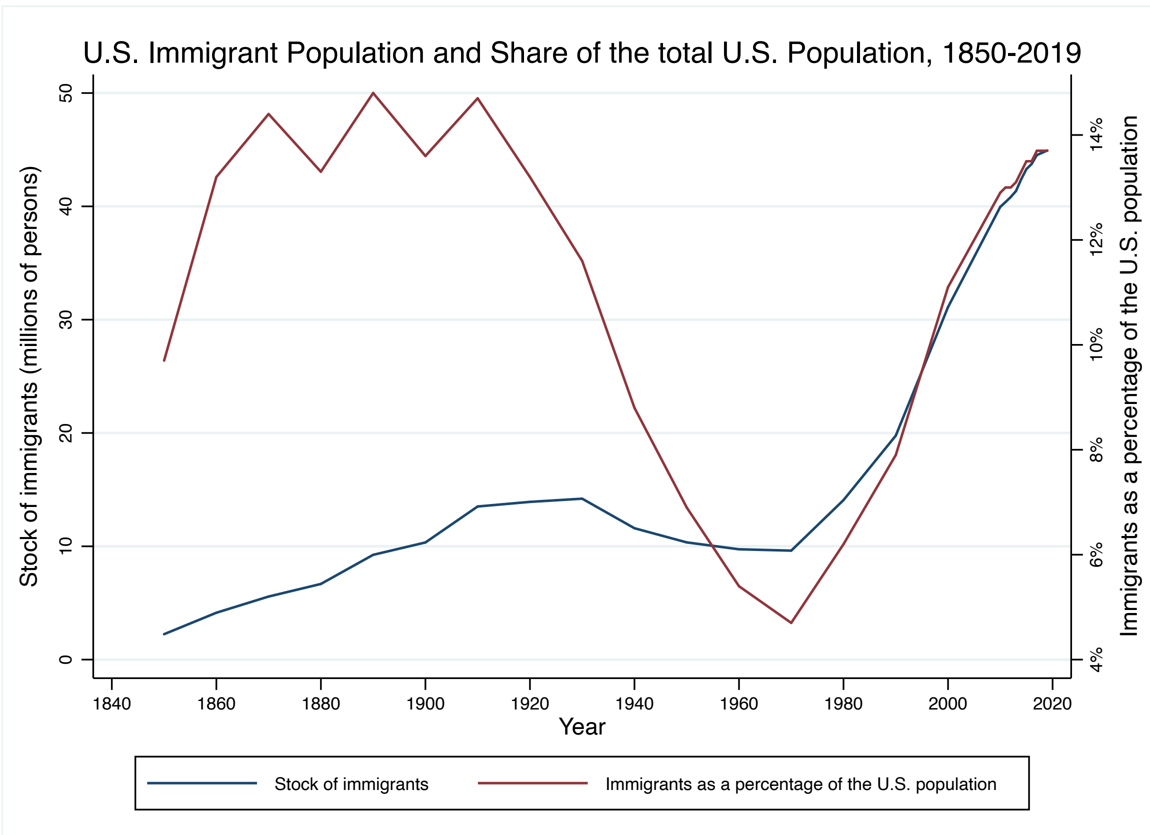

Figure A.1: Historical data of U.S. immigrant population.

Source: Migration Policy Institute (MPI) tabulation of data from U.S. Census Bureau, 2010-2019 American Community Surveys (ACS), and 1970, 1990, and 2000 Decennial Census.

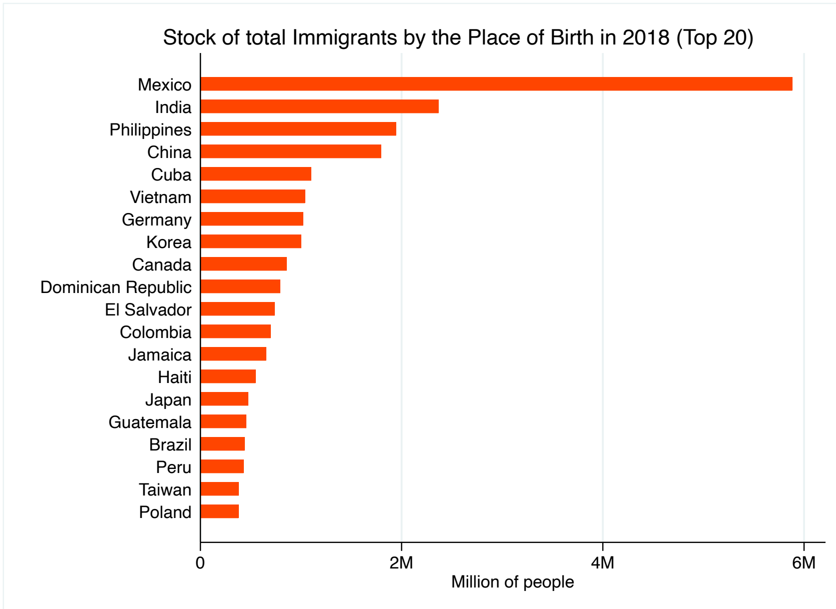

Figure A.2: Top 20 labor-sending countries.

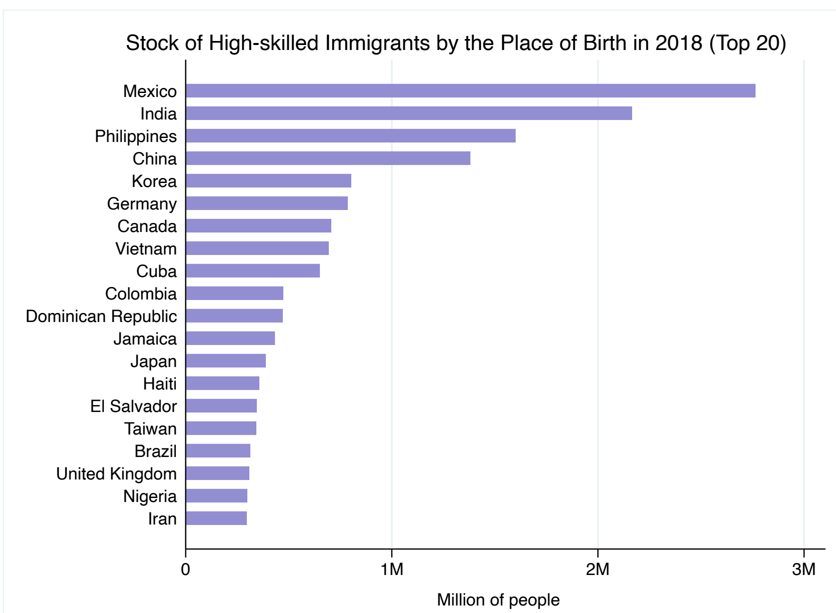

Figure A.3: Top 20 high-skilled labor-sending countries.

Source: U.S. Census Bureau, American Community Survey, 1-Year Estimates-Public Use Microdata Sample.

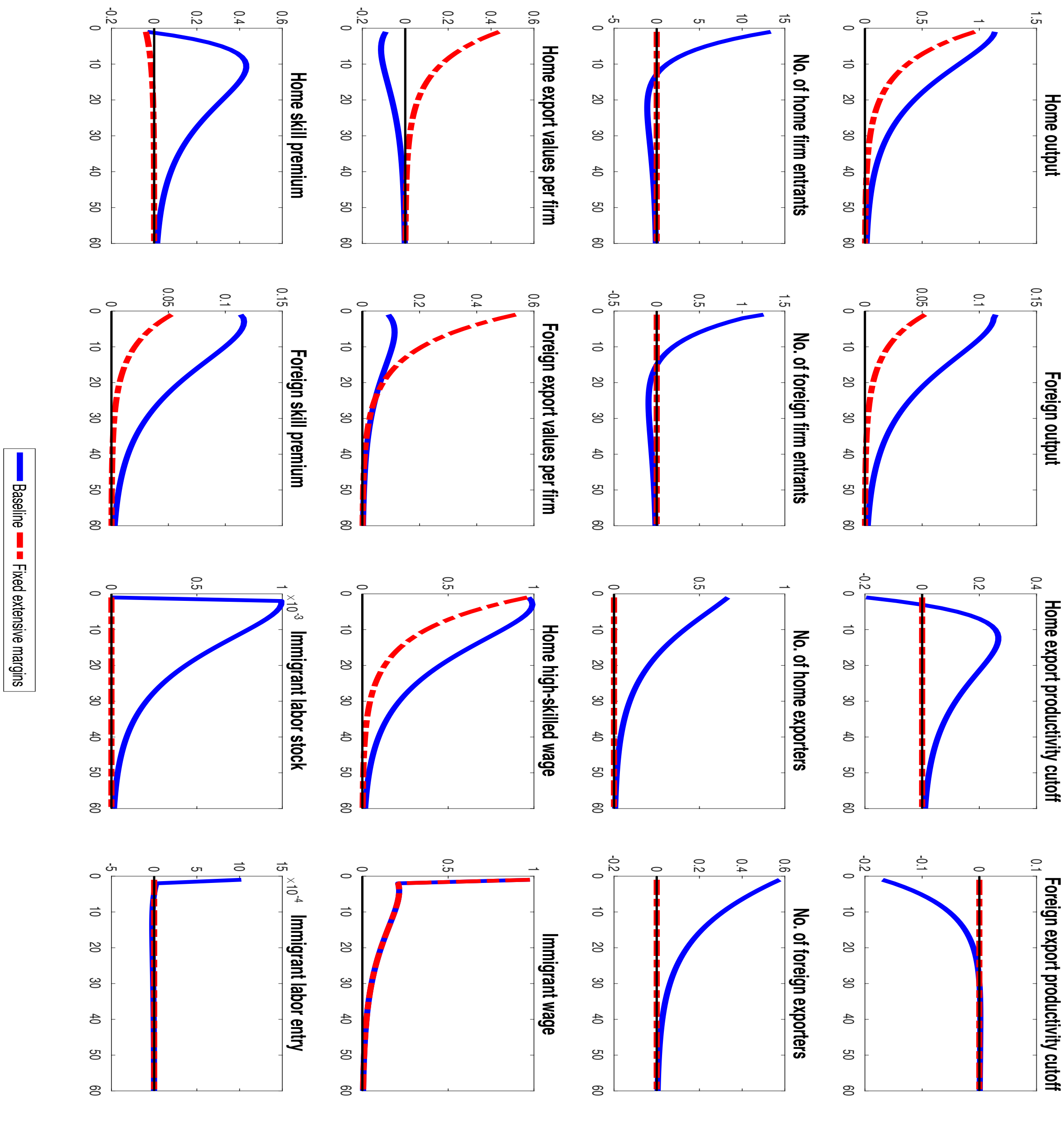

Figure A.4: Impulse responses to a positive aggregate productivity shock in home, baseline model vs. model with fixed extensive margins.

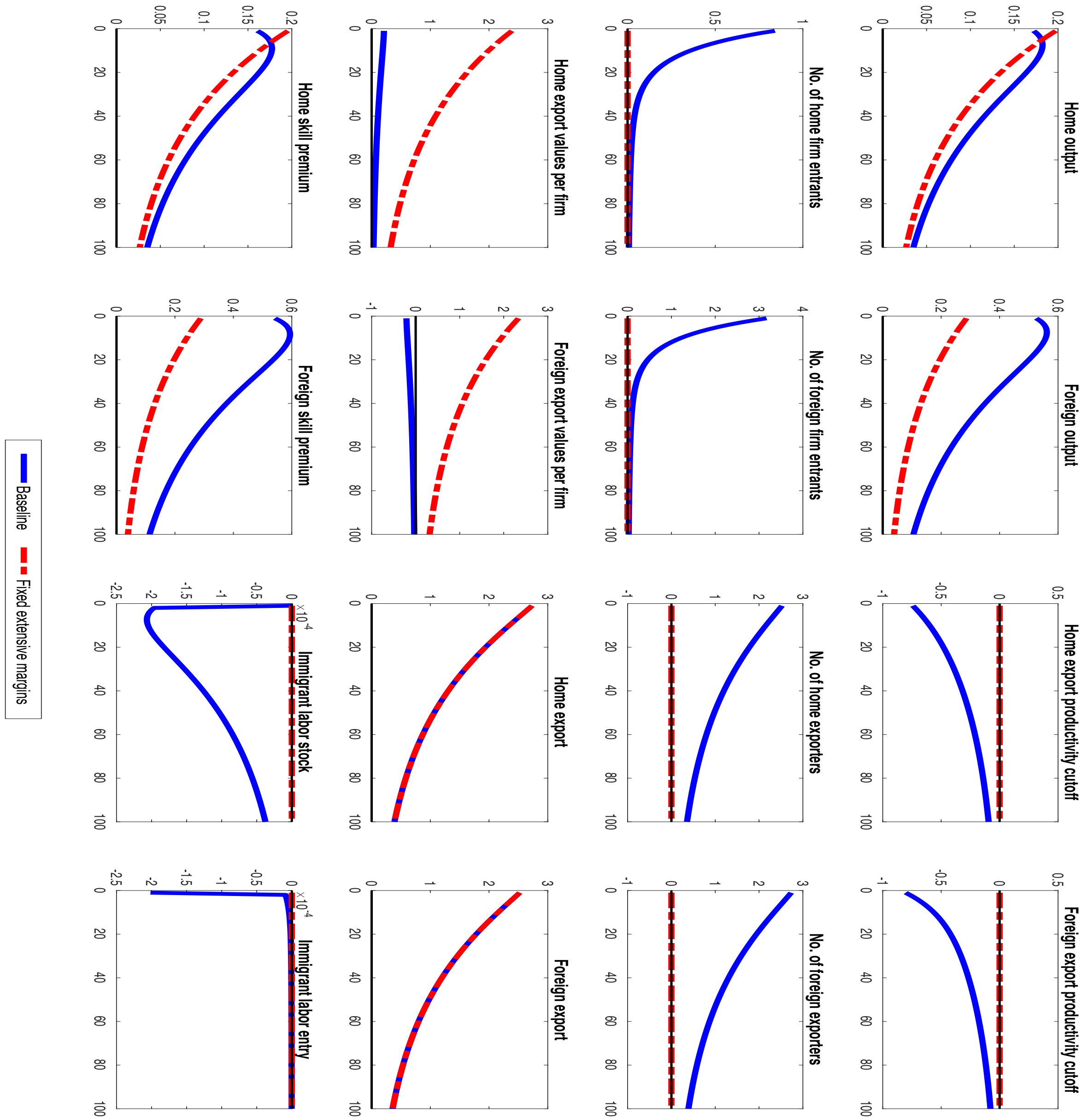

Figure A.5: Impulse responses to a decrease in iceberg trade costs, baseline model vs. model with fixed extensive margins.

Table A.1: Percentage changes of U.S. immigrants and bilateral trade between U.S. and the main labor-sending countries, 2004-2018

Source or partner countries	Total immigrants	High-skilled immigrants	U.S. exports	U.S. imports
China	105.49	117.57	248.99	167.55
India	97.59	103.29	448.38	243.18
Mexico	45.65	65.98	139.71	121.17
Philippines	44.29	41.59	23.04	35.16
Vietnam	47.04	40.18	775.21	795.47
World	44.69	70.93	104.37	71.21

Note: All values are in percent. Source: U.S. Census Bureau and UN-WITS.

Table A.2: Pairwise correlations between trade and migration, United States

	1870-1910	1910-1950	1950-2000	2004-2018
Gross bilateral export and migrant shares	0.422	0.177	0.207	0.095
Gross bilateral import and migrant shares	-0.116	-0.110	0.175	0.105
Gross bilateral export and skilled migrant shares	n/a	n/a	n/a	0.111
Gross bilateral import and skilled migrant shares	n/a	n/a	n/a	0.121

Note: The correlation data, 1870-2000, is from Table 1 in Jacks and Tang (2018). The years used in the correlation analysis are every decade between 1870 and 2000. Between 2004 and 2018, I calculate immigration shares using the database of the foreign born population over 25 years and the total U.S. population.

A.2 Model Steady State

I denote constant, steady-state levels of variables by dropping the time subscript and assume $f_e = f_e^*$, $\tau = \tau^*$, $z_{min} = z_{min}^* = 1$.

Profits:

The Euler equation for share holdings: $\tilde{v} = \beta(1-\delta_e)(\tilde{v} + \pi)$, so the average total profit can be written as: $\tilde{\pi} = \frac{1-\beta(1-\delta_e)}{\beta(1-\delta_e)}\tilde{v}$. Combining the total profit equation with the free entry condition $\tilde{v} = f_e$ implies that

$$\begin{aligned} \frac{1-\beta(1-\delta_e)}{\beta(1-\delta_e)} f_e &= \tilde{\pi}_d + \frac{N_x}{N_d}\tilde{\pi}_x \\ &= \tilde{\pi}_d + \left(\frac{z_{min}}{z_x}\right)^{\kappa} \tilde{\pi}_x \end{aligned}$$

The steady-state zero profit export cutoff equation implies that

$$\tilde{\pi}_x = \frac{\theta - 1}{\kappa - (\theta - 1)} f_x$$

Two steady-state profit equations $\tilde{\pi}_d = \frac{1-\alpha}{\theta}\rho_d^{(1-\theta)}\rho_s^{(\theta-\rho)}Y$ and $\tilde{\pi}_x = (1-\alpha^*)\tilde{\rho}_x^{1-\theta}\rho_s^{*(\theta-\rho)}Y^*Q/\theta - f_x$ imply that

$$\tilde{\pi}_d = (\tilde{\pi}_x + f_x)\frac{1-\alpha}{1-\alpha^*}\left(\frac{\tilde{\rho}_d}{\tilde{\rho}_x}\right)^{1-\theta}\left(\frac{\rho_s}{\rho_s^*}\right)^{\theta-\rho}\frac{Y}{Y^*Q}$$

Two optimal pricing equations $\tilde{\rho}_d = \frac{\theta}{\theta-1}\frac{\phi_h w_h + \phi_m w_m}{\tilde{z}_d \Phi}$ and $\tilde{\rho}_x = \tau Q^{-1}\frac{\theta}{\theta-1}\frac{\phi_h w_h + \phi_m w_m}{\tilde{z}_x \Phi}$ imply that $\frac{\tilde{\rho}_d}{\tilde{\rho}_x} = \frac{Q\tilde{z}_x}{\tau\tilde{z}_d}$. Hence, we get

$$\tilde{\pi}_d = (\tilde{\pi}_x + f_x)\frac{1-\alpha}{1-\alpha^*}\left(\frac{Q\tilde{z}_x}{\tau\tilde{z}_d}\right)^{1-\theta}\left(\frac{\rho_s}{\rho_s^*}\right)^{\theta-\rho}\frac{Y}{Y^*Q}$$

Given $\tilde{z}_x = \nu z_x$ and $\tilde{z}_d = \nu z_{min}$, where $\nu = \left(\frac{\kappa}{\kappa-(\theta-1)}\right)^{1/(\theta-1)}$. The average domestic profit can be derived as

$$\tilde{\pi}_d = \left(\frac{\theta-1}{\kappa-(\theta-1)}f_x + f_x\right)\frac{1-\alpha}{1-\alpha^*}\left(\frac{Qz_x}{\tau z_{min}}\right)^{1-\theta}\left(\frac{\rho_s}{\rho_s^*}\right)^{\theta-\rho}\frac{Y}{Y^*Q}$$

Hence, the total profit equation in the home economy is

$$\frac{1-\beta(1-\delta_e)}{\beta(1-\delta_e)}f_e = \left(\frac{z_{min}}{z_x}\right)^{\kappa}\frac{\theta-1}{\kappa-(\theta-1)}f_x + \left(\frac{\kappa}{\kappa-(\theta-1)}f_x\right)\frac{1-\alpha}{1-\alpha^*}\left(\frac{Qz_x}{\tau z_{min}}\right)^{1-\theta}\left(\frac{\rho_s}{\rho_s^*}\right)^{\theta-\rho}\frac{Y}{Y^*Q}$$

Similarly, since $\tilde{\pi}_d^* = (\tilde{\pi}_x^* + f_x^*)\left(\frac{\tilde{\rho}_{d,t}^*}{\tilde{\rho}_{x,t}^*}\right)^{1-\theta}\left(\frac{\rho_s^*}{\rho_s}\right)^{\theta-\rho}\frac{Y^*Q}{Y}$, the total profit equation in foreign economy:

$$\frac{1-\beta(1-\delta_e)}{\beta(1-\delta_e)}f_e^* = \left(\frac{z_{min}^*}{z_x^*}\right)^{\kappa}\frac{\theta-1}{\kappa-(\theta-1)}f_x^* + \left(\frac{\kappa}{\kappa-(\theta-1)}f_x^*\right)\frac{1-\alpha^*}{1-\alpha}\left(\frac{z_x^*}{\tau Q z_{min}^*}\right)^{1-\theta}\left(\frac{\rho_s^*}{\rho_s}\right)^{\theta-\rho}\frac{Y^*Q}{Y}$$

Zero-cutoff Profits:

Since the zero profit conditions of exports $\pi_x = \pi_x^* = 0$, the final output in home Y and foreign Y^* can be expressed as

$$Y = \frac{\theta Q f_x^*}{1-\alpha}{\rho_s}^{\rho-\theta}(z_x^*)^{1-\theta}\left(\frac{\theta\tau w_h^*}{\theta-1}\right)^{\theta-1}$$

$$Y^* = \frac{\theta f_x}{(1-\alpha^*)Q}\rho_s^{*\rho-\theta}(z_x)^{1-\theta}\left(\frac{\theta\tau(w_h\phi_h + w_m\phi_m)}{Q\Phi(\theta-1)}\right)^{\theta-1}$$

Price Indexes:

The relatively price of the skilled sector in the home and foreign economy can be written respectively as

$$
\begin{aligned}
\rho_s^{1-\theta} =& N_d \tilde{\rho}_d^{1-\theta} + N_x^* \tilde{\rho}_x^{*1-\theta} \\
=& N_d \left(\frac{\theta}{\theta-1} \frac{\phi_h w_h + \phi_m w_m}{\nu z_{min} \Phi} \right)^{1-\theta} + N_d^* (\frac{z_{min}^*}{z_x^*})^{\kappa} \left(\frac{\theta}{\theta-1} \frac{\tau w_h^* Q}{\nu z_x^*} \right)^{1-\theta}
\end{aligned}
$$

$$
\begin{aligned}
\rho_s^{*1-\theta} =& N_d^* \tilde{\rho}_d^{*1-\theta} + N_x \tilde{\rho}_x{}^{1-\theta} \\
=& N_d^* \left(\frac{\theta}{\theta-1} \frac{w_h^*}{\nu z_{min}^*} \right)^{1-\theta} + N_d (\frac{z_{min}}{z_x})^{\kappa} \left(\frac{\theta}{\theta-1} \frac{\tau(\phi_h w_h + \phi_m w_m) Q^{-1}}{\nu z_x \Phi} \right)^{1-\theta}
\end{aligned}
$$

The aggregate home price index can be written respectively as:

$$
P = \left[(1-\alpha)(P_s)^{1-\rho} + \alpha (P_u)^{1-\rho} \right]^{\frac{1}{1-\rho}}
$$

$$
1 = (1-\alpha)\rho_s^{1-\rho} + \alpha \rho_u^{1-\rho}
$$

The foreign price index is

$$
1 = (1-\alpha^*)\rho_s^{*1-\rho} + \alpha^* \rho_u^{*1-\rho}
$$

Law of Motion for Numbers of Firms:

$$
N_e = \frac{\delta_e}{1-\delta_e} N_d \qquad\qquad N_e^* = \frac{\delta_e^*}{1-\delta_e^*} N_d^*
$$

Free Entry Condition for Firms :

$$
\tilde{\pi} = \frac{1-\beta(1-\delta_e)}{\beta(1-\delta_e)} \tilde{v} = f_e \qquad\qquad \tilde{\pi}^* = \frac{1-\beta^*(1-\delta_e^*)}{\beta^*(1-\delta_e^*)} \tilde{v}^* = f_e^*
$$

Law of Motion for Numbers of Immigrants:

$$m_e = (\delta_m/(1-\delta_m))m$$

Free Migration Condition:

The steady-state ratio between the immigrant wage in home and the high-skilled wage in foreign is

$$f_m = \frac{\beta(1-\delta_m)}{1-\beta(1-\delta_m)}(w_m Q^{-1} - w_h^*)$$

If the sunk emigration is set to zero, high-skilled workers migrate from foreign to home until the wage difference between countries is close to zero in equilibrium.

Resource Constraints of the Final Good:

The final good is used for consumption and investment for entering the domestic and export markets. In the foreign country, the final good is consumed for investment in emigration as well. Given the labor leisure condition, the law of motion for firms and the number of exporters, resource constraints of the final goods can be expressed as the following:

$$\begin{aligned} Y =& \gamma c_h + (1-\gamma)c_l + \gamma^* c_m + N_e f_e + N_x f_x \\ =& \frac{\gamma w_h}{\chi_h h^\nu} + \frac{(1-\gamma)w_l}{\chi_l l^\nu} + \gamma^* w_m m + \frac{\delta_e}{1-\delta_e} N_d f_e + N_d (z_{min}/z_x)^\kappa f_x \end{aligned}$$

$$
\begin{aligned}
Y^* =& \gamma^* c_h^* + (1-\gamma^*) c_l^* - Q^{-1}\gamma^* c_m + N_e^* f_e^* + N_x^* f_x^* + f_m \gamma m_e \\
=& \gamma^* \frac{w_h^*}{\chi_h h^{*\mu}} + (1-\gamma^*) \frac{w_l^*}{\chi_l l^{*\mu}} - Q^{-1}\gamma^* w_m m + \frac{\delta_e}{1-\delta_e} N_d^* f_e^* \\
&+ N_d^* (z_{min^*}/z_x^*)^{\kappa} f_x^* + f_m \gamma m_e
\end{aligned}
$$

Assuming that all labor income of immigrants are used for consumption, thus there exists $w_m m = c_m$.

A.3 Regression Analysis

Gould (1994) and Head and Ries (1998) are the pioneering empirical work to study trade and immigration. A lot of other empirical studies based on the gravity model also show that immigration has a potential positive influence on trade.[1] Does the number of U.S. immigrants really simulate U.S. trade with countries of origin? To document the linkages between trade and immigration, I run regressions to estimate the effects of immigration on bilateral trade. According to the gravity model, the volume of trade, $X_{i,j}$ between the countries i and j is determined by the economic size of the countries (GDP), denoted as Y, the distance between them, denoted as $D_{i,j}$, and the gravitational constant c, so

$$
X_{i,j} = c\frac{Y_i Y_j}{D_{i,j}}
$$

I use a panel data set of 116 U.S. trading partners from year 2004 to 2018 to estimate the impact of U.S. immigrants on trade. The gravity model is augmented by a control variable for the number of people born in country i but resident in the U.S., and there are two types of foreign born population, high-skilled and low-skilled.

[1] Rauch and Trindade (2002) show the trade-creation effect of immigrants with gravity-type regressions. Bandyopadhyay et al. (2008) provides estimates of the effects of ethnic networks on U.S. exports with two departures from previous studies. Peri and Requena-Silvente (2010) find that immigrants significantly increase the extensive margin of exports due to a reduction in fixed costs of exporting.

A.3.1 Empirical Strategy

The common gravity model (expressed in natural logs) with specification of labor immigrants F is

$$ln(X_{US,i,t}) = \gamma_{i,t} + \beta_0 ln(F_{US,i,t}) + \beta_1 ln(Y_{US,t}) + \beta_2 ln(Y_{i,t}) + \beta_3 ln(P_{US,t}) + \beta_4 ln(P_{i,t}) + \beta_5 ln(D_{US,i}) + G\delta_i + \epsilon_t$$

where $X_{US,i,t}$ refers to the U.S. exports (imports) to (from) country i or the U.S. extensive margin of exports (imports); $\gamma_{i,t}$ is the year fixed effect; $F_{US,i,t}$ is the number of total immigrants from country i; P and Y are denoted as the population and GDP levels respectively; G is a vector variable that controls for the effects of colony and contiguity between the U.S. and country i, and whether they share a common language and if country i is a member of WTO.

The gravity model does not allow for fixed effects, so it could provide biased estimates. Following Bandyopadhyay et al. (2008), unrestricted intercept is allowed to account for unobserved time-invariant factors and address the problem of bias. The new intercept $\alpha_{US,i}$ is the sum of a common intercept, all dummy variables and all variables that are fixed over time but differ across country pairs. The fixed-effect regression is

$$ln(X_{US,i,t}) = \alpha_{US,i} + \gamma_{i,t} + \beta_0 ln(F_{US,i,t}) + \beta_1 ln(Y_{US,t}) + \beta_2 ln(Y_{i,t}) + \beta_3 ln(P_{US,t}) + \beta_4 ln(P_{i,t}) + \epsilon_t$$

For robustness check, first differencing is applied to eliminate omitted, time-invariant variables, and the first difference of LOG also represents the growth rate. The regression equation of first differencing is:

$$\Delta ln(X_{US,i,t}) = \Delta\gamma_{i,t} + \beta_0 \Delta ln(F_{US,i,t}) + \beta_1 \Delta ln(Y_{US,t}) + \beta_2 \Delta ln(Y_{i,t}) + \beta_3 \Delta ln(P_{US,t}) + \beta_4 \Delta ln(P_{i,t}) + \Delta\epsilon_t$$

Departing from the literature, I split the total immigrants into high-skilled and low-skilled immigrants ($F_{US,i} = H_{US,i,t} + L_{US,i,t}$) to distinguish their effects on international trade. The fixed-effect and first-difference regression equations can be expressed as

$$ln(X_{US,i,t}) = \alpha_{US,i} + \gamma_{i,t} + \beta_0^H ln(H_{US,i,t}) + \beta_0^L ln(L_{US,i,t}) + \beta_1 ln(Y_{US,t}) + \beta_2 ln(Y_{i,t}) + \beta_3 ln(P_{US,t}) + \beta_4 ln(P_{i,t}) + \epsilon_t$$

$$\Delta ln(X_{US,i,t}) = \Delta\gamma_{i,t} + \beta_0^H \Delta ln(H_{US,i,t}) + \beta_0^L \Delta ln(L_{US,i,t}) + \beta_1 \Delta ln(Y_{US,t}) + \beta_2 \Delta ln(Y_{i,t}) + \beta_3 \Delta ln(P_{US,t}) + \beta_4 \Delta ln(P_{i,t}) + \Delta\epsilon_t$$

A.3.2 Results Summary

Although previous empirical studies based on the gravity model find that immigrants foster bilateral trade under OLS estimations, an 10% increase in the amount of U.S. immigrants from country i leads to a reduction in U.S. imports from this labor-sending country by 1.35 % under the fixed-effect specification in Table A.3 Panel A. The effect of U.S. immigration on the extensive margin of imports is also significantly negative. Interestingly, the linkages between immigration and exports are weak between 2004 and 2018 in the Unites States. In addition, the impact of immigration on trade is insignificantly negative under the first-differenced specifications. Overall, the relationship of trade and immigration is relatively weaker under the first-differenced specifications since unobserved heterogeneity is not captured by the fixed-effect estimation, leading to an overestimate of the impacts of immigration on trade between the U.S. and labor-sending countries.

Table A.3 Panel B specifies immigrants by skill levels. In general, both high-skilled and low-skilled immigrants do not greatly affect the extensive margins of exports and imports. The effect of high-skilled immigrants on exports are significantly positive while low-skilled immigrants have a reverse influence on exports. In particular, an 10% increase in the amount of U.S. high-skilled immigrants from country i leads to an increase in U.S. exports to this labor-sending country by 1.26 % under the fixed-effect specification. However, U.S. exports to country i decrease by 1.35% when the amount of U.S. low-skilled immigrants born in country i raises about 10%. In the meantime, high-skilled immigrants create a slightly negative impact on imports. Hence, it could be concluded that there is an export promotion effect of high-skilled immigration, as well as an import substitution effect based on these empirical results. It is plausible that high-skilled immigrants reduce production costs and increase firm productivity, resulting in stimulating exports, and they could be substitutes for imported varieties since there might be a reduction in costs of goods produced domestically by immigrants.

The historical evidence of trade and immigration could be mixed. For example, Ottaviano et al. (2018) point out that immigration leads to an export promotion effect but an import substitution effect (offshore production) in the U.K. Jacks and Tang (2018) find that immigration and trade act as substitutes for the United States in the interwar period. Immigration has a negligible or negative impact on trade in the longer run as discussed in Parsons (2012). Moreover, according to the correlation data from 1870-2018 in the United States shown in Table A.2, the correlation between gross bilateral exports and migrant shares is getting weaker though it is still positive, but the correlation between gross bilateral imports and migrant shares start to become positive since 1950. Therefore, labor migration could both stimulates and diverts international trade based on these empirical results.

This empirical study focuses on the impact of immigration on trade, which is unilateral. It does not address the role of trade in labor mobility, as well as the difference between the short-term and long-term linkages of trade and immigration.

A.4 VAR Analysis

Since the data of tariff rates and high-skilled immigrants is only available at annual frequency, I estimate a panel structure VAR for a sample of 116 U.S trading partners over the period 2004-2018.

Empirical Strategy

A structural VAR is estimated:

$$A\Pi_t = \Theta + \sum_{s=1}^{p} \vartheta_s \Pi_{t-s} + \mu_t$$

where Π_t is a vector that collects that the immigration policy measure, trade policy measure and the macroeconomic variables, including GDP and trade flows; A is the matrix links

Table A.3: The effects of immigration on trade

Panel A: The effect of total immigrants on trade								
	Exports		Imports		Extensive margin of exports		Extensive margin of imports	
	FE	FD	FE	FD	FE	FD	FE	FD
$lnF_{US,i}$	0.021	-0.002	-0.135***	-0.060	-0.020*	-0.004	-0.049***	-0.016
R-squared	0.469	0.191	0.091	0.077	0.280	0.110	0.098	0.042
Panel B: The effect of immigrants by skill levels on trade								
$lnH_{US,i}$	0.126***	0.084**	-0.135**	-0.024	0.010	0.0004	-0.041	-0.026
$lnL_{US,i}$	-0.113***	-0.093***	0.002	-0.044	-0.029*	-0.003	-0.007	0.005
R-squared	0.473	0.197	0.092	0.078	0.281	0.110	0.098	0.043
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observation	1683	1564	1683	1564	1683	1564	1683	1564

F_i is the number of total immigrants from country i. H_i is the number of high-skilled immigrants from country i. L_i is the number of low-skilled immigrants from country i. Other controls include population, GDP, country dummies and year fixed effect. The extensive margin of export (import) is defined as the number of exported (imported) HS6 digit products to (from) US's trading partner i.

structural and reduced-form innovation; μ_t is a vector of structural innovation such that $E(\mu_t \mu_t^{'}) = I_N$. The VAR is estimated with one lag of each variable.

I identify structural migration shocks by exploiting the contemporaneous exogeneity of changes in immigrant labor supply.[2] Changes in the number of U.S. immigrants is assumed to have no responses to macroeconomic shocks within a year. This assumption is plausible since the incentive to loosen immigration policies is to increase labor supply for production and attract talent workers to promote innovation. Macroeconomic shocks do not directly influence the openness in immigration.

Trade policy shocks are identified by exploiting the contemporaneous exogeneity of changes in tariff rates, because the import-weighted average of the applied tariff rates are considered as a trade policy measure. Another assumption is that changes in tariff rates also do not response to labor supply and other macroeconomic shocks.

[2] The introduction of immigration quotas in the 1920s induces a rapid growth in the stocks of immigrants. The H-1B program allows companies and other employers in the United States to temporarily employ foreign high-skilled workers.

Empirical Results

First, I estimate a panel structural VAR with five variables: the number of U.S.high-skilled immigrants, U.S. exports, foreign exports, and the extensive margin of exports in the U.S. and foreign countries. Figure A.6 reports the impulse responses to a one-standard deviation increase in the stock of high-skilled immigrants in the U.S. have slightly negative impacts on bilateral trade flows. These results may not be surprising, which are consistent with previous findings. Weiske (2019) shows that immigration has been of little importance to U.S. business cycles during the 1990s and 2000s with a VAR analysis. Moreover, the impulse responses of a reduction in migration costs in the section 1.5.2 indicates that the dynamic effects of immigration in the home country (U.S.) is less significant than the foreign country.

Second, I add another three observables, U.S. GDP, foreign GDP and tariff rates, to examine the results of macroeconomic variables in response to a trade shock, and emphasize the linkages between trade and labor immigration. As shown in Figure A.7 , a one-standard deviation decrease in U.S. tariff results in a 1% decline in the number of high-skilled immigrants initially and this negative impact is short-lived. This indicates that trade and high-skilled immigration acts as substitutes in the first two years, which is in contrast to the results from regression estimations. A reduction in trade costs leads to a positive influence on the GDP levels of both countries while the foreign country benefits from larger output growth with an average 2% increase in the first two years. Trade openness stimulates faster economic growth in the less developed country, which is in line with the model implications.

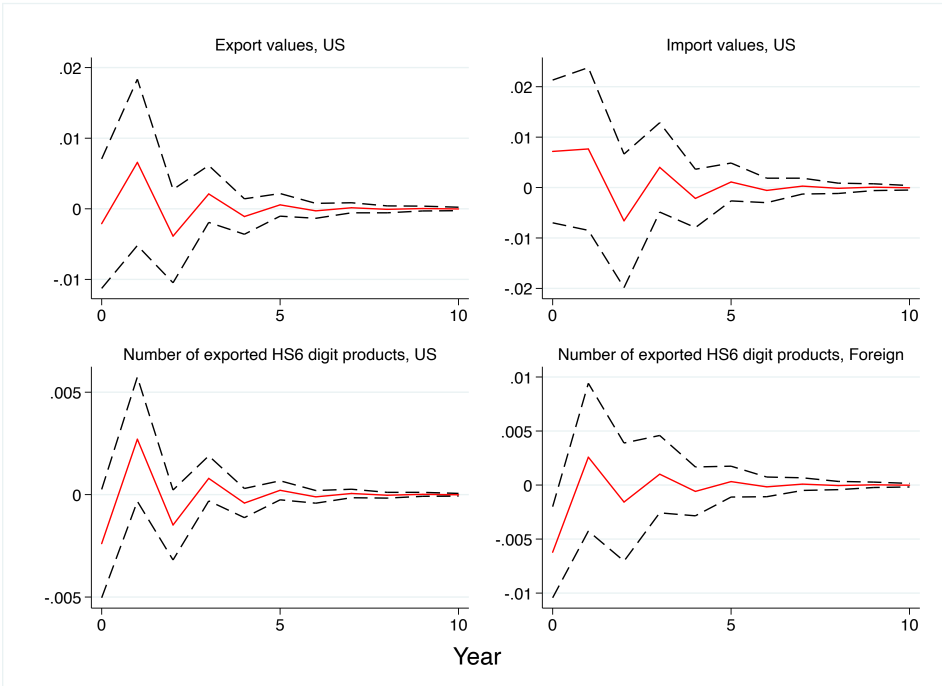

Figure A.6: Impulse responses to a one-standard deviation increase in the stock of high-skilled immigrants in the United States.

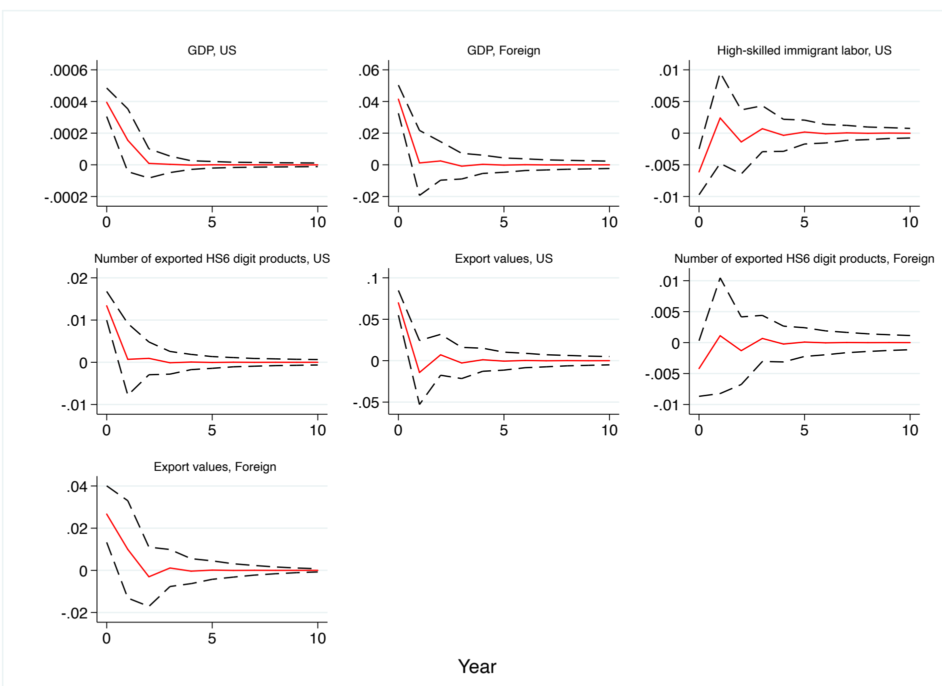

Figure A.7: Impulse responses to a one-standard deviation decrease in detrended U.S. tariffs.

A.5 Data Description

This section describes the database used for regression, VAR, tables and figures.

I use UN-WITS Database of exports, imports, the number of exported HS6 digit products and the number of imported HS6 digit products for regression, VAR and moments in Table 1.3. The number of exported and imported HS6 digit products refer to the extensive margin of trade. The tariff used for VAR is the country AHS weighted average in percentage for all products, which comes from UN-WITS Database as well. I collect the data of GDP, population, distance and other variables of the gravity equation from the Research and Expertise on the World Economy (CEPII).

Immigration data for regression, VAR, Figure A.2, Figure A.3 and Table A.1 are from U.S. Census Bureau, American Community Survey, 1-Year Estimates-Public Use Microdata Sample. The foreign born population data by educational attainment (Figure 1.2, Figure 1.3, Table A.2) is from U.S. Census Bureau, Current Population Survey, Annual Social and Economic Supplement.

In terms of the numbers of firm stock and entrants, I collect the data from U.S. Census Bureau, Business Dynamics Statistics to calculate their standard deviations and correlations with output. Consumption data is from the World Bank, World Development Indicators.

Appendix B

TRADE LIBERALIZATION AND SKILL UPGRADING: EVIDENCE ON THE IMPACT OF APTA ON CHINESE MANUFACTURERS

B.1 Additional Figures

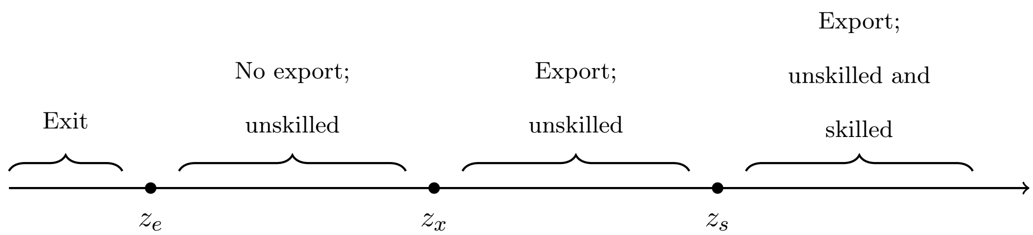

Figure B.1: Productivity cutoffs under the benchmark model

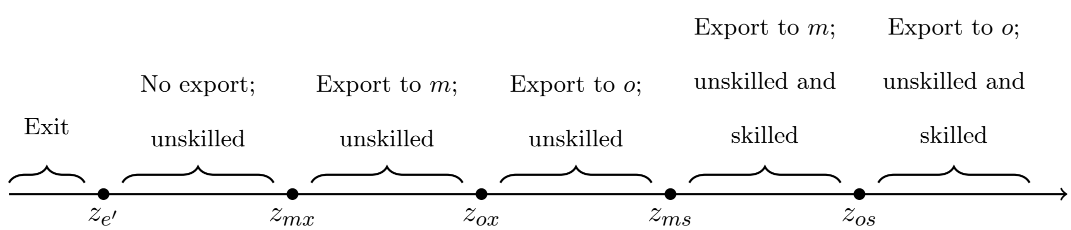

Figure B.2: Productivity cutoffs under the extended model

B.2 More Details of the Theoretical Model

B.2.1 Benchmark Model

Total Cost Function

Per-period fixed export cost f_x and iceberg trade cost τ are required for exporters, thus the total costs for firms that export under the unskilled and skilled sector are respectively

$$TC_u(z) = f_u + f_x + \frac{w_l}{z} y_u^d(z) + \tau \frac{w_l}{z} y_u^x(z)$$

$$TC_s(z) = f_s + f_x + \frac{w_h^\beta w_l^{1-\beta}}{\gamma z} y_s^d(z) + \tau \frac{w_h^\beta w_l^{1-\beta}}{\gamma z} y_s^x(z)$$

Average Profit and Revenue

The average profit $\tilde{\pi} = \tilde{\pi}_u^d + n_x \tilde{\pi}_x^d + n_s \tilde{\pi}_s^x$, where

$$\begin{aligned}
\tilde{\pi}_u^d &= \frac{1}{1 - G(z_e)} \int_{z_e}^{z_x} z^{\theta - 1} g(z) dz \\
\tilde{\pi}_u^x &= \frac{1}{1 - G(z_e)} \int_{z_x}^{z_s} z^{\theta - 1} g(z) dz \\
\tilde{\pi}_s^x &= \frac{1}{1 - G(z_e)} \int_{z_s}^{\infty} z^{\theta - 1} g(z) dz
\end{aligned}$$

The average profit also can be describe in this way: $\tilde{\pi} = \frac{\tilde{r}}{\theta} - f_u - n_x f_x - n_s(\phi - 1) f_u$. The average revenues of surviving firms is

$$\begin{aligned}
\tilde{r} &= \int_{z_e}^{z_x} r_u^d(z) \frac{g(z)}{1 - G(z_e)} dz + \int_{z_x}^{z_s} r_u^x(z) \frac{g(z)}{1 - G(z_e)} dz + \int_{z_s}^{\infty} r_s^x(z) \frac{g(z)}{1 - G(z_e)} dz \\
&= \int_{z_e}^{z_x} r_u^d(z) \frac{g(z)}{1 - G(z_e)} dz + (1 + \tau^{1-\theta}) \int_{z_x}^{z_s} r_u^d(z) \frac{g(z)}{1 - G(z_e)} dz \\
&\quad + \lambda^{\theta - 1}(1 + \tau^{1-\theta}) \int_{z_s}^{\infty} r_d^x(z) \frac{g(z)}{1 - G(z_e)} dz \\
&= \int_{z_e}^{z_x} r_u^d(z) \frac{g(z)}{1 - G(z_e)} dz + \int_{z_x}^{z_s} r_u^d(z) \frac{g(z)}{1 - G(z_e)} dz + \int_{z_s}^{\infty} r_u^d(z) \frac{g(z)}{1 - G(z_e)} dz \\
&\quad + \tau^{1-\theta} \int_{z_x}^{z_s} r_u^d(z) \frac{g(z)}{1 - G(z_e)} dz + \tau^{1-\theta} \int_{z_s}^{\infty} r_u^d(z) \frac{g(z)}{1 - G(z_e)} dz \\
&\quad + \left[\lambda^{\theta - 1}(1 + \tau^{1-\theta}) \left(\frac{\rho_2}{\rho_1} \right)^{\theta - \rho} - 1 - \tau^{1-\theta} \right] \int_{z_s}^{\infty} r_u^d(z) \frac{g(z)}{1 - G(z_e)} dz \\
&= \int_{z_e}^{\infty} r_u^d(z) \frac{g(z)}{1 - G(z_e)} dz \\
&\quad + \tau^{1-\theta} \int_{z_x}^{\infty} r_u^d(z) \frac{g(z)}{1 - G(z_e)} dz \\
&\quad + (1 + \tau^{1-\theta}) \left(\lambda^{\theta - 1} \left(\frac{\rho_2}{\rho_1} \right)^{\theta - \rho} - 1 \right) \int_{z_s}^{\infty} r_u^d(z) \frac{g(z)}{1 - G(z_e)} dz
\end{aligned}$$

Using the zero profit condition, we get $r_u^d(z) = \theta f_u \left(\frac{z}{z_e}\right)^{\theta-1}$. We define $\tilde{z}_j^{\theta-1} = \int_{z_j}^{\infty} z_j \frac{g(z)}{1-G(z_j)} dz$ where $j \in (e, x, s)$, and we derive that both z_x and z_s can be a function of z_e, so

$$\tilde{r} = \theta f_u \left(\frac{\tilde{z}_e}{z_e}\right)^{\theta-1} + n_x \theta f_x \left(\frac{\tilde{z}_x}{z_x}\right)^{\theta-1} + n_s \theta f_u (\phi - 1) \left(\frac{\tilde{z}_s}{z_s}\right)^{\theta-1}$$

Since

$$\begin{aligned}
\left(\frac{\tilde{z}_j}{z_j}\right)^{\theta-1} &= \int_{z_j}^{\infty} \left(\frac{z}{z_j}\right)^{\theta-1} \frac{g(z)}{1-G(z_j)} dz \\
&= z_j^{\kappa+1-\theta} \frac{\kappa z_j^{\theta-1-\kappa}}{\kappa - (\theta-1)} \\
&= \frac{\kappa}{\kappa - (\theta - 1)}
\end{aligned}$$

We get $\tilde{r} = \frac{\theta\kappa}{\kappa-(\theta-1)} \left[f_u + n_x f_x + n_s f_u(\phi - 1)\right]$. After substituting $\tilde{r}$ into the free entry condition, we obtain

$$f_e = \frac{z_e^{-\kappa}}{\delta} \frac{\theta - 1}{\kappa - (\theta - 1)} \left[f_u + n_x f_x + n_s f_u(\phi - 1)\right]$$

Substituting n_x and n_s,

$$\begin{aligned}
z_e =& \left(\frac{1}{f_e \delta} \frac{\theta - 1}{\kappa - (\theta - 1)}\right)^{\frac{1}{\kappa}} \left[f_u + n_x f_x + n_s f_u(\phi - 1)\right]^{\frac{1}{\kappa}} \\
=& \left(\frac{1}{f_e \delta} \frac{\theta - 1}{\kappa - (\theta - 1)}\right)^{\frac{1}{\kappa}} \times \\
& \left[f_u + f_x \tau^{-\kappa} \left(\frac{f_x}{f_u}\right)^{\frac{-\kappa}{\theta-1}} + f_u(\phi - 1) \left(\frac{\phi - 1}{(1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - 1)}\right)^{\frac{-\kappa}{\theta-1}}\right]^{\frac{1}{\kappa}} \\
=& \Lambda \left[1 + \frac{f_x}{f_u} \left(\frac{f_x}{f_u}\right)^{\frac{-\kappa}{\theta-1}} \tau^{-\kappa} + (\phi - 1) \left(\frac{\phi - 1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - 1)}\right)^{\frac{-\kappa}{\theta-1}} (1+\tau^{1-\theta})^{\frac{\kappa}{\theta-1}}\right]^{\frac{1}{\kappa}} \\
=& \Lambda \Phi
\end{aligned}$$

where $\Lambda \equiv \left(\frac{f_u}{f_e \delta} \frac{\theta-1}{\kappa-(\theta-1)}\right)^{\frac{1}{\kappa}}$ and

$$\Phi = \left[1 + \frac{f_x}{f_u} \left(\frac{f_x}{f_u}\right)^{\frac{-\kappa}{\theta-1}} \tau^{-\kappa} + (\phi - 1) \left(\frac{\phi - 1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - 1)}\right)^{\frac{-\kappa}{\theta-1}} (1+\tau^{1-\theta})^{\frac{\kappa}{\theta-1}}\right]^{\frac{1}{\kappa}}.$$

Trade Liberalization

Skill Premium:

$$\frac{R_u}{R_s} = \frac{\int_{z_e}^{z_x} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz + \int_{z_x}^{z_s} r_u^x(z)\frac{g(z)}{1-G(z_e)}dz}{\int_{z_s}^{\infty} r_s(z)\frac{g(z)}{1-G(z_e)}dz}$$
$$= \frac{1}{\lambda^{\theta-1}(1+\tau^{\theta-1})}$$

As τ has a positive effect on λ, $\frac{\partial R_u}{\partial R_s} > 0$. The reduction in trade costs increase the relative revenues of firms producing skilled goods, so the demand for skilled labor increases. This leads to a higher equilibrium skill premium.

Next, a reduction in trade costs increases the share of firms producing skilled good, $\frac{\partial n_s}{\partial \tau} < 0$.

Proof:

τ has a direct negative effect on n_s, but an indirect positive effect through λ since the reduction in tariffs increases the skill premium reducing the cost advantage of firms producing skilled goods. Nevertheless, the direct effect must dominate. To prove this: we suppose it was not the case, n_s falls as trade costs fall. However, we derive that $\frac{\partial R_s}{\partial R_u} > 0$, which is a contraction.

Average Profit:

Given $\tilde{\pi} = \frac{\theta-1}{\kappa-(\theta-1)}\left[f_u + n_x f_x + n_s f_u(\phi-1)\right] = \frac{\theta-1}{\kappa-(\theta-1)}\Phi^\kappa$, $\frac{\partial\tilde{\pi}}{\partial\tau} = \frac{\theta-1}{\kappa-(\theta-1)}\frac{\partial\Phi^\kappa}{\partial\tau}$.

$$\frac{\partial\Phi^\kappa}{\partial\tau} = -\kappa\frac{f_x}{f_u}\left(\frac{f_x}{f_u}\right)^{\frac{-\kappa-1}{\theta-1}}\tau^{-\kappa}$$
$$-(\theta-1)\frac{\kappa}{\theta-1}(\phi-1)\left(\frac{\phi-1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right)^{\frac{-\kappa}{\theta-1}}(1+\tau^{1-\theta})^{\frac{\kappa-\theta+1}{\theta-1}}\tau^{-\theta} < 0$$

Since $\theta > 1$ and $\kappa > (\theta-1)$, we get $\frac{\partial\tilde{\pi}}{\partial\tau} < 0$.

Exit productivity cutoff:

Since $z_e = \Lambda\Phi$ and $\frac{\partial\Phi^\kappa}{\partial\tau} < 0$, we get $\frac{\partial z_e}{\partial\tau} < 0$.

Export productivity cutoff:

Since $z_x = \tau\Lambda\Phi$,

$$\frac{\partial z_x}{\partial \tau} = \left(\frac{f_x}{f_u}\right)^{\frac{1}{\theta-1}} \Lambda\Phi + \left(\frac{f_x}{f_u}\right)^{\frac{1}{\theta-1}} \Lambda \frac{\partial \Phi\tau}{\partial \tau}$$

Given $\Phi\tau = \left[\tau^{\kappa} + \frac{f_x}{f_u}\left(\frac{f_x}{f_u}\right)^{\frac{-\kappa}{\theta-1}} + \tau^{\kappa}(\phi-1)\left(\frac{\phi-1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right)^{\frac{-\kappa}{\theta-1}}(1+\tau^{1-\theta})^{\frac{\kappa}{\theta-1}}\right]^{\frac{1}{\kappa}}$

$$\frac{\partial \Phi\tau}{\partial \tau} = (\Phi\tau)^{1/\kappa-1}\left[\tau^{\kappa-1} + \Xi(\phi-1)\left(\frac{\phi-1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right)^{\frac{-\kappa}{\theta-1}}\right]$$

where $\Xi \equiv \tau^{\kappa-1}(1+\tau^{1-\theta})^{\frac{\kappa}{\theta-1}} - \tau^{\kappa-\theta}(1+\tau^{1-\theta})^{\frac{\kappa}{\theta-1}-1} = \tau^{\kappa-1}(1+\tau^{1-\theta})^{\frac{\kappa}{\theta-1}}\left(1-\frac{\tau^{1-\theta}}{(1+\tau^{1-\theta})}\right)$

As $\frac{\tau^{1-\theta}}{(1+\tau^{1-\theta})} < 1$, $\Xi > 0$. Then, $\frac{\partial \Phi\tau}{\partial \tau} > 0$ and all other terms are positive, thus $\frac{\partial z_x}{\partial \tau} > 0$.

Skill upgrading productivity cutoff:

Since $z_s = z_e\left[\frac{\phi-1}{(1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right]^{\frac{1}{\theta-1}} = \Lambda\Phi\left[\frac{\phi-1}{(1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right]^{\frac{1}{\theta-1}}$,

$$\begin{aligned}\Phi^{\kappa}(1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}} =& (1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}} \\ &+ (1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}}\left(\frac{f_x}{f_u}\right)^{1-\frac{\kappa}{\theta-1}}\tau^{\kappa} \\ &+ (\phi-1)\left(\frac{\phi-1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right)^{\frac{-\kappa}{\theta-1}}\end{aligned}$$

$$\begin{aligned}\frac{\partial \Phi^{\kappa}(1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}}}{\partial \tau} =& \kappa(1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}} \times \\ &\left[(1+\tau^{1-\theta})^{-1}\tau^{-\theta}\left(1+\left(\frac{f_x}{f_u}\right)^{1-\frac{\kappa}{\theta-1}}\tau^{\kappa}\right) - \left(\frac{f_x}{f_u}\right)^{1-\frac{\kappa}{\theta-1}}\tau^{-\kappa-1}\right]\end{aligned}$$

As $\kappa(1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}} > 0$, the sign of $\frac{\partial \Phi^{\kappa}(1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}}}{\partial \tau}$ depends on the second term. We can derive that $\frac{\partial \Phi^{\kappa}(1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}}}{\partial \tau} > 0$ as long as $\tau^{\theta-1}f_x > f_u$. Then $\frac{\partial z_s}{\partial \tau} > 0$ as all terms are positive.

B.2.2 Extended Model

Total cost and Price

$$TC_u^d(z) = f_u + \frac{w_l}{z}y_u^d(z)$$

$$TC_u^{mx}(z) = f_u + f_{mx} + \frac{w_l}{z} y_u^d(z) + \tau_m \frac{w_l}{z} y_u^{mx}(z)$$

$$TC_u^{ox}(z) = f_u + f_{ox} + \frac{w_l}{\gamma_u z} y_u^d(z) + \tau_o \frac{w_l}{\gamma_u z} y_u^{ox}(z)$$

$$TC_s^{mx}(z) = f_{ms} + f_{mx} + \frac{w_h^{\beta} w_l^{1-\beta}}{\gamma_m z} y_s^{md}(z) + \tau_m \frac{w_h^{\beta} w_l^{1-\beta}}{\gamma_m z} y_s^{mx}(z)$$

$$TC_s^{ox}(z) = f_{os} + f_{ox} + \frac{w_h^{\alpha} w_l^{1-\alpha}}{\gamma_o z} y_s^{od}(z) + \tau_o \frac{w_h^{\alpha} w_l^{1-\alpha}}{\gamma_o z} y_s^{ox}(z)$$

where $f_{ox} > f_{mx}$, $f_{os} > f_{ms} > f_u$, $\alpha > \beta$ and $\gamma_o > \gamma_m > \gamma_u > 1$.

The profit maximization of both sectors yields the following pricing rules of domestic sales:

$$\rho_u^{md}(z) = \frac{\theta}{\theta - 1} \frac{w_l}{z}$$
$$\rho_u^{od}(z) = \frac{\theta}{\theta - 1} \frac{w_l}{\gamma_u z}$$
$$\rho_s^{md}(z) = \frac{\theta}{\theta - 1} \frac{w_h^{\beta} w_l^{1-\beta}}{\gamma_m z}$$
$$\rho_s^{od}(z) = \frac{\theta}{\theta - 1} \frac{w_h^{\alpha} w_l^{1-\alpha}}{\gamma_o z}$$

The four pricing rules of exporting are $\rho_u^{mx}(z) = \tau_m \rho_u^{md}(z)$, $\rho_u^{ox}(z) = \tau_o \rho_u^{od}(z)$, $\rho_s^{mx}(z) = \tau_m \rho_s^{md}(z)$, $\rho_s^{ox}(z) = \tau_o \rho_s^{od}(z)$. Hence, $\rho_s^{md}(z) = \rho_u^{md}(z)/\lambda_m$ where $\lambda_m = \gamma_m \left(\frac{w_l}{w_h}\right)^{\beta}$; $\rho_s^{od}(z) = \rho_u^{od}(z)/\lambda_o$ where $\lambda_o = \gamma_o \left(\frac{w_l}{w_h}\right)^{\alpha}$.

Average Profit and Revenue

The average profit $\tilde{\pi}^{'} = \tilde{\pi}_u^{d'} + n_{mx}\tilde{\pi}_u^{mx} + n_{ox}\tilde{\pi}_u^{ox} + n_{ms}\tilde{\pi}_s^{mx} + n_{os}\pi_s^{ox}$, where

$$\tilde{\pi}_u^{d'} = \frac{1}{1-G(z_e^{'})}\int_{z_e^{'}}^{z_{mx}} z^{\theta-1}g(z)dz$$
$$\tilde{\pi}_u^{mx} = \frac{1}{1-G(z_e^{'})}\int_{z_{mx}}^{z_{ox}} z^{\theta-1}g(z)dz$$
$$\tilde{\pi}_u^{ox} = \frac{1}{1-G(z_e^{'})}\int_{z_{ox}}^{z_{ms}} z^{\theta-1}g(z)dz$$
$$\tilde{\pi}_s^{mx} = \frac{1}{1-G(z_e^{'})}\int_{z_{ms}}^{z_{os}} z^{\theta-1}g(z)dz$$
$$\tilde{\pi}_s^{ox} = \frac{1}{1-G(z_e^{'})}\int_{z_{os}}^{\infty} z^{\theta-1}g(z)dz$$

The average profit also can be describe in this way:

$$\begin{aligned}
\tilde{\pi}^{'} =& \frac{\tilde{r}^{'}}{\theta} - (1-n_{ms})f_u - n_{mx}f_{mx} - n_{ox}(f_{ox}-f_{mx}) - n_{ms}(\phi_m f_u + f_{mx} - f_{ox}) \\
& - n_{os}(\phi_o f_u - \phi_m f_u + f_{ox} - f_{mx}) \\
=& \frac{\tilde{r}^{'}}{\theta} - f_u - n_{mx}f_{mx} - n_{ox}(f_{ox}-f_{mx}) - n_{ms}((\phi_m - 1)f_u + f_{mx} - f_{ox}) \\
& - n_{os}((\phi_o - \phi_m)f_u + f_{ox} - f_{mx})
\end{aligned}$$

The average revenues of surviving firms is

$$\begin{aligned}
\tilde{r}^{'} =& \int_{z_e}^{z_{mx}} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz + \int_{z_{mx}}^{z_{ox}} r_u^{mx}(z)\frac{g(z)}{1-G(z_e)}dz + \int_{z_{ox}}^{z_{ms}} r_u^{ox}(z)\frac{g(z)}{1-G(z_e)}dz \\
& + \int_{z_{ms}}^{z_{os}} r_s^{ms}(z)\frac{g(z)}{1-G(z_e)}dz + \int_{z_{os}}^{\infty} r_s^{os}(z)\frac{g(z)}{1-G(z_e)}dz \\
=& \int_{z_e}^{\infty} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz \\
& + \tau_m^{1-\theta}\int_{z_{mx}}^{\infty} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz \\
& + ((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - 1 - \tau_m^{1-\theta})\int_{z_{ox}}^{\infty} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz \\
& + \left[(1+\tau_m^{1-\theta})\lambda_m^{\theta-1}\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u^{\theta-1}\right]\int_{z_{ms}}^{\infty} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz \\
& + \left[\lambda_o^{\theta-1}(1+\tau_o^{1-\theta})\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta})\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho}\right]\int_{z_{os}}^{\infty} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz
\end{aligned}$$

We derive that z_{mx}, z_{ox}, z_{ms} and z_{ox} can be a function of $z_e^{'}$, so

$$\begin{aligned}\tilde{r}^{'} =&\theta f_u\left(\frac{\tilde{z}_e^{'}}{z_e^{'}}\right)^{\theta-1}+n_{mx}\theta f_{mx}\left(\frac{\tilde{z}_{mx}}{z_{mx}}\right)^{\theta-1}+n_{ox}\theta(f_{ox}-f_{mx})\left(\frac{\tilde{z}_{ox}}{z_{ox}}\right)^{\theta-1}\\&+n_{ms}\theta(f_u(\phi_m-1)+f_{mx}-f_{ox})\left(\frac{\tilde{z}_{ms}}{z_{ms}}\right)^{\theta-1}\\&+n_{os}\theta(f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u)\left(\frac{\tilde{z}_{os}}{z_{os}}\right)^{\theta-1}\end{aligned}$$

Given $\left(\frac{\tilde{z}_j}{z_j}\right)^{\theta-1}=\frac{\kappa}{\kappa-(\theta-1)}$ and the free entry condition, we get

$$z_e^{'}=\left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\Psi\right)^{1/\kappa}$$

$$\begin{aligned}\Psi^{\kappa} =&f_u+n_{mx}f_{mx}+n_{ox}(f_{ox}-f_{mx})\\&+n_{ms}(f_u(\phi_m-1)+f_{mx}-f_{ox})+n_{os}(f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u)\\=&f_u+f_{mx}\tau_m^{-\kappa}\left(\frac{f_{mx}}{f_u}\right)^{\frac{-\kappa}{\theta-1}}+(f_{ox}-f_{mx})\left(\frac{f_{ox}-f_{mx}}{((1+\tau_o^{1-\theta})\gamma_u^{\theta-1}-1-\tau_m^{1-\theta})f_u}\right)^{\frac{-\kappa}{\theta-1}}\\&+(f_u(\phi_m-1)+f_{mx}-f_{ox})\\&\times\left[\frac{((\phi_m-1)f_u+f_{mx}-f_{ox}}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-(1+\tau_o^{1-\theta})\gamma_u^{\theta-1})f_u}\right]^{\frac{-\kappa}{\theta-1}}\\&+(f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u)\\&\times\left[\frac{f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u}{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta})-\lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}f_u}\right]^{\frac{-\kappa}{\theta-1}}\\=&f_u+f_{mx}\tau_m^{-\kappa}\left(\frac{f_{mx}}{f_u}\right)^{\frac{-\kappa}{\theta-1}}+(f_{ox}-f_{mx})^{\frac{-\kappa}{\theta-1}}A+(f_u(\phi_m-1)+f_{mx}-f_{ox})B^{\frac{-\kappa}{\theta-1}}\\&+(f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u)C^{\frac{-\kappa}{\theta-1}}\end{aligned}$$

where $A\equiv(1+\tau_o^{1-\theta})\gamma_u^{\theta-1}-1-\tau_m^{1-\theta}$, $B\equiv\frac{((\phi_m-1)f_u+f_{mx}-f_{ox}}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-(1+\tau_o^{1-\theta})\gamma_u^{\theta-1})f_u}$ and $C\equiv\frac{f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u}{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta})-\lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}f_u}$.

Changes in Trade Costs to Country m

Average Profit:

Given $\tilde{\pi}' = \frac{\theta-1}{\kappa-(\theta-1)}\Psi^\kappa$, $\frac{\partial\tilde{\pi}'}{\partial\tau_m} = \frac{\theta-1}{\kappa-(\theta-1)}\frac{\partial\Psi^\kappa}{\partial\tau_m}$.

$$\frac{\partial\Psi^\kappa}{\partial\tau_m} = -\kappa f_{mx}\left(\frac{f_{mx}}{f_u}\right)^{\frac{-\kappa}{\theta-1}}\tau_m^{-\kappa-1} + \kappa A^{\frac{\theta-1-\kappa}{\theta-1}} f_u\tau_m^{-\theta} - \kappa B^{\frac{\theta-1-\kappa}{\theta-1}} f_u\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}\tau_m^{-\theta}$$
$$+ \kappa C^{\frac{\theta-1-\kappa}{\theta-1}} f_u\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}\tau_m^{-\theta}$$

Since $f_{mx} > f_u$, $\left(\frac{f_{mx}}{f_u}\right)^{\frac{-\kappa}{\theta-1}}\tau_m^{-\kappa} > A$, $\tau_m^{-1} > \tau_m^{-\theta}$ and $B > C$, $\frac{\partial\Psi^\kappa}{\partial\tau_m} < 0$. Thus, $\frac{\partial\tilde{\pi}'}{\partial\tau_m} < 0$.

Exit productivity cutoff:

$$z_e' = \left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\Psi\right)^{1/\kappa}$$

Thus, $\frac{\partial z_e'}{\partial\tau_m} < 0$

Export Productivity Cutoff, Country m:

$$z_{mx} = \left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\right)^{1/\kappa}\left[\frac{1}{n_{mx}}f_u + f_{mx} + \frac{n_{ox}}{n_{mx}}(f_{ox}-f_{mx}) + \frac{n_{ms}}{n_{mx}}(f_u(\phi_m-1)\right.$$
$$\left. + f_{mx} - f_{ox}) + \frac{n_{os}}{n_{mx}}(f_{ox} - f_{mx} + (\phi_o-\phi_m)f_u)\right]$$

Proof:

(1)

$$\frac{1}{n_{mx}} = \left(\frac{z_{mx}}{z_e'}\right)^\kappa = \left(\tau_m\left(\frac{f_{mx}}{f_u}\right)^{\frac{1}{\theta-1}}\right)^\kappa$$

When τ_m falls, $\frac{1}{n_{mx}}$ goes down.

(2)

$$\frac{n_{ox}}{n_{mx}} = \left(\frac{z_{mx}}{z_{ox}}\right)^\kappa = \left(\frac{f_{mx}}{f_{ox}-f_{mx}}\right)^{\frac{\kappa}{\theta-1}}\left[\tau_m^{\theta-1}(\gamma_u^{\theta-1}(1+\tau_o^{1-\theta}) - \tau_m^{1-\theta} - 1)\right]^{\frac{\kappa}{\theta-1}}$$

Let $D \equiv \tau_m^{\theta-1}(\gamma_u^{\theta-1}(1+\tau_o^{1-\theta}) - \tau_m^{1-\theta} - 1)$

$$\frac{\partial\frac{n_{ox}}{n_{mx}}}{\partial\tau_m} = \left(\frac{f_{mx}}{f_{ox}-f_{mx}}\right)^{\frac{\kappa}{\theta-1}}\kappa D^{\frac{\kappa}{\theta-1}-1}\tau_m\theta\left(\gamma_u^{\theta-1}(1+\tau_o^{1-\theta}) - 1\right) > 0$$

Since $\gamma_u^{\theta-1}(1+\tau_o^{1-\theta}) > 1$, $\frac{n_{ox}}{n_{mx}}$ falls when τ_m drops.

(3)

$$\begin{aligned}
\frac{n_{ms}}{n_{mx}} &= \left(\frac{z_{mx}}{z_{ms}}\right)^{\kappa} \\
&= \left(\frac{f_{mx}}{(\phi_m - 1)f_u + f_{mx} - f_{ox}}\right)^{\frac{\kappa}{\theta-1}} \times \\
&\quad \left[\tau_m^{\theta-1}((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u^{\theta-1})\right]^{\frac{\kappa}{\theta-1}} \\
&= \left(\frac{f_{mx}}{(\phi_m - 1)f_u + f_{mx} - f_{ox}}\right)^{\frac{\kappa}{\theta-1}} \times \\
&\quad \left[\frac{1+\tau_m^{1-\theta}}{\tau_m^{1-\theta}}\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - \frac{1+\tau_o^{1-\theta}}{\tau_m^{1-\theta}}\gamma_u^{\theta-1}\right]^{\frac{\kappa}{\theta-1}}
\end{aligned}$$

When τ_m falls, $\tau_m^{1-\theta}$ increases, $\frac{1+\tau_m^{1-\theta}}{\tau_m^{1-\theta}}$ decreases and λ_m also decreases. Thus, $\frac{n_{ms}}{n_{mx}}$ falls.

(4)

$$\begin{aligned}
\frac{n_{os}}{n_{mx}} &= \left(\frac{z_{mx}}{z_{os}}\right)^{\kappa} \\
&= \left(\frac{f_{mx}}{f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u}\right)^{\frac{\kappa}{\theta-1}} \times \\
&\quad \left[(\tau_m^{\theta-1}(\lambda_o^{\theta-1} - \lambda_m^{\theta-1}) + \tau_m^{\theta-1}\lambda_o^{\theta-1}\tau_o^{\theta-1} - \lambda_m^{\theta-1})(\rho_2/\rho_1)^{\theta-\rho}\right]^{\frac{\kappa}{\theta-1}}
\end{aligned}$$

Since $(\lambda_o^{\theta-1} - \lambda_m^{\theta-1}) > 0$, $\frac{n_{os}}{n_{mx}}$ decreases with a lower τ_m.

Therefore,

- $\tau_m \downarrow \Rightarrow \frac{1}{n_{mx}} \downarrow$
- $\tau_m \downarrow \Rightarrow \frac{n_{ox}}{n_{mx}} \downarrow$
- $\tau_m \downarrow \Rightarrow \frac{n_{ms}}{n_{mx}} \downarrow$
- $\tau_m \downarrow \Rightarrow \frac{n_{os}}{n_{mx}} \downarrow$,

We show that $\frac{\partial z_{mx}}{\partial \tau_m} > 0$.

Skill Upgrading Productivity Cutoff, Country m

$$z_{ms} = \left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\right)^{1/\kappa}\left[\frac{1}{n_{ms}}f_u + \frac{n_{mx}}{n_{ms}}f_{mx} + \frac{n_{ox}}{n_{ms}}(f_{ox}-f_{mx}) + (f_u(\phi_m-1) + f_{mx} - f_{ox}) + \frac{n_{os}}{n_{ms}}(f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u)\right]$$

Proof:

(1)

$$\begin{aligned}\frac{1}{n_{ms}} &= \left(\frac{z_{ms}}{z_e}\right)^{\kappa} \\ &= \left[\frac{(\phi_m-1)f_u + f_{mx} - f_{ox}}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)f_u}\right]^{\frac{\kappa}{\theta-1}}\end{aligned}$$

Since $\theta > 1$ and $\kappa > \theta - 1$, $\frac{1}{n_{ms}}$ falls when τ_m decreases.

(2)

When τ_m falls, $\frac{n_{ms}}{n_{mx}}$ decreases; thus $\frac{n_{mx}}{n_{ms}}$ increases.

(3)

$$\begin{aligned}\frac{n_{ox}}{n_{ms}} &= \left(\frac{z_{ms}}{z_{ox}}\right)^{\kappa} \\ &= \left[\frac{(\phi_m-1)f_u + f_{mx} - f_{ox}}{f_{ox}-f_{mx}}\frac{((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - \tau_m^{1-\theta} - 1)}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)}\right]^{\frac{\kappa}{\theta-1}}\end{aligned}$$

Since $\tau_m \downarrow \Rightarrow \tau_m^{1-\theta} \uparrow$, $\frac{n_{ox}}{n_{ms}}$ falls with a lower τ_m.

(4)

$$\begin{aligned}\frac{n_{os}}{n_{ms}} &= \left(\frac{z_{ms}}{z_{os}}\right)^{\kappa} \\ &= \left[\frac{(\phi_m-1)f_u + f_{mx} - f_{ox}}{f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u}\frac{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta}) - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)}\right]^{\frac{\kappa}{\theta-1}}\end{aligned}$$

Since $\tau_m \downarrow \Rightarrow \tau_m^{1-\theta} \uparrow$, $\frac{n_{os}}{n_{ms}}$ falls with a lower τ_m.

Therefore,

- $\tau_m \downarrow \Rightarrow \frac{1}{n_{ms}} \downarrow$
- $\tau_m \downarrow \Rightarrow \frac{n_{mx}}{n_{ms}} \uparrow$
- $\tau_m \downarrow \Rightarrow \frac{n_{ox}}{n_{ms}} \downarrow$
- $\tau_m \downarrow \Rightarrow \frac{n_{os}}{n_{ms}} \downarrow$,

We can get $\frac{\partial z_{ms}}{\partial \tau_m} > 0$ when the second effect $\frac{n_{mx}}{n_{ms}}$ is dominated by the other three effects.

Changes in Trade Costs to Country o

Average Profit:

Given $\tilde{\pi}' = \frac{\theta-1}{\kappa-(\theta-1)}\Psi^\kappa$, $\frac{\partial \tilde{\pi}'}{\partial \tau_o} = \frac{\theta-1}{\kappa-(\theta-1)}\frac{\partial \Psi^\kappa}{\partial \tau_o}$.

$$\frac{\partial \Psi^\kappa}{\partial \tau_o} = -\kappa A^{\frac{\theta-1-\kappa}{\theta-1}} f_u \gamma_u^{\theta-1}\tau_o^{-\theta} + \kappa B^{\frac{\theta-1-\kappa}{\theta-1}} f_u \gamma_u^{\theta-1}\tau_o^{-\theta} - \kappa C^{\frac{\theta-1-\kappa}{\theta-1}} f_u \lambda_o^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}\tau_o^{-\theta}$$

As $A > B$, $\frac{\partial \Psi^\kappa}{\partial \tau_o} < 0$ and then, $\frac{\partial \tilde{\pi}'}{\partial \tau_o} < 0$.

Exit Productivity Cutoff:

Similarly, $\frac{\partial z_e'}{\partial \tau_o} < 0$.

Export Productivity Cutoff, Country o:

$$z_{ox} = \left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\right)^{1/\kappa}\left[\frac{1}{n_{ox}}f_u + \frac{n_{mx}}{n_{ox}}f_{mx} + (f_{ox} - f_{mx}) + \frac{n_{ms}}{n_{ox}}(f_u(\phi_m - 1) + f_{mx} - f_{ox}) + \frac{n_{os}}{n_{ox}}(f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u)\right]$$

Proof:

(1)

$$\frac{1}{n_{ox}} = \left(\frac{z_{ox}}{z_e}\right)^\kappa = \left[\frac{f_{ox} - f_{mx}}{((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - \tau_m^{1-\theta} - 1)f_u}\right]^{\frac{\kappa}{\theta-1}}$$

Since $\theta > 1$ and $\kappa > \theta - 1$, $\frac{1}{n_{ox}}$ falls when τ_o decreases.

(2)

$$\begin{aligned}\frac{n_{mx}}{n_{ox}} &= \left(\frac{z_{ox}}{z_{mx}}\right)^{\kappa} \\ &= \left(\frac{f_{ox} - f_{mx}}{f_{mx}}\right)^{\frac{\kappa}{\theta-1}} \left[\frac{(\gamma_u^{\theta-1}(1+\tau_o^{1-\theta}) - \tau_m^{1-\theta} - 1)}{\tau_m^{\theta-1}}\right]^{\frac{\kappa}{\theta-1}}\end{aligned}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{n_{mx}}{n_{ox}}$ increases with a lower τ_o.

(3)

$$\begin{aligned}\frac{n_{ms}}{n_{ox}} &= \left(\frac{z_{ox}}{z_{ms}}\right)^{\kappa} \\ &= \left[\frac{f_{ox} - f_{mx}}{(\phi_m - 1)f_u + f_{mx} - f_{ox}} \frac{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)}{((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - \tau_m^{1-\theta} - 1)}\right]^{\frac{\kappa}{\theta-1}}\end{aligned}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{n_{ms}}{n_{ox}}$ falls with a lower τ_o.

(4)

$$\begin{aligned}\frac{n_{os}}{n_{ox}} &= \left(\frac{z_{ox}}{z_{os}}\right)^{\kappa} \\ &= \left[\frac{f_{ox} - f_{mx}}{f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u} \frac{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta}) - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}}{((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - \tau_m^{1-\theta} - 1)}\right]^{\frac{\kappa}{\theta-1}}\end{aligned}$$

Let $E \equiv (\lambda_o^{\theta-1}(1+\tau_o^{1-\theta}) - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}$ and $F \equiv ((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - \tau_m^{1-\theta} - 1)$.

$$\frac{\partial \frac{n_{os}}{n_{ox}}}{\tau_o} = \left[\frac{f_{ox} - f_{mx}}{f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u}\right]^{\frac{\kappa}{\theta-1}} \kappa \frac{-\lambda_o^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}\tau_o^{-\theta}F - \gamma_u^{\theta-1}\tau_o^{-\theta}E}{F^2}$$

Since $-\lambda_o^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}\tau_o^{-\theta}F - \gamma_u^{\theta-1}\tau_o^{-\theta}E < 0$ and other terms are positive, $\frac{\partial \frac{n_{os}}{n_{ox}}}{\tau_o} < 0$.

Hence,

- $\tau_o \downarrow \Rightarrow \frac{1}{n_{ox}} \downarrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{mx}}{n_{ox}} \uparrow$

- $\tau_o \downarrow \Rightarrow \frac{n_{ms}}{n_{ox}} \downarrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{os}}{n_{ox}} \uparrow$,

$\frac{\partial z_{ox}}{\partial \tau_o} > 0$ if and only if the total effects of τ_o on $\frac{1}{n_{ox}}$ and $\frac{n_{ms}}{n_{ox}}$ dominate the other two effects.

Skill Upgrading Productivity Cutoff, Country o:

$$z_{os} = \left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\right)^{1/\kappa}\Bigg[\frac{1}{n_{os}}f_u + \frac{n_{mx}}{n_{os}}f_{mx} + \frac{n_{ox}}{n_{os}}(f_{ox}-f_{mx}) + \frac{n_{ms}}{n_{os}}(f_u(\phi_m-1)+f_{mx}-f_{ox}) + (f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u)\Bigg]$$

Proof:

(1)

$$\frac{1}{n_{os}} = \left(\frac{z_{os}}{z_e}\right)^{\kappa} = \left[\frac{f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u}{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta})-\lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}f_u}\right]^{\frac{\kappa}{\theta-1}}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{1}{n_{os}}$ falls with a lower τ_o.

(2)

$$\frac{n_{mx}}{n_{os}} = \left(\frac{z_{os}}{z_{mx}}\right)^{\kappa} = \left[\frac{f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u}{f_{mx}}\frac{\tau_m^{1-\theta}}{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta})-\lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}f_u}\right]^{\frac{\kappa}{\theta-1}}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{n_{mx}}{n_{os}}$ falls with a lower τ_o.

(3)

As $\frac{\partial \frac{n_{os}}{n_{ox}}}{\tau_o} < 0$, $\frac{n_{ox}}{n_{os}}$ decreases if τ falls.

(4)

$$\frac{n_{ms}}{n_{os}} = \left(\frac{z_{os}}{z_{ms}}\right)^{\kappa} = \left[\frac{f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u}{(\phi_m-1)f_u+f_{mx}-f_{ox}}\frac{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-(1+\tau_o^{1-\theta})\gamma_u)}{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta})-\lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}f_u}\right]^{\frac{\kappa}{\theta-1}}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{n_{ms}}{n_{os}}$ falls with a lower τ_o.

Hence,

- $\tau_o \downarrow \Rightarrow \frac{1}{n_{os}} \downarrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{mx}}{n_{os}} \downarrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{ox}}{n_{os}} \downarrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{ms}}{n_{os}} \downarrow$,

We prove that $\frac{\partial z_{os}}{\partial \tau_o} > 0$.

Export Productivity Cutoff, Country m:

$$z_{mx} = \left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\right)^{1/\kappa}\left[\frac{1}{n_{mx}}f_u + f_{mx} + \frac{n_{ox}}{n_{mx}}(f_{ox}-f_{mx}) + \frac{n_{ms}}{n_{mx}}(f_u(\phi_m-1)\right.$$
$$\left. + f_{mx} - f_{ox}) + \frac{n_{os}}{n_{mx}}(f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u)\right]$$

Proof:

(1)

$$\frac{1}{n_{mx}} = \left(\frac{z_{mx}}{z_e'}\right)^{\kappa} = \left(\tau_m\left(\frac{f_{mx}}{f_u}\right)^{\frac{1}{\theta-1}}\right)^{\kappa}$$

τ_o has no effects on $\frac{1}{n_{mx}}$.

(2)

$$\frac{n_{ox}}{n_{mx}} = \left(\frac{z_{mx}}{z_{ox}}\right)^{\kappa} = \left(\frac{f_{mx}}{f_{ox}-f_{mx}}\right)^{\frac{\kappa}{\theta-1}}\left[\tau_m^{\theta-1}(\gamma_u^{\theta-1}(1+\tau_o^{1-\theta}) - \tau_m^{1-\theta}-1)\right]^{\frac{\kappa}{\theta-1}}$$

When τ_o falls, $\tau_0^{1-\theta}$ increases and $\frac{n_{ox}}{n_{mx}}$ goes up.

(3)

$$\begin{aligned}
\frac{n_{ms}}{n_{mx}} &= \left(\frac{z_{mx}}{z_{ms}}\right)^{\kappa} \\
&= \left(\frac{f_{mx}}{(\phi_m - 1)f_u + f_{mx} - f_{ox}}\right)^{\frac{\kappa}{\theta-1}} \times \\
&\quad \left[\tau_m^{\theta-1}((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u^{\theta-1})\right]^{\frac{\kappa}{\theta-1}} \\
&= \left(\frac{f_{mx}}{(\phi_m - 1)f_u + f_{mx} - f_{ox}}\right)^{\frac{\kappa}{\theta-1}} \times \\
&\quad \left[\frac{1+\tau_m^{1-\theta}}{\tau_m^{1-\theta}}\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - \frac{1+\tau_o^{1-\theta}}{\tau_m^{1-\theta}}\gamma_u^{\theta-1}\right]^{\frac{\kappa}{\theta-1}}
\end{aligned}$$

When τ_o falls, $\tau_o^{1-\theta}$ increases; thus $\frac{n_{ms}}{n_{mx}}$ falls.

(4)

$$\begin{aligned}
\frac{n_{os}}{n_{mx}} &= \left(\frac{z_{mx}}{z_{os}}\right)^{\kappa} \\
&= \left(\frac{f_{mx}}{f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u}\right)^{\frac{\kappa}{\theta-1}} \times \\
&\quad \left[(\tau_m^{\theta-1}(\lambda_o^{\theta-1} - \lambda_m^{\theta-1}) + \tau_m^{\theta-1}\lambda_o^{\theta-1}\tau_o^{\theta-1} - \lambda_m^{\theta-1})(\rho_2/\rho_1)^{\theta-\rho}\right]^{\frac{\kappa}{\theta-1}}
\end{aligned}$$

When τ_o falls, $\tau_o^{\theta-1}$ falls and $\frac{n_{os}}{n_{mx}}$ goes down.

Therefore,

- $\tau_o \downarrow \Rightarrow \frac{n_{ox}}{n_{mx}} \uparrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{ms}}{n_{mx}} \downarrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{os}}{n_{mx}} \downarrow$.

A reduction in τ_o decreases z_{mx} when the impact of τ_o on $\frac{n_{ox}}{n_{mx}}$ is dominated by the other two effects.

Skill Upgrading Productivity Cutoff, Country m:

$$z_{ms} = \left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\right)^{1/\kappa}\left[\frac{1}{n_{ms}}f_u + \frac{n_{mx}}{n_{ms}}f_{mx} + \frac{n_{ox}}{n_{ms}}(f_{ox}-f_{mx}) + (f_u(\phi_m-1) + f_{mx} - f_{ox}) + \frac{n_{os}}{n_{ms}}(f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u)\right]$$

Proof:

(1)

$$\frac{1}{n_{ms}} = \left(\frac{z_{ms}}{z_e}\right)^{\kappa} = \left[\frac{(\phi_m-1)f_u + f_{mx} - f_{ox}}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)f_u}\right]^{\frac{\kappa}{\theta-1}}$$

When τ_o falls, $\tau_o^{1-\theta}$ increases and $\frac{1}{n_{ms}}$ goes up.

(2)

When τ_o falls, $\frac{n_{ms}}{n_{mx}}$ decreases; thus $\frac{n_{mx}}{n_{ms}}$ increases.

(3)

$$\frac{n_{ox}}{n_{ms}} = \left(\frac{z_{ms}}{z_{ox}}\right)^{\kappa} = \left[\frac{(\phi_m-1)f_u + f_{mx} - f_{ox}}{f_{ox}-f_{mx}}\frac{((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - \tau_m^{1-\theta} - 1)}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)}\right]^{\frac{\kappa}{\theta-1}}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{n_{ox}}{n_{ms}}$ increases with a lower τ_o.

(4)

$$\frac{n_{os}}{n_{ms}} = \left(\frac{z_{ms}}{z_{os}}\right)^{\kappa} = \left[\frac{(\phi_m-1)f_u + f_{mx} - f_{ox}}{f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u}\frac{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta}) - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)}\right]^{\frac{\kappa}{\theta-1}}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{n_{os}}{n_{ms}}$ rises with a lower τ_o.

Therefore,

- $\tau_o \downarrow \Rightarrow \frac{1}{n_{ms}} \uparrow$

- $\tau_o \downarrow \Rightarrow \frac{n_{mx}}{n_{ms}} \uparrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{ox}}{n_{ms}} \uparrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{os}}{n_{ms}} \uparrow$,

We derive that $\frac{z_{ms}}{\tau_o} < 0$.

B.3 Data Description

B.3.1 Computation of Input Tariffs

We computed input tariffs for each 4-digit CIC industry in a similar way as Amiti and Konings (2007) and Bustos (2011b). The input tariff for each industry is computed as weighted average of the tariffs of all inputs used, where the weights are based on the cost share of each input, according to the following formula:

$$\tau_{jt}^{im} = \sum_i w_{ij} \times \tau_{it}^{im} \text{ where } w_{ij} = \frac{a_{ij}}{\sum_i a_{ij}} \tag{B.1}$$

where j indexes the 4-digit CIC industry for which the input tariff is computed; i indexes the 4-digit CIC industry producing the input, and t indexes time. w_{ij} denotes the cost share of each input i in the production of output j, and a_{ij} is total expenditure in input i by industry j. These expenditure shares include both domestic and imported inputs. We estimated a_{ij} based on China's input-output (I-O) table in 2007. The data are aggregated at the sector level, and we use the same value for all the industries in the same sector.

B.3.2 Proxy for Initial Productivity

In the model, heterogeneity is given by labor productivity holding skill level constant, which is not directly observed in the data. As a proxy for initial productivity, we use initial firm size in terms of employment relative to the 4-digit industry average.

B.3.3 Measures of Capital and Skill Intensity

Average capital and skill intensity in the industry in the United States in the 1980s is obtained from the NBER productivity database. The measure of capital intensity is capital (real equipment plus real structures) per worker, and the measure of skill intensity is the ratio of non-production to production workers in the industry.

B.3.4 Summary Statistics

Table B.1: Summary statistics of variables of interest in 2004

Variables	All	Exporters	Non-exporters	Observations	Firms
Employment	361.055	691.605	190.219	131,460	110,632
	[1806.685]	[2867.222]	[785.306]		
Total sales	160.362	373.104	50.412	131,460	110,632
	[1826.812]	[3061.618]	[426.793]		
Export share of sales, Exports>0		0.028		23,964	44,792
		[0.048]			
1{Export to India}, Exports>0		0.090		23,964	44,792
		[0.286]			
1{TS>0}	0.443	0.466	0.432	131,460	110,632
	[0.497]	[0.499]	[0.495]		
Total training spending	43.139	82.403	22.846	131,460	110,632
	[432.506]	[639.843]	[266.359]		
Total training spending, TS>0	97.279	176.890	52.899	58,296	48,525
	[645.421]	[928.517]	[403.346]		
Training spending per worker	111.912	117.462	109.044	131,460	110,632
	[591.856]	[561.849]	[606.766]		
Training spending per worker, TS>0	252.367	252.149	252.488	58,296	48,525
	[868.612]	[802.307]	[903.476]		
Observations	131,460	44,792	86,668		
Firms	110,632	23,964	86,668		

Standard deviations in brackets. Employment in number of workers, sales in millions of 2004 RMB yuan, total training spending in thousands of 2004 RMB yuan, and training spending per capita in 2004 RMB yuan.

Appendix C

HEALTH INVESTMENT AND TRADE OPENNESS

C.1 Additional Empirical Evidence

In this section, we study the macroeconomic effects of productivity, health and trade policy shocks on health expenditure and trade. We use quarterly measures of U.S. macroeconomic data and we convert yearly tariffs data into quarterly rates. The data covers from 1990Q1 to 2019Q1.

First, Figure C.1 indicates that one-standard deviation increase in the growth rate of labor productivity results in more personal healthcare consumption due to the income effect. To investigate the effect of a health shock, we estimate a VAR with four observables: personal health consumption over GDP, exports over GDP, imports over GDP and GDP growth rate. Figure C.2 reports the dynamic effects of an increase in personal healthcare services consumption at quarterly frequency on the U.S. exports and imports. More healthcare consumption creates higher GDP growth rate, reflecting greater health improvement and higher productivity in the country. Thus, the economic growth leads to more trade.

Next, we attempt to see whether a reduction in trade barriers stimulates more healthcare consumption and improves health indirectly. The impacts of tariffs on trade over GDP and healthcare spending over GDP are not significant as shown in Figure C.3. In addition, we take natural logs of exports, imports and healthcare expenditure and take the first difference to get detrended variables. Figure C.4 shows that one standard deviation decrease in import-weighted average tariffs leads to an increase in healthcare expenditure slightly. Trade openness creates a small positive effect on healthcare spending, which could also increase the stock of health capital hold by households.

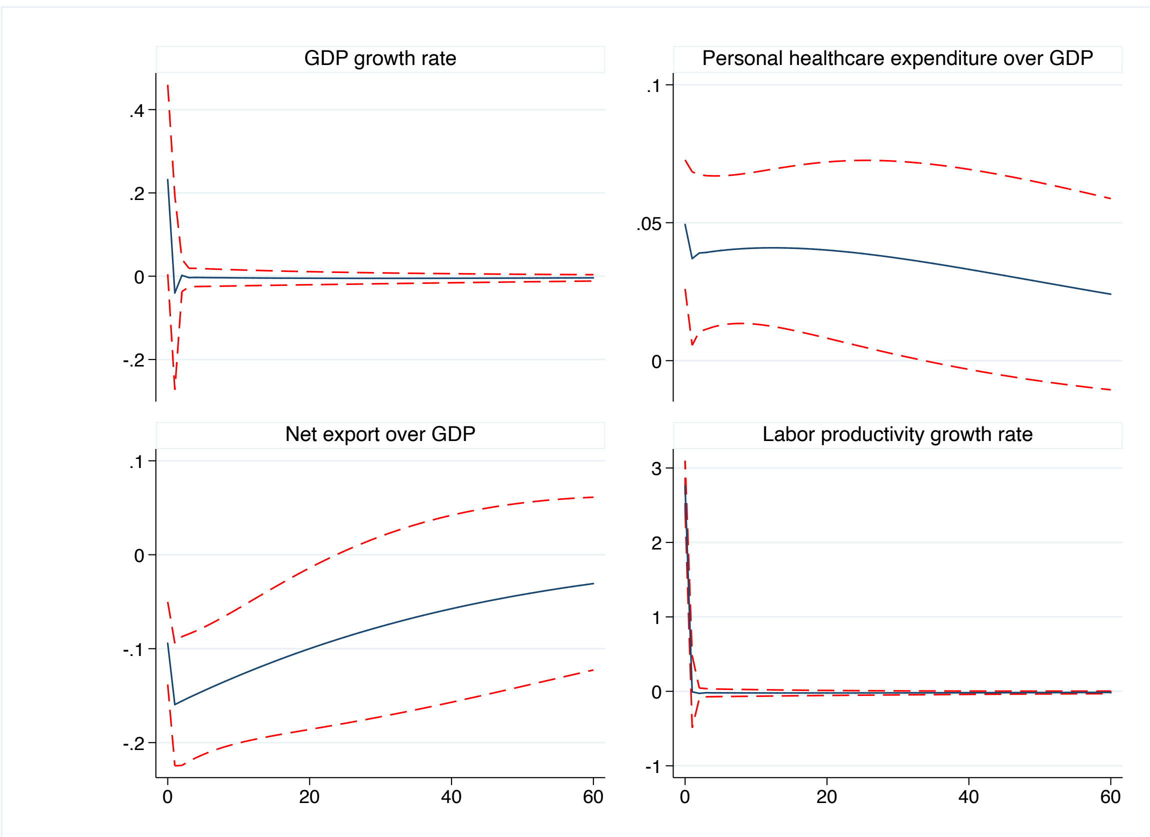

Figure C.1: Quarterly VAR, one-standard deviation increase in labor productivity

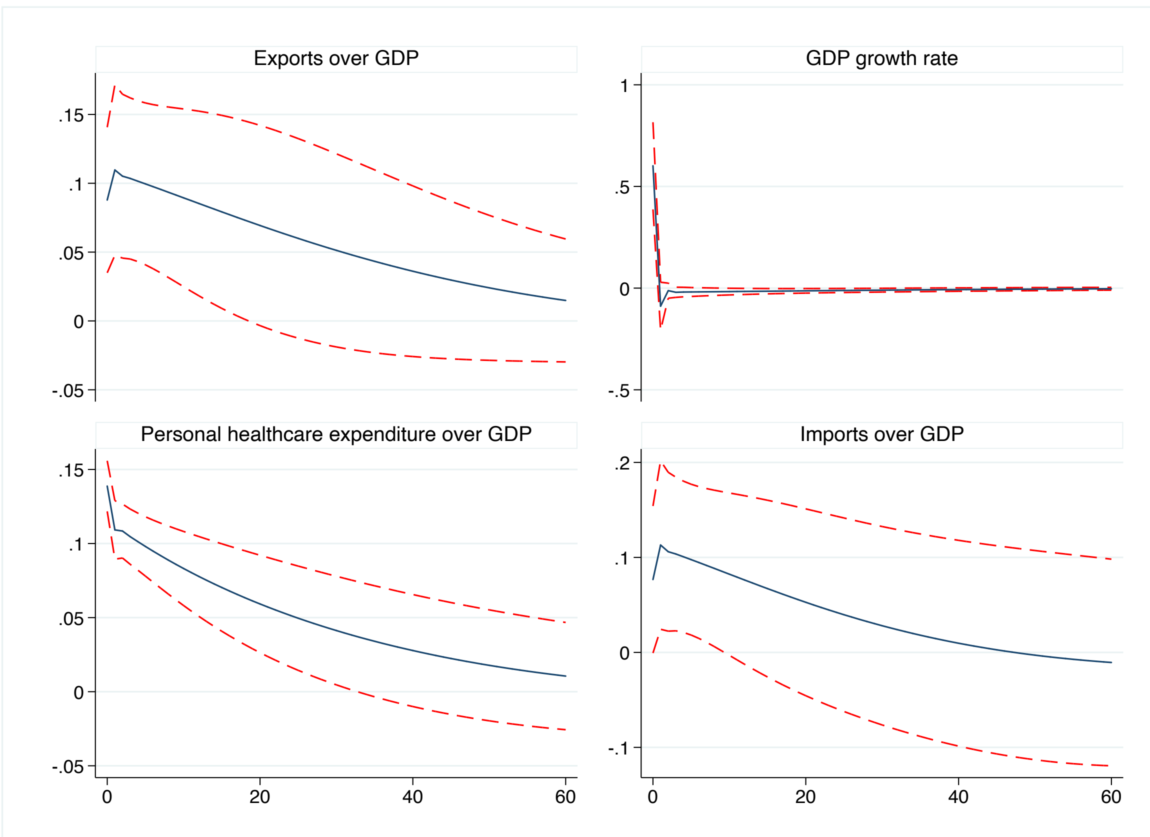

Figure C.2: Quarterly VAR, one-standard deviation increase in healthcare consumption

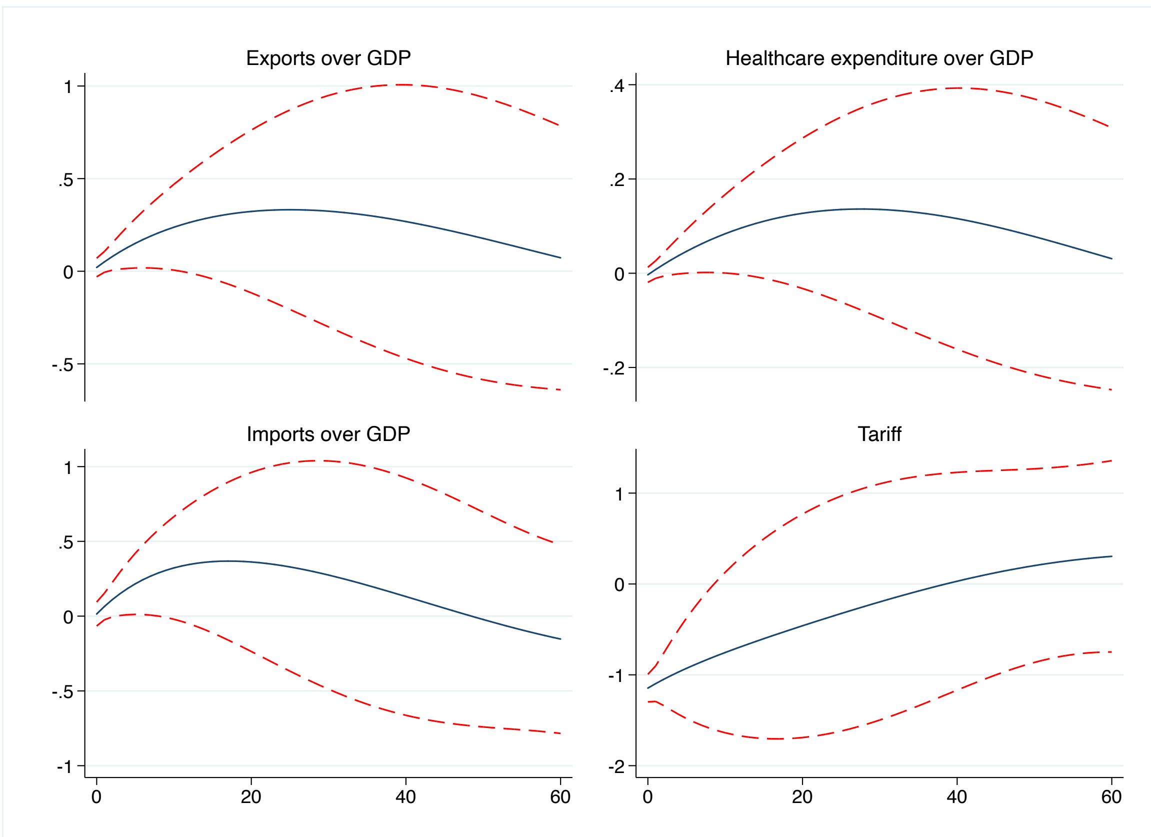

Figure C.3: Quarterly VAR, one-standard deviation decrease in import-weighted average tariffs

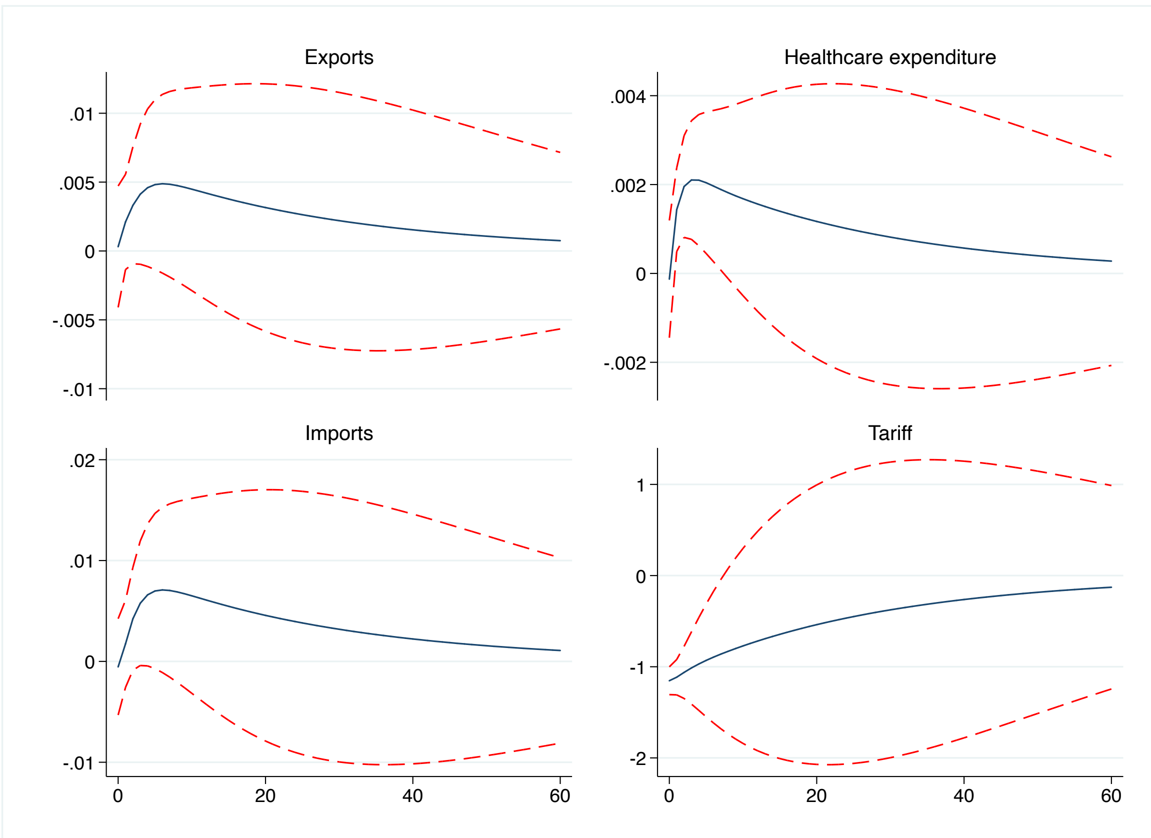

Figure C.4: Quarterly VAR, one-standard deviation decrease in import-weighted average tariffs

C.2 Data Description

The data of scatter plots are from the World Bank World Development Indicators, 2019. There are 162 countries. Exports (imports) are the export (import) values of goods and services in current US dollars. As described in the data source, infant mortality rate is the number of infants dying before reaching one year of age, per 1,000 live births in a given year, and life expectancy at birth refers to the number of years a newborn infant would live. Private expenditures on health per capita is expressed in current US dollars, and its sources include funds from households, corporations and non-profit organizations.

Annual data of the U.S. health spending and pharamaceutical spending are collected from OECD. Health spending meeasures the final consumption of healthcare goods and services. Pharamaceutical spending includes expenditure on prescription medicines and self-medication.

The quarterly data of consumption of healthcare services, export, imports and GDP growth rate are collected from U.S. Bureau of Economic Analysis, and it is retrieved from FRED, Federal Reserve Bank of St. Louis. The labor productivity (output per hour) of all business sectors is the percentage change from previous quarter at annual rate, and these data are also from U.S. Bureau of Economic Analysis.

Tariff data are from UN-WITS Database. We aggregate HS-2 product-level applied tariff rates using an import-weighted average of tariffs and convert them to quarterly rates.