Essays on Trade Liberalization and Labor Market Outcomes

Zhe Jiang

A dissertation
submitted in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy

University of Washington

2020

Reading Committee:

Fabio Ghironi, Chair

Stephen Turnovsky

Kar-yiu Wong

Program Authorized to Offer Degree:
Economics

University of Washington

Abstract

Essays on Trade Liberalization and Labor Market Outcomes

Zhe Jiang

Chair of the Supervisory Committee:
Professor Fabio Ghironi
Department of Economics

This dissertation studies trade liberalization and labor market outcomes. The first two chapters examine the impact of China's trade liberalization on the adjustment of U.S. labor market for skilled and unskilled workers in a dynamic general equilibrium framework with firm heterogeneity and factor proportions. In the first chapter, I most specifically look into the effect of trade cost reduction on U.S. skill premium in an environment which I abstract from labor market friction. Featuring labor market search and matching frictions, the second chapter is part of a broader agenda on the labor market effect of China's trade liberalization and U.S. firms' offshoring decisions, with a greater focus on the dynamics of unemployment of skilled and unskilled workers. The third chapter investigates the impact of the China's increased trade openness on its local labor market. It examines the effects of China's domestic migration policy change and trade liberalization on wage inequality in China using a dynamic general equilibrium model of international trade and internal migration across regions. This dissertation showcases some of the ways trade policy can interact with firms' endogenous offshoring and entry decisions, workers' mobility choices, as well as labor market frictions in a dynamic fashion.

More specifically, the first chapter studies how wage inequality between skilled and unskilled workers interacts with multinational firms' decisions and countries' different factor endowments using a two-country dynamic stochastic model featuring task-offshoring, hetero-

geneous firms and factor proportions. It shows that besides the traditional Stolper-Samuelson mechanism that shifts factors of production towards a country's comparative advantage sectors, there also exist other firm-level adjustment mechanisms that widen the wage gap after trade liberalization. It finds that offshoring widens wage inequality between skilled and unskilled workers through increasing high-skilled wage and lowering low-skilled wage. Such effect is more announced in the beginning phase of the adjustment. The intensive margin and the extensive margin are both active in shaping rising wage gap in the home country, with the latter playing a more important role in the short to medium run compared to the beginning stage following the shock.

The second chapter studies the dynamic effects of offshoring on the unemployment rates and wage inequality across the high-skilled and low-skilled workers through the dynamics of firms' production location and entry decisions in general equilibrium. First, I examine the dynamic effects of offshoring cost reduction due to China's trade liberalization. Estimates from vector autoregressions (VARs) show that a decrease in offshoring costs is associated with a short-lived increase in low-skilled unemployment, but a persistent decline in high-skilled unemployment and a less persistent expansion of wage gap in the source country. Second, I build a two-country trade-in-task model with firm heterogeneity, endogenous selection into entry and offshoring as well as search and matching frictions to study the channels through which offshoring cost reductions affect the labor market outcomes for different skill groups over time. The model successfully reproduces the VAR evidence and highlights the importance of endogenous firm entry and labor market frictions in generating the empirical dynamic responses of wage and unemployment across different skill groups.

The third chapter investigates China's labor market's responses to its own trade liberalization, which is a relatively less explored topic compared to the relationship between the China shock and labor market changes in other countries. Using data from CHIP (Chinese Household Income Project), this chapter aims to fill this gap by estimating the effects of trade liberalization on Chinese local labor markets. In addition, it investigates changes in urban to rural wage inequality and skill premium in urban and rural areas separately with the availability of surveys conducted in urban and rural households. In the model, a dynamic general equilibrium framework with heterogeneous firms, heterogeneous workers and internal migration is used to study the impact of policy-generated trade cost reduction and easing of migration restrictions on Chinese wage inequality. I focus on the role of labor mobility that characterizes the large rural-to-urban migration in the midst of trade liberalization in shaping skill premium and urban to rural wage inequality. Calibrating the changes in policy-generated migration cost reduction and trade cost decline, as well as productivity increase in the tradable sector, this paper analyzes the responses of different measures of wage inequality and other macroeconomics variables following these shocks.

This dissertation highlights the role of interaction of firm dynamics, factor endowments and labor market frictions in shaping the labor market adjustments. The positive effects of offshoring on the labor market for workers regardless of skill levels suggest that more trade frictions designed to restrict offshoring is likely to hinder firm entry, which is a key driver that contributes to higher wages and lower unemployment rates of both skilled and unskilled workers over time. It also points to the importance of labor market reforms by showing that easing of migration restriction and search and matching frictions are both beneficial to exports and wages of all workers, with consequences of rising wage inequality though.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Table Number Page

ACKNOWLEDGMENTS

The dissertation would not have been possible without the help of many people in numerous ways.

I would like to express my deepest gratitude to my advisor, Professor Fabio Ghironi, for his extensive support, encouragement, and insightful guidance. He not only galvanized my interest in international macroeconomics and international trade where I found exciting research projects, but also worked selflessly to help me bring this dissertation to fruition. His hard-working attitude and passion for research makes him a great role model from whom I will continue to learn in the future. Moreover, a caring, responsible and enthusiastic teacher who is immensely knowledgable in his fields, he has always inspired me to become a great teacher like him.

I am truly thankful to my committee members Professor Stephen Turnovsky and Professor Kar-yiu Wong, both of whom have shown great kindness and patience to me. I benefited greatly from their insightful advice and ongoing support as my committee member. I thank Professor Stephen Turnovsky for always making him available to have conversations with me, sharing me with his thoughts and suggestions, and giving me great encouragement along the way. Professor Kar-yiu Wong has also offered me help and advice whenever I need them.

To my amazing parents, I would like to extend my sincere gratefulness to their unconditional love, care, support. They raised me up with love and vision; they taught me to be brave, to venture, to combat prejudice and to pursue the life I want. Once my guiding lights when I was little, they have later become my sweetest, dearest and most trusted friends. They have given me everything I could ever hope for. I also thank my fiancé, Xuetao Shi, without whose companion, discussions, and support, I would not have been able to complete my Ph.D. degree with joy. His persistent hard work and powerful self-discipline as a peer is what motivates me to keep working hard and going forward.

Chapter 1

MULTINATIONAL FIRMS' SOURCING DECISION AND WAGE INEQUALITY: A DYNAMIC ANALYSIS

1.1 Introduction

It is now the fourth decade since the beginning of China's economic reforms launched the country on perhaps the most spectacular growth and poverty reduction performance in the history of world. This achievement has been accompanied by equally dramatic outcomes in other economic spheres domestically as well its impact on the rest of the world. Due to its size, China has been the subject of extensive introspection over global issues such as manufacturing jobs, wages, investment and savings imbalances, exchange rates and so on. Analysis on the impact of China's import growth on the U.S. economy has also been extended to cover the labor market outcomes. This paper looks into how wage inequality between skilled and unskilled workers interact with firms' offshoring decisions and countries' different factor endowments in a dynamic setting.[1]

Using data from the FDI statistics from China's Ministry of Commerce, figure 1.1 shows that at the beginning stage of China's market economy orientation and opening to the world, late 1980s, US FDI to China remained at a very low level. It was not until 1992 when the number of foreign-invested enterprises reached its peak. What happened that year was that Special Economic Zones (SEZs) were created, which allowed foreign companies to set up factories that imported inputs free of tax and exported outputs, with substantial reductions in income taxes as well, easier access to foreign markets and free from government interference. Effectively, the realized FDI values kept increasing and reached the peak in the

[1] Offshoring refers to the sourcing of inputs from foreign countries which enables the fragmentation of production process. One of the main motivations for fragmenting the production process is the ability to procure these inputs at a lower cost from abroad than at home.

early 2000s, roughly around post WTO entry period, and stayed quite high for the following few years. What is also true of offshoring statistics is that as shown in figure 1.2, the United States ranks the third among all the regions in the world in terms of total number of offshoring firms in China since 1987, only lower than Hong Kong and Taiwan, which are two most China-dependent economies. According to Antras et al. (2017), for the US, China is also the second largest sourcing country that firms source from, only second to Canada.

With multinational enterprises moving their factories to China, China saw a further increase in processing trade activity. According to Fan et al. (2014), the share of exports by FIEs in total exports increased from 12.6 per cent in 1990 to 47.9 per cent in 2000, and the share of processing exports in total exports rose rom 40.9 per cent in 1990 to 55.2 per cent in 2000. The ratio of processing exports started to climb up in the mid 1980s and is kept at a level above 50 percent after 1995.

While there is a surge of multinational firms' offshoring activities in China especially in the processing trade industries, the issue of expanding wage inequality in the United States has received great attention. The larger wage gap has been studied extensively in the literature. Many studies point to the role of changes in the economic environment, particularly in production technologies, that favored skilled workers and widened the wage distribution.[2] A completing explanation emphasizes international trade, which hit hard on domestic low-skilled workers with competition from cheaper imported goods. In particular, trade with China has been recently identified as an important driver of wage inequality in developed countries. [3]

This paper examines how firms' offshoring decisions and countries' different factor endowments affect wage inequality between skilled and unskilled workers in a dynamic framework. Featuring factor proportions and firm heterogeneity in the model, this paper provides a dynamic view of how the skilled and unskilled workers respond to trade cost reduction under the offshoring context in the short run and over time.

[2]See for instance Acemoglu and Autor (2011), Acemoglu et al. (2015) and Burstein and Vogel (2017).

[3]Some examples include Ebenstein et al. (2015), Pierce and Schott (2016).

Why is the dynamic framework important for studying wages of skilled and unskilled workers following trade liberalization? One of the reasons is that it is important for us to understand the adjustment path of wages of different skill groups following trade policy changes. which is critical for understanding the time-varying impact of policies. Lack of support of one or another trade policy regime depends crucially on the adjustment to changes during the dynamics. The dynamic analysis allows one to obtain implications of steady state results without ignoring the short run costs and the transition dynamics. In reality, the negative impact on blue-collar workers in the States as well as their slow adjustments have received great attention with China's integration into the global trade system, commonly referred to as the China shock. The policy debate on the China shock, for instance, Autor et al. (2016), puts great emphasis on how painful the adjustment has been for workers and firms. This happens along the dynamics, not in the steady state. Therefore, it is highly important to study this issue in a dynamic environment and to offer a framework that examines the impact of the China shock from a dynamic perspective to capture the wage adjustments to changes during the dynamics for workers with different skill levels. For these reasons, which point to the role of the dynamics, I make the model fully dynamic general equilibrium model in the spirit of the recent international macro and trade literature.

To map the empirical evidence from US offshoring to China, I build a two-country dynamic general equilibrium model with country-level differences in factor proportions, firm heterogeneity and endogenous firm entry. I then use the model to study the channels through which offshoring cost reductions affect wages of different skill groups and the wage gap along different time horizon. Results of the model show that offshoring does have distributional consequences: wage gap between high-skilled and low-skilled workers does increase substantially in the initial periods following the shock. The rise in wage wage then slows down. Over time, low-skilled workers experience increase in their wage, which leads to slower growth of wage gap. The intensive margin and the extensive margin both operate in shaping rising wage gap in the home country, with the latter playing a more important role in the short to medium run compared to the beginning stage following the shock.

1.1.1 *Related Literature*

This paper is closely related to the task-based framework including Acemoglu (2003), Acemoglu and Autor (2011), Feenstra and Hanson (1999) and Grossman and Rossi-Hansberg (2008), particularly the last two. In Feenstra and Hanson (1999), firms offshore some of their labor-intensive activities following liberalization of capital markets, thereby reducing the demand for skilled labor in the U.S. I extend their framework by introducing firm-level heterogeneity and examine the implications of within-sector productivity channel. On the other hand, Grossman and Rossi-Hansberg (2008) predict that offshoring may have positive effect on both the low-skilled and the high-skilled when certain conditions hold. In their model there exist complementarities between domestically performed and offshored tasks whereas in my model the two tasks are perfect substitutes so that the demand for the low-skilled labor falls in response to trade liberalization.

The dynamic framework of this paper builds on Ghironi and Melitz (2005). In a dynamic stochastic environment, Zlate (2016) studies the synchronization of business cycle linked by offshoring. Mandelman (2016) focuses on the polarization of the labor market in the US. Regarding the impact of offshoring on labor markets, Ottaviano et al. (2013) looks at the impact of offshoring and immigration on home country's employment; Mandelman and Zlate (2016) model the impact of offshoring and low-skill labor migration on labor market polarization; Cacciatore (2014) examines the role of labor market rigidities in shaping business cycle comovement. Lechthaler and Mileva (2014b) introduces Heckscher-Ohlin comparative advantage and labor adjustment costs to examine the effect of trade liberalization on wage inequality between high-skilled and low-skilled workers. Their paper focuses on trade in goods rather than trade in tasks and multinational production. Another paper that is closely related to mine under the dynamic stochastic environment is Goel (2017), which studies the impact of offshoring on wages and employment for low-skilled and high-skilled workers, though it does not feature cross-country differences in factor proportions and only models the home country.

My work contributes to the literature studying the impact of the China shock such as Autor et al. (2013), Autor et al. (2016), Asquith et al. (2019), Bloom et al. (2019),Eriksson et al. (2019), Feenstra and Sasahara (2018) and Feenstra et al. (2019). My main contribution to the literature is that I build a dynamic and stochastic framework with uncertainty that embeds in the standard Heckscher-Ohlin model the firm heterogeneity mechanisms under a task offshoring environment.

This paper is also related to the large literature that studies offshoring to low-wage countries, such as Feenstra and Hanson (1996), Harrison and McMillan (2011), Kohler (2004) and Rodríguez-Clare (2010). However, these papers do not feature firm heterogeneity. Some examples of papers in the trade literature studying offshoring with firm heterogeneity include Antras and Helpman (2004), Egger et al. (2015), Sethupathy (2013). For instance, Egger et al. (2015) also studies the implications of offshoring in a model with firm heterogeneity, focusing on the implications of offshoring for income inequality, both within and between entrepreneurs and workers. Groizard et al. (2014) introduces a more general production structure where there exists a continuum of inputs with the fraction of offshored inputs depending on offshoring costs while also allowing for firm heterogeneity. Apart from examining the wage effects of offshoring in particular, Bernard et al. (2007), Burstein and Vogel (2017) looks at the impact of trade on wage inequality between high-skilled and low-skilled workers, abstract from an environment that features trade in tasks and multinational production.

Recent empirical work studying the relationship between the wage effects of offshoring include Baumgarten et al. (2013), Becker et al. (2013), Crinò (2012), Criscuolo and Garicano (2010), Ebenstein et al. (2015), Hummels et al. (2014), Mion and Zhu (2013) etc.

The rest of the paper is structured as follows. Section 1.2 presents the theoretical model. Section 1.3 analyzes the steady state comparison between autarky and open economy where firms can self select into offshoring. Section 1.4 describes calibration of parameters in the model. Section 1.5 focuses on the dynamic effects of offshoring cost reduction and other exogenous shocks. Section 3.4 concludes. Technical details of the derivations and proofs are provided in the appendix.

1.2 The model: two country, trade-in-tasks

1.2.1 Model environment

This section presents a stylized model of offshoring with heterogeneous firms and country-level different factor endowments in a trade-in-tasks environment. The representative households and firms' problems are described below.

Although I do not explicitly model multiple sectors, the framework nevertheless highlights the micro-level characteristics of sectors (the production share of low-skilled task, the level of product differentiation, firm entry and exit rates, levels of sunk costs and trade costs) that would generate differences in persistence rates for cross-country sector-level price differentials.

Household's Problem

There are two countries- home and foreign. Foreign variables are denoted with an asterisk. The two countries are endowed with different amounts of skilled labor H, and unskilled labor L. Home is asumed to be more skill abundant than foreign, so that the relative skill abundance is higher for the home country than for the foreign: $\frac{H}{L} > \frac{H^*}{L^*}$. Each economy consists of a unit mass of atomistic households and a continuum of monopolistically competitive firms with different levels of labor productivity. As in Ghironi and Melitz (2005), all contracts are written in nominal terms. Since prices are flexible, the variables solved for are all in real terms.

The representative household maximizes expected lifetime utility:

$$\max_{B_{t+1},x_{t+1}} E_t \sum_{s=t}^{\infty} \beta^{s-t} \frac{C_s^{1-\gamma}}{1-\gamma},$$

where $\beta \in (0,1)$ is the subjective discount factor, C_t is aggregate consumption, and $\gamma > 0$ is the inverse of the inter-temporal elasticity of substitution. The budget constraint is:

$$C_t + (N_t + N_{e,t})\,\tilde{v}_t x_{t+1} + B_{N,t+1} = \left(\tilde{v}_t + \tilde{d}_t\right) N_t x_t + (1+r_t)\,B_{N,t} + w_{h,t}H + w_{l,t}L. \quad (1.1)$$

The household purchases two types of assets. First, it purchases x_{t+1} shares in a mutual fund of Northern firms, which includes N_t incumbent firms producing either domestically or offshore at time t, and also $N_{e,t}$ new entrants in period t. The date t price of a claim to the future profit stream of the mutual fund of $N_t + N_{e,t}$ home firms is equal to the average nominal price of claims to future profits of home firms, $P_t \tilde{v}_t$. The mutual fund pays a total profit that is equal to the average total profits of all home firms that produce in that period, $P_t \tilde{d}_t N_t$. The household also receives dividends equal to the average firm profit $\tilde{d}_t$ proportional to the mass of firms N_t. The household also purchases the risk free bond issued by its own country $B_{N,t+1}$, denominated in units of the issuing country's consumption basket. The domestic risk-free bond pays interest rate r_t. Entering period t, the household has share holdings x_t in a mutual fund of N_t home firms whose average market value is $\tilde{v}_t$. There are two types of labor – high-skilled labor and low-skilled labor, supplied inelastically, earning real wages $w_{h,t}$ and $w_{l,t}$ and pooling income together.

The consumption basket for the Northern household includes varieties produced by the Northern firms either domestically or offshore:

$$C_t = \left[\int_{z_{min}}^{z_{o,t}} y_{D,t}(\omega)^{\frac{\theta-1}{\theta}} d\omega + \int_{z_{o,t}}^{\infty} y_{v,t}(\omega)^{\frac{\theta-1}{\theta}} d\omega \right]^{\frac{\theta}{\theta-1}}. \tag{1.2}$$

Each variety ω is produced by a different firm. Firms with productivity above the offshoring cutoff $z_{o,t}$ supply the offshored varieties whereas firms with productivity above z_{min} but below $z_{o,t}$ supply the domestically produced varieties. The consumption-based price index for the home economy is then $P_t = \left(\int_{\omega \in \Omega_t} p_t(\omega)^{1-\theta} d\omega \right)^{1/(1-\theta)}$. Setting the consumption basket C_t as numeraire, the price index for the North is $1 = \left[\rho_t(\omega)^{1-\theta} d\omega \right]^{\frac{1}{1-\theta}}$, and $\rho_t(\omega)$ is the real price of goods of different varieties. The household's demand for each individual good variety ω is $c_t(\omega) = (p_t(\omega)/P_t)^{-\theta} C_t$.

The foreign household earns nominal wage rate $W^*_{l,t}$ and $W^*_{h,t}$, denominated in units of foreign currency. It maximizes a similar utility function. However, the composition of the consumption basket is different. The subset of goods available for consumption in the foreign country Ω^*_t only consists of goods produced by foreign firms selling in the foreign country, which is expressed as:

$$C_t^* = \left[\int_{z_{min}}^{\infty} y_t^* \left(\omega \right)^{\frac{\theta}{\theta - 1}} d\omega \right]^{\frac{\theta}{\theta - 1}}.$$

The Euler equation for bonds for the North is:

$$1 + B_{N,t+1} = \beta \left(1 + r_{t+1} \right) E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} \right]. \tag{1.3}$$

The Euler equations for stocks is:

$$\tilde{v}_t = \beta \left(1 - \delta \right) E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} \left(\tilde{d}_{t+1} + \tilde{v}_{t+1} \right) \right], \tag{1.4}$$

where δ is firms' exit rate, which reflects the random exit shock that can hit all firms including the entrants every period with probability δ.

Firms entry

Firm entry requires an entry cost that is equal to f_e effective labor units, which is equal to $\frac{f_e}{Z_t} \left(\frac{w_l}{1-\alpha} \right)^{1-\alpha} \left(\frac{w_h}{\alpha} \right)^{\alpha}$ units of the home (foreign) consumption good. After paying the sunk entry cost, each firm is randomly assigned an idiosyncratic productivity z which is drawn from a Pareto distribution over the interval $[z_{min}, \infty)$, and it stays the same for the firm's entire operation term. Foreign firms draw productivity levels from an identical distribution over the same interval. Therefore, there are $N_{e,t}$ new firms entering the market every period and start producing at the next period. With all firms, including the new entrants, being subject to a random death shock with probability δ at the end of every period, the law of motion for the mass of firms is therefore $N_{t+1} = (1 - \delta) (N_t + N_{e,t})$.

Every period, the new entrants have expectation of their post-entry firm value $\tilde{v}_t$, which is a function of the stochastic discount factor, the probability of exit δ and the expected monopolistic stream of profits $\tilde{d}_t$. Eq. 1.4 yields the expected post-entry value of the average firm:

$$\tilde{v}_t = E_t \sum_{s=t+1}^{\infty} [\beta(1 - \delta)]^{s-t} (\frac{C_s}{C_t})^{-\gamma} \tilde{d}_s \tag{1.5}$$

As a result, every period, potential entrants make their decision to enter or not by comparing the sunk entry cost that they need to pay up front before entry with the expected profits after entry. In equilibrium, firm entry takes place until the expected value of the average firm value is equal to the sunk entry cost : $\tilde{v}_t = f_e \left(\frac{w_{l,t}}{1-\alpha}\right)^{1-\alpha} \left(\frac{w_{h,t}}{\alpha}\right)^{\alpha}$, which is f_e times the effective unit of labor.

Firms' production function and choice of production location

There is one final-good sector. Firms are all final-good producers with heterogeneity in their productivities, each producing a different variety of the final goods. Production of the final good requires two tasks – y_h and y_l. Task y_h uses high skilled labor only and task y_l uses low skilled labor only. The production function is assumed to take the following form: $y_t(z) = zZ_t \left[y_{h,t}(z)\right]^{\alpha} \left[y_{l,t}(z)\right]^{1-\alpha}$.[4] Every firm has a different level of productivity z with which it transforms the two tasks into the final output. Production are also dependent on the country-level productivity Z_t. The productivity differences across firms translate into differences in the unit cost of production. This cost, measured in units of the consumption good C_t, is $\frac{1}{zZ_t} \left(\frac{w_{l,t}}{1-\alpha}\right)^{1-\alpha} \left(\frac{w_{h,t}}{\alpha}\right)^{\alpha}$, where $w_{l,t} = W_{l,t}/P_t$ is the real wage for low-skilled labor and $w_{h,t} = W_{h,t}/P_t$ is the real wage for high-skilled labor. Similarly for the foreign firms, their unit cost measured in units of the foreign consumption good is $\frac{1}{zZ_t^*} \left(\frac{w_l^*}{1-\alpha}\right)^{1-\alpha} \left(\frac{w_h^*}{\alpha}\right)^{\alpha}$, where $w_{l,t}^* = W_{l,t}^*/P_t^*$ and $w_{h,t}^* = W_{h,t}^*/P_t^*$.

The high-skilled and low-skilled endowment of both countries are set up in a way that delivers the wage relationship that $w_l^* < w_l$ so that firms have incentive to offshore the low-skilled task in order to utilize the low-skilled cost advantage of producing in the foreign country. And the assumption that the high-skilled task cannot be offshored is made.[5].

[4] In Antras and Helpman(2004), the output of a firm z is a Cobb-Douglas function of two inputs that use domestic and foreign inputs respectively, $y_{v,t} = [\frac{Z_t z l_t}{\alpha}]^{\alpha}[\frac{Z_t^* z l_t^*}{1-\alpha}]^{1-\alpha}$.

[5] Using German individual-level data, Baumgarten et al. (2013) shows that there is a tendency that high skilled workers are more likely to hold jobs that use tasks that are less offshorable. In the case of US offshoring to China, offshoring low-skilled is more relevant due to the labor-intensive content of processing trade.

Every period, firms choose to produce either domestically or offshore. If the firm decides to produce both tasks domestically, then $y_{h,t}(z) = h_t(z)$ and $y_{l,t}(z) = l_t(z)$. If the firm instead decides to offshore the low-skilled task, then since the high-skilled task can only be produced domestically, $y_{h,t}(z) = h(z)$ but $y_{l,t}(z) = \frac{l^*(z)}{\tau}$. τ is the variable iceberg trade cost that firms need to pay if the low-skilled task is performed in the foreign country. It can be interpreted as a friction (e.g., a trade barrier) and as a cost or productivity disadvantage (less control and monitor over the products) due to distance. [6] Therefore, the output of producing both tasks domestically is $y_{D,t}(z) = zZ_t\,[h_t(z)]^{\alpha}\,[l_t(z)]^{1-\alpha}$ whereas keeping the high-skilled task produced in-house and offshoring the low-skilled tasks give firms output $y_{V,t}(z) = zZ_t\,[h_t(z)]^{\alpha}\left[\frac{l_t^*(z)}{\tau}\right]^{1-\alpha}$.

Monopolistic competitive firms maximize profits for the two different production strategies. Before that, the first step, cost minimizing pins down the number of high-skilled and low-skilled workers each firm hires, depending on the wages, firm-level productivity and aggregate productivity. The marginal costs of production for the two strategies then follow– $mc_{D,t}(z) = \frac{1}{Z_t z}\left(\frac{w_{l,t}}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_{h,t}}{\alpha}\right)^{\alpha}$ for firms producing both products domestically and $mc_{V,t}(z) = \frac{1}{Z_t z}\left(\frac{\tau w_l^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_h}{\alpha}\right)^{\alpha}$ for firms that offshore the low-skilled task to the foreign country.

$$\max_{\rho_{D(z)}} d_{D,t}(z) = \rho_{D,t}(z)y_{D,t}(z) - \frac{1}{Z_t z}\left(\frac{w_{l,t}}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_{h,t}}{\alpha}\right)^{\alpha} y_{D,t}(z), \tag{1.6}$$

$$\max_{\rho_{V(z)}} d_{V,t}(z) = \rho_{V,t}(z)y_{V,t}(z) - \frac{1}{Z_t z}\left(\frac{\tau w_l^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_h}{\alpha}\right)^{\alpha} y_{V,t}(z) - \frac{f_V}{Z_t}\left(\frac{w_l^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_h}{\alpha}\right)^{\alpha}, \tag{1.7}$$

where $\rho_{D(z)}$ and $\rho_V(z)$ are the real prices of the two production strategies. Prices are markup over marginal costs, thus generating the pricing conditions: $\rho_{D,t} = \frac{\theta}{\theta-1}\frac{1}{zZ_t}\left(\frac{w_{l,t}}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_{h,t}}{\alpha}\right)^{\alpha}$ and $\rho_{V,t} = \frac{\theta}{\theta-1}\frac{1}{zZ_t}\left(\frac{\tau w_l^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_h}{\alpha}\right)^{\alpha}$. w_l is the home country's real low-skilled real and w_h is home country's real high-skilled wage. Offshoring firms also need to pay the fixed offshoring cots f_V in terms of these firms' effective unit of labor, which is associated with building up

[6] Iceberg trade cost implies that, for every t¿1 units produced offshore, only one unit arrives in the North, with the difference lost due to factors such as trade barriers, transportation costs and so on.

and running maintenance of the factories and facilities offshore. Following Zlate (2016), I assume that firms hire workers from their respective offshoring low-skilled labor market to cover these fixed offshoring costs. Therefore, the fixed offshoring cost is $\frac{f_V}{Z_t}\left(\frac{w_l^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_h}{\alpha}\right)^{\alpha}$ units of the home consumption good. The melting-iceberg trade cost τ is embedded in offshoring firms' marginal cost. Firms with different levels of productivity z incur different costs of production. More productive firms have higher levels of output and revenue. In addition, there is a positive correlation between firms' productivity and the intensive use of labor, since $\frac{\partial h(z)}{\partial z} > 0$ $\frac{\partial l(z)}{\partial z} > 0$. More productive firms demand more labor input, for both high-skilled and low-skilled workers.

The demand for variety produced by firm z using the two production strategies are $y_{D,t}(z) = \rho_{D,t}(z)^{-\theta}C_t$ and $y_{V,t}(z) = \rho_{V,t}(z)^{-\theta}C_t$. Profits are $d_{D,t}(z) = \frac{1}{\theta}\rho_{D,t}(z)^{1-\theta}C_t$ for domestic production and $d_{V,t}(z) = \frac{1}{\theta}\rho_{V,t}(z)^{1-\theta}C_t - f_V\frac{1}{Z_t}\left(\frac{w_l^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_h}{\alpha}\right)^{\alpha}$ for offshoring the low-skilled task. Higher firm-level productivity implies that a given cost reduction from offshoring yields larger gains in profits.

The offshoring cutoff $z_{o,t}$ is pinned down by equalizing profits of the two strategies for firms' production: $z_{o,t} = \{z : d_{D,t}(z_{o,t}) = d_{V,t}(z_{o,t})\}$. It indicates that at this productivity level $z_{o,t}$, producing both tasks domestically and offshoring the low-skilled task generate the same profit. The linkage between the average profit of offshoring and that of domestically producing the low-skilled task is:

$$\tilde{d}_{v,t} = \frac{k}{k-(\theta-1)}\left(\frac{z_{V,t}}{\tilde{z}_{D,t}}\right)^{\theta-1}\tilde{d}_{D,t} + \frac{\theta-1}{k-(\theta-1)}\frac{f_V}{Z_t}\left(\frac{w_{l,t}^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_{h,t}}{\alpha}\right)^{\alpha}.$$

From the above relationship, it can be noted that the average profit of offshoring firms is higher than that of domestically producing firms because firms above the productivity cutoff would self select into offshoring.

Every period, firms compare, based on their productivity level, whether the strategy of producing both tasks domestically or that of offshoring the low-skilled task gives the firm higher profits. The cutoff is time-varying; it is responsive to changes in the labor cost of two types of labor across the two countries as well as the iceberg trade cost. The set of offshoring firms fluctuates over time with changes in the profitability of the offshoring. A lowering of the tariff or the wage cost of the low-skilled workers abroad increases the profitability of offshoring and thus lowers the offshoring cutoff, incentivizing more firms to offshore.

Consistent with the implications of Zlate (2016), firms with productivity level higher than the cutoff productivity self select into offshoring since the benefit of offshoring outweighs the cost of doing so for these firms. In order to ensure the existence of the offshoring cutoff, the condition $\tau w_l^* < w_l$ has to be satisfied, which implies that $\tau^{1-\alpha}TOP = \tau^{1-\alpha}\frac{(w_l^*)^{1-\alpha}(w_h)^{\alpha}/Z_t}{(w_l)^{1-\alpha}(w_h)^{\alpha}/Z_t} < 1$.

Averages

The model is isomorphic to a framework with two representative firms in the home country: one produces both tasks domestically, one offshores the low-skilled task and only produces the high-skilled task in the home country.

Average productivity, prices and profits

Firms' productivity are drawn from the Pareto distribution over the interval $[z_{min}, \infty)$, where the common distribution is G(z) with density g(z). Every period, there are $N_{D,t}$ firms whose idiosyncratic productivities are below the offshoring cutoff $z_{min} < z_t < z_{o,t}$ that produce both tasks domestically; and there are $N_{v,t}$ firms with productivity levels above the cutoff $z_t > z_{V,t}$. The average productivity of domestically producing firms is $\tilde{z}_{D,t}$ whereas that of offshoring firms is $\tilde{z}_{V,t}$. The average productivity levels follow as:

$$\tilde{z}_{D,t} = \left[\frac{1}{G\left(z_{v,t}\right)} \int_{z_{min}}^{z_{o,t}} z^{\theta-1} g(z) dz\right]^{\frac{1}{\theta-1}} \text{ and}$$

$$\tilde{z}_{V,t} = \left[\frac{1}{1-G\left(z_{V,t}\right)} \int_{z_{o,t}}^{\infty} z^{\theta-1} g(z) dz\right]^{\frac{1}{\theta-1}}.$$

With the assumption that the Pareto distribution of the productivity has p.d.f. $g(z) = k z_{min}^k / z^{k+1}$and c.d.f. $G(z) = 1 - \left(z_{min}/z\right)^k$, the average productivity levels $z_{d,t}$ and $z_{v,t}$ can both be expressed as function of offshore productivity cutoff $z_{o,t}$:

$$\tilde{z}_{D,t} = \nu z_{min} z_{V,t} \left[\frac{z_{V,t}^{k-(\theta-1)} - z_{min}^{k-(\theta-1)}}{z_{V,t}^{k} - z_{min}^{k}} \right]^{\frac{1}{\theta-1}} \text{ and}$$

$$\tilde{z}_{v,t} = \nu z_{V,t},$$

where $\nu = \left[\frac{k}{k-(\theta-1)}\right]^{\frac{1}{\theta-1}}$, $k > \theta - 1$, and the cutoff is $z_{o,t} = z_{min} \left(N_t/N_{V,t}\right)^{1/k}$. Firms in the Southern country only has the strategy of producing domestically. Their average productivity remains constant at $\tilde{z}_t^* = \nu z_{min}^*$.

The average price indexes for the North and the South also follow as $1 = N_{D,t}\left(\tilde{\rho}_{D,t}\right)^{1-\theta} + N_{V,t}\left(\tilde{\rho}_{V,t}\right)^{1-\theta}$ and $1 = N_t^*\left(\tilde{\rho}_t^*\right)^{1-\theta}$. The total profits of firms in the North and the South are $N_t\tilde{d}_t = N_{D,t}\tilde{d}_{D,t} + N_{V,t}\tilde{d}_{V,t}$ and $N_t^*\tilde{d}_t^* = N_t^*\tilde{d}_t^*$.

Labor market clearing

Denote $\tilde{h}_{D,t}$ as the average amount of high skilled labor used by domestically producing firms $N_{D,t}$. Similarly, $\tilde{h}_{V,t}$ is the average number of high skilled labor used by offshoring firms $N_{V,t}$. The labor market clearing conditions under offshoring become the following:

$$H = N_{D,t}\tilde{h}_{D,t} + N_{V,t}\tilde{h}_{V,t} + N_{E,t} f_E \left(\frac{\alpha w_{l,t}}{(1-\alpha) w_{h,t}}\right)^{1-\alpha} + N_{V,t} f_V \left(\frac{\alpha w_{l,t}^*}{(1-\alpha) w_{h,t}}\right)^{1-\alpha}$$

$$L = N_{D,t}\tilde{l}_{D,t} + N_{E,t} f_E \left(\frac{(1-\alpha)\, w_{h,t}}{\alpha w_{l,t}}\right)^{\alpha}$$

Home country's high skilled labor is used by domestically producing firms using high-skilled labor, offshoring firms using high-skilled labor as well as high skilled labor used for the sunk entry cost and fixed offshoring cost activities. In contrast, the low skilled labor is used only by domestically producing firms and those used to pay fixed entry cost. The opposite is true for the foreign country.

Aggregate accounting

Aggregating the budget constraint (2) across home households and imposing the equilibrium conditions under financial autarky ($B_{t+1} = B_t = 0$ and $x_{t+1} = x_t = 1$) yields the aggregate accounting equation $C_t = w_{l,t}L + w_{h,t}H + N_t\tilde{d}_t - N_{E,t}\tilde{v}_t$. A similar equation holds abroad. Consumption in each period must equal labor income plus investment income net of the cost of investing in new firms.

1.3 Steady state comparison: autarky to open economy

1.3.1 Autarky equilibrium

Under autarky, firms are all producing using domestic factors. Prices are mark up over the marginal cost of production using both types of the country's factors. Profits are derived from producing domestically. Total number of firms N only includes all domestically producing firms N_D. Therefore, $1 = N_t(\tilde{\rho}_{D,t})^{1-\theta}$. The factor market clearing conditions in both countries incorporates factor used by firms' production, as well as those used for the sunk entry cost. $H = N_t\tilde{h}_t + N_{E,t}f_E\left(\frac{\alpha w_{l,t}}{(1-\alpha)w_{h,t}}\right)^{1-\alpha}$ and $L = N_t\tilde{l}_t + N_{E,t}f_E\left(\frac{(1-\alpha)w_{h,t}}{\alpha w_{l,t}}\right)^{\alpha}$. Under autarky, a key implication on wages in equilibrium is that the wage ratio of high skilled to low skilled labor within a country is solely determined by factor proportions and high skilled cost share α, as $\frac{w_l}{w_h}\frac{\alpha}{1-\alpha} = \frac{H}{L}$, $\frac{w_l^*}{w_h^*}\frac{\alpha}{1-\alpha} = \frac{H^*}{L^*}$. Proofs are shown in the appendix. Given that the foreign country is relatively more labor abundant than the home country, the wage gap between high skilled and low skilled is lower than that for the foreign country: $\frac{w_h}{w_l} < \frac{w_h^*}{w_l^*}$. The ratio of domestic low skilled wage over foreign low skilled wage is dependent on both country's factor endowments as well as the ratio of the entry costs. The same results hold for the high-skilled factor: $\frac{w_l}{w_l^*} = \left(\frac{L^*}{L}\right)^{\frac{\alpha\theta-1}{\theta-1}}\left(\frac{H^*}{H}\right)^{\frac{\alpha\theta}{\theta-1}}\left(\frac{f_E^*}{f_E}\right)^{\frac{1}{\theta-1}}$, $\frac{w_h}{w_h^*} = \left(\frac{L}{L^*}\right)^{\frac{\theta(1-\alpha)}{\theta-1}}\left(\frac{H^*}{H}\right)^{\frac{\alpha\theta}{\theta-1}+1}\left(\frac{f_E^*}{f_E}\right)^{\frac{1}{\theta-1}}$. These factor endowments, entry costs are set up in a way that delivers the equilibrium wage values relationships that home's low skilled wage is higher than foreign's. It generates the result that when trade is allowed, we only see some of the Northern firms offshoring to the South and only offshoring low skilled tasks, with high-skilled tasks offshoring prohibited as a simplifying assumption. Factor endowments pin down wages through the factor market clearing conditions.

1.3.2 Open economy equilibrium: The impact of trade liberalization

In the open economy context, the final consumption good is non-tradable and the low-skilled tasks are tradable, namely, offshorable. Proofs for this section are included in the appendix.

With the possibility of offshoring, the first difference lies in Northern firms' production location decisions. Now firms need to compare, based off their productivity, whether in house production or offshoring is more profitable. To engage in offshoring, firms need to pay the fixed offshoring cost f_V in terms of the effective units of labor used for offshoring production, as well as the variable offshoring cost acted on the low-skilled task. Firms above the offshoring productivity cutoff would choose to offshore. Besides firms' production strategies and profits, what's also different now under open trade is that the labor market clearing conditions become different. Now, the market clearing condition for factors in both countries incorporates factors used by the firms producing domestically, as well as factors used for the sunk entry cost and fixed offshoring cost activities if there are any.

Opening up to trade has impacts on the economy in the following aspects: First, it increases the average profits $\tilde{d}_t$ for Northern firms. As some of the previously domestic producing firms turn into offshoring firms, we can see here now the average profits capture the fixed offshoring cost that these firms have paid, thus making the average profits now higher than the autarky value. It is easy to see that prohibitive costs of offshoring (when $f_V = \infty$, $z_o = \infty$ (no firm offshores)) lead to an equality between these two values. So this additional positive term reflects the offshoring cost related activities by the offshoring firms. These offshoring firms are firms with productivity higher than the cutoff; for these firms, offshoring gives them higher profits than producing domestically. What can also be noticed is that, since average profits is also equal to this positive term times the average value of firms, which is the fixed entry costs, as average profits go up, the marginal cost of producing domestically increases as well.

Secondly, opening up to trade-in-tasks increases the number of firms N in the North in equilibrium mainly by creating an increase in the number of offshoring firms N_V. What's more, just as mentioned, as firms accumulate profits, average firm value also goes up, allowing for more entry of firms. As a result, there is an increase in the total number of firms.

As for the wage ratio between low-skilled and high-skilled, it is lower under offshoring than in autarky. The simple expression of the ratio of factor endowments disappear because of the assymetry of offshorability of the two tasks. The effective labor used for offshoring is also different from the effective labor used for entry. The wage gap in the home country expands when offshoring is made possible, with the real wage for high-skilled getting higher and that for low-skilled getting lower. Since offshoring reduces the relative demand for each country's scarce factor, we expect a lower w_l and w_h^* when offshoring costs are not prohibitive. For the foreign country, because of the increase in foreign low-skilled labor cost due to the increasing demand by home country's offshoring firms, foreign firms are going to experience lowering of profits, fewer number of firms in equilibrium and lower w_h^* because of the reduction of demand by Southern firms.

1.3.3 The mechanisms of rising skill premium

The Heckscher-Ohlin mechanism

Just as what Heckscher-Ohlin model implies, reductions in trade costs shift factors of production towards a country's comparative advantage sectors and raise the relative return to the factor that is used intensively in these sectors. In this model specifically, international trade increases the skill premium in the country that is more skill abundant and decreases the that in the country that is more labor abundant. It also increases skill premium in sectors with comparative advantage in skill-intensive sectors (high α^j sectors) and decreases that elsewhere.

The production fragmentation mechanism

Only the low-skilled task is tradable, and the high-skilled task needs to be completed using domestic high-skilled labor as a complementary part of production.. Therefore, the more firms offshore the low-skilled task due to the reduction in the cost of offshoring, the higher the demand for high-skilled and the lower the demand for low-skilled at home.

The firm-level productivity channel

Looking at the relationship between firm-level labor demand and productivity, another useful result is that more productive firms hire more of both types of labor on average, as $\frac{\partial h(z)}{\partial z} > 0$ and $\frac{\partial l(z)}{\partial z} > 0$. The ratio of labor demand across firms with different production locations are: $\frac{\tilde{h_V}}{\tilde{h_D}} = (\frac{\tilde{z_D}}{\tilde{z_V}})^{1-\theta} \frac{\tau w_l^*}{w_l})^{(1-\alpha)(1-\theta)} > 1$ and $\frac{\tilde{l_V}}{\tilde{l_D}} = (\frac{\tilde{z_D}}{\tilde{z_V}})^{1-\theta} (\frac{\tau w_l^*}{w_l})^{\alpha(\theta-1)-\theta} \tau > 1$. This means that on average, offshoring firms hire more high-skilled and low-skilled labor than domestically producing firms do. What's more, offshoring firms are the ones that are more productive, and they hire more labor on average, exacerbating the negative effect on the low-skilled wage and the positive effect on the high-skilled wage.

The high-skilled to low-skilled ratio used is the same among the same type of firm: $\frac{h_D(z)}{l_D(z)} = \frac{w_l}{w_h} \frac{\alpha}{1-\alpha}$ for domestically producing firms, $\frac{h_V(z)}{l_V(z)} = \frac{w_l^*}{w_h} \frac{\alpha}{1-\alpha}$ for offshoring firms. What's more, comparing this ratio between domestically producing firms and offshoring firms, $\frac{h_v}{l_v} / \frac{h_D}{l_D} = \frac{w_l^*}{w_l} < 1$. So, not only do offshoring firms hire more domestic skilled labor and more foreign low-skilled labor, they also use higher ratio of low-skilled to high-skilled workers, exaggerating the fall in low-skilled wage.

In sum, in response to a trade cost decline, for the low-skilled, the extensive margin indicates that more firms offshore, reducing the demand for domestic low-skilled labor. The intensive margin indicates that offshoring firms are more productive firms that hire more domestic skilled labor and more foreign low-skilled labor. They also use higher ratio of low-skilled to high-skilled workers, exacerbating the fall in low-skilled wage. For the high-skilled, facing a decline in trade cost, total number of firms increase over time, increasing the demand for high-skilled labor.

1.4 Calibration

Firm's exit rate δ, is set equal to 0.025 which implies an annual rate of depreciation of 10 percent. Kydland and Prescott (1982) found this to be a good compromise given that different types of capital depreciate at different rates. The discount factor, β, is set equal to 0.99, which implies a steady state annual real rate of interest of 4%. The relative risk aversion coefficient is $\gamma = 2$. The intra-temporal elasticity of substitution is $\theta = 3.8$, as specified in Ghironi and Melitz (2005).

The other parameters are calibrated to match steady state of targets of wage ratios between skill groups in both U.S. and China, the cost ratio of low-skilled in the two countries, the fraction of offshoring firms out of the total number of firms in the U.S. in the period before China's entry into WTO. In the analysis of the dynamic adjustment of trade cost reduction, the tariff decline is calibrated into an AR (1) process and delivers quantitative results on how much of the decline of the low-skilled wage and the increase in the high-skilled wage in reality can be explained by the model.

The entry cost in the two countries are calibrated to match with the data from world bank that indicates the entry costs to be 1.1 times in the U.S. and 0.6 times in China in units of income. The Pareto distribution parameter k, iceberg trade cost τ, the fixed offshoring cost f_v are calibrated so that the model in steady state matches the wage ratios of high-skilled and low-skilled in the U.S. and in China (WIOD socio economic accounts data) as well as the proportion of offshoring firms over the total number of firms in the U.S. [7].

The sunk entry costs, along with the values for $k, \tau,\ f_v$, generate a steady state value for the terms of production that is far less than unity ($TOP = (\frac{w_l^*/Z_t^*}{w_l/Z_t})^{1-\alpha} = 48\%$). The steady-state wage of low-skilled labor in the South is 15% (compared to 8% in the WIOD data) of that in the North.

[7] BEA MNE activities data

1.5 Dynamic adjustments in response to trade liberalization and other shocks

I log-linearize the model around the steady state and compute impulse responses for key variables to different shocks in the home country.

1.5.1 Decline in iceberg trade costs

The tariff data is from WTO, covering China's MFN applied duty rates on an aggregation of products from 1996 to 2017. I construct the time series of the simple averages of tariffs using the tariff line averaging method and calibrate the persistence of an AR(1) model of applied MNF tariff to be 0.97 over the time period of the data. The average tariff drops from 23.66% collected from 6549 lines in 1996 to 9.64% collected from 8377 lines in 2017.

In response to a decline in trade cost, productivity cutoff is lowered. Offshoring firms' demand for foreign low-skilled tasks and domestic high-skilled tasks both increase, thus leading to an increase in domestic high-skilled wage and foreign low-skilled wage. Even though on impact, foreign low-skilled wage increases whereas domestic low-skilled wage declines, the wage relationship for low-skilled labor still falls under foreign lower than domestic. Therefore, there would still exhibit a continuous increase in the number of offshoring firms utilizing the increased but still lower foreign low-skilled cost.

In periods after the shock, notice that even though the offshoring cutoff z_o goes down continuously, w_l^* is kept at a rather constant level because the demand of foreign low-skilled by foreign firms decrease as N^* becomes lower. Home country's high-skilled wage rises continuously since the demand from N_D and N_V both increase continuously as N goes up every period. After a decline on impact, home country's low-skilled wage sees an increase along the transition path as the number of domestically producing firms rise up steadily following the increase in the total number of firms. As for the continuous decline in the offshoring cutoff in the periods after the shock, it is caused by the greater rise of w_l than w_l^*. In the new steady state, w_l decreases. Intuitively, for a given $z_o = z_o^{'}$, the relative demand for the abundant factor in the home country increases, as offshoring is now subject to a lower variable cost. Thus, a decrease in τ decreases w_l. As for the on impact levels of other variables, N declines on impact because the fall in N_D much outweighs the rise in N_V as soon as the trade cost shock occurs, with the level of N_D and N_V getting pinned down by the labor market clearing conditions. However, over time, with the accumulation of increased firm entry, there will be an increase in the number of domestically producing firms as well, driving up the total number of firms N and thus consumption.

For the foreign country, as shown in fig.1.4, consumption, average firm value, average firm profit and the number of entrants all go down.

The impact of decline in fixed offshoring cost has similar effect as decline in iceberg trade cost, and is shown in fig A.1 in the appendix.

different factor intensity across sectors

Although I do not explicitly model multiple sectors, this framework nevertheless highlights the micro-level characteristics of sectors (the production share of low-skilled task, the level of product differentiation, firm entry and exit rates, levels of sunk costs and trade costs) that would generate differences in persistence rates for cross-country sector-level price differentials.

In case of trade liberalization, the higher the share of low-skilled labor used in the production, the higher the wage inequality between high-skilled and low-skilled (skill premium) in the home country and lower for the foreign country. For the sectors that use skilled factor more intensively (reflected by the red line), the less negatively affected for these sectors' low-skilled workers following the trade cost decline since the total amount of work offshored to be produced by foreign low-skilled workers is lower compared to the case where low-skilled factor intensity is higher in the production.

However, the higher the factor intensity of the low-skilled used in production (shown by the blue line in fig 1.5), the lower the offshoring productivity cutoff, which increases profit opportunities in the domestic economy. Therefore, there will be larger increase in the number of offshoring firms as well as the number of entrants. As a result, the total number of firms experiences larger rise over time, so does the increase in consumption. Due to higher demand for labor to be used in production as more firms are operating in the domestic economy, high-skilled wage rises by more, contributing to a larger increase in wage gap under the case of higher low-skilled factor intensity.

Fixed extensive margin and fixed entry

This section closely examines the role of intensive margin and extensive margin in shaping the rising skill premium after trade liberalization. I also compare the baseline case with the fixed extensive margins case and the fixed entry case. In the fixed extensive margins case, both entry and the offshoring cutoff are fixed so that both total number of firms and the number of offshoring firms remain unchanged in the new steady state. In the fixed entry case, entry is fixed but the offshoring cutoff is able to vary in response to exogenous changes, meaning that even though the total number of firms is the same in the new steady state, the number of offshoring firms changes. As shown in fig 1.6, the blue line remains at zero for entry of firms but changes for the productivity cutoff.

Fixed extensive margins In order to hold the extensive margin fixed, both entry of firms and the offshoring cutoff need to be fixed. Holding the cutoff of offshoring fixed means that the fraction of offshoring firm remains constant over time. If the offshoring cutoff is fixed but entry is not, the number of offshoring firms still varies due to changes in the stock of firms.

To hold firm entry fixed, I follow Jaef and Lopez (2014) in assuming the sunk cost is convex in the deviations of firm entry from its steady-state level, as is also used by Zlate (2016): $f_{E,t} = f_E + \pi_f[exp(N_{E,t} - \bar{N_E}) - 1]$. Fixing the offshoring cutoff follows a similar assumption of the fixed offshoring cost: $f_{v,t} = f_v + \pi_f[exp(N_{v,t} - \bar{N_v}) - 1]$. π_f is set to be very large ($\pi_f = 1,000$). In this fashion, the entry cost and offshoring cost both become stochastic variables that change instantaneously every period with the number of new firms and the number of offshoring firms. More specifically, when entry rises above the steady state value, the entry cost rises immediately to offset the hike in entry. When entry falls below the steady state level, the entry cost decreases rapidly as well to compensate for such decline in the number of firms entered. The similar logic applies to the number of offshoring firms. As a result, both the number of new firms and the number of offshoring firms stay virtually constant.

Shutting down the extensive margin highlights the effect of intensive margin of firms on wages. Without the possibility of changes in the number of firms and the number of offshoring firms, lowering the trade cost affects the wages through the intensive margins. Under this scenario, following a decline in the trade cost, even though the increase in the number of offshoring firms is ruled out, those offshoring firms increase their production due to the fall of production cost associated with offshoring the low-skilled task. Accompanying the increase in demand for the foreign low-skilled task is the increase in that for the domestic high-skilled task to complete the production of the final good.

The difference in the red dashed line and the green line captures the importance of extensive margin of firms (both extensive margin of producing firms and offshoring firms). Both the intensive margin and the extensive margin play roles in shaping the rising skill premium after a trade cost reduction. The intensive margin plays a more important role at the beginning stage and the extensive margin becomes more and more important over time in shaping the wage gap between skilled and unskilled in both countries.

The difference in the red dashed line and the blue dashed line reflects the extensive margin of new firms, whereas the gap between the blue and the green line indicates the extensive margin of offshoring firms. Compared to the baseline model, shutting down firm entry makes domestic low-skilled wage even lower and persistently lower since the number of domestic producing firms still experiences decline rather than increase in the short to medium run.

Fixed entry Shutting down the entry of firms while keeping the cutoffs of offshoring variable delineates the role of extensive margin of producing firms. Adding in the extensive margin adjustment of producing firms (allowing for firm entry) increases home high-skilled wage, foreign high-skilled wage and decreases foreign low-skilled wage by more. However, surprisingly, just as mentioned above, allowing for firm entry dynamics would dampen the effect of the lowering of low-skilled wage following deeper trade liberalization. With the stock of firms remain constant throughout periods after the shock, the demand for low-skilled labor becomes even lower since the number of domestically producing firms shrink by more due to the lowering of the offshoring cutoff. Meanwhile, the total demand for high-skilled is also lower compared to the baseline model because the total number of firms, which is fixed even when there's a reduction in the trade cost, is lower than the case when firm entry is allowed to vary. With the same logic, for the foreign workers, allowing for the entry of firms increases the wage of foreign low-skilled workers by more and reduces that of foreign high-skilled workers by more.

Fixing home entry (under both fixed entry and fixed extensive margins case) implies that there is zero entry of home firms over time, the total number of firms decline on impact (after the trade cost shock) and then eventually increases until it reaches the before shock level. It still climb up to the original level of stock because even though entry is fixed, it is not zero– entry is always kept at the before shock level in every period. Therefore, the number of new firms is kept at a certain level, adding up to the stock of total firms. Following a decline in the trade cost, the number of total firms fall on impact because the fall in the number of domestic producing firms is larger than the increase in the number of offshoring firms. This indicates that the competition from the lower foreign low-skilled wage (the competition from the offshoring production strategy) due to the decline in trade cost has substantial negative impact on domestically producing firms N_D, pointing to a competition effect.

For the fixed extensive margin case (both entry of firms and the offshoring cutoffs are fixed), the number of offshoring firms N_V remains constant, and the fall in the total number of firms on impact exactly reflects the fall in N_D on impact. This reflects the logic that N_D adjusts to the shock first, and this affects N.

In sum, the intensive margin and the extensive margin are both active in shaping the rising (declining) skill premium in the home (foreign) country, with the latter being more and more important over time compared to the beginning stage. Allowing for entry of firms is beneficial to the low-skilled wage: w_l is higher under the baseline case than the fixed entry case because higher entry of firms leads to a larger increase of the number of domestically producing firms.

Destination country's labor abundance

U.S. firms' offshoring decisions are mainly motivated by the cost advantage of low skilled labor in a range of foreign countries with larger supply of low skilled labor and thus cheaper low-skilled cost. However, the sudden possibility of offshoring to a country with incomparably high supply of labor like China might lead to outcomes that are also incomparable with offshoring to countries that are moderately more labor abundant than the U.S. This section evaluates the role of factor proportions feature of the offshoring destination country by comparing the outcomes of offshoring to two countries that are both more labor abundant than the home country but with different levels of labor abundance. Assume H=1.05, L=1. For the foreign country A, H=1, L^*=2.4. For the other foreign country B, which is slightly more labor abundant than the home country but yet much less labor abundant than country A, H=1, L^*=1.6. Fig 1.7shows the comparison of impulse responses under these two scenarios.

In response to the declining trade costs, offshoring to the more labor abundant country A gives the home country higher high-skilled wage both on impact and along the transition dynamics than offshoring to country B mainly because of the higher rise in demand for the domestic high-skilled tasks complementary to that for the foreign low-skilled tasks due to country A's lower low-skilled wage than country B. It leads to a slightly larger reduction of low-skilled wages on impact but faster increase along the transitional path. What this indicates is that if the U.S. multinational firms have to offshore part of their production, namely, the low-skilled tasks to countries with relative labor abundance higher than U.S. to utilize the lower low-skilled cost, offshoring to the most labor abundant one actually generates the best effects on the domestic labor market in the sense that it leads to larger increase in high-skilled wages and faster catch up of low-skilled wages during the transition. Wage inequality becomes higher somewhere along the transitional path but mainly driven by the higher increase in high-skilled wages. For the foreign workers, wage for the low-skilled in country A falls below that for country B both on impact and along the transition since the foreign country A has larger labor supply to absorb the increase in home country's demand for the low-skilled labor abroad following the decline in trade costs.The difference in high-skilled wages between the two foreign countries tend to be very small.

Following a negative iceberg trade cost shock, the average domestically producing firms' increasing demand for low skilled labor is higher under offshoring to the more labor abundant country and the decrease in demand for high skilled labor is also smaller in this case. The magnitude of an average offshoring firm's decrease in demand for both low-skilled and high-skilled labor are lower under the case of offshoring to the country with larger labor supply. For the foreign country, the average firms' low-skilled demand are almost the same under two different offshoring locations; high-skilled demand decreases more on impact for foreign country B but catches up faster than foreign country A.

This suggests that offshoring to China compared to offshoring to other countries enlarges the wage gap between skilled and unskilled in the United States mainly through increasing the income of high-skilled labor without lowering the low-skilled wage by more than any offshoring destinations.

1.5.2 Productivity shock at the home country

In this section, I linearize the model around the steady state and compute impulse responses for key variables to a transitory one-percent increases in aggregate productivity in the North. Aggregate productivity follows the autoregressive process $logZ_{t+1} = \rho logZ_t + \xi_t$, with persistence $\rho = 1$.

As shown in fig 1.8, following a productivity shock, average price decreases on impact, which leads to a decline in the number of firms on impact. In the quarters after the shock, as aggregate productivity persist above its steady state, firm entry leads to a gradual increase in the stock of firms. Home country's wages both experience upward pressures due to higher demand of labor. The number of offshoring firms increases gradually in periods after the shock because of the same reasons as in Zlate (2016): First, the increase in the entry of Northern firms facilitates a portion of the new entrants that are above the productivity cutoff to produce offshore. Second, as the terms of production decreases on impact and persist lower than its steady state level, the productivity cutoff decreases after the period of impact, prompting more firms to offshore the low-skilled task. To be more specific about changes in the productivity cutoff of offshoring, looking at the expression of z_o in the appendix, apart from changes in wages, it is negatively affected by consumption, which decreases on impact, giving z_o an upward push.[8] Since N falls on impact, consumption at home also falls since consumers now are faced with a narrower variety of products produced by firms. But average firm profits increases on impact because now production now incorporates a higher aggregate productivity. Therefore, entry of firms rise on impact, taking expectation of future average firm profits, building on the stock of firms eventually. The demand for domestic low-skilled labor increase continuously, pushing up the low-skilled wage whereas the demand for domestic high-skilled labor decrease in net on impact since the decline by offshoring firms outweigh the increase by domestically producing firms. On the other hand, the foreign low-skilled demand increases on impact due to the larger increase in demand by foreign firms than the decline in demand by offshoring firms, and it continues to increase because of the rise in demand by offshoring firms in the periods after the shock.The foreign high-skilled demand increases on impact and then decreases to a lower level since the foreign number of firms see a gradual decline.

Similar to the implications in Zlate (2016), a positive productivity shock in the home country leads the productivity cutoff to decrease in transition, which implies that the number of offshoring firms increases over time. Also, the number of firms decline on impact. There is in this model a force that puts downward pressure on the number of firms on impact that's missing compared to Zlate (2016). In this model, the changes in average prices happen

[8]In this scenario where only production of the final good is subject to the aggregate productivity shock, the aggregate productivity of producing domestically and offshoring is the same. Therefore, a change in Z_t is exerted equally on these two strategies of production.

instantaneously in response to shocks, which then pins down the on impact levels of other macroeconomic variables (N, $\tilde{v}$, $\tilde{d}$). Then gradually, these variables adjust to the entry of firms (adjustment along the extensive margin) and in turn determine the changes and trends of wages.

1.5.3 Decline in entry cost at the home country

In response to a decline in home country's entry cost, the wage for both high-skilled and low-skilled reach a higher level in the new steady state, as pictured in fig. 1.9. A decline in the entry cost for firms in the home country is beneficial for both types of workers since it encourages more entry of firms which stimulates more hirings of both types of domestic workers. From the graphs, on impact, low-skilled wage increases and high-skilled wage decreases. Notice that the productivity cutoff first goes up and number of offshoring firms decrease on impact. On impact, fewer firms choose to offshore since home's environment becomes more attractive due to the lowering of the entry cost, exerting a downward pressure on the demand of foreign low-skilled and home high-skilled by offshoring firms. The trends of both low-skilled and high-skilled wage exhibit a continuous upward hike from the start, with the high-skilled wage persisting to stay at the peak level and the low-skilled wage start to slowly fall down little by little. The reason why the upward trend of wage for high-skilled workers will persist longer is because the high-skilled is demand by both home production and offshoring firms whereas the low-skilled is demanded only by firms producing domestically. Home country's wage gap between skilled and unskilled falls on impact and starts to go up right away until it reaches the new steady state which is higher than before shock. On impact, N decreases, N_D and N_V both decreases.

In the new steady state, there are more firms in the home country, with both N_D and N_V increase. The productivity cutoff is lowered. Home's low and high skilled wage, foreign low skilled wage higher; foreign high-skilled wage lower. Home consumption higher. The steady state level of N is pinned down by all variables, but after the shock happens, N is just reflected by N_E. The cutoff is higher on impact then going down to become lower than before shock.

Therefore, decreasing the entry cost can make remedies to the increasing skill premium caused by trade liberalization.

1.5.4 Positive productivity shock in the foreign country

The responses of variables in response to a positive productivity shock in the home country somewhat mirrors the labor market outcomes over the past for US: low-skilled wage experiences declines and high-skilled wage keeps hiking up. What this may not be matching with China's growth is that the foreign low-skilled wage in this setting decreases, whereas in reality it increased as well. Just like what many skepticism of HO theory suggest, unlike what the theory indicates, high skilled wage increases almost everywhere across the world. Fig. 1.10 plots the behaviors of key variables in response to a positive productivity shock in the foreign country. When the foreign country experiences productivity growth, just like what China has witnessed after its reforms, we do see home low-skilled wage going down, while foreign low-skilled, high-skilled and home high-skilled wage all going up. The mechanism is that foreign firms also become more profitable due to the productivity growth, creating more firms, increasing foreign consumption as well, pushing up the demand for foreign high-skilled labor as well as foreign firms' demand for low-skilled labor. Thus, we see an even higher increase in foreign high-skilled wage and a reduction in home low-skilled wage.

1.6 Conclusion

The paper examines the dynamic effects of offshoring to China on wage gap between skilled and unskilled workers in an environment of factor proportions and firm dynamics using a dynamic general equilibrium model. It finds that in the short run, offshoring widens wage inequality between skilled and unskilled workers through increasing high-skilled wage and lowering low-skilled wage. Such effect is more announced in the beginning phase of the adjustment, and slows down over time as low-skilled wage rises faster than the cool-down of high-skilled wage increase. The intensive margin and the extensive margin are both active in shaping rising wage gap in the home country, with the latter playing a more important role in the short to medium run compared to the beginning stage following the shock.

What's more, endogenous entry of firms is beneficial to domestic low-skilled wage as low-skilled wage is higher in the baseline model than the fixed entry scenario. This is because positive entry of firms in response to larger profitability due to lower trade costs eventually leads to a larger increase of the number of domestically producing firms, contributing to a rise in the total demand for low-skilled workers.

Comparing the baseline case with a scenario of offshoring to a country that is slightly less low-skilled labor abundant than China, the results also suggests that offshoring to China compared to offshoring to other countries enlarges the wage gap between skilled and unskilled in the United States mainly through increasing the income of high-skilled labor by more. Low-skilled workers are better off over time, but the positive effect on high-skilled wage much outweigh that on low-skilled wage.

The paper also examines policies associated with reforming the product market to alleviate the issue of expanding wage inequality during the adjustment after the trade shock. Product market reform such as decreasing the entry cost helps dampen the increase in skill premium following trade liberalization which affect firms' offshoring activities. For industries with higher low-skilled share used in production that face persistently larger wage inequality, they might need such market reform more to help low-skilled workers that are hit particularly hard by easier offshoring.

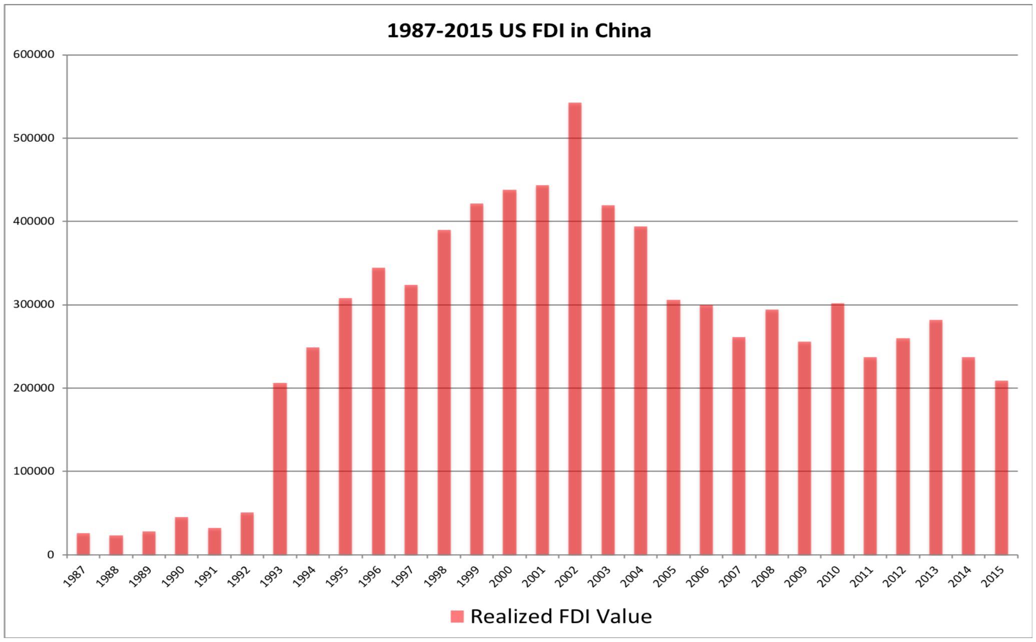


Figure 1.1: US Realized FDI values in China, 1987-2015

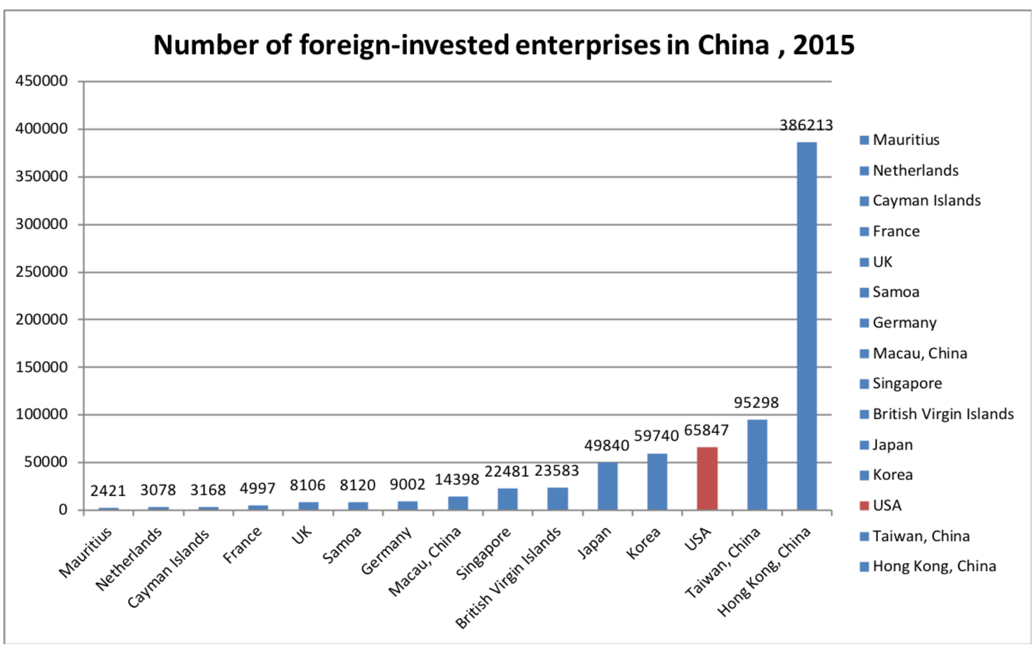


Figure 1.2: FDI in China by country, 2015

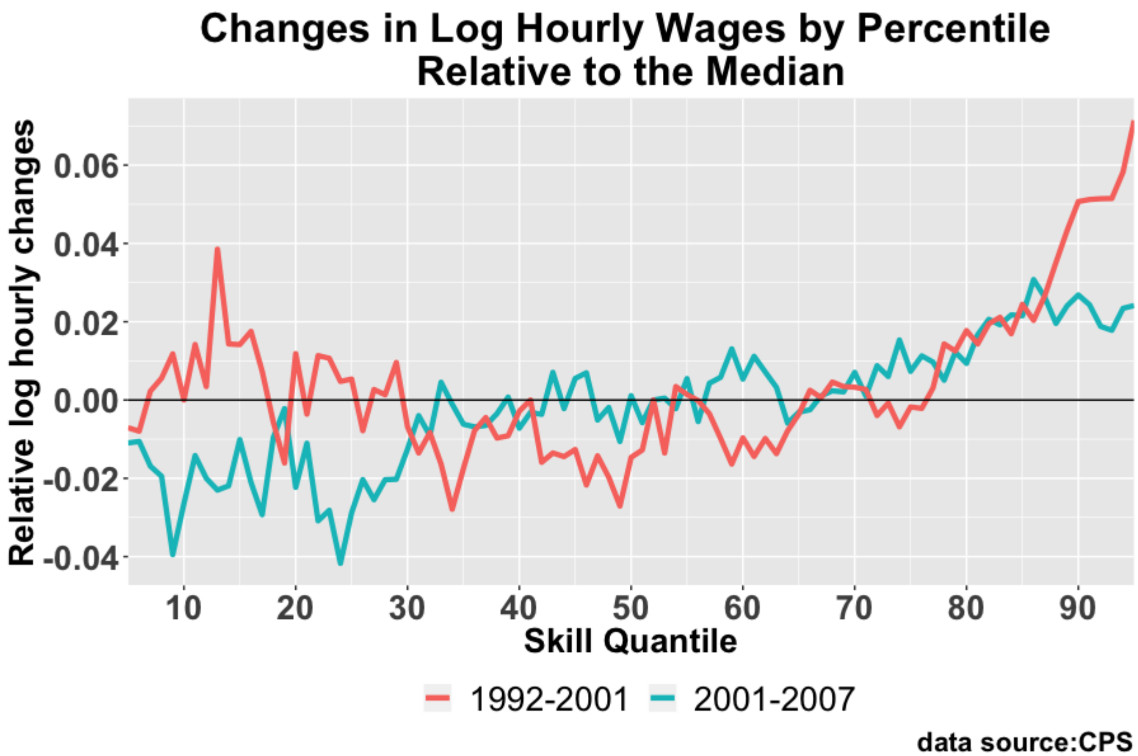


Figure 1.3: Changes in wage by percentile, 1992-2997

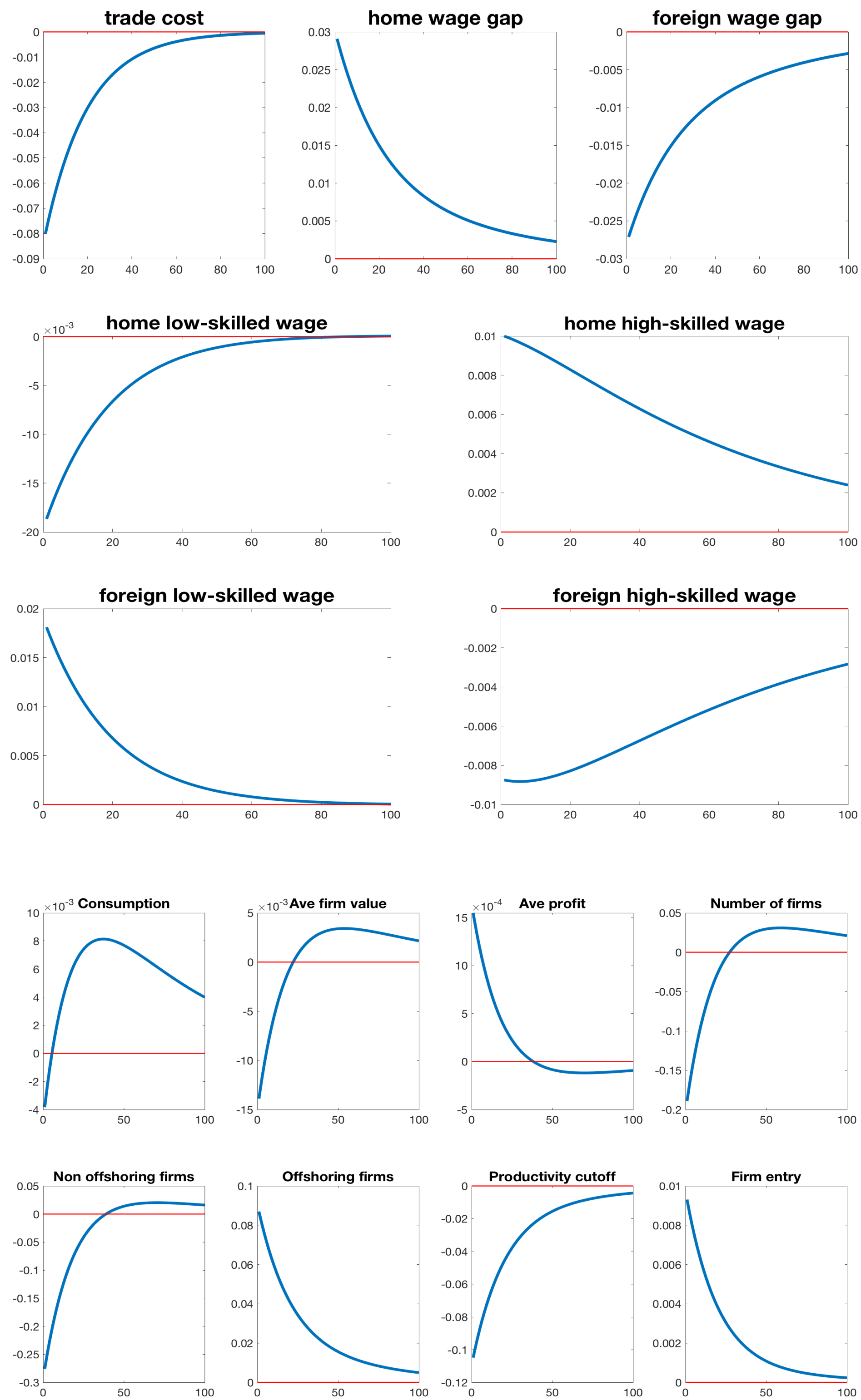


Figure 1.4: Impulse responses following a decline in trade cost τ.

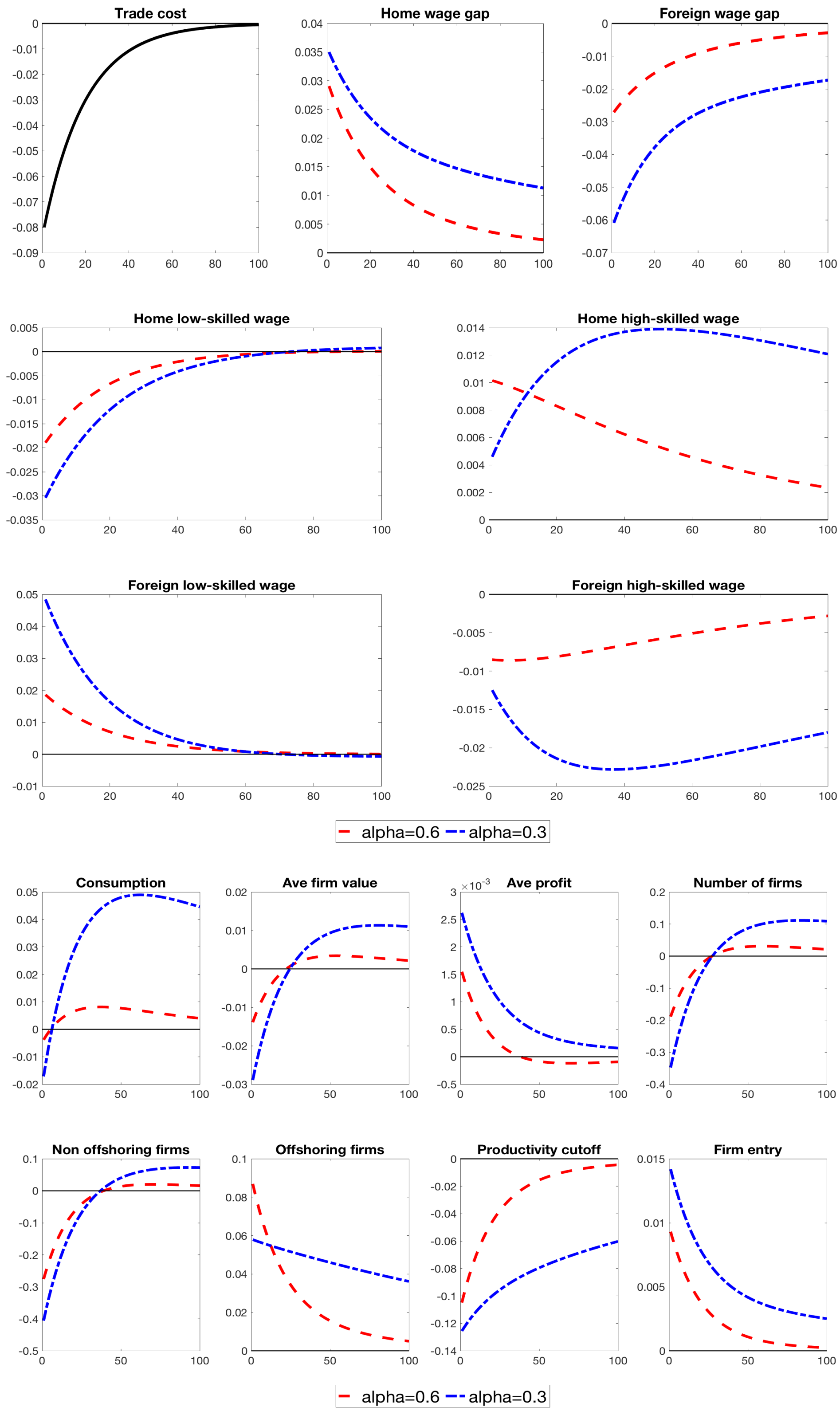


Figure 1.5: Impulse responses of variables under different cost shares of high-skilled labor following a trade cost reduction.

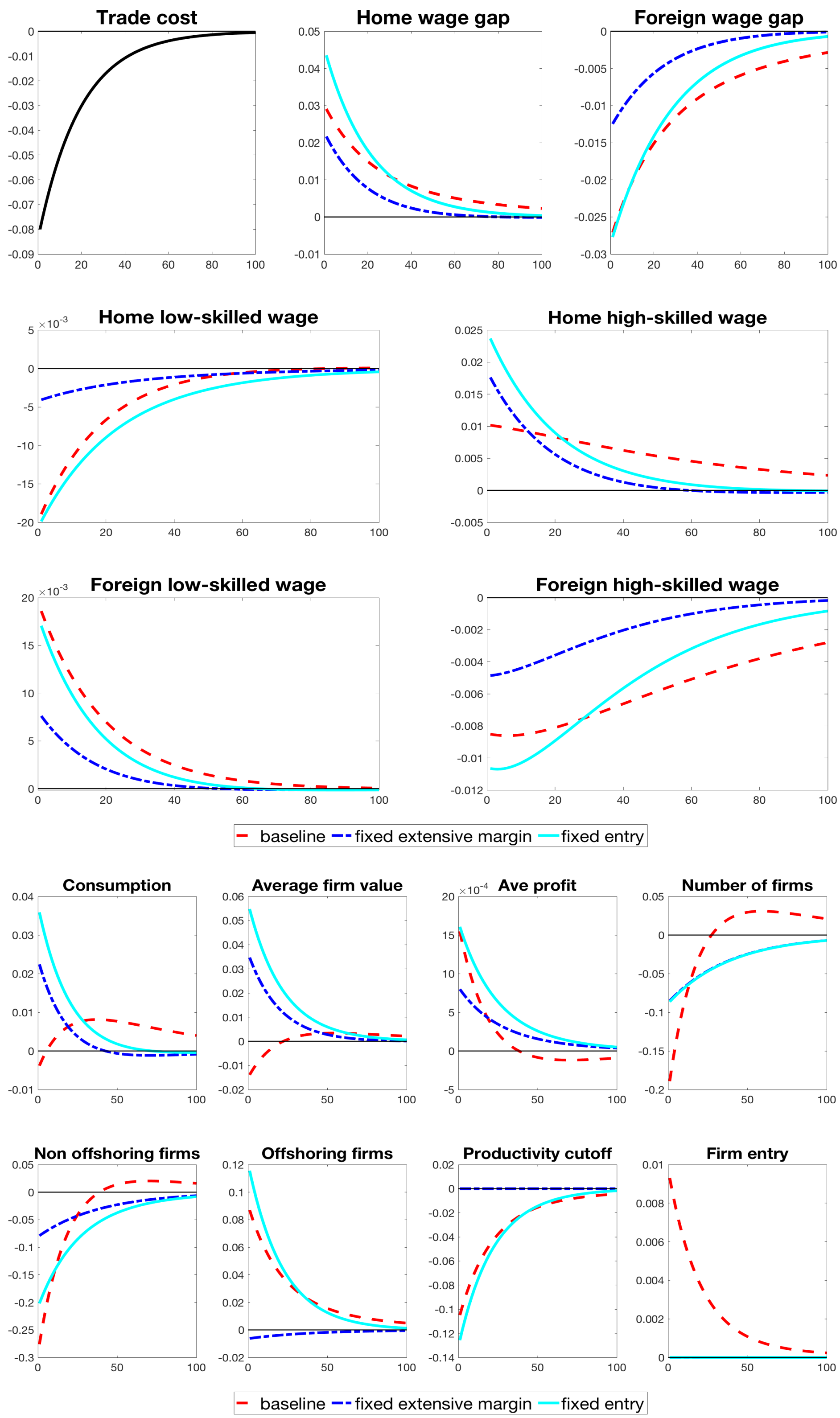


Figure 1.6: Baseline, the fixed extensive margin scenario and fixed entry scenario following trade cost reduction.

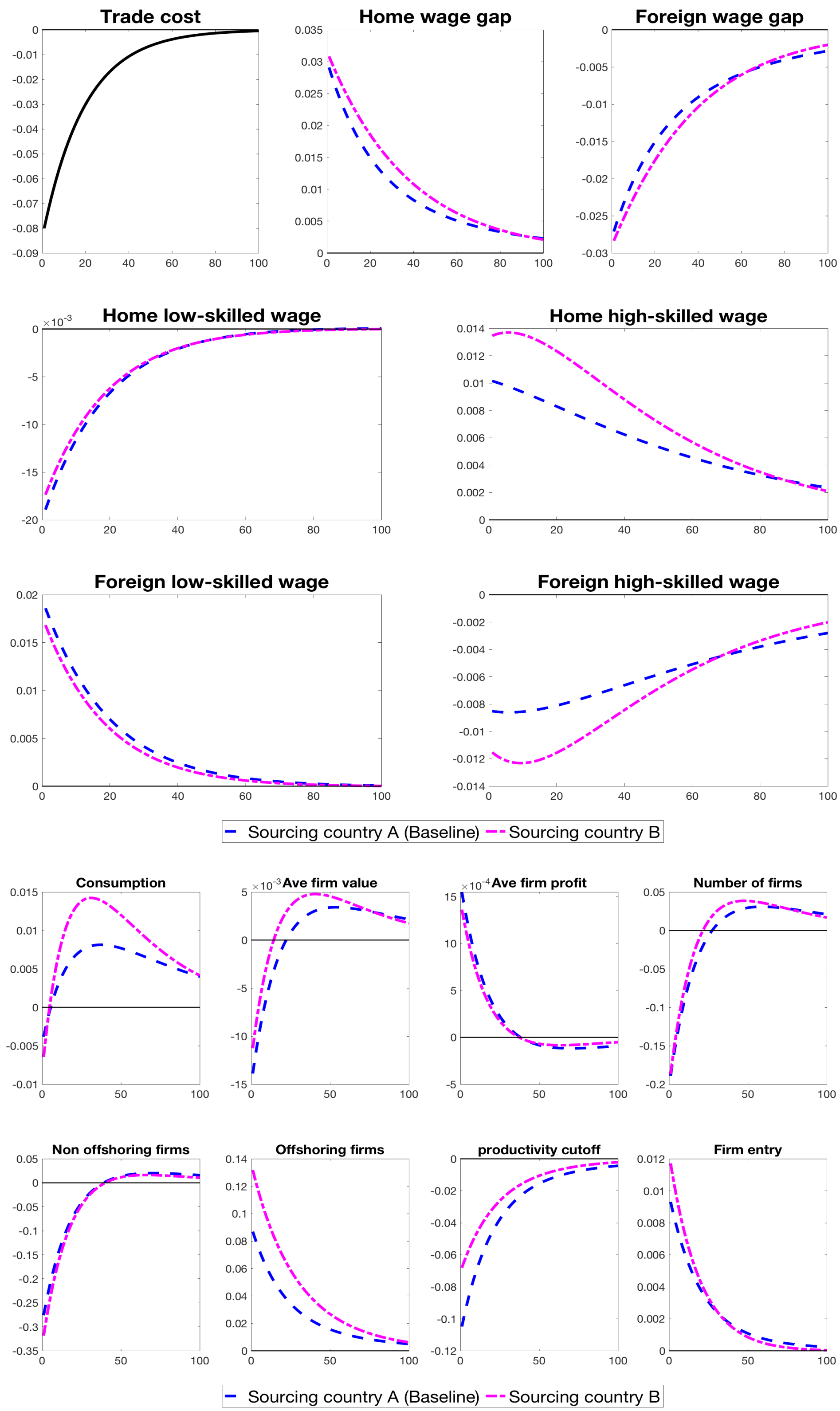


Figure 1.7: Baseline vs lower foreign low-skilled endowment following trade cost reduction

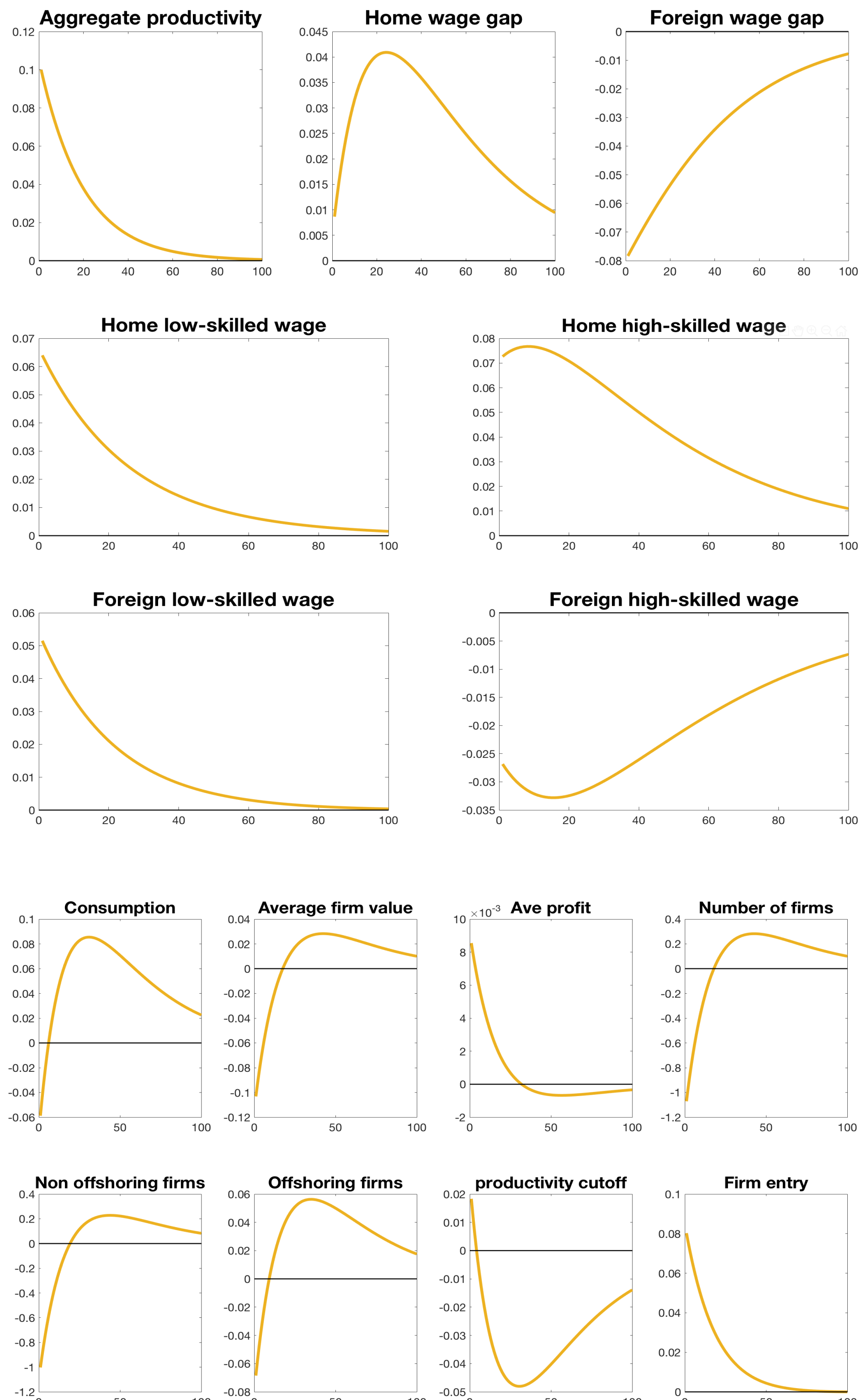


Figure 1.8: Impulse responses of variables following a positive productivity shock.

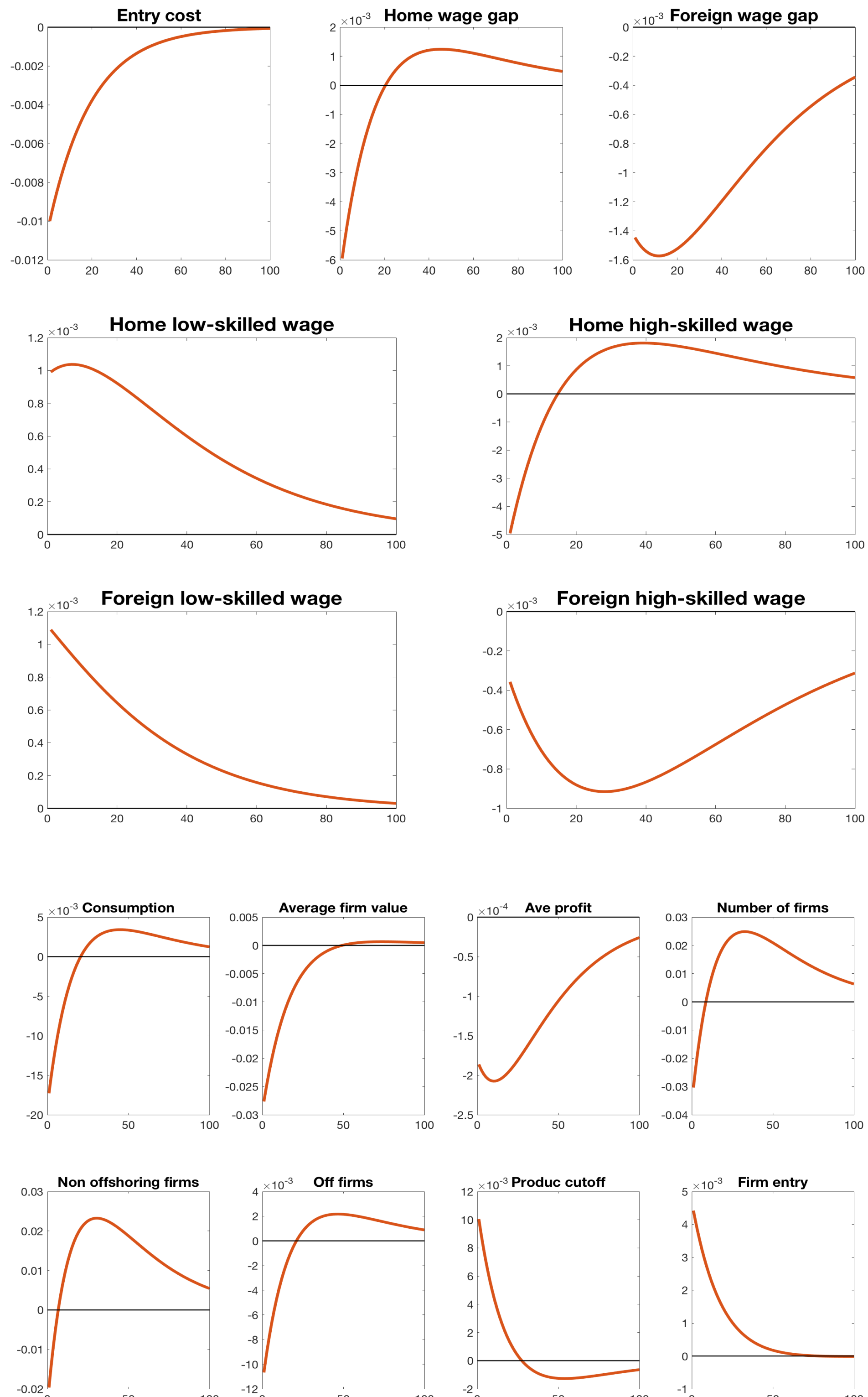


Figure 1.9: Impulse responses of variables following a reduction in entry cost.

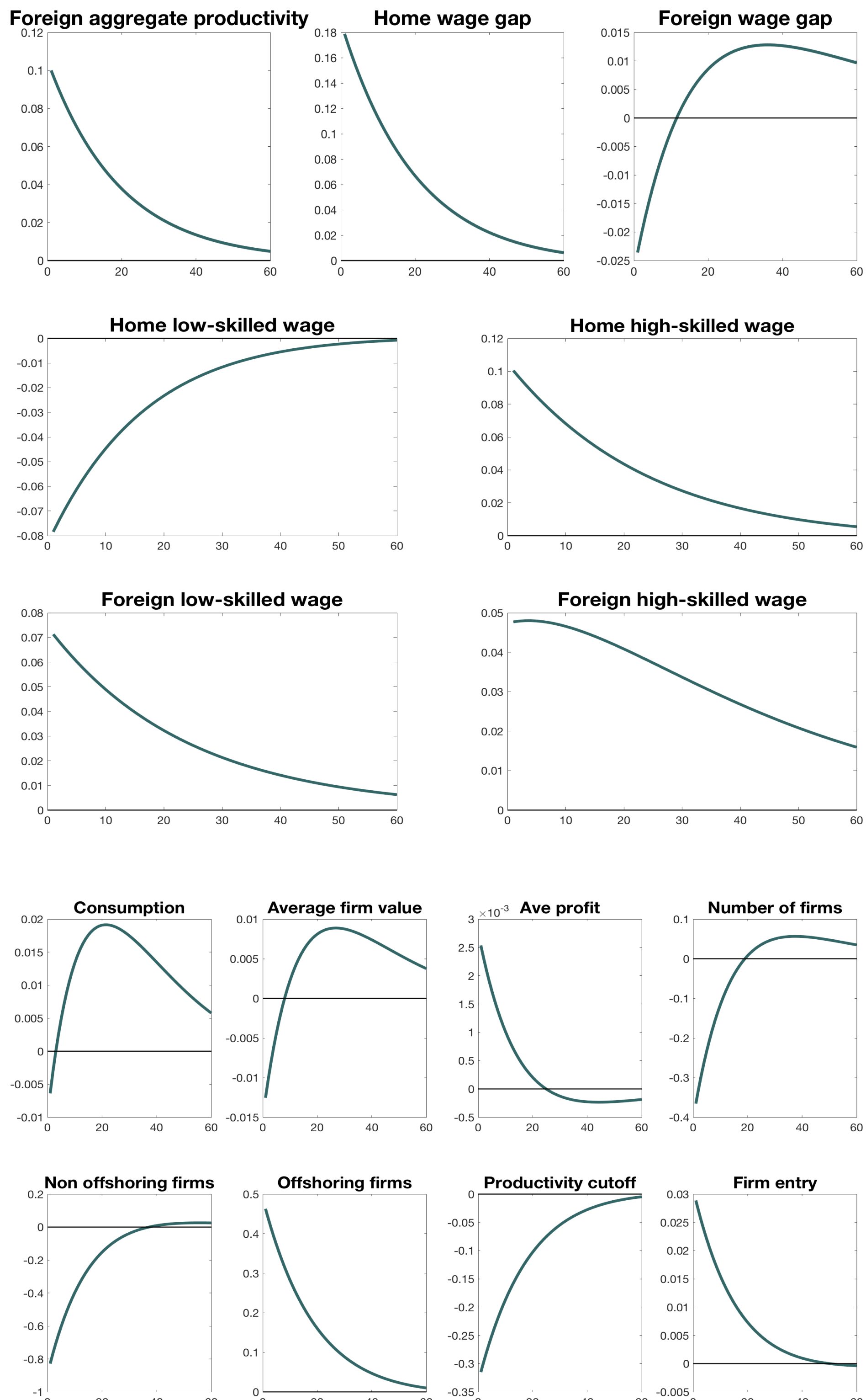


Figure 1.10: Impulse responses of key variables following a positive productivity shock in the foreign country.

Table 1.1: Model equations

Euler equation, bonds	$1+B_{N,t+1}=\beta\left(1+r_{t+1}\right)E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\right]$
	$1+B^*_{S,t+1}=\beta^*\left(1+r^*_{t+1}\right)E_t\left[\left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\gamma}\right]$
Euler equations, stocks	$\tilde{v}_t=\beta\left(1-\delta\right)E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\left(\tilde{d}_{t+1}+\tilde{v}_{t+1}\right)\right]$
	$\tilde{v}^*_t=\beta^*\left(1-\delta^*\right)E_t\left[\left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\gamma}\left(\tilde{d}^*_{t+1}+\tilde{v}^*_{t+1}\right)\right]$
Free entry	$\tilde{v}_t=f_e\left(\frac{w_l}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_h}{\alpha}\right)^{\alpha}$
	$\tilde{v}^*_t=f_e\left(\frac{w^*_l}{1-\alpha}\right)^{1-\alpha}\left(\frac{w^*_h}{\alpha}\right)^{\alpha}$
Law of motion, firms	$N_{t+1}=\left(1-\delta\right)\left(N_t+N_{E,t}\right)$
	$N^*_{t+1}=\left(1-\delta^*\right)\left(N^*_t+N^*_{E,t}\right)$
Price index	$1=N_{D,t}\left(\tilde{\rho}_{D,t}\right)^{1-\theta}+N_{V,t}\left(\tilde{\rho}_{V,t}\right)^{1-\theta}$
	$1=N^*_{D,t}\left(\tilde{\rho}^*_{D,t}\right)^{1-\theta}$
Aggregate accounting	$C_t+N_{E,t}\tilde{v}_t+B_{N,t+1}=w_{l,t}L_t+w_{h,t}H_t+N_t\tilde{d}_t+\left(1+r_t\right)B_{N,t}+T$
Total profits	$N_td_t=N_{D,t}d_{D,t}+N_{V,t}d_{V,t}$
	$N^*_td^*_t=N^*_{D,t}d^*_{D,t}$
Number of firms	$N_t=N_{D,t}+N_{V,t}$
Offshoring profit links	$\tilde{d}_{v,t}=\frac{z^k_{o,t}-1}{z^{k-\theta+1}_{v,t}-1}\tilde{d}_{D,t}+\frac{\theta-1}{k-\theta+1}f_v\left(\frac{w^*_{l,t}}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_{h,t}}{\alpha}\right)^{\alpha}$
Average productivity	$\tilde{z}_{D,t}=\left(\frac{k}{k-\theta+1}\right)^{\frac{1}{\theta-1}}z_{min}z_{o,t}\left[\frac{z^{k-\theta+1}_{o,t}-z^{k-\theta+1}_{min}}{z^k_{o,t}-z^k_{min}}\right]^{\frac{1}{\theta-1}}$
	$\tilde{z}_{V,t}=\left(\frac{k}{k-\theta+1}\right)^{\frac{1}{\theta-1}}z_{o,t}$
	$\tilde{z}^*_{D,t}=\left(\frac{k}{k-\theta+1}\right)^{\frac{1}{\theta-1}}z_{min}$

Table 1: Model equations, continued

High-skilled demand	$\tilde{h}_{D,t} = \frac{1}{Z_t \tilde{z}_{D,t}} \left(\frac{\alpha}{1-\alpha} \frac{w_{l,t}}{w_{h,t}})^{1-\alpha} \right) \rho_{\tilde{D},t}^{-\theta} C_t$
	$\tilde{h}_{V,t} = \frac{1}{Z_t z_{\tilde{V},t}} \left(\frac{\alpha}{1-\alpha} \frac{\tau w^*_{l,t}}{w_{h,t}})^{1-\alpha} \right) \rho_{\tilde{V},t}^{-\theta} C_t$
	$\tilde{h}^*_t = \frac{1}{Z^*_t z^*_{\tilde{D},t}} \left(\frac{\alpha}{1-\alpha} \frac{w^*_l}{w^*_h})^{1-\alpha} \right) \rho^*_{\tilde{D},t}{}^{-\theta} C^*_t$
Low-skilled demand	$\tilde{l}_{D,t} = \frac{1}{Z_t z_{\tilde{D},t}} \left(\frac{1-\alpha}{\alpha} \frac{w_{h,t}}{w_{l,t}} \right)^{\alpha} \rho_{\tilde{D},t}^{-\theta} C_t$
	$\tilde{l}_{V,t} = \frac{1}{Z_t z_{\tilde{V},t}} \left(\frac{1-\alpha}{\alpha} \frac{w_{h,t}}{w^*_{l,t}} \right)^{\alpha} \rho_{\tilde{V},t}^{-\theta} C_t \tau^{1-\alpha}$
	$\tilde{l}^*_t = \frac{1}{Z^*_t z^*_{\tilde{D},t}} \left(\frac{1-\alpha}{\alpha} \frac{w^*_{h,t}}{w^*_{l,t}} \right)^{\alpha} \rho^*_{\tilde{D},t}{}^{-\theta} C^*_t$
Labor market clearing	$H = N_{D,t}\tilde{h}_{D,t} + N_{V,t}\tilde{h}_{V,t} + N_{E,t} f_E \left(\frac{\alpha w_{l,t}}{(1-\alpha) w_{h,t}} \right)^{1-\alpha} + N_{V,t} f_V \left(\frac{\alpha w^*_{l,t}}{(1-\alpha) w_{h,t}} \right)^{1-\alpha}$
	$L = N_{D,t}\tilde{l}_{D,t} + N_{E,t} f_E \left(\frac{(1-\alpha) w_{h,t}}{\alpha w_{l,t}} \right)^{\alpha}$
	$H^* = N^*_t \tilde{h}^*_t + N^*_{E,t} f^*_e \left(\frac{\alpha w^*_{l,t}}{(1-\alpha) w^*_{h,t}} \right)^{1-\alpha}$
	$L^* = N^*_t \tilde{h}^*_t + N_{V,t}\tilde{l}_{V,t} + N^*_{E,t} f^*_e \left(\frac{\alpha w^*_{l,t}}{(1-\alpha) w^*_{h,t}} \right)^{-\alpha} + N_{V,t} f_v \left(\frac{\alpha w^*_{l,t}}{(1-\alpha) w_{h,t}} \right)^{-\alpha}$

Table 1.2: Some calibration parameters

	Parameter	Value	Source:
Risk aversion	γ	2	Literature
Discount factor	β	0.99	Literature
Shape parameter	κ	4.19	Literature
Firm exit rate	δ	0.025	Literature
Variety elasticity of substitution	θ	3.8	Literature
Entry cost ratio	$\frac{f_e}{f_e^*}$	0.5	Data
Factor proportion	$\frac{H}{L}$	0.44	Data
Low-skilled labor ratio	$\frac{L^*}{L}$	8.16	Data

Other calibration parameters and steady-state targets

Calibration parameters:		Steady-state targets:	Data	Model
Production share	$\alpha = 0.6$	$\frac{w_h}{w_l}$	2.12%	2.49%
Iceberg trade cost	$\tau = 1.7$	$\frac{w_l^*}{w_l}$	8.1%	14.9%
Fixed off. cost	$f_v = 0.44$	$\frac{N_v}{N}$	1.8%	1.8%

Chapter 2

OFFSHORING, FIRM-LEVEL ADJUSTMENT AND LABOR MARKET OUTCOMES

2.1 Introduction

How does offshoring to China affect unemployment rates and wage inequality across high-skilled (college) and low-skilled (non-college) U.S. workers? The literature has provided a mixture of conclusions about the labor market effects of offshoring, with some conclusions contradicting others.[1] There is no consensus on the sign of offshoring effects, not to mention their magnitude. However, most of the previous empirical and quantitative studies of the impact of offshoring on the labor market are based on the predictions of steady state trade models, in which the aggregate variables remain constant over time. Even though it has been widely acknowledged that frictions interfered with the dynamic adjustment of the labor market in response to the China shock, there is no existing dynamic analysis of this problem in the literature.[2] This paper develops a two-country dynamic general equilibrium model with cross-country differences in factor endowments, heterogeneous firms, search and matching frictions, and endogenous firm entry. The model is used to study the adjustments of wage inequality and unemployment rates of high-skilled and low-skilled workers after trade liberalization that allows for easier offshoring to a low-wage country like China. A VAR analysis is also performed to validate the model results.

Why are the domestic labor market effects of offshoring important? Offshoring through

[1]Recent empirical work testing the implications of existing theories with respect to the wage and employment effects of offshoring includes Crino (2010); Hummels et al. (2014); Harrison and McMillan (2011);Wright (2014) and Kovak et al. (2017). The results are discussed more in details in the next section.

[2]The China shock is commonly referred to as increasing import competition from China since the 1990s.

vertical FDI refers to the relocation abroad of a part of a firm's production process to benefit from lower production costs, either within the firm's boundary or through arm's length trade.[3] When part of the production of multinational firms move to foreign countries, the fear at home is that jobs will be lost, wages will fall, for workers in industries and tasks that are subject to offshoring. These labor market effects make offshoring a salient public policy issue. Over the past few decades, the increasing capacity and popularity of low-wage countries like China, India and Mexico as offshoring destinations have exacerbated such fears in developed countries. While more and more labor-intensive tasks are offshored to countries with large low-skilled labor supplies and lower low-skilled labor costs, the low-skilled blue-collar workers in developed-country manufacturing have suffered from such competition. Thus, a growing population of voters have begun to associate offshoring with the disappearance of domestic jobs. However, before painting offshoring as the main source of job losses, we need to understand its short- and long-run labor market effect and not just the immediate job-relocation effect.

In the literature, the rise of China has generated a wave of China shock studies recently, as the shock has provided a rare opportunity for studying the impact of a large trade shock on labor markets in developed economies.[4] However, these studies do not take into account the dynamic adjustment aspect of the shock. Why should we examine the China shock using a dynamic framework? First, while empirical work studying the China shock, like that of Autor et al. (2016), points to the role of labor market frictions in slowing down labor market

[3]As opposed to offshoring through horizontal FDI, under which firms relocate production abroad to save on transport cost for supplying the local market, the type of offshoring that I study is vertical FDI, which is motivated by cross-country differences in the cost of effective labor as a motive for the foreign location of some stages of production, producing goods that are then shipped back to the country of origin.

[4]Most of these empirical works point to the negative impact of surging imports from China on the labor market. For instance, Autor et al. (2016) suggest that import competition from China catalyzes a significant fall in manufacturing wage and employment decline; Pierce and Schott (2016) identify trade with China as an important driver of wage inequality in developed countries; Asquith et al. (2019) focus on the job loss from the death of establishments affected by the China shock. On the contrary, the positive effect of the China shock has received much less attention. Using a multi-country sourcing model, Antras et al. (2017) show that a 10 point increase in the growth rate of Chinese imports is associated with a one point increase in the firm's U.S. employment.

adjustment, theoretical models neglect these frictions in the context of the China shock. Second, trade models typically treat firms' decisions as static, while in reality firms' offshoring decisions are dynamic and forward looking. A shock does not only affect firms' period profit. Rather, it changes the whole stream of expected profits from the production strategies of a firm. Such forward-looking offshoring decisions turn out to be very important in modeling the China shock and labor market adjustment dynamics, because the shock interacts with labor market conditions intertemporally, generating dynamic effects. In particular, the relative importance of the extensive and intensive margins of firms' decisions varies over time following the shock. So, a model that incorporates these dynamic aspects of labor market adjustments is needed.

A comprehensive study of the effects of offshoring to China on wage inequality and unemployment should, in my view, contain the following features: i) adjustment dynamics, as changes do not happen over night and short-run costs have been found to be sizable; ii) search and matching labor market frictions, because these frictions are important in shaping employment and wage dynamics at different time horizons; iii) trade-in-task elements that incorporate the link between the offshorability of tasks and skills; iv) factor proportion differences in the context of offshoring to more low-skilled labor abundant countries; v) firm heterogeneity, endogenous firm entry and selection into offshoring markets, because these features of firms dynamics have been shown to be important ingredients of offshoring empirically.

Taking account each of these aspects, this paper reexamines the labor market effects of the China shock from a dynamic perspective by providing a DSGE model that embeds the search and matching friction into a two country trade-in-task environment featuring firm heterogeneity, endogenous selection into entry and offshoring of the low-skilled task by firms in the skill abundant country.

In the model, there are two countries (home and foreign) that differ in their relative factor abundance. The home country is relatively more skill abundant than the foreign country.

Production of the final good requires combining low-skilled and high-skilled tasks.[5] For the home country, the low-skilled task is offshorable, which is in line with the assumptions in other studies of task offshoring to low-wage countries.[6]

Firms are final good producers with heterogeneous productivity in assembling the two tasks. More productive firms self-select into offshoring. This microeconomic structure endogenously determines the extent of offshoring and the composition of consumption baskets in both countries. There are two types of workers, the high-skilled and the low-skilled, that search for jobs in each of their own market.

Importantly, the model features endogenous firm entry. Forward-looking firms formulate entry and offshoring decisions based on their expectations of future market conditions. Exogenous shocks to trade costs, labor market regulation, aggregate productivity, or entry induce firms to shift the location of their low-skilled tasks, thus altering the composition of consumption baskets across countries over time. Firm entry is crucial in contributing to the size distribution of offshoring firms and thus relative factor price movements, which generates an additional margin that affects the labor market.

The predictions of the model match the robust empirical evidence: the negative impact of offshoring on the domestic low-skilled workers is actually very short-lived -- there is an increase in low-skilled unemployment and a decrease in low-skilled wage and then quickly moves the opposite way. On the contrary, the decrease in high-skilled unemployment and the increase in their wage are quite persistent. Fig.2.1 shows a comparison between VAR results and the model's responses.

---

[5]One can also think of these two tasks as two production stages in Feenstra and Hanson (1996). Alternatively, they can be also interpreted as two inputs -- headquarter services and manufacturing in a benchmark vertical FDI model shown in Antras and Helpman (2004) and Antràs and Yeaple (2014).

[6]This pattern of production is supported by an unskilled-labor wage which is strictly higher at Home ($w_l > w_l^*$) and a skilled-labor wage being strictly higher in Foreign ($w_h < w_h^*$).

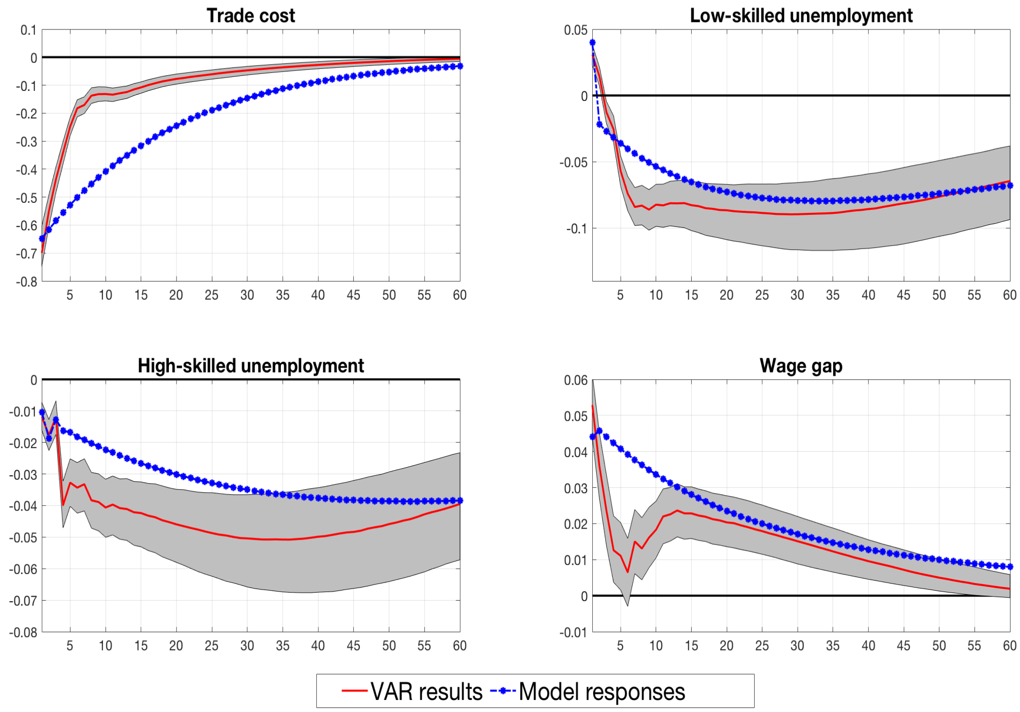


Figure 2.1: VAR results and model responses

The mechanisms driving the short run rise of low-skilled unemployment and wage inequality reflect a combination of forces in the literatures of Heckscher-Ohlin factor proportions, firm heterogeneity and task offshoring. First, reductions in trade costs reward a country's abundant factor and raise the skill premium in the country that is more skill abundant, which is the standard Stolper–Samuelson channel. This mechanism drives up labor demand for high-skilled labor in the home country and the demand of low-skilled labor in the foreign country. Second, the more firms offshore the low-skilled task, due to the reduction in the cost of offshoring, the higher the skill premium and unemployment divergence in the home country. This extensive-margin channel is due to the necessity of the high-skilled task to be completed domestically. I refer to this extensive margin channel as the *product fragmentation* channel. Third, a productivity mechanism works at the intensive margin: Offshoring firms are more productive and hire more labor on average, both low-skilled and high-skilled.

Furthermore, they use a higher ratio of low-skilled to high-skilled than non-offshoring firms, exacerbating the drop in low-skilled wage and employment. The picture for high-skilled workers is the opposite. The latter two channels are both about firms' offshoring decision, one along the extensive margin and the other along the intensive margin.

However, why do we still see rising wage and declining unemployment rate for the low-skilled group? Driving the positive effects on the low-skilled over time are the endogenous entry effect and the search and matching friction effect. Entry increases firm offshoring in the beginning stage as the goods market become more competitive, driving up wages. However, with endogenous entry generated by the increase in the average value of firms due to larger average profitability of firms, the number of domestically producing firms also rises by more over time, thus benefiting low-skilled workers.[7] As an example, when Apple becomes more profitable by offshoring more labor-intensive tasks to China, it is able to invest more in R&D and open more product lines in the United States. Therefore, a good way to understand this entry effect is that following the trade cost reduction, as firms become more profitable on average, more product lines become available in the home economy. Labor market search and matching friction dampen the magnitude of changes in the labor market over time by dampening changes in firms' offshoring and hiring decisions, both along the extensive and the intensive margins. With the labor market for the low-skilled becoming looser because of the expanding pool of unemployed workers separated from firms that switched to offshoring (extensive margin), the remaining non-offshoring firms are able to match with more low-skilled workers. Also, with the incorporation of the search and matching frictions, firms make their offshoring decisions more cautiously compared to the model without such frictions. Therefore, there is a lower number of offshoring firms in the search and matching scenario. Furthermore, there is more entry when search and matching friction is present. These effects combined lead to a better outcome for the low-skilled.

---

[7] Following the language convention of most of the macroeconomic literature, I assume coincidence between a producer, a product and a firm. However, as in Ghironi and Melitz (2005), each unit in the model is best interpreted as a production line that could be part of a multi-product firm whose boundary is left undetermined.

My work contributes to the literature studying labor market adjustments to the China shock. I emphasize the interaction between firm dynamics and labor market search and matching frictions in propagating the shock on wages and unemployment rates for workers with different skill levels in a DSGE framework.

My work also contributes to a large literature that extends traditional theories of international trade, such as the Heckscher-Ohlin models, to analyze dynamic adjustment after trade liberalization. With the presence of labor market search and matching frictions in the model, this paper provides a dynamic view of how high-skilled and low-skilled workers respond to a trade cost reduction in the presence of offshoring, when the speed of adjustment dynamics is affected by frictions in the labor market. The dynamic approach allows me to tease out the changes in the margins at play at different time horizon, and thus my work provides new insights into the dynamic mechanisms that shape labor market outcomes for different skill groups of workers.

My work also contributes to the literature studying the labor market outcomes of the China shock by broadening the traditional focus exclusively on manufacturing to explore the impact of offshoring on the high-skilled and low-skilled workers in all sectors. A more detailed discussion of related literature is provided in Section 2.

The rest of the paper is structured as follows. Section 2 provides a brief overview over the other related literature. Section 3 shows the empirical evidence. Section 4 describes the theoretical model. Section 5 describes calibration and impulse responses of the model. In section 6, I describe steady state results, long run implications and some robustness checks. Section 7 concludes.

2.2 Related Literature

My work relates to the recent studies of the China shock. Autor et al. (2013) find that workers employed in sectors that are exposed to competition from Chinese imports suffer lower wages and lower employment. Autor et al. (2016) point out the slow adjustment in local labor markets, with wages and labor-force participation rates remaining depressed and unemployment rates remaining elevated for at least a decade after the start of the China trade shock. Pierce and Schott (2016) link the sharp drop in US manufacturing employment after 2000s to increasing Chinese imports. Asquith et al. (2019) show that U.S. net job destruction due to the China shock is mainly driven by an increase in the rate of job destruction caused by deaths of establishments. Cabral et al. (2018) show that the negative employment effect of the China shock is mainly generated by the loss of export opportunities or volumes to other foreign markets due to the competition from China's exports to those foreign markets. While these literature focus on the negative impacts of the China shock, Feenstra et al. (2019) point to the positive effect generated by US exports on employment by looking at both manufacturing sector and the service sector. They find a substantial net job gain in the service sector large enough to offset the net job losses in the manufacturing and natural resources sector. Most of the studies of the China shock are under the context of import competition, however, with the exception of Antras et al. (2017), which includes a discussion of the employment effect of the China shock under the context of offshoring opportunities. They show that a 10 point increase in the growth rate of Chinese imports is associated with a one point increase in the firm's U.S. employment. In a similar attempt as Antras et al. (2017), my paper also examines labor market outcomes of the China shock under the offshoring context. However, none of the above papers look at the dynamic changes of the labor market variables following the China shock. Thus, my work contributes to this strand of literature by providing a model to examine the dynamic adjustment of the China shock under the offshoring context. It also extends the view focused exclusively on manufacturing sector to explore the impact of offshoring on workers with different skills in all sectors.

The offshoring structure in the model of this paper is related to the trade-in-tasks structure of the model of Grossman and Rossi-Hansberg (2008).[8] In their model there exist com-

[8]Other foundational task trading framework literature include Feenstra and Hanson (1999), Acemoglu (2003), Acemoglu and Autor (2011), and Feenstra and Hanson (1999). In Feenstra and Hanson (1999), firms offshore some of their labor-intensive activities following liberalization of capital markets, thereby reducing the demand for high-skilled labor in the U.S. I extend their framework by introducing firm-level heterogeneity and examine the implications of within-sector productivity channel.

plementarities between domestically performed and offshored tasks whereas in my model the two tasks are imperfect substitutes under the Cobb-Douglass specification of production function so that the demand for domestic low-skilled labor declines in response to trade liberalization to reflect the reality of rising skill premium. Also, Grossman and Rossi-Hansberg (2008) do not have labor market frictions, and they do not consider firm heterogeneity. Bernard et al. (2007) study the implications of final-good trade liberalization for gross job flows in their Heckscher–Ohlin model with Melitz-type firm heterogeneity. Featuring both skill abundance differences across countries and firm heterogeneity, Burstein and Vogel (2017) adds in skill intensity differences across firms and sectors to examine the consequences of trade liberalization on skill premium. However, neither do these two papers feature any labor market frictions nor do they study the impact of offshoring. More importantly, these models do not study the dynamic adjustments following trade liberalization.

The trade-in-task framework in my model embeds multinational firms' production segmentation element into Melitz (2003). While only the most productive firms trade internationally in the Melitz model, my model demonstrates that more productive firms self select into offshoring and their production structure determines that they demand domestic high-skilled workers and foreign low-skilled workers. The macroeconomics setup in my model is built upon Ghironi and Melitz (2005), which appends the Melitz setup with a dynamic stochastic international business cycle framework. Several extensions of this last model also are related to this paper: Lechthaler and Mileva (2014b) introduce Heckscher-Ohlin comparative advantage and labor adjustment costs, Cacciatore (2014) adds DMP labor market frictions, Mandelman (2016) allows for skill heterogeneity and occupational choice, Zlate (2016) incorporates offshoring through vertical foreign direct investment, and Mandelman and Zlate (2016) integrates both offshoring and immigration. None of these models, allow for both skill heterogeneity and search and matching frictions to study unemployment rates for two skill groups of workers and skill premium. Among these papers, my model is most closely related to Lechthaler and Mileva (2014b) and Mandelman and Zlate (2016). The first one develops a dynamic version of Bernard et al. (2007) along the line of Ghironi and Melitz (2005) and adds low-skilled workers training to become high-skilled workers and labor adjustment costs across sectors to study the effect of trade liberalization on wage inequality. In a similar vein, I add search and match frictions into a dynamic general equilibrium model with factor proportions and examine both wage inequality and unemployment rates. While Mandelman and Zlate (2016) examine the joint impact of offshoring of middle-skill tasks and low-skilled immigration on labor market polarization, I focus on the effect of offshoring of low-skilled tasks and search and matching friction on skill premium and unemployment rates. In my approach, offshoring decision resembles endogenous firing in Cacciatore (2014), in the sense that trade cost reduction induces more domestic firms to switch to offshoring, thus acting as firing of the domestic low-skilled workers at the same time. Another paper that is closely related to mine is Goel (2017), which also features two types of labor in a dynamic setting. The difference is that I look at the unemployment and wage effect of offshoring, whereas Goel (2017) studies the impact of offshoring on wages and employment for low-skilled and high-skilled workers. Therefore, that paper does not feature labor market frictions, thus the interaction between labor market frictions and offshoring, which is a key interest of my paper. And it does not feature factor proportions differences, an important element in my model that studies offshoring to a country that is more low-skill labor abundant.

The paper also belongs to the growing literature on the impact of globalization on labor markets with search frictions. Pioneers of this literature are Carl Davidson and Steven Matusz, who in a series of papers study the implications of introducing unemployment arising from labor market frictions in trade models. Moore and Ranjan (2005) show how trade liberalization in a skill-abundant country can reduce the unemployment of high-skilled workers and increase the unemployment of low-skilled workers. Felbermayr and Prat (2011) study the impact of a reduction in the cost of trading final goods on unemployment in a one-sector model with firm heterogeneity. Finally, Alessandria and Choi (2014), Burstein and Melitz (2013), Costantini and Melitz (2008), and Kambourov (2009) study the transition dynamics following trade liberalization, abstracting from the role of search and matching market frictions in the labor market. None of these papers study the implications of offshoring on unemployment.

My paper also contributes to the trade literature by studying the effect of offshoring with the presence of search-induced unemployment. Davidson et al. (2008) focus on the impact of offshoring of high-tech jobs on low- and high-skilled workers' wages, and on overall welfare under a job-search model. Mitra and Ranjan (2010) study the impact of offshoring on unemployment in a two-sector model where firms in one of the two sectors offshore. Groizard et al. (2014) introduces a more general production structure where there exists a continuum of inputs with the fraction of offshored inputs depending on offshoring costs while also allowing for firm heterogeneity. Egger et al. (2015) also studies the implications of offshoring in a model with firm heterogeneity, focusing on the implications of offshoring for income inequality, both within and between entrepreneurs and workers, with an extension that allows for unemployment. Again, all of these papers mentioned are under static trade models, thus ignoring the dynamic adjustment aspect of trade liberalization.

Recent empirical work testing the implications of existing theories with respect to the wage and employment effects of offshoring includes Crino (2010); Harrison and McMillan (2011); Hummels et al. (2014); Wright (2014); Kovak et al. (2017) and Boehm et al. (2019). The interest of this paper is to estimate the impact of offshoring to China on wage inequality and unemployment rates for high-skilled and low-skilled workers in the short and medium run.

2.3 Empirical Evidence

In this section, I study the labor market outcomes of the China shocks by applying structural vector autoregression methods.

I take a new look at time series evidence by using vector autoregressions to investigate the short-run effects of offshoring costs on unemployment rates for high-skilled workers and low-skilled workers and wage gap between them. Trade cost shocks are identified by exploiting the contemporaneous exogeneity of destination country's FDI liberalization policies with respect to source country's labor market variables. I use Chinese import tariffs and FDI restrictions as separate measures of trade cost. The former represents the variable cost of offshoring and the latter corresponds to the fixed cost of offshoring. I use these two measures as the key explanatory variables because they provides the most accurate and detailed information on trade openness and offshoring easiness that act as motivation for multinational firms to invest and offshoring in China. I also implement the VAR analysis using other measures of the China shock in the literature as checks. The main conclusion is that offshoring cost reduction has a very short-lived negative impact and then a persistently positive impact on low-skilled labor.

Offshoring cost measures:

The baseline measure of the China shock under the offshoring context is the Chinese import tariff, which corresponds to the variable cost of offshoring (the iceberg trade cost) in the model. Tariff data is from UNCTAD, which documents the drop of average tariff from 32.17% collected from 6549 lines in 1992 to 5.07% collected from 8377 lines in 2007. The reason why I use Chinese import tariff to proxy for trade cost reduction is because one of the most effective trade policies by China to attract offshoring by multinational firms is lower import tariff. Lower import tariff translates to lower cost of materials of the downstream production, for the offshoring firms that are mostly engaged in processing trade. Multinational firms in manufacturing sector have more incentive to reallocate their low-skilled task production to China when they are charged lower import tariff, modeled as a per-unit cost associated with the low-skilled task in the model part. Thus, decline in Chinese tariff is tied to a lowering of the variable cost of offshoring in my paper. Fig. (2.2) plots import tariff and fraction of industries subject to high tariffs (higher than 15 percent). Chinese import tariff declined from as high as above 40 percent in 1992 to 16.59 percent in 1997, remained stable around that number and declined again since 2001, dropping persistently to around 9 percent in 2007. The fraction of industries facing high tariffs also experienced a rather monotonic decline from above 80 percent in 1992 to 20 percent in 2001, with a large and persistent decline happening since WTO entry. The two series exhibit great commovement during the throughout the sample period, both pointing to substantial per-unit cost reduction for offshoring firms in the manufacturing sector.

I also consider fixed offshoring cost, measured by changes in the barriers and restrictions for firms to engage in FDI and offshoring in China. Following Brandt et al. (2017), I use the fraction of manufacturing sectors subject to FDI restrictions or import and export licenses (non-tariff trade barriers). The reason is that besides import tariff cuts that substantially reduced the cost of raw inputs of the offshored low-skill labor intensive tasks, liberalization policies related to FDI restrictions and other barriers also opened the gate for foreign firms to enter. China's low-skilled wage had always been low compared to United States. The Chinese to American low-skilled real hourly wage ratio averages 6.7% from 1995 to 2000 before China's accession into WTO (calculated from the WIOD dataset). What were preventing foreign firms to move part of their production to China were a list of factors including protectionist measures such as FDI restrictions, uncertainty and so on. As an effort to promote trade openness and to eventually meet the requirements for joining WTO, China implemented a series of trade liberalization policies to attract foreign investment and foreign production in China. Fig.2.3 plots the fraction of industries that contain at least one 8-digit product line subject to some form of FDI restriction. It shows that the FDI restrictions dropped drastically at the moment of WTO entry, with the number of sectors subject to FDI restrictions declining from a high of 87 out of 424 industries in 1995 to 47 in 2007. The total number of industries subject to some form of import licenses also fell from 15.3 percent in 1997 to 22.6 percent in 2000 and only 1.2 percent in 2007.

Using data from Autor (2014), Fig.2.4 plots the real weekly earnings relative to 1992 of workers with different educational attainments. It is noted that earnings difference between the top two series (high-skilled) and bottom three series (low-skilled) expand more after China joined WTO in 2001.

Other China shock measures:

Besides the tariff measure, two other influential measures of the China shock in the recent literature: the increase in Chinese import penetration in the U.S. (from Autor et al. (2013), and its variant, import exposure in Asquith et al. (2019) are also implemented. Lastly, I also do a robustness check with the measure being US to China FDI flow from BEA MNE dataset, which is particularly relevant in this paper's offshoring context. To guide the empirical exercise, I build on the comprehensive work of Acemoglu et al. (2016)— who in addition to a local labor markets analysis of the China shock conclude on net employment.

Empirical Strategy

The following structural VAR equation is estimated

$$Y_t = \Theta + \sum_{i=1}^{p} \Phi_i Y_{t-i} + Au_t,$$

where Y_t is a vector that represents offshoring cost measures and labor market variables including skill premium and unemployment rates for high-skilled; u_t is a vector of structural innovations which satisfy the condition of $E(u_t u_t^{'}) = I_N$; A is a matrix that links structural and reduced-form innovations. Estimating this relation at different horizons t produces a set of coefficients $\{\Phi_i\}_{i=1:p}$ that can be interpreted as an impulse response of the variable Y to the China shock.

Trade shocks are identified by exploiting the contemporaneous exogeneity of trade cost changes with respect to labor market variables.[9] The assumption is that changes in China's input tariff and its restriction measures do not respond to American labor market variables within the period. Such assumption is plausible to make as the main incentive and objective for China to lower tariff was to promote trade openness, attract more foreign investment and to meet the requirements for joining WTO. Changes in US labor market variables do not directly affect the incentive of China's trade policy changes.

Identification is achieved by imposing short-run restrictions, computed with a Cholesky decomposition of the reduced-form residuals' covariance matrix.

Results

[9]Direct evidence on trade costs are from two major categories, costs imposed by policy like tariffs and costs imposed by the environment such as transportation, insurance and time costs. See Anderson and Van Wincoop (2004) for more details.

I now examine the results of labor market variables in response to a trade shock.

I estimate a monthly structural VAR with four variables: Chinese import tariff, high-skilled unemployment rate, low-skilled unemployment rate and skill premium. Data covers the period Jan 1992 to Dec 2007. For the estimation with FDI restrictions and non-tariff barriers, data covers the period Jan 1997 to Dec 2007. Appendix discusses the details of the data.

Fig.2.5 reports the impulse responses to a one-standard deviation shock to China's tariff. The impact of tariff decline on the domestic low-skilled workers is actually very short-lived and close zero, with the decrease in unemployment for the high-skilled workers being quite persistent. This negative impact goes away shortly. It does enlarge the wage gap, much so in the short run, by 11 percent immediately, and then the impact dies down a little bit. A one standard deviation decrease in tariff leads to an average 1.5 percent decline in the high-skilled unemployment rate and an average 2 percent points decline during this period. The results for the fixed offshoring measure, as in Fig.2.6, are very similar to the import tariff measure case. The levels are slightly lower, and the responses are less persistent.

Using import penetration from Autor et al. (2013) as the measure of the China shock, the findings shown in Fig.2.7 are quite similar to the baseline results, except for a more pronounced increase in the low-skilled unemployment rates in the initial phase of the adjustment and a less persistent climb in wage gap. The unemployment rates for both types of labor in the medium to long run also exhibit less decline compared to the baseline responses. Fig.2.8 shows the results of using import exposure as a measure of the shock, which follows from the approaches in Asquith et al. (2019). The VAR responses and level of the low-skilled unemployment rate are almost identical to that using the previous measure– import penetration. However, the high-skilled unemployment rate behaves just like the baseline result, with a less persistent decline over time though. Using FDI flow as the exogenous shock variable, Fig. 2.9 depicts a similar pattern of the dynamic adjustment of labor market variables as those shown by using the measures above. These findings are just in line with what Asquith et al. (2019) find with gross job flows, which shows the net job creation in the non-exposed sector is as large as the net job destruction in the exposed sector, resulting in an almost neutral net effect of the China shock. Feenstra et al. (2019) on the other hand, find a positive overall effect of the China shock since their unit of analysis includes not only the manufacturing sector, but also the service sector. They find a substantial net job gain in the service sector large enough to offset the net job losses in the manufacturing and natural resources sector. In my analysis, by looking at the responses of high-skilled and low-skilled workers in the aggregate economy, the results incorporate both changes in the exposed and non-exposed sector, as well as a combination of the manufacturing sector and the service sector.

All of these results suggest that the trade shock which allows easier offshoring to China is correlated with increase in the wage gap and declines in the unemployment rate for both high-skilled and low-skilled workers over time, with slight differences in terms of the unemployment rate of low-skilled workers in the initial phase of adjustment.

2.4 The model

2.4.1 Overview

This section presents a stylized model of offshoring with firm-level heterogeneous productivities and country-level different relative factor abundance in a trade-in-tasks environment. I model a world economy that consists of two countries, Home and Foreign. Foreign variables are denoted with asterisks.

The two countries are endowed with different amounts of high-skilled labor and low-skilled labor -- $\bar{H}$ ($\bar{H}^*$) high-skilled labor and $\bar{L}$ ($\bar{L}^*$) low-skilled labor for the home (foreign) country, where the bars indicate country endowments. I assume that home is relatively more skill abundant than foreign, so that $\frac{\bar{H}}{\bar{L}} > \frac{\bar{H}^*}{\bar{L}^*}$. Each economy consists of a continuum of monopolistically competitive firms with different levels of labor productivity and one representative household, which can be thought of as an extended family with two types of agents: $\bar{H}$ high-skilled workers, $\bar{L}$ low-skilled workers in the home country and $\bar{H}^*$ high-skilled workers, $\bar{L}^*$ low-skilled workers in the foreign country. The number of family members who work is not chosen by the household, but rather determined by a labor matching process.

As in Ghironi and Melitz (2005), all contracts are written in nominal terms. Since prices are flexible, the variables I solve for are all in real terms.

Firms are final good producers with idiosyncratic productivity level of technology specific to their own with which they combine the high-skilled task and the low-skilled task into the final good. Each firm produces a different variety of goods. Production of the high-skilled task requires a match with a high-skilled worker; similarly, production of the low-skilled task requires a match with a low-skilled worker.[10] Firms in the home country can choose to either produce domestically or offshore the low-skilled task, but they keep the high-skilled task in house by assumption.[11] However, firms in the foreign country are assumed to produce both tasks in their own country, due to prohibitive costs of offshoring.

I focus on the home country in presenting the model, with the exception of when the foreign country shares asymmetric characteristic with home. Full model summaries are in the Appendix.

2.4.2 Household's Problem

Following Andolfatto (1996), Merz (1995) and much of the subsequent literature, I assume full consumption insurance between employed and unemployed individuals, so that there is no ex post heterogeneity across individuals in the household.

The representative household maximizes the expected intertemporal utility function:

$$E_t \left\{ \sum_{s=t}^{\infty} \beta^{s-t} \left[\frac{C_s^{1-\gamma}}{1-\gamma} - \nu^l L_s - \nu^h H_s \right] \right\},$$

where $\beta \in (0,1)$ is the subjective discount factor, C_t is a consumption basket that aggregates a variety of final goods, and $\gamma > 0$ is the inverse of intertemporal elasticity of substitution. L_t

[10]Firms have access to the final goods technology and no search is required to find the two tasks. A firm simply purchases the tasks and use them to produce the final good.

[11]Using German individual-level data, Baumgarten et al. (2013) shows that there is a tendency that high high-skilled workers are more likely to hold jobs that use tasks that are less offshorable. In the case of US offshoring to China, offshoring low-skilled tasks is more relevant due to the labor-intensive content of processing trade.

and H_t are the number of employed low-skilled and high-skilled workers. $\nu^l > 0$ is low-skilled labor's disutility of work, and $\nu^h > 0$ is high-skilled labor's disutility of work.[12]

The consumption basket C_t is defined over a continuum Ω: $C_t = \left(\int_{\omega\in\Omega} c_t(\omega)^{\frac{\theta-1}{\theta}} d\omega\right)^{\frac{\theta}{\theta-1}}$, where $\theta > 1$ is the elasticity of substitution across goods. Following Ghironi and Melitz (2005), at any given point in time only a subset of goods $\Omega_t \in \Omega$ is available. Ω_t contains varieties produced by domestically producing firms and those produced by firms offshoring the relevant low-skilled task. 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 then $P_t = \left(\int_{\omega\in\Omega_t} p_t(\omega)^{1-\theta} d\omega\right)^{\frac{1}{1-\theta}}$. Setting the consumption basket C_t as numeraire, the price index for the North is $1 = \left(\rho_t(\omega)^{1-\theta} d\omega\right)^{\frac{1}{1-\theta}}$, and $\rho_t(\omega)$ is the real price of goods of different varieties. The household's demand for each individual good variety ω is $c_t(\omega) = (p_t(\omega)/P_t)^{-\theta} C_t$.

The foreign representative household maximizes a similar utility function with foreign variables. However, the composition of the foreign consumption basket is different: $C_t^* = \left(\int_{\omega\in\Omega^*} c_t^*(\omega)^{\frac{\theta-1}{\theta}} d\omega\right)^{\frac{\theta}{\theta-1}}$. The subset of goods available for consumption in the foreign country at every point in time $\Omega_t^* \in \Omega^*$ only consists of goods produced by foreign firms that produce both tasks in the foreign country.

2.4.3 Firms and the labor market

Varieties are produced by monopolistically competitive firms, with heterogeneous productivity level z. Prior to entry, firms are identical and face a sunk entry cost, to be explained later on. After paying the sunk entry cost, each firm is randomly assigned an idiosyncratic productivity z which is drawn from a Pareto distribution over the interval $[z_{min}, \infty)$ and remains the same during the entire operation term of the firm. Foreign firms draw productivity levels from an identical distribution over the same interval.

There is one final-good sector. Firms are all final-good producers with heterogeneity in their productivities, each producing a different variety of the final goods. Production of the

[12] Arseneau (2014) calibrate the scaling for disutility of low-skill participation to be 9.793 and 11.470 for disutility of high-skill participation.

final good requires two tasks -- y_1 and y_2. Task y_1 uses high-skilled labor only and task y_2 uses low-skilled labor only. I assume the production function takes the following form: $y_t(z) = zZ_t [y_{1,t}(z)]^{\alpha} [y_{2,t}(z)]^{1-\alpha}$.[13] Every firm has a different level of productivity z with which it transforms the two tasks into the final output. Production also depends on the country-level productivity Z_t. As explained in 2.4.3, every period, firms face the decision of whether to produce both tasks domestically or to offshore the low-skilled task. If the firm decides to produce both tasks domestically, then $y_1(z) = h(z)$ and $y_2(z) = l(z)$. If the firm instead decides to offshore the relevant low-skilled task, then since the high-skilled task can only be produced domestically, $y_1(z) = h(z)$ but $y_2(z) = \frac{l^*(z)}{\tau}$. τ is the variable iceberg trade cost that firms need to pay if the low-skilled task is performed in the foreign country. It can generally be interpreted as a friction (e.g., a trade barrier) and as a cost or productivity disadvantage (less control and monitor over the products) due to distance.[14] Yet, it is best to interpret τ as costs of policy-related trade barriers imposed on per-unit offshored low-skilled task under the context of the China shock. Therefore, the output of producing both tasks domestically is:

$$y_{D,t}(z) = zZ_t [h_t(z)]^{\alpha} [l_t(z)]^{1-\alpha}, \tag{2.1}$$

whereas keeping the high-skilled task produced in-house and offshoring the low-skilled tasks give firms output as the following:

$$y_{v,t}(z) = zZ_t [h_t(z)]^{\alpha} \left[\frac{l_t^*(z)}{\tau}\right]^{1-\alpha}. \tag{2.2}$$

The labor market model follows Pissarides (2000). Every period, each worker has one unit of labor to devote to market activities. The labor markets are characterized by a matching technology that depends on the number of unemployed searchers and the number

[13] In Antras and Helpman (2004), the output of a firm z is a Cobb-Douglas function of two inputs that use domestic and foreign inputs respectively, $y_{v,t} = \left[\frac{Z_t z l_t}{\alpha}\right]^{\alpha} \left[\frac{Z_t^* z l_t^*}{1-\alpha}\right]^{1-\alpha}$.

[14] Iceberg trade cost implies that, for every $\tau > 1$ units produced offshore, only one unit arrives in the North, with the difference lost due to factors such as trade barriers, transportation costs and so on.

of job vacancies. For each task, the firm posts vacancies for matches. High-skilled and low-skilled workers search in their respective sectors. For simplicity, I assume a Cobb-Douglas matching function, identical for the two tasks. Let u^i denote the unemployment rate and v^i the vacancy rate (the number of vacancies divided by the labor force) for a type i worker ($i = l, h$). Define $\theta^i = v^i/u^i$ as a measure of market tightness for type i workers, and let χ be the scale parameter in the matching function. Then, the flow of matches for each type of labor at every period can be written as: $M\left(u^h \bar{H}, v^h \bar{H}\right) = \chi\left(u^h\right)^{\epsilon}\left(v^h\right)^{1-\epsilon} \bar{H} = \chi\theta^{1-\epsilon}u^h\bar{H}$ and $M\left(u^l \bar{L}, v^l \bar{L}\right) = \chi\left(u^l\right)^{\epsilon}\left(v^l\right)^{1-\epsilon} \bar{L} = \chi\theta^{1-\epsilon}u^l\bar{L}$, with $0 < \epsilon < 1$. Define $m^h = M\left(u^h\bar{H}, v^h\bar{H}\right)/\bar{H}$ and $m^l = M\left(u^l\bar{L}, v^l\bar{L}\right)/\bar{L}$ as the matching rates in the two tasks. Then, the job finding rate for an unemployed type i searcher is $\iota^i = m^i/u^i = \chi\left(\theta^i\right)^{1-\epsilon}$ and the vacancy filling rate for a firm is $q^i = m^i/v^i = \chi\left(\theta^i\right)^{-\epsilon}$. The job finding rate for a worker is an increasing function of market tightness, whereas the job filling rate for a firm is a decreasing function of market tightness. Once a vacancy is matched with a worker, the match remains effective until it is destroyed by an exogenous shock with probability $\lambda \in (0, 1)$, which can be viewed as an arrival rate of a shock that leads to job destruction within a firm. The workers who get hit by the exogenous separation shock enter the unemployment pool immediately.

The timing of hiring proceeds as follows. At the beginning of each period, a fraction $(1 - \lambda)$ of workers survive from the exogenous separation shock and remain hired within the firm. Aggregate shock are then realized, after which firms post vacancies for both tasks. The newly matched workers become productive the same period in which they are hired. Therefore, once the new matches are generated, all of the newly matched along with the workers who have survived job destruction from the last period produce start producing in the current period. The law of motion of employment for the two types of worker for producer z are thus given by:

$$l_{z,t} = (1 - \lambda)\, l_{z,t-1} + q_t^l v_{z,t}^l \text{ and} \tag{2.3}$$

$$h_{z,t} = (1 - \lambda)\, h_{z,t-1} + q_t^h v_{z,t}^h. \tag{2.4}$$

When a firm leaves the market, its entire stock of workers become unemployed, joining the pool of searchers in the next period. When a firm switches from domestic production to offshoring, all of the domestic low-skilled workers it hires join the unemployment pool and some of the unemployed foreign low-skilled workers get matched. The law of motion of low-skilled employment for offshoring firms then become:

$$l^*_{z,t} = (1 - \lambda)\, l^*_{z,t-1} + q^{l*}_t v^{l*}_{z,t}, \tag{2.5}$$

which is the same as that for foreign firms.

Production location strategy

Every period, firms have to make the production location decision regarding the low-skilled task: either produce that domestically or produce that in the foreign country. For either of these two production strategies, a firm maximizes expected present discounted value of future profits subject to the law of motion for both types of workers and the production function, the forms of which are all dependent on the specific location decision. In every period, each firm compares the expected present discounted value of offshoring and that of domestic production and chooses the production strategy that yields a higher expected value of production.

If a firm produces both tasks domestically, it chooses the employment levels and vacancies to post for both type of workers to maximize the expected present discounted sum of current and future profits:

$$\max \; d_{D,t} + E_t \sum_{s=t+1}^{\infty} [\beta(1-\delta)]^{s-t} \frac{U'(C_s)}{U'(C_t)} \left[(1-\xi_s) d_{D,s}(z) + \xi_s d_{O,s}(z)\right],$$

where the period profit of domestic production is

$$d_{D,s}(z) = \left[\rho_{D,s}(z)\, y_{D,s}(z) - w^l_s l_s(z) - w^h_s h_s(z) - \kappa^l v_{l,s}(z) - \kappa^h v_{h,s}(z)\right],$$

and $\beta_{t,s} \equiv \beta(C_s/C_t)^{-\gamma}$ denotes the stochastic discount factor of domestic households, who own domestic firms by assumption. The above profit maximization problem is subject to the law of motion of employment for both high-skilled and low-skilled shown above as Eq. (2.3) and Eq. (2.4), as well as the production function (2.1).

For firms that choose to produce offshore, the cost associated with the high-skilled is the same since the high-skilled task can only be produced in the home country, but the cost for hiring and paying for the low-skilled labor is the foreign low-skilled wage plus the cost of searching and matching with them in the foreign labor market. In addition, offshoring firms need to pay the per period fixed offshoring cost f_v, which can be interpreted as the cost associated with building and maintaining production facilities abroad. The profit maximization problem associated with offshoring in period t thus follows:

$$\max \; d_{O,t} + E_t \sum_{s=t+1}^{\infty} \left[\beta(1-\delta)\right]^{s-t} \frac{U'(C_s)}{U'(C_t)} \left[(1-\xi_s) d_{D,s}(z) + \xi_s d_{O,s}(z)\right],$$

where the period profit is

$$d_{O,s}(z) = \left[\rho_{v,s}(z)\, y_{v,s}(z) - w^*_{l,s} l^*_s(z) - w_{h,s} h_s(z) - \kappa^{l*} v^*_{l,s}(z) - \kappa^h v_{h,s}(z) - f_v\right].$$

Apart from the lower low-skilled labor cost in the foreign country, the foreign country's labor market rigidities can provide another source of cost advantage that induces more offshoring. If the labor market is more flexible in the foreign country than the home country, firms would have additional source of motivation for offshoring the low-skilled task. The cost minimization problem is subject to the law of motion of employment for home high-skilled labor Eq.(2.4) and that for foreign low-skilled labor Eq.(2.5), as well as the offshoring production function (2.2).

Define ξ_{t+1} as the probability of being an offshoring firm in the next period. Every period, every firm faces probability ξ_{t+1} of being an offshoring firm and $1-\xi_{t+1}$ of being a non-offshoring firm in the next period. Since every firm has the same information regarding exogenous shock and aggregate outcomes in the next period, they each face the same probability of being a specific type of firm in the next period. In other words, two firms with productivity levels z_a and z_b face a same probability ξ_{t+1} of being an offshoring firm and a same probability $1-\xi_{t+1}$ of being a domestically producing firm because of the same set of information about their productivity position relative to productivity cutoff in the next period. Moreover, the probability of being an offshoring firm ξ_{t+1} in the next period can be pinned down by next period's productivity cutoff $z_{c,t+1}$: $\xi_{t+1} = 1 - G\left(z_{c,t+1}\right) = \left(\frac{z_{min}}{z_{c,t+1}}\right)^k$, which is the same for every firm. Denote the expected discounted present value of offshoring and domestic production as $V_{V,t}\left(z\right)$ and $V_{D,t}\left(z\right)$. It follows that:

$$V_{D,t}(z) = d_{D,t}(z) + E_t \sum_{s=t+1}^{\infty} \left[\beta(1-\delta)\right]^{s-t} (\frac{C_s}{C_t})^{s-t} \left[(1-\xi_s)d_{D,s}(z) + \xi_s d_{O,s}(z)\right] \text{ and}$$

$$V_{O,t}(z) = d_O, t(z) + E_t \sum_{s=t+1}^{\infty} \left[\beta(1-\delta)\right]^{s-t} (\frac{C_s}{C_t})^{s-t} \left[(1-\xi_s)d_{D,s}(z) + \xi_s d_{O,s}(z)\right].$$

The present discounted value of the two strategies can also be written in Bellman equations as the following: the discounted present value of offshoring today is equal to this period's profit plus the discounted present value as of tomorrow, similarly for the offshoring strategy. The present discounted value of domestically producing the low-skilled task today is equal to the period profit of domestic production plus the present discounted value of domestic production tomorrow, which is adjusted for the probability of remaining a domestically producing firm tomorrow and that of being an offshoring firm tomorrow. The present discounted value of offshoring follows a similar logic, as the following:

$$V_{D,t} = d_{D,t} + \beta_{t,t+1}\left[(1-\xi_{t+1}))\, V_{D,t+1} + \xi_{t+1} V_{O,t+1}\right] \text{ and}$$

$$V_{O,t} = d_{O,t} + \beta_{t,t+1}\left[(1-\xi_{t+1})\, V_{D,t+1} + \xi_{t+1} V_{O,t+1}\right],$$

where $\beta_{t,t+1} = \beta E_t \frac{U'(C_{t+1})}{U'(C_t)}$ is the stochastic discount factor.

Productivity cutoff for new entrants at period t is defined where the present discounted value of the two strategies is equal $z_{V,t} = \{z : V_{D,t}(z_{V,t}) = V_{V,t}(z_{V,t})\}$. Every period, a firm may decide to stop offshoring not just based off the profit today, but based on the expected present discounted stream of future profits. However, from the value functions above, it is noted that the comparison of values of the two production strategies boils down to comparison of period profits of the two strategies. Therefore, the productivity cutoff $z_{V,t}$ can also be written as $z_{V,t} = \{z : d_{D,t}(z_{V,t}) = d_{V,t}(z_{V,t})\}$ At every period, the firm is reoptimizing.

The first-order conditions for vacancies and employment imply the following job creation equation:

$$\frac{\kappa^i}{q_t^l} = (1-\delta)(1-\lambda) E_t \left(\beta_{t,t+1} (1-\xi_{t+1}) \frac{\kappa^i}{q_{z,t+1}^i} \right) + \varphi_{z,t}^i z Z_t - w_t^i, \tag{2.6}$$

where $\varphi_{z,t}^i (i = l, h)$ is the Lagrange multiplier attached to the constraint (2.1) with respect to i, corresponding to the real marginal cost of type i worker used for production. Eq.(2.6) equalizes the marginal cost and the marginal benefit of posting a vacancy for each task of type i. The marginal benefit of a filled vacancy includes expected discounted savings on the future vacancy postings, further discounted by the exogenous probability of the survival rate of the match $(1-\delta)(1-\lambda)$, plus the average profits generated by the match. Profits from the match equals marginal revenue product from the match minus the wage cost paid to the type i worker. Forward iteration implies that, the expected discounted value of the stream of profits generated by a match for type i worker over the span of its expected lifetime is equal to k^i/q_t^i, the marginal cost of the match at the optimum.

Marginal cost of production for a domestically producing firm with productivity z is: $mc_{D,t}(z) = \frac{1}{zZ_t} \left(\frac{\varphi_{z,t}^l}{1-\alpha} \right)^{1-\alpha} \left(\frac{\varphi_{z,t}^h}{\alpha} \right)^{\alpha}$, where $\varphi_{z,t}^l = w_t^l + \frac{\kappa^l}{q_t^l} - (1-\delta)(1-\lambda) E_t \left(\beta_{t,t+1} (1-\xi_{t+1}) \frac{\kappa^l}{q_{t+1}^l} \right)$ and $\varphi_{z,t}^h = w_t^h + \frac{\kappa^h}{q_{t-1}^h} - (1-\delta)(1-\lambda) E_t \left(\beta_{t,t+1} (1-\xi_{t+1}) \frac{\kappa^h}{q_t^h} \right)$. Profit maximization with respect to price yields that the price charged by firms is the mark-up over the marginal cost $\rho_{D,t}(z) = \frac{\theta}{\theta-1} mc_{D,t}(z)$. Profits of producing domestically is $d_{D,t}(z) = \frac{1}{\theta} \rho_{D,t}(z)^{1-\theta} C_t$. The period profit of offshoring the low-skilled task while keeping the high-skilled task produced in house is $d_{V,t}(z) = \frac{1}{\theta} \rho_{V,t}(z)^{1-\theta} C_t - f_v \left(\frac{\varphi_{z,t}^h}{\alpha} \right)^{\alpha} \left(\frac{\varphi_{z,t}^l}{1-\alpha} \right)^{1-\alpha}$ where $\rho_{V,t}(z) = \frac{\theta}{\theta-1} mc_{V,t}(z)$. The marginal cost of offshoring is similarly a Cobb-Douglass combination of the costs of the foreign low-skilled labor and domestic high-skilled labor, which is $mc_{V,t}(z) = \frac{1}{zZ_t} \left(\frac{\tau \varphi_{z,t}^{l^*}}{1-\alpha} \right)^{1-\alpha} \left(\frac{\varphi_{z,t}^h}{\alpha} \right)^{\alpha}$, where $\varphi_{z,t}^{l^*} = w_l + \frac{\kappa^{l^*}}{q_t^{l^*}} - (1-\delta)(1-\lambda) E_t \left(\beta_{t,t+1} \xi_{t+1} \frac{\kappa^{l*}}{q_{t+1}^{l*}} \right)$. The marginal cost of offshoring the low-skilled tasks takes into account the fact that these tasks are subject to foreign wage and foreign labor market rigidities for the low-skilled workers whereas the marginal cost of high-skilled task remains the same as producing domestically. If the marginal cost of job creation is lower too in the foreign country, then introducing labor market search and matching essentially has similar effect as reduction in the iceberg trade cost, which lowers the productivity of offshoring than the previous case without labor market frictions. Therefore, the productivity cutoff also reflects the labor market frictions of both countries. Changes in the labor market rigidities in both countries affects the productivity cutoff.

2.4.4 Wage determination

Following much of the labor search and matching literature, I assume that the wage is the solution of an individual Nash bargaining schedule that splits the surplus of the match between the firm and the worker. The equilibrium sharing rule resulting from the bargaining between a type i worker and a producer with productivity z can be written as $\eta F^i_{z,t} = (1-\eta)S^i_{z,t}(i)$, where $\eta \in (0,1)$ represents the worker's bargaining share, $F^i_{z,t}$ is firm surplus and $S^i_{z,t}$ is worker surplus. The bargained wage $w^i_{z,t}$ for type i worker is a weighted average between the marginal revenue product of the worker i and the worker's outside option ϖ^i_t:

$$w^i_{z,t} = \eta\varphi^i_{z,t} z Z_t + (1-\eta)\varpi^i_t. \tag{2.7}$$

The worker's outside option is given by the utility gain from leisure in terms of consumption, $\nu/C_t^{-\gamma}$, an unemployment benefit from the government, u_b, and the expected discounted value of searching for jobs in the next period:

$$\varpi^i_t = \nu^i C^\gamma_t + u_b + (1-\lambda)(1-\delta) E_t \left[\beta_{t,t+1}\iota^i_{t,t+1}\tilde{S}^i_{t+1}\right]. \tag{2.8}$$

The unemployment benefit u_b is denominated in units of the final consumption basket, and it is financed with lump sum taxes of the government T^g_t. Workers are paid the same wage within its own type, regardless of which firm they are hired in.

2.4.5 Firm averages

The model is isomorphic to a framework with two representative firms in the home country: one produces both tasks domestically, one offshores the low-skilled task and only produces the high-skilled task in the home country.

Firms' productivity are drawn from the Pareto distribution over the interval $[z_{min}, \infty)$, where the common distribution is G(z) with density g(z). Every period, there are $N_{D,t}$ firms whose idiosyncratic productivities are below the offshoring cutoff $z_{min} < z_t < z_{V,t}$ that produce both tasks domestically; and there are $N_{V,t}$ firms with productivity levels above the cutoff $z_t > z_{V,t}$. The average productivity of domestically producing firms is $\tilde{z}_{D,t}$ whereas that of offshoring firms is $\tilde{z}_{V,t}$. The average productivity levels follow as:

$$\tilde{z}_{D,t} = \left[\frac{1}{G(z_{v,t})} \int_{z_{min}}^{z_{v,t}} z^{\theta-1} g(z)\, dz \right]^{\frac{1}{\theta-1}} \text{ and}$$
$$\tilde{z}_{V,t} = \left[\frac{1}{1-G(z_{v,t})} \int_{z_{V,t}}^{\infty} z^{\theta-1} g(z)\, dz \right]^{\frac{1}{\theta-1}}.$$

With the assumption that the Pareto distribution of the productivity has p.d.f. $g(z) = kz_{min}^k/z^{k+1}$and c.d.f. $G(z) = 1 - (z_{min}/z)^k$, the average productivity levels $\tilde{z}_{D,t}$and $\tilde{z}_{V,t}$ can both be expressed as function of offshore productivity cutoff $z_{V,t}$:

$$\tilde{z}_{D,t} = \xi z_{min} z_{o,t} \left[\frac{z_{V,t}^{k-(\theta-1)} - z_{min}^{k-(\theta-1)}}{z_{V,t}^k - z_{min}^k} \right]^{\frac{1}{\theta-1}} \text{ and } \tilde{z}_{V,t} = \xi z_{V,t},$$

where $\xi = \left[\frac{k}{k-(\theta-1)}\right]^{\frac{1}{\theta-1}}$ and $k > \theta - 1$, and the cutoff is $z_{V,t} = z_{min} \left(N_t/N_{V,t}\right)^{1/k}$.

Firms in the Southern country only has the strategy of producing domestically. Their average productivity remains constant at $\tilde{z_t^*} = \xi z_{min}^*$.

The average price indexes for the North and the South also follow as $1 = N_{D,t} \left(\tilde{\rho_{D,t}}\right)^{1-\theta} + N_{V,t} \left(\tilde{\rho_{V,t}}\right)^{1-\theta}$ and $1 = N_t^* \left(\tilde{\rho_t^*}\right)^{1-\theta}$. The total profits of firms in the North and the South are $N_t \tilde{d}_t = N_{D,t} \tilde{d_{D,t}} + N_{V,t} \tilde{d_{V,t}}$ and $N_t^* \tilde{d_t^*} = N_t^* \tilde{d_t^*}$.

2.4.6 Firm entry and exit

The expected post-entry value for firms $\tilde{e}_t$ is the present discounted value of the expected stream of per-period profits: $\tilde{e}_t = E_t \left[\sum_{s=t+1}^{\infty} \beta_{t,s} (1-\delta)^{s-t} \tilde{d}_s \right]$ where $\beta_{t,s} = \left(\frac{C_s}{C_t}\right)^{-\gamma}$.

Before entry, the firms face a sunk entry cost $f_e = f_r + \kappa^l v_{e,t}^{\tilde{l}} + \kappa^h v_{e,t}^{\tilde{h}} = f_r + \kappa^l \frac{\tilde{l}}{q^l} + \kappa^h \frac{\tilde{h}}{q^h}$. The first term, $f_{r,t}$, represents the regulation cost for entry, in units of consumption. The second and third term are the real cost of hiring type i labor and putting them into production. The representative new entrant posts $v_{e,t}^{\tilde{l}} = \frac{\tilde{l}_t}{q_t}$ and $v_{e,t}^{\tilde{h}} = \frac{\tilde{h}_t}{q_t}$. Entry takes place until the average firm value equals the entry cost, $\tilde{e}_t = f_e$. Every period, there are $N_{E,t}$ new firms entering the market every period and start producing in the next period. With all firms, including the new entrants, being subject to a random death shock with probability $\delta \in (0,1)$ at the end of every period, the law of motion for the mass of firms is $N_{t+1} = (1-\delta)(N_t + N_{E,t})$.

Entry occurs until firm value equals the entry cost, leading to the free-entry condition $f_{e,t} = \tilde{e}_t$. Observe that changes in labor market conditions trigger variations in the cost of recruiting workers, affecting the profitability of market entry; firm dynamics, in turn, feed back into labor market outcomes, contributing to the determination of equilibrium unemployment. Sunk costs and time-to-build transform N_t into a state variable that behaves like a capital stock, with an endogenously fluctuating price given by $\tilde{e}_t$. Therefore, there are two endogenous state variables in the model: labor and the number of producers.

2.4.7 Household budget constraint

The budget constraint is:

$$\begin{aligned} C_t + (N_t + N_{E,t})\,\tilde{e}_t x_{t+1} + B_{N,t+1} &= \left(\tilde{e}_t + \tilde{d}_t\right) N_t x_t + (1+r_t)\,B_{N,t} \\ &\quad + w_{h,t}H_t + w_{l,t}L_t + u_l^b\left(\bar{L} - L_t\right) + u_h^b\left(\bar{H} - H_t\right) + T_t^g, \end{aligned}$$

where T_t^g is lump-sum taxes the representative household receives from the government. In equilibrium, $T_t^g = -\left[u_l^b\left(\bar{L} - L_t\right) + u_h^b\left(\bar{H} - H_t\right)\right]$.

At period t, the household purchases x_{t+1} shares in a mutual fund of Northern firms, which includes N_t incumbent firms engaged in domestic production or offshoring, and also $N_{E,t}$ new entrants. Meanwhile, the household has share holdings x_t in a mutual fund at time t of N_t home firms whose average market value is $\tilde{v}_t$. The date t price of a claim to the future profit stream of the mutual fund of $N_t + N_{E,t}$ home firms is equal to the average nominal price of claims to future profits of home firms, $P_t\tilde{e}_t$. Besides the shares x_{t+1} in the mutual fund, the household also holds risk-free, real bonds from its own country $B_{N,t+1}$, denominated in units of the issuing country's consumption basket. Every period, the mutual fund pays a total profit that is equal to the average total profits of all home firms that produce in that period, $P_t\tilde{d}_t N_t$. The household also receives dividends equal to the average firm profit $\tilde{d}_t$ proportional to the mass of firms N_t, as well as the real rates of return r_t from the country's own bonds.. The employed high-skilled labor and low-skilled labor pool income together, earning real wages $w_{h,t}$ and $w_{l,t}$.

The Euler equation for bonds is:

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

The Euler equation for stocks is:

$$\tilde{e}_t = \beta\left(1 - \delta\right) E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\left(\tilde{e}_{t+1} + \tilde{v}_{t+1}\right)\right].$$

2.4.8 Equilibrium

Aggregate employment is $L_t = N_{D,t}\tilde{l_{D,t}}$ and $H_t = N_t\tilde{h}_t$, while the total number of vacancies posted is $V_t^l = N_{D,t}\tilde{v_t^l} + N_{e,t}\tilde{v_{e,t}^l}$ and $V_t^h = N_t\tilde{v_t^h} + N_{e,t}\tilde{v_{e,t}^h}$. Labor market clears by the following equations determining that labor supply is equal to labor demand:

$$\begin{aligned}(1-u_l)\bar{L} &= \rho\tilde{_{D,t}}^{-\theta} Y_t^l \left(z\tilde{_{D,t}}Z\right)^{-1}\left(\frac{\alpha\varphi_t^l}{(1-\alpha)\,\varphi_t^h}\right)^{-\alpha} N_{D,t} \text{ and}\\ (1-u_h)\bar{H} &= \rho\tilde{_{D,t}}^{-\theta} Y_t^h \left(z\tilde{_{D,t}}Z\right)^{-1}\left(\frac{\alpha\varphi_t^l}{(1-\alpha)\,\varphi_t^h}\right)^{1-\alpha} N_{D,t}\\ &\quad + \tau^{1-\alpha}\rho\tilde{_{V,t}}^{-\theta} Y_t^h \left(z\tilde{_{V,t}}Z\right)^{-1}\left(\frac{\alpha\varphi_t^{l*}}{(1-\alpha)\,\varphi_t^h}\right)^{1-\alpha} N_{V,t},\end{aligned}$$

where aggregate demand for each type of labor Y_t^l and Y_t^h are given by

$$Y_t^l = C_t + N_{e,t}f_{r,t} + \kappa^l V_t^l \text{ and } Y_t^h = C_t + N_{e,t}f_{r,t} + N_{V,t}f_{V,t} + \kappa^h V_t^h.$$

Home country's high high-skilled labor is used by domestically producing firms using high-skilled labor, offshoring firms using high-skilled labor as well as high high-skilled labor used for the sunk entry cost and fixed offshoring cost activities. Home country's low high-skilled labor is used only by domestically producing firms and those used to pay fixed entry cost. The opposite is true for the foreign country.

2.5 *Calibration and model properties*

The model is calibrated to the home (U.S.) and foreign economy (China), which is relevant to the China shock debate in the US. The foreign economy is not restricted to the focus of China; it can easily be calibrated to other developing countries that host offshoring activities from multinational firms of any developed economy. Periods are interpreted as months. I choose parameter values from the literature and to match features of macroeconomic and labor market data of these two economies.

Discount factor β is set to 0.99, corresponding to an annual real interest rate of 4%. The value of risk aversion γ is the standard value 2. Following Ghironi and Melitz (2005), the dispersion parameter of firm productivity draws k equal to 3.4, z_{min} normalized to 1, probability of firm exit $\delta = 0.025$ and elasticity of substitution across product varieties θ equal to 3.8. Iceberg trade cost is calibrated to be 1.8, which generates the Fixed offshoring cost f_v is chosen to match with the share of firms engaged in offshoring to China out of the total number of firms ($N_V/N = 8\%$) during the sample period 1992-2007 from BEA MNE dataset.

I set workers' bargaining share η equal to 0.4, in line with the empirical estimates of the Nash bargaining power in Flinn (2006). Elasticity of matching function $\varepsilon = 0.4$, as in Blanchard and Diamond (1991). Unemployment benefits for workers are assumed to be equal across skill groups, and calibrated to have $u_b/\tilde{w}$ equals 0.54 as reported in OECD (2004). I calibrate vacancy posting cost κ^i, matching elasticity χ^i to match the steady state job finding rate ι^i and the vacancy filling rate q^i. The model generates the following steady state unemployment rates for different skill groups: $u^l = 8.3\%$, $u^h = 2.4\%$, $u^{l*} = 3.5\%$ and $u^{l*} = 2\%$.

The production share of high-skilled task α, regulation costs for entry f_r, iceberg trade cost τ are calibrated so that the model in steady state matches the wage ratios of high-skilled and low-skilled in the U.S. and in China (WIOD socio economic accounts data) as well as share of firm entry. The sunk regulation cost f_r, along with the values for α, τ, f_v, generate a steady state value for the terms of production that is far less than unity (TOP=$(\frac{\varphi^{l*}/Z_t^*}{\varphi^l/Z_t})^{1-\alpha} =$ 28%). The steady-state wage of low-skilled labor in the South is 12% (compared to 10% in the data) of that in the North. Disutility weight on low-skilled labor and that of high-skilled labor are set to equal to 0.92 and 1.12 to match the relative shares of labor in production, 0.6 of low-skilled and 0.4 of high-skilled.

Tariff decline is calibrated into an AR (1) process using data from WTO's tariff data from 1992 to 2007, with the persistence coefficient equal to 0.95. Table 2 shows all parameterization values and targets.

2.6 Results

This section explores the consequences of trade liberalization under the offshoring environment by studying the transition dynamics and long-run effects of a permanent reduction in the per-unit trade cost τ in the model. I discuss the implications of some key steady state relationships by showing the quantitative results.

2.6.1 Steady-state analysis

The steady state is defined by setting all variables constant and it is the long run position for the economy. In each country, the unemployment rate depends on the incidence and duration of unemployment. The incidence of unemployment is defined by the rate of transition from employment to unemployment, $\lambda^{i,TOT}$ $(i = l, h)$. The duration of unemployment, $\iota = \chi\vartheta^{1-\epsilon}$, is the inverse of the job-finding rate, which captures job creation. The unemployment rate increases with the incidence and duration of unemployment, since $u^i = \frac{\lambda_i^T}{\chi^i(\vartheta^i)^{1-\epsilon}+\lambda_i^T}$.

In equilibrium, ι and λ_i^{TOT} depend on the average marginal revenue of a match φ^i. To see this, let $\theta \equiv V/U$ denote labor market tightness, and use $\iota = \chi\vartheta^{1-\epsilon}$ mentioned above. Combining Eqs. (2.5), (2.6), (2.7), and (2.8), I obtain the following steady-state relationships for different types of labor.

Low-skilled unemployment

$$\lambda^{l,TOT} = \frac{1}{(1-\lambda)(1-\delta)} - \frac{1}{1-\delta+\delta[1-(z_V^{-k})]}, \text{and}$$

$$\vartheta^l = \left\{ \frac{\chi^l}{k^l} \left[(1-\eta)(\varphi^l - b) + \tilde{\beta}\frac{\kappa^l}{\chi^l}(\vartheta^l)^\epsilon - \eta\tilde{\beta}\kappa^l\vartheta^l \right] \right\}^{\frac{1}{\epsilon}},$$

where $\tilde{\beta} = (1-\lambda)(1-\delta)\beta$. Other things equal, an increase in the average marginal revenue of a match φ^i reduces the incidence and duration of unemployment.

The steady state equation of low-skilled unemployment is affected by two variables: $\lambda^{l,TOT}$, which is a decreasing function of the productivity cutoff z_o, and labor market tightness ϑ^l, an increasing function of the average marginal revenue φ^l. When there is a negative trade cost shock, whether it's a lowering of variable offshoring cost τ or the fixed offshoring cost f_v, first, the productivity cutoff is lowered, so that more firms select into offshoring. Meanwhile, when more firms engage in offshoring, more of the domestic low-skilled labor get separated from their employers, leading to an increase in the total separation rate for home low-skilled workers $\lambda^{l,TOT}$. This is the substitution effect that is standard in the literature.

The second variable ϑ^l, labor market tightness for low-skilled market, is an increasing function of the marginal revenue product of low-skilled labor φ^l, which is determined by the number domestically producing firms N_D as well as the average productivity of these firms $\tilde{z_D}$, as $\varphi^l = [N_D^{\frac{1}{\theta-1}}\tilde{z_D}\mu(\frac{\alpha}{\varphi_h})^\alpha C]^{\frac{1}{1-\alpha}}(1-\alpha)$. When trade cost ($\tau$ or f_V) falls, $\tilde{z_D}$ decreases following the lowering of the productivity cutoff z_V, which lowers low-skilled labor demand from domestically producing firms on average. This is what I call the "reverse scale effect" as opposed to the scale effect in the literature, which describes the increase in labor demand due to headquarter firms' higher productivity from offshoring cost reduction (e.g. Antras and Helpman (2004), Grossman and Rossi-Hansberg (2008)) . Here in this model, the scale effect for low-skilled labor is reversed as the demand for them only comes from domestically producing firms, which experience lower productivity and thus shrink after the shock. For the extensive margin captured by N_D, there are two opposite effects. On the one hand, offshoring cost reduction induces more firms to switch from domestic production to offshoring, exerting a negative effect on N_D. On the other hand, it also increases profit opportunities encouraging entry. When the shock generates an entry effect that is large enough, φ^l increases after the shock. Then, the sign of u^l depends on the size of the increase in φ^l and that of the decrease in $\lambda^{l,TOT}$. Basically, when the endogenous entry effect dominates the substitution effect and the (reverse) scale effect, low-skilled unemployment rate falls.

In a nutshell, when a firm switches from domestic production to offshoring, all of the domestic low-skilled workers it hires join the unemployment pool and some of the unemployed foreign low-skilled workers get matched and employed. However, when a shock spurs more entry in the home market, more domestic workers get employed.

High-skilled unemployment

$$\lambda^{h,TOT} = \frac{1}{(1-\lambda)(1-\delta)} - 1, \text{and}$$

$$\vartheta^h = \{\frac{\chi^h}{k^h}[(1-\eta)(\varphi^h - b) + \tilde{\beta}\frac{\kappa^h}{\chi^h}(\vartheta^h)^\epsilon - \eta\tilde{\beta}\kappa^h\vartheta^h]\}^{\frac{1}{\epsilon}}.$$

The steady state equation of high-skilled unemployment is very similar to a standard one type of labor setting, in the sense that the total separation rate λ^h is not directly affected by the shock-- it is solely dependent on the exogenous death probability of firms δ and exogenous separation rate for workers λ. This is because when domestic firms choose to instead offshore the low-skilled task, the high-skilled who were already hired and still employed are not affected by this transition. Thus, for the high-skilled labor, there is no substitution effect. Rather, the unemployment rate for high-skilled is merely affected by high-skilled labor market tightness ϑ^h, which is an increasing function of high-skilled workers average marginal revenue product φ^h. An increase in the number of firms and average productivity level raises marginal revenue product of high-skilled labor, since $\varphi^h = \frac{\mu}{\alpha}N^{\frac{1}{\theta-1}}\tilde{z}^{\frac{1}{\theta-1}}$. This is because even though the switch from domestic production into offshoring due to lower trade cost does not affect the employed high-skilled, it does have an impact on the unemployed high-skilled labor since firms are able to hire more and there is an elevation of entry spurred by the tariff reduction. Focusing on the equation of high-skilled labor market tightness ϑ^h, with a decline in τ, the average productivity of firms go up, generating an increase in high-skilled labor demand for the average firm, as the scale effect. Also, the total number of firms N rises due to the entry effect. This finding is consistent with the recent findings in Kovak et al. (2017) on the labor market outcomes of offshoring. They find that within US multinationals, the positive scale effects resulting from a fall in offshoring costs just outweigh the negative substitution effects on average. Specifically, a 10 percent BTT-induced increase in affiliate employment leads to a 1.8 percent increase in employment at the US parent firm.

In sum, there are two forces exerted on firms: (1) A lowering of trade cost makes offshoring more profitable for some existing domestically producing firms whose productivity level now passes the offshoring productivity cutoff, leading to a flow of laid-off low-skilled workers. (2) Trade cost reduction makes firms become more profitable on average due to the lower cost of production and more firms select into offshoring, which elevates firm entry. As more firms enter, the number of both types of firms go up, spurring an increase in demand for both low-skilled and high-skilled domestic workers, as well as foreign low-skilled workers. Since firms are all forward looking, the transition from negative to positive effect is quite rapid.

2.6.2 Dynamic adjustment, impulse responses

I now quantitatively evaluate the effects of offshoring by analyzing the dynamic adjustment and of a reduction in τ. I assume that τ declines at a constant rate over the sample period, consistent with the gradual reduction in trade costs observed in the data.[15]

Baseline model

Fig. 2.10 plots the impulse responses of wage gap and unemployment rates following a reduction in trade cost, and Fig. 2.11 shows the responses of other labor market and macroeconomic variables. Along the transition, trade integration induces job losses for the low-skilled

[15] For example, Novy (2013) estimates that U.S. trade costs with major trading partners declined steadily over the period 1970–2000. The author considers that the estimated reduction ranges from 20 to 40% over the sample period.

in the very short run and then quickly converts the negative impact into positive gains while generating a continuing positive change in wage and employment for the high-skilled in the home country. For the offshoring-competing domestic low-skilled, in the initial phase of trade cost reduction, they experience decrease in wage rate and increase in unemployment because in the initial stage, the negative impact of trade liberalization on domestically producing firms outweighs the positive effect of firm entry. The negative effect on the low-skilled is short-lived because after the tariff decline, firms on average become more profitable which increases the average firm value and boosts firm entry. With the accumulation of firm entry, which gradually builds to the stock of domestically producing firms, the total demand for low-skilled labor from these domestically producing firms increase, leading to positive outcomes for the low-skilled. In contrast, the high-skilled group see immediate rise in their wage rate accompanied by a sudden decline in unemployment rate simultaneously since the high-skilled workers do not suffer from offshoring competition as they are still hired within the firms that transitioned from domestic production to offshoring. The employment status of the workers within these newly transitioned firms remain the same. Along the intensive margin, offshoring firms hire more of both types of labor on average ($\frac{\tilde{h_V}}{\tilde{h_D}} = (\frac{\tilde{z_D}}{\tilde{z_V}})^{1-\theta}(\frac{\tau\varphi_l^*}{\varphi_l})^{(1-\alpha)(1-\theta)} > 1$), and a decline in tariff τ increases the ratio of high-skilled hired by offshoring firms over the number hired by domestically producing firms. Therefore, even though the total number of firms declines in the short run, the total demand for high-skilled still increases, leading to an increase in wage and lowering of unemployment rate for the high-skilled workers. From the consumption channel, lower price due to the tariff cut increases the variety of goods available to consumers which level up their consumption. As consumption increases, the demand for individual firm's demand go up, increasing the number of labor hired by all firms, which in turn, yields more positive outlook for the labor market. This increase in demand for all firms captures the spillover effect of offshoring. Over time, due to easier offshoring and entry of firms in the more attractive home environment, the number of vacancies firms post increases for both types of workers, increasing the labor market tightness for them, lowering the unemployment rate and increasing the wage rate.

Fixed entry

How does offshoring impact the economy if it does not generate the entry effects? To examine the role of entry in this model, this subsection compares the baseline model (represented by the blue line) with an alternative model in which entry is fixed (represented by the black dashed line). To hold firm entry fixed, I follow Jaef and Lopez (2014) in assuming the sunk cost is convex in the deviations of firm entry from its steady-state level, as is also used by Zlate (2016) : $f_{E,t} = f_E + \pi_f[exp(N_{E,t} - \bar{N_E}) - 1]$, where π_f is set to be very large ($\pi_f = 1,000$). In this fashion, the entry cost becomes a stochastic variable that change instantaneously every period with the number of new firms and the number of offshoring firms. More specifically, when entry rises above the steady state value, the entry cost rises immediately to offset the hike in entry. When entry falls below the steady state level, the entry cost decreases rapidly as well to compensate for such decline in the number of firms entered. As a result, the number of new firms stays virtually constant.

In the previous subsection when analyzing the impulse responses of the low-skilled wage and unemployment, it is clear that entry plays a vital role in generating the positive effect of offshoring on the domestic low-skilled over time. From Fig 2.12, it is noted that entry is the driving force that stimulates the positive effects of offshoring on the low-skilled outcomes as well the persistent effect on the high-skilled over time.

As for the distribution of firms, allowing for endogenous entry yields positive entry as the tariff reduction increases average firm value. Therefore, even though domestically producing firms are hit hard in the initial phase of the trade cost shock, due to positive firm entry, there is a continuing increase in the total number of firms in the home country after the on-impact decline. There is an overshooting pattern in wages and unemployment rates under the fixed entry model.[16] Yet, over time, endogenous entry makes the product market more

[16]In the model with fixed entry, when firms are faced with a decline in trade cost, along the intensive margin, individual firms are able to expand and hire more labor, in the presence of less competition. However, there is also the extensive margin along which both domestically producing firms' and offshoring firms' mass shrink as entry is fixed at the pre-shock level. In the short run, the intensive margin dominates – the average firm hires more labor. Over time, the extensive margin plays a more important role, leading

competitive, exerting upward pressure on labor costs in the case with firm entry. Therefore, the initial low-skilled wage decreases by less in the baseline case with firm entry. Similarly, the on impact increase in high-skilled wage is higher under endogenous entry. Compared to a persistent lowering of wage over time in the fixed entry case, the low-skilled see an extended increase in their wage when endogenous entry is allowed. What's more, rather than an increase in the unemployment rate of the low-skilled labor in the fixed entry case, endogenous entry generates a decline in the low-skilled unemployment rate. The positive effect of tariff decline on the high-skilled labor is more persistent under the baseline model featuring endogenous entry. Endogenous entry makes the wage rate for high-skilled wage higher and unemployment rate lower over time because with entry fixed at the pre-shock level, the total number of firms still fall below the pre-shock level, which leads to a lowering of wage rate and rise in unemployment rate for both types of workers. What's more, without endogenous entry, consumption level would go down as the increase in the number of offshoring firms is dampened compared to the baseline model and so is the total number of firms, providing fewer varieties for consumers.

Fixed offshoring cutoff

The way I hold offshoring cutoff fixed is very similar to holding entry fixed as described in the previous subsection: $f_{v,t} = f_v + \pi_f[exp(N_{v,t} - \bar{N_v}) - 1]$ and $(\pi_f = 1,000)$. When the extensive margin of offshoring is shut down, entry is subdued. However, since the endogenous entry channel is still operating, a negative trade cost shock still generates positive labor market outcome for both the low-skilled workers and the high-skilled workers. The effects on wages, skill premium unemployment and consumption are dampened over time compared to the baseline model. Fig.2.13 plots the comparison between baseline model and the model with fixed offshoring cutoff.

Table 3 shows a comparison of the percentage changes between steady states of key labor

---

to the overshooting pattern.

market and aggregate variables among models with different specifications. Table 4 presents the results of the baseline model as well as the results in Goel (2017), which does not feature search and matching unemployment. Therefore, the results for unemployment in the baseline model are changed to employment to offer a comparison with that paper.

Search and matching

To examine the role of search and matching unemployment in the model, this subsection compares the impulse responses under the baseline model with the model without unemployment. Except for the existence of unemployment, the main difference is the way firms make their production location decision, one intertemporal due to the intertemporal hiring decision and the other simply per period static. Regarding the labor market outcomes, the major difference between the baseline model and the model without unemployment lies in the low-skilled group. Without search and matching unemployment, the model generates a definite and large decline in the low-skilled wage, both on impact and along the transitional path, thus a lowering of wage gap, as shown in 2.14. Incorporating search and matching unemployment into the model introduces an additional layer of friction to firms' decisions of offshoring as well as hiring. Along the extensive margin, there is now a larger decline in the total mass of firms, with productivity cutoff also lowered by less, yielding a dampened increase in the number of offshoring firms. Yet, the friction of unemployment leads to a higher rise in firm entry since firms now make intertemporal offshoring decisions based on the expected present discounted value of future profits, which is higher than the per period profit of offshoring, generating a higher average firm value following a reduction of trade cost. Firm entry now also takes into account the labor market conditions including labor market tightness, which gives firms more information in forming their entry decisions. Higher average firm value stimulates more entry of firms.

Role of labor market rigidity Comparing the baseline results with the scenario where labor market rigidity for low-skilled labor is lower gives us insights into the role of labor market rigidity in shaping the labor market adjustment under the low-skilled task offshoring environment. As shown in Fig.2.15, Lower labor market rigidity for low-skilled search and match speeds up the adjustment of wage and unemployment and improves the outlook for both types of workers. In another note, labor market frictions do slow down labor market adjustment following the China shock, just as conjectured in Autor et al. (2016). However, on the aggregate level, the effects of the shock on the labor market are still positive for both the high-skilled and low-skilled labor, even in the presence of labor market frictions.

Destination country characteristics

The impact of reductions in trade costs on the rise in the skill premium and the lowering of unemployment rates implied by the model varies systematically with country characteristics. The effects are larger when destination countries are even more low-skilled labor abundant than the baseline case. Fig.2.16 shows that under the case where the foreign country is endowed with larger amount of low-skilled labor, low-skilled unemployment in the home country drops by substantially more whereas wage gap and high-skilled unemployment experience much smaller changes.

Sensitivity Analysis

Fig.2.17 assesses the sensitivity of the results to tariff shocks of different size (I consider tariff shocks of size equal to 10, 30, and 60 percent). The short-run responses of unemployment rates and wage gap are essentially monotonic in the size of the shock, implying that the positive wage and unemployment effects are the larger the tariff declines.

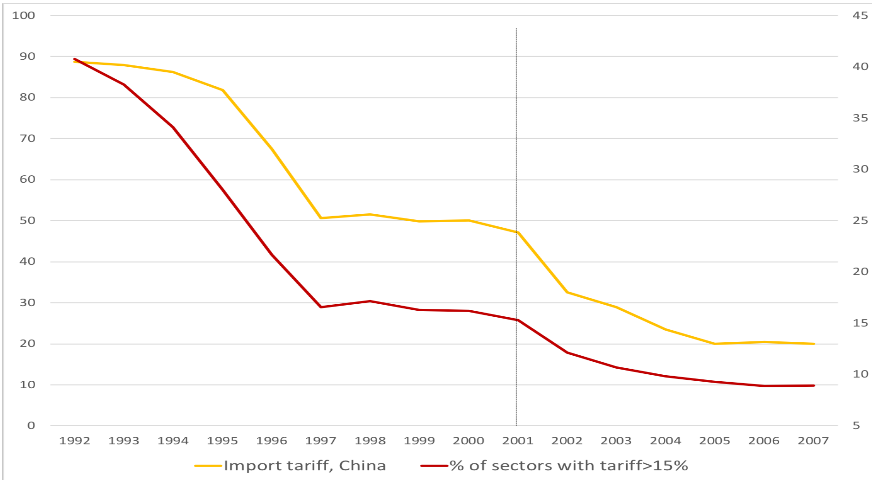
Instead of a decline in trade cost τ, I also examine the impact of a fall in fixed offshoring cost f_V. The main difference is that low-skilled unemployment exhibits larger and longer increase and smaller decrease over time.

2.7 Conclusion

This paper examines the effect of offshoring motivated by lower production costs on the unemployment rates and wage inequality across high-skilled and low-skilled U.S. workers from a dynamic perspective in a model with heterogeneous firms, firms' endogenous decisions of entry offshoring. Besides the conventional substitution effect and scale effect in the literature, it identifies and evaluates the endogenous entry effect. That is, a rise in offshoring to low-wage countries induces more entry and more hiring by firms, which generates increase in wages and decline in unemployment rates for both high-skilled and low-skilled labor, as shown by the empirical evidence. The mechanism of positive labor market effects arises from the link between endogenous firm entry, firms' offshoring and hiring decisions.

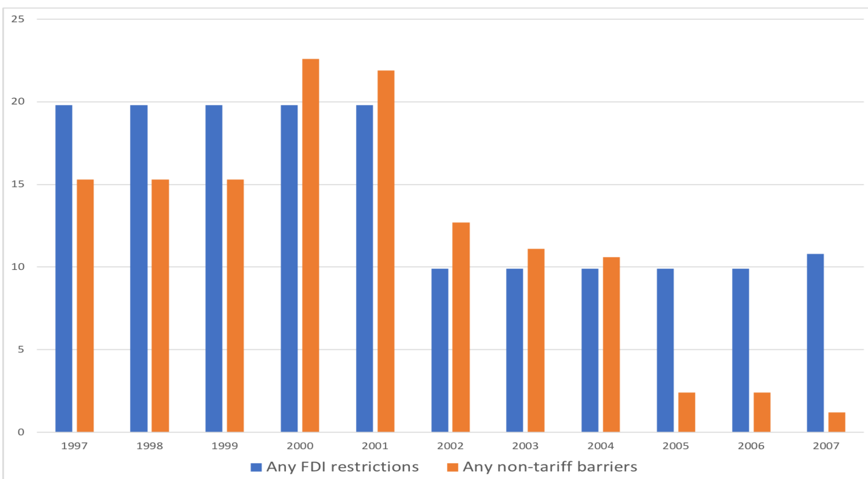
The findings in this paper has important policy implications. The positive effects of offshoring on the labor market for workers regardless of skill levels suggest that more trade frictions designed to restrict offshoring is likely to hinder firm entry, which is a key driver that contributes to a better labor market outlook for all over time. Apart from the labor market variables, aggregate consumption and output also experience increase. What's more, larger labor market frictions can have discouraging effects on firms' decision to enter and to offshore (extensive margin), as well as to hire labor (intensive margin). Product market reform such as lowering the regulation costs also has potential positive impact on the economy under the offshoring context. When firm entry is low, policy makers should take into account the resulting negative impact on the low-skilled wage and unemployment and the entry-inducing effect of offshoring.

The two-country model framework proposed here also allows for the study of business cycle characteristics of task offshoring that distinguishes between different skill levels of workers. It can also be extended to study the spillover effects of a shock from the trading partner.



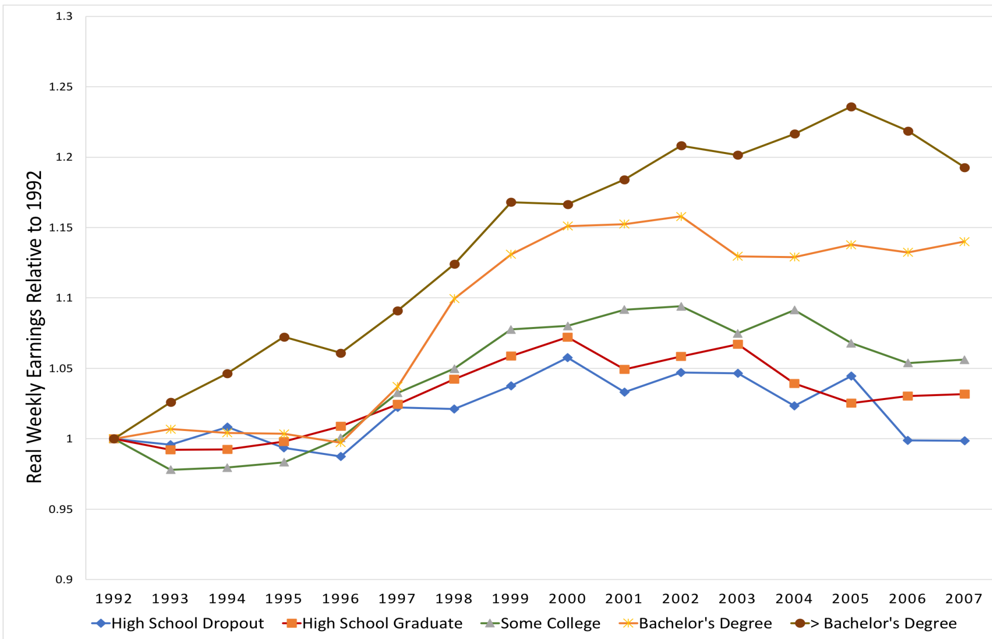
Source: Brandt et al. (2017).

Figure 2.2: China's import tariff and fraction of sectors subject to high tariffs.



Source: Brandt et al. (2017).

Figure 2.3: Fraction of sectors subject to FDI restrictions and non-tariff barriers.



Source: Autor (2014)

Figure 2.4: Real weekly earnings relative to 1992 according to educational attainment.

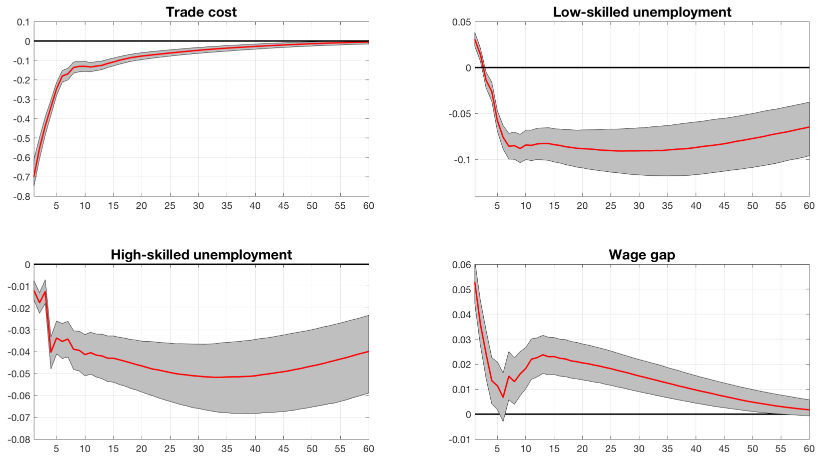


Figure 2.5: Monthly VAR, one-standard deviation decrease in *China's import tariff*. Tariff rate is annualized.

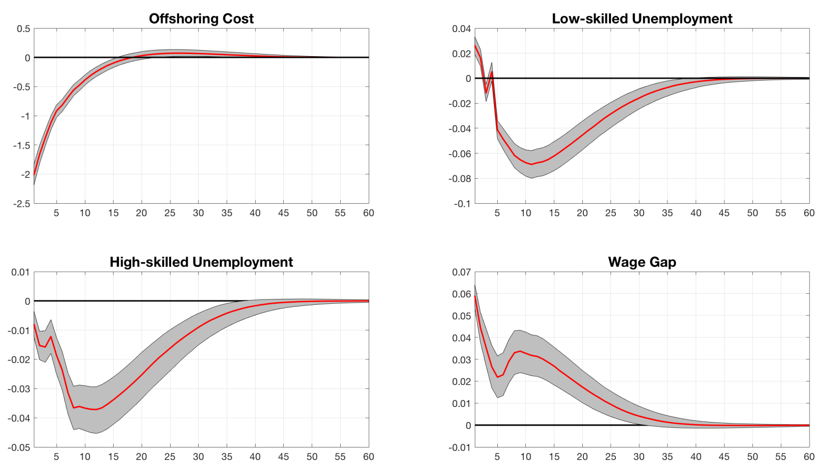


Figure 2.6: Monthly VAR, one-standard deviation decrease in *FDI restrictions*. Tariff rate is annualized.

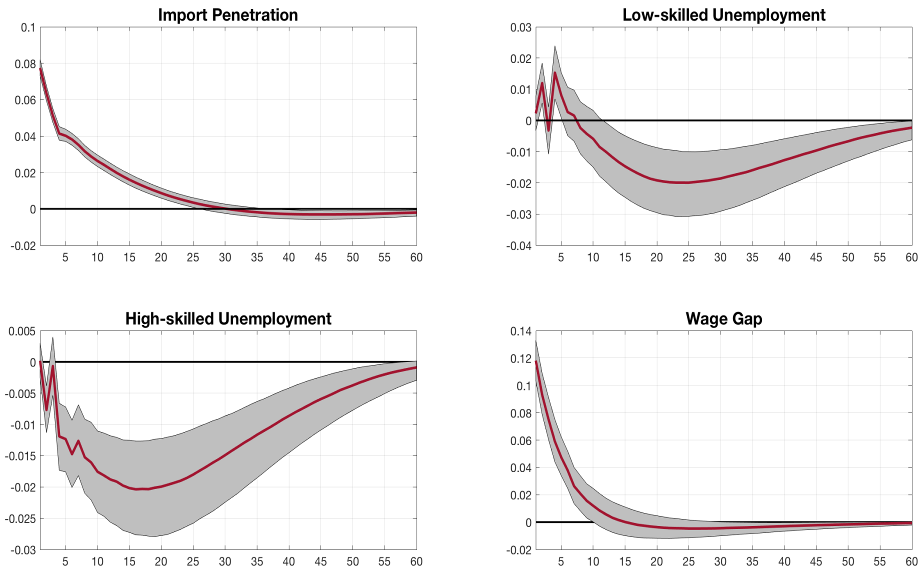


Figure 2.7: Monthly VAR, one-standard deviation increase in *import penetration* from China. Import penetration is annualized.

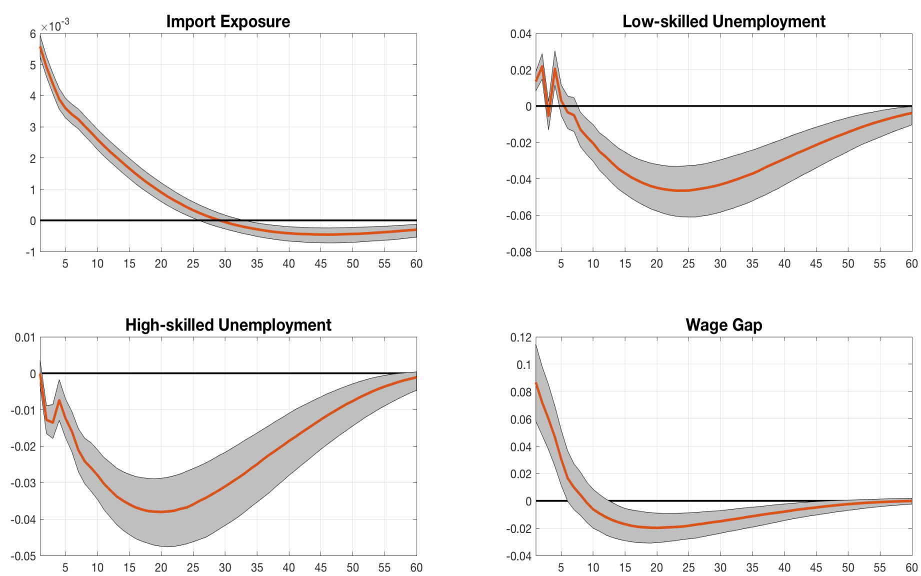


Figure 2.8: Monthly VAR, one-standard deviation decrease in US *import exposure* from China. Import exposure is annualized.

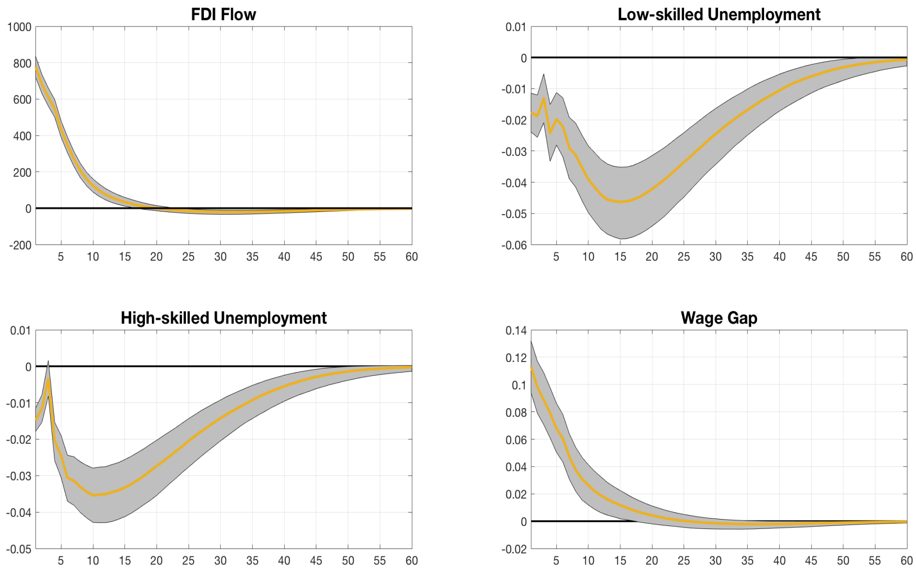


Figure 2.9: Monthly VAR, one-standard deviation increase in *FDI flows from US to China*.

Model equations, foreign country

$$1+\pi B_{S,t+1}=\beta^{*}\left(1+r_{t+1}^{*}\right)E_{t}\left[\left(\frac{C_{t+1}^{*}}{C_{t}^{*}}\right)^{-\gamma}\right]$$

$$\tilde{e_{t}^{*}}=\beta^{*}\left(1-\delta\right)E_{t}\left[\left(\frac{C_{t+1}^{*}}{C_{t}^{*}}\right)^{-\gamma}\left(\tilde{e^{*}}_{t+1}+\tilde{d^{*}}_{t+1}\right)\right]$$

$$N_{t+1}^{*}=\left(1-\delta\right)\left(N_{t}^{*}+N_{E,t}^{*}\right)$$

$$1=N_{t}^{*}(\tilde{\rho_{D,t}^{*}})^{1-\theta}$$

$$\tilde{e_{t}^{*}}=\tilde{f_{e}^{*}}$$

$$(1-u_{l}^{*})\bar{L^{*}}=\tau^{1-\alpha}\tilde{\rho_{V,t}}^{-\theta}Y_{t}^{l^{*}}\left(\tilde{z_{V,t}}Z\right)^{-1}\left(\frac{\alpha\varphi_{t}^{l^{*}}}{(1-\alpha)\varphi_{t}^{h}}\right)^{1-\alpha}N_{V,t}+\tilde{\rho_{t}^{*}}^{-\theta}Y_{t}^{l^{*}}\left(\tilde{z_{t}^{*}}Z^{*}\right)^{-1}\left(\frac{\alpha\varphi_{t}^{l^{*}}}{(1-\alpha)\varphi_{t}^{h^{*}}}\right)^{-\alpha}N_{t}^{*}$$

$$(1-u_{h}^{*})\bar{H^{*}}=\tilde{\rho_{t}^{*}}^{-\theta}Y_{t}^{h^{*}}\left(\tilde{z_{t}^{*}}Z^{*}\right)^{-1}\left(\frac{\alpha\varphi_{t}^{l^{*}}}{(1-\alpha)\varphi_{t}^{h^{*}}}\right)^{1-\alpha}N_{t}^{*}$$

$$\varphi_{z,t}^{l^{*}}=w_{t}^{l^{*}}+\frac{\kappa^{l^{*}}}{q_{t}^{l^{*}}}-\left(1-\delta\right)\left(1-\lambda\right)E_{t}\left(\beta_{t,t+1}\frac{\kappa^{l^{*}}}{q_{t+1}^{l^{*}}}\right)$$

$$\varphi_{z,t}^{h^{*}}=w_{t}^{h^{*}}+\frac{\kappa^{h^{*}}}{q_{t-1}^{h^{*}}}-\left(1-\delta\right)\left(1-\lambda\right)E_{t}\left(\beta_{t,t+1}\frac{\kappa^{h^{*}}}{q_{t}^{h^{*}}}\right)$$

Table 2.1: Model equations, home country

$1+\pi B_{N,t+1}=\beta\left(1+r_{t+1}\right)E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\right]$
$\tilde{e}_t=\beta\left(1-\delta\right)E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\left(\tilde{e}_{t+1}+\tilde{d}_{t+1}\right)\right]$
$N_{t+1}=\left(1-\delta\right)\left(N_t+N_{E,t}\right)$
$1=N_{D,t}(\tilde{\rho_{D,t}})^{1-\theta}+N_{v,t}(\tilde{\rho_{v,t}})^{1-\theta}$
$\tilde{e}_t=f_e$
$(1-u_l)\bar{L}=\tilde{\rho_{D,t}}^{-\theta}Y_t^l\left(\tilde{z_{D,t}}Z\right)^{-1}\left(\frac{\alpha\varphi_t^l}{(1-\alpha)\varphi_t^h}\right)^{-\alpha}N_{D,t}$
$(1-u_h)\bar{H}=\tilde{\rho_{D,t}}^{-\theta}Y_t^h\left(\tilde{z_{D,t}}Z\right)^{-1}\left(\frac{\alpha\varphi_t^l}{(1-\alpha)\varphi_t^h}\right)^{1-\alpha}N_{D,t}+\tau^{1-\alpha}\tilde{\rho_{V,t}}^{-\theta}Y_t^h\left(\tilde{z_{V,t}}Z\right)^{-1}\left(\frac{\alpha\varphi_t^{l*}}{(1-\alpha)\varphi_t^h}\right)^{1-\alpha}N_{V,t}$
$\varphi_{z,t}^l=w_{l,t}+\frac{\kappa^l}{q_t^l}-\left(1-\delta\right)\left(1-\lambda\right)E_t\left(\beta_{t,t+1}\frac{\kappa^l}{q_{t+1}^l}\right)$
$\varphi_{z,t}^h=w_{h,t}+\frac{\kappa^h}{q_{t-1}^h}-\left(1-\delta\right)\left(1-\lambda\right)E_t\left(\beta_{t,t+1}\frac{\kappa^h}{q_t^h}\right)$
$N_t\tilde{d}_t=N_{D,t}\tilde{d_{D,t}}+N_{v,t}\tilde{d_{v,t}}$
$N_t=N_{D,t}+N_{v,t}$
$\tilde{z_{D,t}}=\xi z_{min}z_{v,t}\left(\frac{z_{v,t}^{k-(\theta-1)}-z_{min}^{k-(\theta-1)}}{z_{v,t}^k-z_{min}^k}\right)^{\frac{1}{\theta-1}}$
$\tilde{z_{v,t}}=\xi z_{min}\left(\frac{N_t}{N_{v,t}}\right)^{\frac{1}{k}}$
$d_{D,t}(z_{V,t})=d_{V,t}(z_{V,t})$

Table 2.2: Calibration Parameters

	Parameter	Value	Source:
Risk aversion	γ	2	Literature
Discount factor	β	0.99	Literature
Firm exit rate	δ	0.025	Literature
Variety elasticity of substitution	θ	3.8	Literature
Bargaining power	η	0.6	Literature
Matching elasticity	ϵ	0.6	Literature
Matching efficiency	χ	0.6	Literature
Exogenous Separation	λ	0.026	Literature
Unemployment benefit	u_b	0.02	Data
Unemployment benefit(*)	u_b^*	0.015	Data
Regulation cost ratio	$\frac{f_r}{f_r^*}$	0.5	Data
Factor proportion	$\frac{H}{L}$	0.44	Data
Low-skilled labor ratio	$\frac{L^*}{L}$	8.16	Data

Table 2.3: Comparison of baseline and alternative models

	Baseline	Low VFDI	Fixed entry	Fixed ext.margins (entry, cutoff)	Fixed cutoff
% change between non-stochastic steady states					
Low-skilled unemployment	-2.0	-1.4	2.1	1.5	-1.8
High-skilled unemployment	-1.5	-1.6	0.8	0.7	-1.2
Total unemployment	-1.8	-1.5	1.5	0.1	-1.5
Low-skilled wage	16.2	11.2	-17.5	-12.2	14.0
High-skilled wage	19	18.2	-9.5	-9.1	15.2
Skill premium	4.9	3.9	-1.8	-2.2	4.0
Output	21	16	-37	-25	19
Consumption	12.6	12.4	-10.8	-10	9.8

Table 2.4: Comparison with other papers

	Baseline	Goel(2017)
% change between non-stochastic steady states		
Low-skilled employment	2	-8
High-skilled unemployment	1.5	8
Total unemployment	1.8	-3
Low-skilled wage	16.2	24
High-skilled wage	19	44
Skill premium	4.9	16
Output	21	62
Consumption	12.6	34

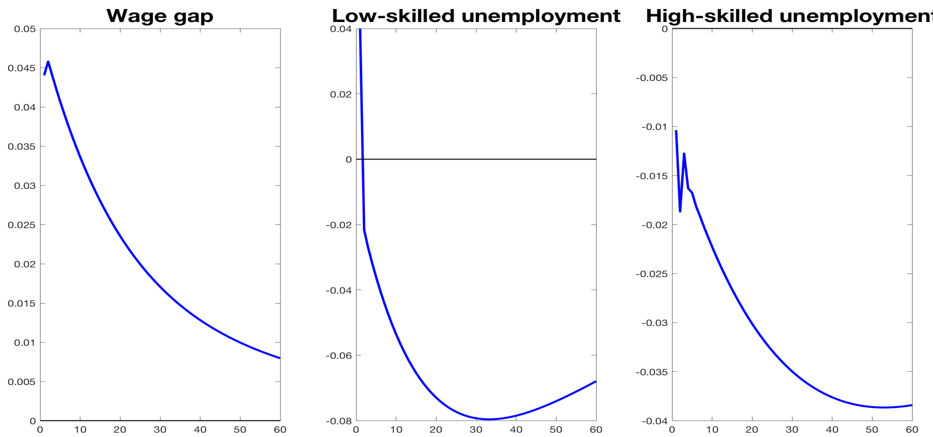


Figure 2.10: Impulse response functions of wage gap and unemployment rates following a negative trade cost shock.

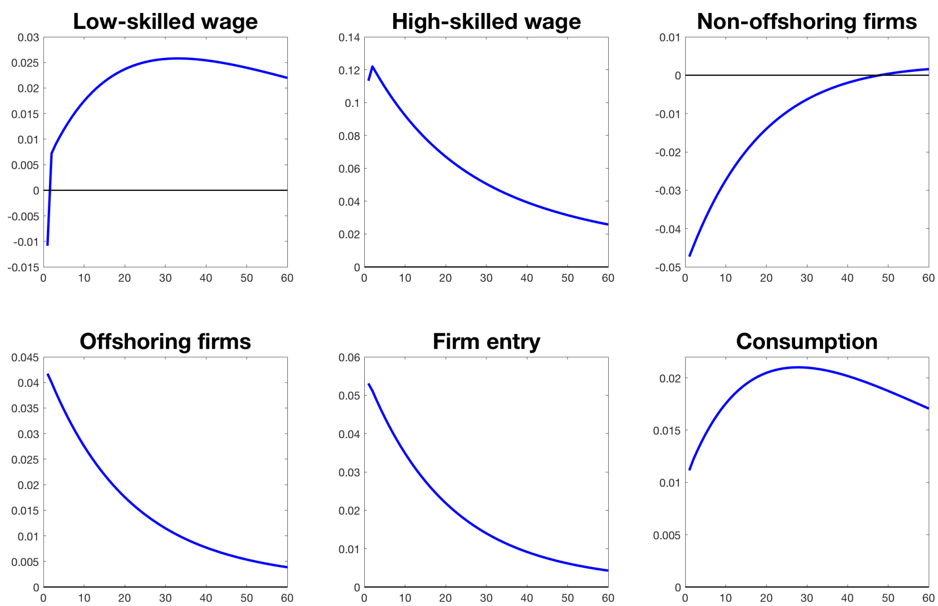
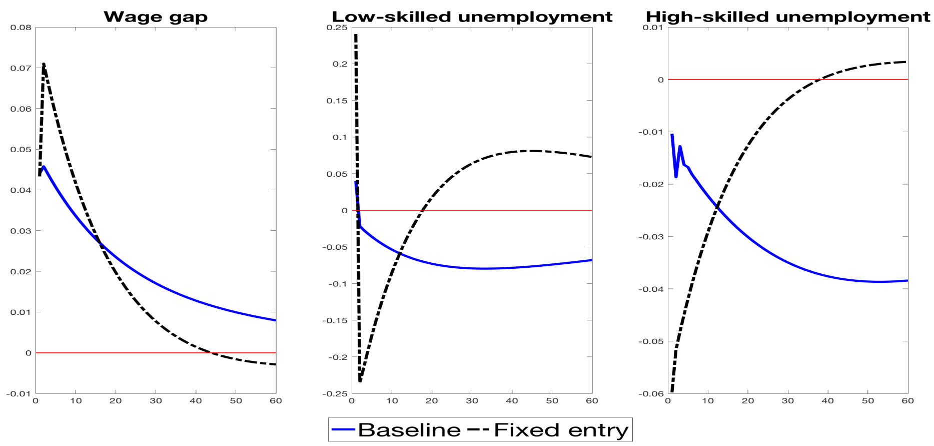
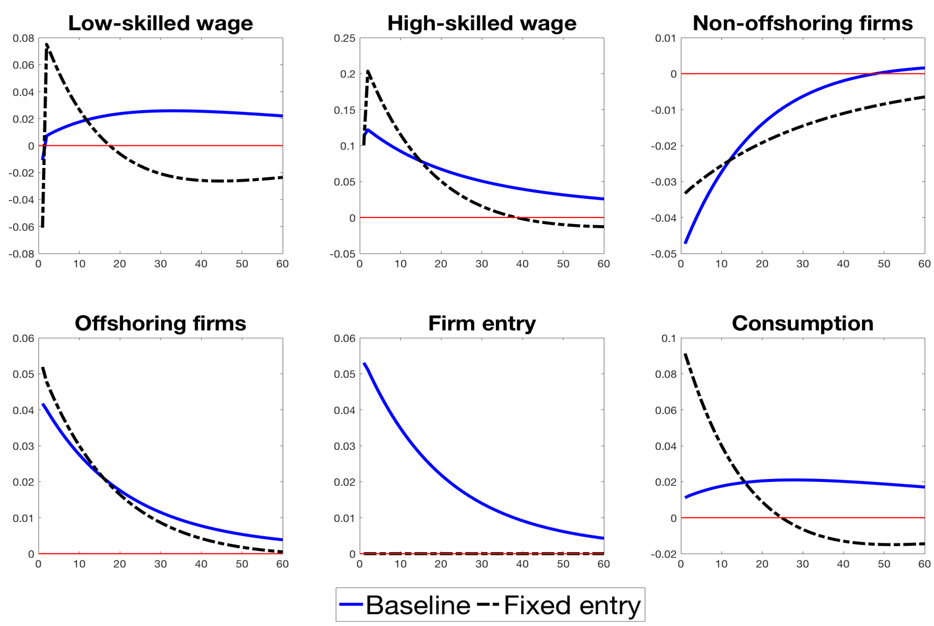


Figure 2.11: Impulse response functions of other variables in the home country following a negative trade cost shock.



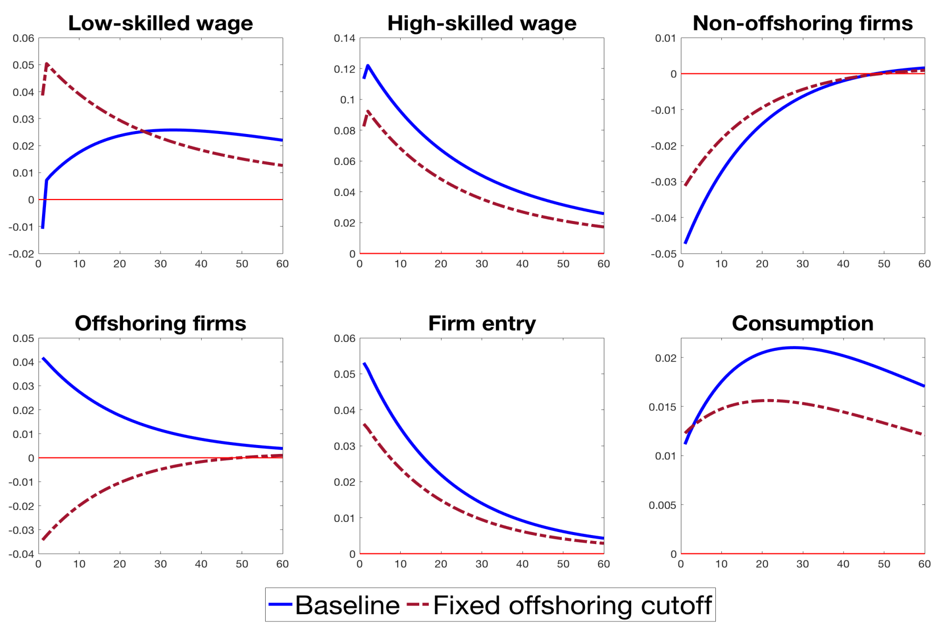
(a) This figure compares the impulse responses of wage gap and unemployment rates under baseline with the model where entry is fixed at the steady state level.



(b) IRFs of other variables under baseline vs fixed entry.

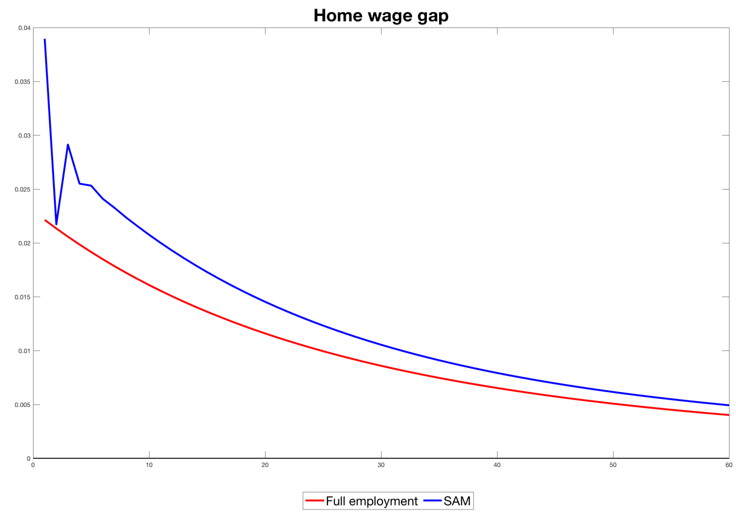
Figure 2.12: Baseline vs Fixed entry

(a) This figure compares the impulse responses of wage gap and unemployment rates under baseline with the scenario where offshoring cutoff is fixed at the steady state level.

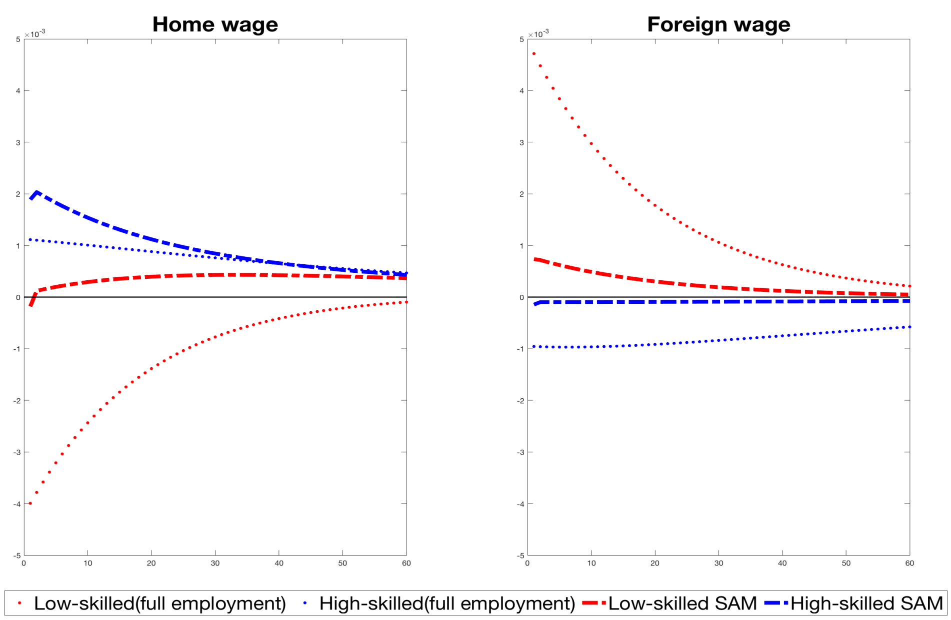


(b) IRFs of other variables under baseline vs fixed offshoring cutoff.

Figure 2.13: Baseline vs Fixed offshoring cutoff

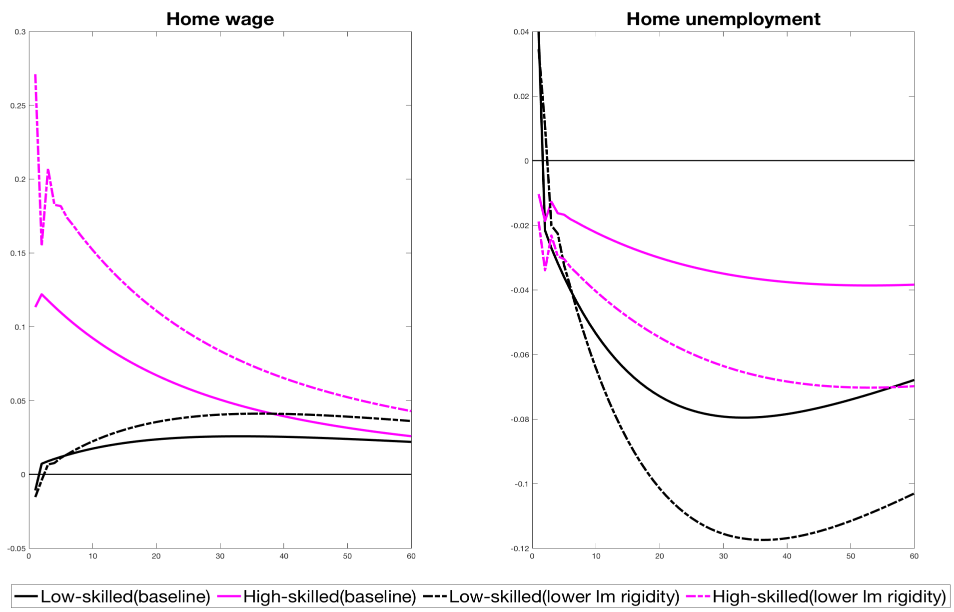


(a) This figure compares wage gap in the baseline model represented by the blue line, with one which does not feature search and matching frictions, represented by the red line.



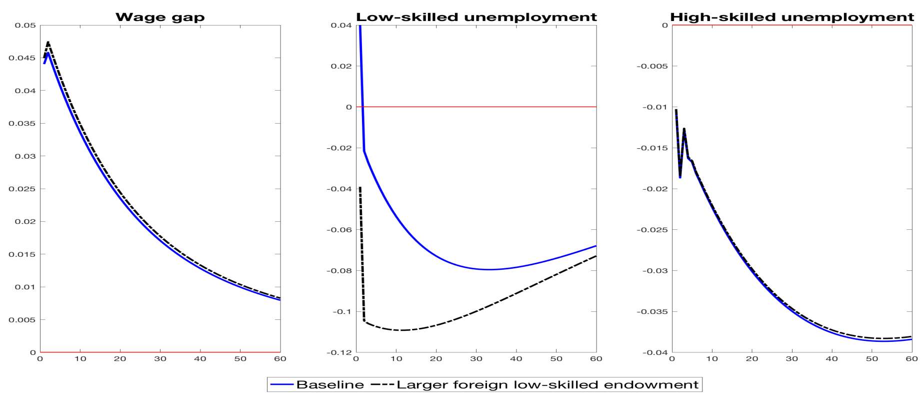
(b) IRFs of wages and unemployment rates for low-skilled and high-skilled workers in H and F following a negative trade cost shock in the benchmark case versus in a model with full employment. Red line represents variables associated with low-skilled workers and blue line corresponds to those of high-skilled workers. Dashed line– benchmark case. Dotted line – the model with full employment.

Figure 2.14: Benchmark model vs Model with full employment



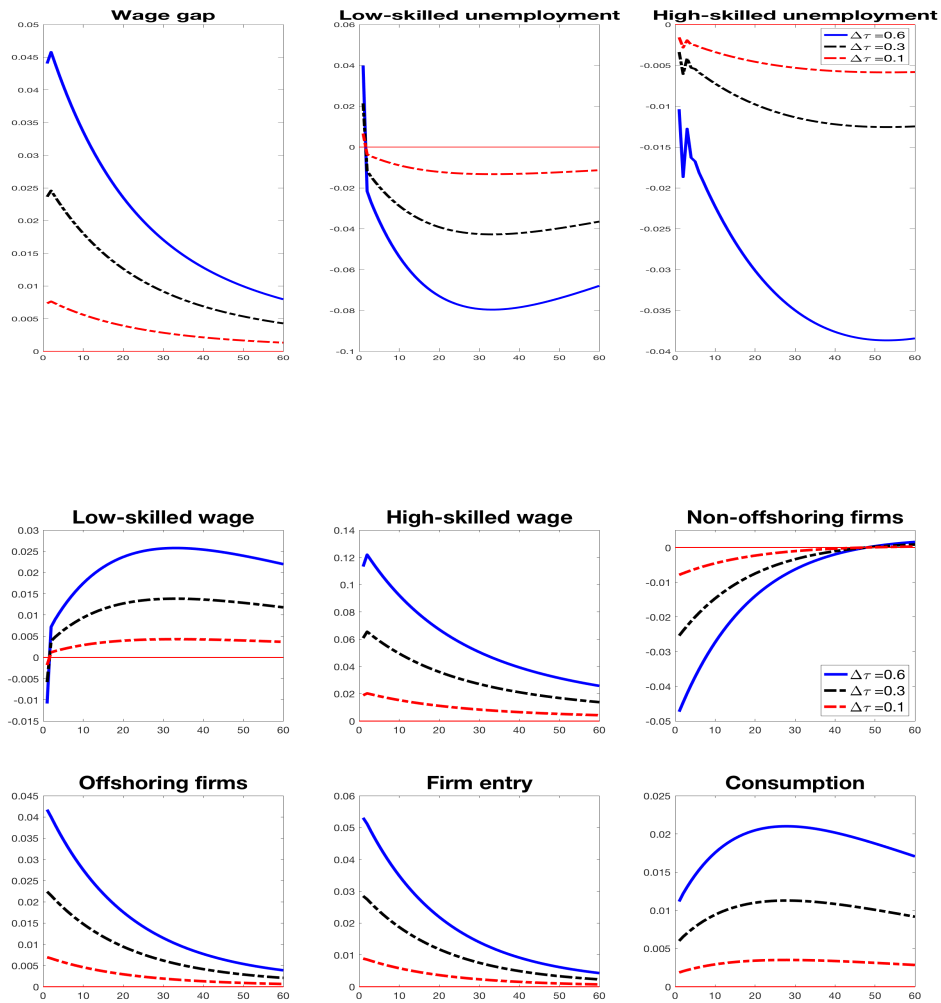
Impulse response functions of wages and unemployment rates following a negative trade cost shock in the benchmark case (solid line) versus the case where labor market rigidity is lower captured by lower cost of posting vacancies(dashed line). Black line represents variables associated with the low-skilled workers and purple line corresponds to those of the high-skilled workers.

Figure 2.15: Benchmark model vs Model with lower labor market rigidity



Impulse response functions of wage gap and unemployment rates for both types of workers following a negative trade cost shock in the benchmark case (blue line) versus the case where the foreign low-skilled labor endowment is more abundant than the baseline case(black line).

Figure 2.16: Benchmark modelvs Model where foreign low-skilled labor endowment is more abundant than benchmark



Responses to a temporary increase in Home tariffs, shocks of different sizes (10, 30, and 60percent). Responses are in percentage deviations from the steady state.

Figure 2.17: Responses to a temporary increase in Home tariffs, shocks of different sizes.

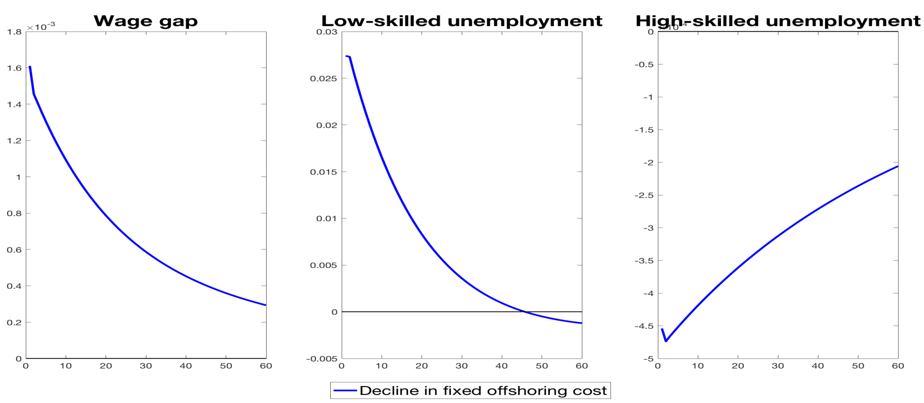


Figure 2.18: Responses of a reduction in fixed offshoring cost.

Chapter 3

TRADE, MIGRATION, AND INEQUALITY: AN ANALYSIS OF CHINA

3.1 Introduction

In the early 2000s, there were two policies in China that left far-reaching effects on both of its domestic economy and the global economy. First is China's profound trade liberalization, which culminated with its WTO accession in 2001 and has been linked with large employment changes around the world. [1] Second is the easing of migration restrictions, which generated an internal migration with a size of perhaps the largest flow of migration recorded in world history. However, the study of Chinese labor market's responses to trade liberalization is a relatively less explored topic. Moreover, little work has been done, examining the impact of China's expansion of both international trade and internal migration on Chinese local labor market. This paper aims to bridge this gap by investigating these three questions: How does China's trade liberalization affect its own wage inequality? What role does rural to urban migration play in China's skill premium and rural-urban inequality? How does China's domestic labor market reform regarding migration policy interact with its trade liberalization policies in shaping China's export growth and inequality?

In exploring these questions, this paper uses a two-country dynamic general equilibrium model with internal labor migration within country to study the adjustments of wage inequality in response to trade liberalization and migration cost reduction. The combination of these two policies, one aiming at promoting international trade openness, the other targeting at internal labor market reform that mobilizes labor across regions, contributed to huge

[1] According to International Labour Organization, the flow of workers across regions within China represents one of the most extensive migration in human history. In 2015 a total of 277.5 million migrant workers (36% of the total workforce of 770 million) existed in China.

growth in China's exports and productivity. It also has large impacts on wage inequality across workers in various scopes: skill premium at the aggregate level, skill premium within the rural area and that within the rural area, as well as urban to rural wage inequality. This paper looks into changes of these three different measures of wage inequality in China and examines the channels through which increasing trade openness and labor mobility interact and affect these wage inequality measures.

On the migration policy side, in 1958, China established a household registration system known as the *hukou* system to control population mobility. Each Chinese citizen is assigned a *hukou* (registration status), classified as "non-agricultural (urban)" or "agricultural (rural)" in one's local administrative unit. In order to change the status of *hukou,* individuals need to get approvals from local governments, which are extremely difficult to obtain. The prohibition of working outside one's *hukou* location or category was prohibited was relaxed in the 1980s but, prior to 2003, workers without local *hukou* still had to apply for a temporary residence permit. It was however, still very difficult to get. In sum, before the early 2000s, barriers and frictions imposed on migration across regions within China remained immensely high. Starting early 2000s, the demand for migrant workers in labor-intensive industries hiked with China's productivity growth and export surge. As a consequence, many provinces eliminated the requirement of temporary residence permit for migrant workers after 2003. There was also a nationwide reform in that same year that accelerated the process for getting a temporary residence permit in other provinces. These policy changes greatly reduced the barriers faced by migrant workers and spawned large migration flows from the rural area to the urban area and also from lower-paid poorer regions to more developed, industrialized and open regions. Tombe and Zhu (2019)estimates that between 2000 and 2005, migration costs did indeed decline by 29 percent on average. Despite the reforms, the costs of being a migrant worker remain high because of limited access to local public services, health care and educational system.

Motivated by these stylized facts, the paper employs a two-country dynamic model featuring internal migration from the rural area to the urban area. The model consists of two countries, Home (H) and Foreign (F). Home is interpreted as China and Foreign can be one of its trade partner. The non-agricultural sector which is housed in the urban area is more skill-intensive than the agricultural sector in the rural area. In the home country, the rural area is endowed with unskilled workers $\bar{L}_{ag,t}$ and skilled workers $\bar{S}_{ag,t}$, whereas the urban area is endowed with $\bar{L}_{na,t}$ unskilled workers and skilled workers $\bar{S}_{na,t}$. Workers with rural *hukou* draw idiosyncratic migration cost and self select into working in the city, which is motivated by China's huge flow of rural to urban migration. There are two sectors of production. The rural area produces agricultural goods while the urban area produces non-agricultural goods. The agricultural goods are consumed by domestic household and are thus non-tradable. The non-agricultural goods are tradable – they are consumed both domestically and exported to the foreign country.

The model is calibrated to match with changes in migration cost, trade cost and productivity increase in the tradable sector and analyzes the impulse responses of different measures of wage inequality and other variables in the home and foreign country in responses to these shocks. The findings of the paper show that migration cost reduction is associated with a fall in urban to rural wage inequality but widening of skill premium in both agricultural sector and non-agricultural sector , as well as in the aggregate level. However, negative trade cost shock and positive productivity shock in the tradable sector each leads to increase in all three measures of wage inequality. The results are consistent with the findings of Li et al. (2013) which show that wage inequality increased post 2000.

The mechanisms driving the changes in wage inequality are rather different across different shocks. First, migration cost reduction affects variables by changing the relative payoffs across sectors, without directly impacting the demand side like productivity. It increases migration cost cutoff for both unskilled and skilled rural workers. Unskilled workers' wage in the non-agricultural sector $w^l_{na,t}$ goes down as there are more unskilled workers working the urban non-agricultural sector. Increase of unskilled migration exceeds that of skilled migration. Price of domestic non-agricultural good decreases due to lower cost of production, giving rise to more exports. On the contrary, both skilled and unskilled wage in the rural area increases due to a lower level of total labor remaining there. Urban to rural wage inequality decreases as urban wages fall relative to rural wages. However, skill premium in both the urban area and the rural area, as well as the aggregate level increase. This is consistent with Feenstra (2011), which states that the rural-urban migration might be a key factor driving the export-led growth in Chinese cities. It infers that this migration keeps wage growth suppressed and allows China to maintain its comparative advantage in the non-agricultural sector (e.g. manufacturing).

Second, trade cost reduction affects variables by lowering the price of home exports and thus boosting demand for home non-agricultural exports. As the demand for labor in the non-agricultural sector builds up, wages of skilled and unskilled workers in that sector climb up too. Therefore, migration cost cutoffs increase, generating larger migration flow into the non-agricultural sector. Meanwhile, with diminished labor supply in the agricultural sector, skilled and unskilled wage in the rural area also go up, putting upward pressure on the price of agricultural good as well. Thus, wages of skilled and unskilled workers in both the urban area and the rural area increase. Urban to rural wage inequality expands because wage increments in the urban area more than offsets that in the rural area. Sectoral skill premium and country-level skill premium widen.

Third, a positive non-agricultural sector productivity shock increases migration cutoffs for rural skilled and unskilled workers through increasing wages in the non-agricultural sector, making migration more rewarding. All three measures of wage inequality rises. Urban-rural wage gap broadens because productivity growth in the urban area boosts the relative wages compared to the rural area. Skill premium in the sector level and aggregate level all go up. Productivity growth in the non-agricultural sector lowers the marginal cost of production, tapering price of the non-agricultural good produced at home. Meanwhile, it contracts the agricultural sector, leading to less demand of labor in production of the agricultural good and thus a downward pressure on wages in the agricultural sector.

3.1.1 Related Literature

My paper contributes to two broad literature.

First, my paper also contributes to the recent international macroeconomics literature that study labor migration. In the context of DSGE models, examples include Mandelman and Zlate (2012), Mandelman and Zlate (2016) and Lechthaler and Mileva (2019). My work is closely related to Lechthaler and Mileva (2019), which develops a dynamic version of Bernard et al. (2007) along the line of Ghironi and Melitz (2005) and adds low-skilled workers training to become high-skilled workers and labor adjustment costs across sectors to study the effect of trade liberalization on wage inequality. While Lechthaler and Mileva (2019) features labor mobility between two sectors, they do not study the effect of migration cost reduction on wage inequality, which is a key focus of my paper. This paper is closely related to Mandelman and Zlate (2016), which examines the macroeconomic effects of border enforcement and the transmission of aggregate shocks across countries in the presence of labor migration and remittances using a two-country business cycle model. My paper studies internal migration rather than immigration across borders and focuses on the interaction between internal migration and trade liberalization on wage inequality.

Second, although there has been a growing literature that examines the impact of the China shock, most of them focus on the labor market effects on developed countries. Papers studying the effects of the China shock on the U.S. labor market include Asquith et al. (2019), Autor et al. (2013), Autor et al. (2016), Feenstra et al. (2019),Pierce and Schott (2016). Hummels et al. (2014) quantifies the impact of firms' offshoring to China on Danish workers' wages. Cabral et al. (2018) looks at the Portuguese labor market's responses to competing with Chinese imports. Rodriguez-Lopez and Yu (2017) investigates Chinese firm-level employment changes following China's trade liberalization. However, it does not feature migration and thus abstract from the role of migration on trade and labor market adjustment.

My paper is also related to the literature linking international trade and internal migration. For instance, Dix-Carneiro and Kovak (2015) finds support of the amplifying role of interregional migration on trade liberalization's effects on the slow path of Brazilian local labor market adjustment. Some examples of empirical papers investigating trade's effect on internal migration include Aguayo-Tellez et al. (2010), Hering and Paillacar (2016) and Morten and Oliveira (2018) for Brazil, and McCaig and Pavcnik (2018) for Vietnam.

3.2 Theoretical Model

The model consists of two countries, Home (H) and Foreign (F). The non-agricultural sector which is housed in the urban area is more skill-intensive than the agricultural sector in the rural area. In the home country, the rural area is endowed with unskilled workers $\bar{L}_{ag,t}$ and skilled workers $\bar{S}_{ag,t}$, whereas the urban area is endowed with $\bar{L}_{na,t}$ unskilled workers and skilled workers $\bar{S}_{na,t}$. There is one way migration occurring in the home country: workers with rural *hukou* draw idiosyncratic migration cost and self select into working in the city, which is motivated by China's huge flow of rural to urban migration. There are two sectors of production. The rural area produces agricultural goods while the urban area produces non-agricultural goods. [2] The agricultural goods are consumed by domestic household and are thus non-tradable. The non-agricultural goods are tradable – they are consumed both domestically and abroad. The foreign economy is symmetric with the exception that there is no migration modeled.

3.2.1 Production, trade and goods prices

There are two areas in the economy: the rural area and the urban area . There are two sectors: the agricultural sector and the non-agricultural sector. The former is housed in the rural area and the latter is in the urban area.[3]

[2] See, e.g., Tombe and Zhu (2019).

[3] Such production structure follows Tombe and Zhu (2019).

Home output

Production of both the agricultural and non-agricultural goods $Y_{ag,t}$ and $Y_{na,t}$ require both skilled and unskilled labor working in those two sectors. The output of each sector is $Y_{j,t} = Z_{j,t}[S_{j,t}]^{\eta_j}[L_{j,t}]^{1-\eta_j}$, where $j = ag, na$. $S_{j,t}$ is total skilled labor in sector j, $L_{j,t}$ is total unskilled labor in sector j, $Z_{j,t}$ is sector-specific productivity. η_j is the sector specific cost share of skilled labor, and more specifically, production of the non-agricultural good is more skill-intensive than the agricultural good: $\eta_{na} > \eta_{ag}$. Since there is no heterogeneity in worker productivity within one type of labor, all unskilled workers are paid the same wage $w^l_{j,t}$ and all skilled workers are paid $w^s_{j,t}$ in the same sector j.

Relative labor demand can be described by the following condition:

$$\frac{w^s_{j,t}}{w^l_{j,t}} = \frac{\eta_j}{1-\eta_j}\frac{L_{j,t}}{S_{j,t}},$$

which indicates that relative demand for labor is independent of sectoral productivity and is solely determined by the relative wages paid in that sector. The condition implies that the ratio of the skilled real wage to the unskilled real wage in sector j is equal to the ratio of the marginal contribution of each type of labor input into producing one extra unit of output.

Urban area tradable sector

The urban area produces non-agricultural industrialized goods, which are tradable. Production of the non-agricultural goods takes the form of $Y_{na,t} = Z_{na,t}[S_{na,t}]^{\beta_{na}}[L_{na,t}]^{1-\beta_{na}}$. The price for non-agricultural goods produced at home is equal to marginal cost of production, $p_{na,t} = \frac{\left(w^s_{na,t}\right)^{\beta_{na}}\left(w^l_{na,t}\right)^{\beta_{na}}}{Z_{na,t}}$, where $w^s_{na,t}$ is the real wage paid for skilled workers and $w^l_{na,t}$ is the real wage paid for unskilled workers in the agricultural sector.

The home non-agricultural good is used both domestically and abroad: $Y_{na,t} = Y_{na,h,t} + Y^*_{na,h,t}$, where $Y_{na,h,t}$ denotes the domestic use of the home non-agricultural good, and $Y^*_{na,h,t}$ denotes exports to the foreign country. Consumption basket of the non-agricultural goods are composites of the home and foreign goods:

$$C_{na,t} = \left[\omega^{\frac{1}{\mu}} \left(Y_{na,h,t}\right)^{\frac{\mu-1}{\mu}} + (1-\omega)^{\frac{1}{\mu}} \left(Y_{na,f,t}\right)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}},$$

where $Y_{na,f,t}$ denotes the imports of home from foreign.

The demand functions for the home and foreign non-agricultural goods are:

$$Y_{na,h,t} = \omega \left(p_{na,h,t}\right)^{-\mu} C_{na,t}, \text{and}$$

$$Y_{na,f,t} = (1-\omega) \left(p_{na,f,t} \tau Q_t\right)^{-\mu} C_{na,t},$$

where $p_{na,h,t}$ and $p_{na,f,t}Q_t$ are the prices of the home and foreign non-agricultural goods expressed in units of the home consumption basket. Thus, the demand ratios for domestic use and exports is: $\frac{Y_{na,t}-Y^*_{na,h,t}}{Y_{na,f,t}} = \frac{\omega}{1-\omega}\left(\frac{p_{na,h,t}}{p_{na,f,t}Q_t\tau}\right)^{-\mu}$. Set the price index for the non-agricultural good in the home country to be numeraire: $1 = \omega \left(p_{na,h,t}\right)^{1-\mu} + (1-\omega)\left(p_{na,f,t}\right)^{1-\mu}$.

Rural area non-tradable sector

The rural area specializes in production of agricultural goods and are consumed by the domestic household, thus are non-tradable. The output of the agricultural sector: $Y_{ag,t} = Z_{ag,t}[S_{ag,t}]^{\beta_{ag}}[L_{ag,t}]^{1-\beta_{ag}}$. The price for agricultural goods, $P_{ag,t} = \frac{\left(w^s_{ag,t}\right)^{\beta_{ag}}\left(w^l_{ag,t}\right)^{\beta_{ag}}}{Z_{ag,t}}$, where $w^s_{ag,t}$ is the real wage paid for skilled workers and $w^l_{ag,t}$ is the real wage paid for unskilled workers in the rural area.

3.2.2 Home households

Each economy consists of one large representative household, which maximizes the presented discounted value of utility function:

$$E_t\left[\sum_{s=t}^{\infty}\beta^{s-t}\left(\frac{C_s^{1-\gamma}}{1-\gamma}\right)\right],$$

where $\beta \in (0,1)$ is the subjective discount factor, C_t is aggregate consumption, and $\gamma > 0$ is the inverse of the inter-temporal elasticity of substitution. Following Andolfatto

(1996), Merz (1995) and much of the subsequent literature, I assume that all workers in the home country are members of this large household which pool income. This implies the distribution of labor income can be ignored for consumption decision. The budget constraint the household faces is:

$$\tilde{\pi}_t^l \bar{L}_t + \tilde{\pi}_t^s \bar{S}_t + (1+r_t)B_t + (1+r_t^*)B_{*,t} + T_t = C_t + B_{t+1} + Q_t B_{*,t+1} + \frac{\xi}{2}B_{t+1}^2 + \frac{\xi}{2}Q_t B_{*,t+1}^2.$$

The household spends its income on purchases of international risk-free real home bonds and foreign bonds denominated in the home currency B_{t+1} and $B_{*,t+1}$. Following Turnovsky (1985), the assumption of bond holding adjustment is made. The cost of adjusting home bond is $\frac{\xi}{2}B_{t+1}^2$ and the cost of adjusting foreign bond is $\frac{\xi}{2}Q_t B_{*,t+1}^2$ where ξ is a scalar. The household obtains income from interest on its holdings of home bonds $(1+r_t)B_t$ and foreign bonds $(1+r_t^*)B_{*,t}$, where r_t (r_t^*) is the rate of return of home (foreign) bonds. $Q_t = \frac{P_t^* \epsilon_t}{P_t}$ is the consumption based real exchange rate where ϵ_t is the nominal exchange rate. The household also receives total net labor income $\tilde{\pi}_t^l$ and $\tilde{\pi}_t^s$ from supplying unskilled and skilled labor. $\tilde{\pi}_t^l$ is the average net labor income of unskilled workers, $\tilde{\pi}_t^s$ is the average net labor income of skilled workers, which are to be discussed in details in section 3.2.4. In equilibrium, $T_t = (\xi/2)\left(B_{t+1}^2 + Q_t B_{*,t+1}^2\right)$.

The Euler equations for home bond holdings and foreign bond holdings are:

$$1 + \xi B_{t+1} = \beta\left(1 + r_{t+1}\right) E_t \left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\right], \text{and}$$

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

The consumption basket C_t aggregates the agricultural consumption goods $C_{ag,t}$ and non-agricultural consumption goods $C_{na,t}$ in Cobb-Douglas fashion:

$$C_t = (C_{ag,t})^{\alpha}(C_{na,t})^{1-\alpha},$$

which comprises consumption of non-tradable agricultural goods $C_{ag,t}$ and tradable non-agricultural goods $C_{na,t}$. α is the share of agricultural good in the consumption basket.

From household's expenditure minimization problem, relative demand functions for the two goods follow as:

$$C_{ag,t} = \alpha \frac{P_t}{P_{ag,t}} C_t, \text{ and}$$

$$C_{na,t} = (1-\alpha) \frac{P_t}{P_{na,t}} C_t.$$

The consumer price index is: $P_t = \left(\frac{P_{ag,t}}{\alpha}\right)^{\alpha} \left(\frac{P_{na,t}}{1-\alpha}\right)^{1-\alpha}$. No investment demand exists in this version of the model. By definition, $C_{ag,t} = Y_{ag,t}$. The consumption basket of non-agricultural good has been defined in section 3.2.1 as $C_{na,t} = \left[\omega^{\frac{1}{\mu}} \left(Y_{na,h,t}\right)^{\frac{\mu-1}{\mu}} + (1-\omega)^{\frac{1}{\mu}} \left(Y_{na,f,t}\right)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}}$.

3.2.3 Home rural workers' migration decision

Each worker is registered to either an agricultural or a non-agricultural *hukou*. There are $\bar{L}_{na,t}$ unskilled workers and $\bar{S}_{na,t}$ skilled workers with *hukou* in the urban area, and $\bar{L}_{ag,t}$ unskilled workers and $\bar{S}_{ag,t}$ skilled workers with *hukou* in the rural area. Rural workers can choose to move to the city, but doing so implies a positive migration cost, which is represented by a common cost variable X_t that all skilled and unskilled migrant workers face and an idiosyncratic $\varepsilon^i \in [1, \infty)$ $(i = l, s)$. Skilled rural workers draw their migration cost ε^s from a common distribution $G(\varepsilon^s)$, and unskilled rural workers draw their cost ε^l from a different distribution $G(\varepsilon^l)$. The migration cost can be interpreted similarly as iceberg trade cost. When rural workers move to the city, a certain portion of their value $\pi^i_{m,t}$ $(i = l, s)$ in the city "melts" away, so that $\frac{1}{X_t \varepsilon^l}$ is left. When there is a negative migration cost shock that lowers X_t, migrant workers' value of working in the city increases. Since skilled and unskilled rural workers face similar rural to urban mobility decisions, it suffices to describe the decision of rural unskilled workers. Analogous equations hold for skilled workers in the rural area. Migration costs are flow costs that workers incur in each period that they work as migrant worker in the city. Following the same spirit of Tombe and Zhu (2019), migration cost is modeled as ongoing cost rather than sunk cost because of the recurring nature of costs that migrants in China have to pay working in the city under the unique *hukou* system (e.g. restricted access to local educational and medical resources, social welfare, employment benefits, etc).

An unskilled rural worker decides to migrate to the city if the net labor income earned in the non-agricultural sector (wage income subject to migration cost) is higher than the labor income earned from staying at the agricultural sector in the rural area: $\frac{w^l_{na,t}}{X_t \varepsilon^l_{na,t}} > w^l_{ag}$. Define rural workers' net labor income as $\pi_{j,t}$, then the migration decision can be rewritten as: $\pi_{na,t} > \pi_{ag,t}$. If the worker chooses to migrate to work in the non-agricultural sector in the urban area, he needs to pay the migration cost ε^l that he drew. Thus, $\pi^l_{na,t} = \frac{w^l_{na,t}}{X_t \varepsilon^l_{na,t}}$. However, if he decides to remain in the rural area, he would not pay such cost, earning full wage rate at the agricultural sector: $\pi_{ag,t} = w^l_{ag}$.

Every period, the rural worker with idiosyncratic migration cost level ε^l compares the net return of remaining working in the rural area and that of moving to the city to work in the non-agricultural sector. Given the migration cost he faces, If $w^l_{ag,t} > \frac{w^l_{na,t}}{X_t \varepsilon^l_{na,t}}$, he would decide to remain in the rural area and continue to work in the agricultural sector because it pays more than the non-agricultural wage discounted by the specific migration cost he needs to pay. However, if $\frac{w^l_{na,t}}{X_t \varepsilon^l_{na,t}} > w^l_{ag}$, he chooses to become a migrant worker and works in the non-agricultural sector in the city. In the next period, if the worker still finds it pays out more to continue to be a migrant worker, he still needs to pay the cost ε^l. Since there is no sunk cost of migration, and that per-period migration cost ε^l works like a flow cost that rural workers need to pay whenever they choose to be migrant workers working in the urban area, workers' migration decision is merely a static decision. It is a decision that workers make every period, evaluating the net payoffs of working in the two areas in the current period.

A threshold, $\overline{\varepsilon}^l_t$, for which a worker is indifferent between moving and not moving to the city can be defined as: $\overline{\varepsilon}^l_t = \frac{1}{X_t}\left(w^l_{na,t} - w^l_{ag,t}\right)$. Share of different categories of unskilled workers can be pinned down by $\overline{\varepsilon}^l$. Rural unskilled workers with idiosyncratic migration cost below the threshold will self select into migration whereas those with cost above the threshold will find net labor income earned in the city lower than that in the rural area and therefore choose to stay.

The migration cost cutoff $\overline{\varepsilon}_t^l$ responds to fluctuations in the relative cost of labor across regions, and thus affects migration flow and labor supply in the rural area and the urban area. When there are exogenous shocks that change the payoffs (wages) in the two regions, the migration cutoff will be affected. For any given level of rural-worker-specific migration cost, a relatively higher wage in the city implies higher net labor income, and therefore leads to a larger fraction of migrant workers in equilibrium. For instance, if there is a positive productivity shock happening in the non-agricultural sector which increases $Z_{na,t}$, wages in the urban non-agricultural sector w_{na} rises, increasing the cost cutoff $\overline{\varepsilon}_t^l$. It makes more rural workers to find it more profitable to work in the city, leading to a larger wave of rural to urban migration.

In equilibrium, the existence of productivity cutoff $\overline{\varepsilon}_t^l$ requires a cross-country asymmetry in the cost of effective labor, which ensures that some of the rural workers have an incentive to work in the city. To illustrate this point, fig.3.4 plots the two sets of net labor income for unskilled rural workers as functions of the idiosyncratic migration cost ε^l over the support interval $[\varepsilon_{min}, \infty)$, with $\pi_{ag,t}^l = w_{ag,t}^l$, $\pi_{m,t}^l = \frac{w_{na,t}^l}{X_t \varepsilon^l}$. The net income function from migrating is steeper than the net income function from staying in the countryside $slope\{\pi_{m,t}^l\} > slope\{\pi_{ag,t}^l\}$ as $\frac{w_{na,t}^l}{X_t\left(\varepsilon^l\right)^2} > 0$. Therefore, to ensure that the cost cutoff $\overline{\varepsilon}_t^l$ exists in equilibrium, the net payoff at ε_{min} must be greater than w_{ag}^l, which implies that $\frac{w_{na,t}^l}{X_t \varepsilon_{min}} > w_{na}^l$ at all times. Same applies to $\overline{\varepsilon}_t^s$, the condition that $\frac{w_{na,t}^s}{X_t \varepsilon_{min}} > w_{na}^s$ must be satisfied. The model calibration and the magnitude of exogenous shocks ensure that these conditions are satisfied every period. The graph visually shows that becoming a migrant worker generates larger net payoff than remaining in the rural area for the subset of workers with idiosyncratic cost ε^i in the interval $(\varepsilon_{min}, \overline{\varepsilon}_t^i)$.

3.2.4 Worker averages and distributions

Assume the worker-specific labor migration cost for skilled workers ε^s are random draws from a common Pareto distribution $G(\varepsilon^s)$ with density $g(\varepsilon^s)$. Therefore, migrant workers are heterogeneous in the sense that they face heterogeneous costs of migration. All the information about $G(\varepsilon^s)$ that is relevant for aggregate outcomes can be summarized by means of average cost levels, as in average productivity levels in Melitz (2003). The average cost level for workers whose migration cost fall below the threshold can be defined as: $\tilde{\varepsilon}^l_{m,t} = \left[\frac{1}{G(\bar{\varepsilon}^l_t)}\int_{\varepsilon^l_{min}}^{\bar{\varepsilon}^l_t}\left(\varepsilon^l\right)^{-1}g(\varepsilon^l)d\varepsilon^l\right]$. The average net labor income for unskilled rural migrant worker is $\tilde{\pi}^l_{m,t} = \pi^l_{m,t}\left(\tilde{\varepsilon}^l_{m,t}\right) = \frac{w^l_{na,t}}{X_t\tilde{\varepsilon}^l_{m,t}}$, whereas the average net labor income for rural workers who choose to remain in the rural area is $\pi^l_{ag,t} = w^l_{ag,t}$. For urban workers who do not face the mobility decision, their net labor income is just their wage income working in the non-agricultural sector $\pi^l_{na,t} = w^l_{na,t}$. The intuitions for the net labor income for these three types of workers ($L_{na,t}$, $L_{ag,t}$ and $L_{m,t}$) are the following: because of the assumption that there is no heterogeneity across unskilled workers with urban *hukou*, native unskilled workers in the urban area all face the same wage. Similarly, for unskilled workers in the rural area who choose to stay in the rural area, they do not pay the actual migration costs and are thus ex-post homogeneous. Therefore, they are also paid the same wage. For rural migrant workers, they are paid the same wage rate as the native unskilled workers with urban *hukou*, which means they are ex-post homogeneous too in terms of the wage they are paid. However, since they paid the migration cost when they selected into moving to work in the urban area, their net labor income are different though since the migration costs are idiosyncratic.

Every period, after rural workers make their migration decision and pay corresponding costs if they choose to move to the city, there will be $L_{ag,t}$ workers working in the rural area and $L_{na,t}$ workers working in the urban area, with $L_{ag,t} = \bar{L}_{ag,t} - L_{m,t}$ and $L_{na,t} = \bar{L}_{na,t} + L_{m,t}$. Average worker return is expressed as the average between net labor income earned by workers working in the urban area and those working in the rural area, weighted by the share of these different workers:

$$\tilde{\pi}^l_t = \frac{L_{na,t}}{L_t}\tilde{\pi}^l_{na,t} + \frac{L_{ag,t}}{L_t}\tilde{\pi}^l_{ag,t},$$

where $\tilde{\pi}^l_{na,t} = \frac{\bar{L}_{na,t}}{\bar{L}_{na,t}+L_{m,t}}\pi^l_{na,t} + \frac{L_{m,t}}{\bar{L}_{na,t}+L_{m,t}}\tilde{\pi}^l_{m,t}$ and $\pi^l_{ag,t} = w^l_{ag,t}$. Since $L_{na,t} = \bar{L}_{na,t} + L_{m,t}$, and $L_{ag,t} = \bar{L}_{ag,t} - L_{m,t}$, average worker net labor income can be expressed as $\tilde{\pi}^l_t = \frac{\bar{L}_{na,t}}{\bar{L}_t}w^l_{na,t} + \frac{L_{m,t}}{\bar{L}_t}\tilde{\pi}^l_{m,t} + \frac{\bar{L}_{ag,t}-L_{m,t,}}{\bar{L}_t}w^l_{ag,t} = \frac{\bar{L}_{na,t}}{\bar{L}_t}w^l_{na,t} + \frac{\bar{L}_{ag,t}}{\bar{L}_t}w^l_{ag,t} + \frac{L_{m,t}}{\bar{L}_t}\left(\tilde{\pi}^l_{m,t} - w^l_{ag,t}\right)$.

The distribution of workers can be written as the following: $\frac{L_{m,t}}{\bar{L}_{ag,t}} = G(\bar{\varepsilon}_t^l)$ and $\frac{L_{ag,t}}{\bar{L}_{ag,t}} = 1 - G(\bar{\varepsilon}_t^l)$. This implies that $\frac{L_{m,t}}{\bar{L}_t} = \frac{L_{m,t}}{\bar{L}_{ag,t}}\frac{\bar{L}_{ag,t}}{\bar{L}_t} = G(\bar{\varepsilon}_t^l)\frac{\bar{L}_{ag,t}}{\bar{L}_t}$. If the migration cost distributions are assumed to be exponential with rate parameter λ, then $\frac{L_{m,t}}{\bar{L}_{ag,t}} = G(\bar{\varepsilon}_t^l) = \left(\bar{\varepsilon}_t^l\right)^{-k}$. Substituting the distribution information and the expression of the share of unskilled migrant workers out of total unskilled labor supply into the average net unskilled labor income: $\tilde{\pi}_t^l = \frac{\bar{L}_{na,t}}{\bar{L}_t} w_{na,t}^l + \frac{\bar{L}_{ag,t}}{\bar{L}_t} w_{ag,t}^l + G(\bar{\varepsilon}_t^l)\frac{\bar{L}_{ag,t}}{\bar{L}_t}\left(\tilde{\pi}_{m,t}^l - w_{ag,t}^l\right)$.

The average cutoffs for rural workers who choose to migrate are:

$$\tilde{\varepsilon}_t^l = \frac{k+1}{k}\varepsilon_{min}\bar{\varepsilon}^l \frac{\left(\bar{\varepsilon}^l\right)^{k+1} - \left(\varepsilon_{min}\right)^{k+1}}{\left(\bar{\varepsilon}^l\right)^k - \left(\varepsilon_{min}\right)^k},$$

$$\tilde{\varepsilon}_t^s = \frac{k+1}{k}\varepsilon_{min}\bar{\varepsilon}^s \frac{\left(\bar{\varepsilon}^s\right)^{k+1} - \left(\varepsilon_{min}\right)^{k+1}}{\left(\bar{\varepsilon}^s\right)^k - \left(\varepsilon_{min}\right)^k}.$$

Therefore, average worker return can be expressed as the following equation:

$$\tilde{\pi}_t^l = \frac{\bar{L}_{na,t}}{\bar{L}_t} w_{na,t}^l + \frac{\bar{L}_{ag,t}}{\bar{L}_t}\left(1 - \left(\bar{\varepsilon}^l\right)^{-k}\right)\frac{w_{na,t}^l}{X_t\tilde{\varepsilon}_t^l} + \frac{\bar{L}_{ag,t}}{\bar{L}_t}\left(\bar{\varepsilon}^l\right)^{-k} w_{ag,t}^l.$$

3.2.5 Foreign households and output

The foreign economy also produces agricultural goods and non-agricultural goods, the former sector being non-tradable and the latter being tradable. Rural to urban migration is not modeled in foreign, so that there is no between sector migration occurring. The foreign non-agricultural good is also used both domestically and abroad: $Y_{na,t}^* = Y_{na,f,t}^* + Y_{na,h,t}^*$, where $Y_{na,f,t}^*$ denotes the use of the foreign non-agricultural good by foreign households, and $Y_{na,h,t}^*$ denotes exports to the home country. The foreign non-agricultural tradable consumption basket is:

$$C_{na,t}^* = \left[(\omega^*)^{\frac{1}{\mu^*}}\left(Y_{na,f,t}^*\right)^{\frac{\mu^*-1}{\mu^*}} + (1-\omega^*)^{\frac{1}{\mu^*}}\left(Y_{na,h,t}^*\right)^{\frac{\mu^*-1}{\mu^*}}\right]^{\frac{\mu^*}{\mu^*-1}},$$

where $Y_{na,f,t}^*$ denotes foreign domestic the foreign country's domestic use of the foreign non-agricultural good and $Y_{na,h,t}^*$ denotes the exports of home to foreign. The demand functions for the home and foreign non-agricultural goods are $Y_{na,f,t}^* = \omega^*\left(p_{na,f,t}\right)^{-\mu*} C_{na,t}^*$

and $Y^*_{na,h,t} = (1-\omega^*)\left(p_{na,h,t}\tau/Q_t\right)^{-\mu*} C^*_{na,t}$, where are the prices of the home and foreign non-agricultural goods expressed in units of the foreign consumption basket. Therefore, the demand ratios for domestic use in the foreign country and exports to the home country is: $\frac{Y^*_{na,f,t}}{Y^*_{na,h,t}} = \frac{\omega^*}{1-\omega^*}\left(\frac{p_{na,f,t}Q_t}{p_{na,h,t}\tau^*}\right)^{-\mu}$. The price index for the non-agricultural good in the foreign country is also normalized to be numeraire, and it can be expressed as: $1 = \omega^*\left(p_{na,f,t}\right)^{1-\mu^*} + (1-\omega^*)\left(p_{na,h,t}\tau^*/Q_t\right)^{1-\mu^*}$.

Budget constraint for foreign household is:

$$\tilde{\pi}^{l*}_t \bar{L}^*_t + \tilde{\pi}^{s*}_t \bar{S}^*_t + (1+r_t)B^*_t + (1+r^*_t)B^*_{*,t} + T^*_t = C^*_t + Q^{-1}_t B^*_{t+1} + B^*_{*,t+1} + \frac{\xi}{2}Q^{-1}_t B^2_{*,t+1} + \frac{\xi}{2}B^{*2}_{*,t+1},$$

where $B^*_t$is Foreign holdings of Home bonds and $B^*_{*,t}$ is Foreign holdings of Foreign bonds.

3.2.6 Aggregate accounting and balanced trade

The change in net foreign assets between t and $t+1$ is determined by the current account:

$$B_{t+1} - B_t + Q_t\left(B_{*,t+1} - B_{*,t}\right) = CA_t \equiv p_{na,h}\tau^* Y^*_{na,h} - p_{na,f,t}\tau Q_t Y_{na,f,t} + r_t B_t,$$

where $p^*_{na,h,t}\tau^* Y^*_{na,h,t} - p_{na,f,t}\tau Q_t Y_{na,f,t} = TB_t$ is the trade balance, which is characterized by total exports minus imports expressed in units of the home consumptions basket. Bond market clearing implies $B_{t+1} + B^*_{t+1} = 0$ and $B_{*,t+1} + B^*_{*,t+1} = 0$. Under financial autarky, trade is balanced, which implies $p_{na,h}\tau^* Y^*_{na,h} = p_{na,f,t}\tau Q_t Y_{na,f,t}$.

3.2.7 Measures of wage inequality

Definition of wage inequality measures:

Since the goal of this paper is to analyze the effect of China's trade liberalization and migration policy change on wage inequality, this section define a set of wage inequality measures. There are three measures of inequality that one can study under the framework of this model: within-area or within-sector skill premium, country-level skill premium, urban to rural wage inequality. Derivations are in the appendix.

First, within-sector skill premium is straightforward to measure:

$$\frac{w^s_{ag,t}}{w^l_{ag,t}} = \frac{\eta_{ag}}{1-\eta_{ag}}\frac{L_{ag,t}}{S_{ag,t}}, \text{ and}$$

$$\frac{w^s_{na,t}}{w^l_{na,t}} = \frac{\eta_{na}}{1-\eta_{na}}\frac{L_{na,t}}{S_{na,t}}.$$

Second, country-level skill premium is by definition $\frac{w^s_t}{w^l_t}$, the ratio of skilled wage over unskilled wage at the aggregate level. Skilled wage w^s_t is the weighted average of skilled wage in the non-agricultural sector and that in the agricultural sector, weighted by corresponding labor share, similarly for unskilled wage w^l_t:

$$w^s_t = \frac{S_{na,t}}{\bar{S}_t}w^s_{na,t} + \frac{S_{ag,t}}{\bar{S}_t}w^s_{ag,t}, \text{ and}$$

$$w^l_t = \frac{L_{na,t}}{\bar{L}_t}w^l_{na,t} + \frac{L_{ag,t}}{\bar{L}_t}w^l_{ag,t}.$$

Third, one can also calculate urban to rural wage inequality, which is the wage difference between the average wage at the non-agricultural sector and that at the agricultural sector $\frac{w_{na,t}}{w_{ag,t}}$, where rural wage and urban wage are defined by:

$$w_{na,t} = \frac{L_{na,t}}{L_{na,t}+S_{na,t}}w^l_{na,t} + \frac{S_{na,t}}{L_{na,t}+S_{na,t}}w^s_{na,t}, \text{ and}$$

$$w_{ag,t} = \frac{L_{ag,t}}{L_{ag,t}+S_{ag,t}}w^l_{ag,t} + \frac{S_{ag,t}}{L_{ag,t}+S_{ag,t}}w^s_{ag,t}.$$

Expression of wage inequality measures:

This section expresses wage inequality measures using other equations described in the theoretical model.

Sector-level skill premium:

Since the share of migrant workers out of total agricultural labor endowment is a function of migration cost cutoffs for skilled and unskilled labor, skill premium in the rural area (the agricultural sector) is derived as:

$$\frac{w^s_{ag,t}}{w^l_{ag,t}} = \frac{\bar{L}_{ag,t}\left(\bar{\varepsilon}_t{}^l\right)^{-k}}{\bar{S}_{ag,t}\left(\bar{\varepsilon}^s\right)^{-k}}\frac{\eta_{ag}}{1-\eta_{ag}}.$$

Similarly, skill premium in the urban area (the non-agricultural sector) can be obtained as:

$$\frac{w^s_{na,t}}{w^l_{na,t}} = \frac{\bar{L}_{na,t} + \left(1 - \left(\bar{\varepsilon}^l_t\right)^{-k}\right)\bar{L}_{ag}}{\bar{S}_{na,t} + \left(1 - \left(\bar{\varepsilon}^s_t\right)^{-k}\right)\bar{S}_{ag}} \frac{\eta_{na}}{1-\eta_{na}}.$$

The sector-level skill premium at period t depends on one endogenous variable: the migration cost cutoffs for skilled migrant workers and unskilled migrant workers $\bar{\varepsilon}^l_t$ and $\bar{\varepsilon}^s_t$. In other words, skill premium within each region depends on the fraction of skilled workers who choose to move and the fraction of unskilled workers who decide to move, which are pinned down by other aggregate variables in the economy.

Country-level skill premium:

After substituting labor demand functions in terms of skilled wage and unskilled wage in the two sectors, country-level skill premium can be expressed as:

$$\frac{w^s_t}{w^l_t} = \left[\frac{\eta_{na}\frac{Y_{na,t}p_{na,h,t}}{Y_{ag,t}P_{ag,t}} + \eta_{ag}}{\left(1-\eta_{na}\right)\frac{Y_{na,t}P_{na,t}}{Y_{ag,t}P_{ag,t}} + \left(1-\eta_{ag}\right)}\right]\frac{\bar{L}_t}{\bar{S}_t}.$$

The above equation means that at the aggregate level, skill premium only depends on one endogenous variables: the ratio of revenue in the urban area non-agricultural sector over that in the rural area agricultural sector $\frac{Y_{na,t}P_{na,t}}{Y_{ag,t}P_{ag,t}}$. Since $\frac{\partial \frac{w^s_t}{w^l_t}}{\partial \frac{Y_{na,t}P_{na,t}}{Y_{ag,t}P_{ag,t}}} > 0$ as $\eta_{na} > \eta_{ag}$, the conclusion that country-level skill premium rises can be easily obtained. Proof is in the appendix.

Urban-rural wage inequality:

$$\frac{w_{na,t}}{w_{ag,t}} = \frac{Y_{na,t}P_{na,t}}{Y_{ag,t}P_{ag,t}}\frac{L_{ag,t}+S_{ag,t}}{L_{na,t}+S_{na,t}}.$$

This implies that urban-rural wage inequality is determined by two forces: ratio of output in these two areas $\frac{Y_{na,t}}{Y_{ag,t}}$ and the ratio of total labor working in the rural area over the total mass of labor working in the urban area $\frac{L_{ag,t}+S_{ag,t}}{L_{na,t}+S_{na,t}}$. These two forces work in opposite directions.

The amount of labor working in the agricultural sector $L_{ag,t}$ and $S_{ag,t}$ equal the total rural labor endowment $\bar{L}_{ag,t}$ and $\bar{S}_{ag,t}$ subtracted by the migrant workers $L_{m,t}$ and $S_{m,t}$.

Similarly, the mass of labor working in the non-agricultural sector $L_{na,t}$ and $S_{na,t}$ are urban labor endowment plus the migration flow. Therefore, urban to rural wage inequality can also be written as:

$$\begin{aligned}\frac{w_{na,t}}{w_{ag,t}} &= \frac{Y_{na,t}P_{na,t}}{Y_{ag,t}P_{ag,t}}\frac{\bar{L}_{ag,t}+\bar{S}_{ag,t}-(L_{m,t}+S_{m,t})}{\bar{L}_{na,t}+\bar{S}_{na,t}+(L_{m,t}+S_{m,t})} \\ &= \frac{Y_{na,t}P_{na,t}}{Y_{ag,t}P_{ag,t}}\frac{\bar{L}_{ag}\left(\bar{\varepsilon}^{l}\right)^{-k}+\bar{S}_{ag}\left(\bar{\varepsilon}^{l}\right)^{-k}}{\bar{L}_{na}+\bar{S}_{na}+\left(\left(1-(\bar{\varepsilon}^{l})^{-k}\right)\bar{L}_{ag}+\left(1-(\bar{\varepsilon}^{s})^{-k}\right)\bar{S}_{ag}\right)}.\end{aligned}$$

Therefore, changes in urban-rural wage inequality depends on change in the ratio of non-agricultural to agricultural output $\frac{Y_{na,t}}{Y_{ag,t}}$, as well as changes in the number of total migrant workers $L_{m,t}+S_{m,t}$.

Derived equations for these three different measures of wage inequality delineate a very interesting phenomenon for inequality. When migration cost is lowered, at the aggregate level, it is straightforward to conclude that skill premium rises as migration into the city increases relative output in the urban area. However, it might not be the case if we dig deeper than the aggregate level and look at skill premium within the urban area and that within the rural area, as well as urban to rural wage inequality. Exogenous shocks may lead to increase or decrease in urban-rural inequality and within-sector wage inequality.

3.3 Long-run effects and adjustment to policy changes in trade liberalization and migration

3.3.1 Steady state analysis

In the steady state, migration cost cutoffs satisfy:

$$\bar{\varepsilon}^{l}=\frac{1}{X}\frac{(1-\eta_{na})(1-\alpha)}{(1-\eta_{ag})\alpha}\frac{\left(\bar{\varepsilon}^{l}\right)^{-k}}{\frac{\bar{L}_{na}}{\bar{L}_{ag}}+1-\left(\bar{\varepsilon}^{l}\right)^{-k}},$$

$$\bar{\varepsilon}^{s}=\frac{1}{X}\frac{\eta_{na}(1-\alpha)}{\eta_{ag}\alpha}\frac{\left(\bar{\varepsilon}^{s}\right)^{-k}}{\frac{\bar{S}_{na}}{\bar{S}_{ag}}+1-\left(\bar{\varepsilon}^{s}\right)^{-k}}.$$

These two equations imply that in the steady state, migration cost cutoff for unskilled workers $\bar{\varepsilon}^{l}$ depends only on common migration cost shock X, ratio of skilled cost share in production $\frac{\eta_{na}}{\eta_{ag}}$, relative share of non-agricultural good to agricultural good in the aggregate consumption basket $\frac{1-\alpha}{\alpha}$ and ratio of urban to rural unskilled endowment $\frac{\bar{L}_{na}}{\bar{L}_{ag}}$. Similarly, migration cost cutoff for skilled workers $\bar{\varepsilon}^s$ depends only on common migration cost shock X, ratio of skilled cost share in production $\frac{\eta_{na}}{\eta_{ag}}$ and ratio of urban to rural unskilled endowment $\frac{\bar{S}_{na}}{\bar{S}_{ag}}$. Once we obtain $\bar{\varepsilon}^s$ and $\bar{\varepsilon}^l$, migration flow L_m and S_m are also derived. Because there is no closed form solution for $\bar{\varepsilon}^s$ and $\bar{\varepsilon}^l$, fig 3.4 plots the relationship between cost cutoff $\bar{\varepsilon}^l$ and common migration cost shock X with plausible values of other variables. The two variables are negatively correlated: the lower the common cost level X, the higher the cost cutoff of migration. This is rather intuitive because lower cost of migration allows more rural workers to find working in the city generating more net income. Thus, when there is a reduction in the common migration cost, the cutoffs for skilled and unskilled workers rise and more rural workers find it profitable to leave their *hukou* location and work in the city, increasing the migration flows L_m and S_m.

The three measures of wage inequality in the steady state are also obtained as the following. First, skill premium in the agricultural sector and that in the non-agricultural sector are:

$$\frac{w^s_{ag,t}}{w^l_{ag,t}} = \frac{\eta_{ag}}{1-\eta_{ag}} \frac{\bar{L}_{ag}\left(\bar{\varepsilon}^l\right)^{-k}}{\bar{S}_{ag}\left(\bar{\varepsilon}^s\right)^{-k}} \quad \text{and} \quad \frac{w^s_{na,t}}{w^l_{na,t}} = \frac{\eta_{na}}{1-\eta_{ag}} \frac{\bar{L}_{na} + \left(1-\left(\bar{\varepsilon}^l\right)^{-k}\right)\bar{L}_{ag}}{\bar{S}_{na} + \left(1-\left(\bar{\varepsilon}^s\right)^{-k}\right)\bar{S}_{ag}}.$$

Within sector skill premium $\frac{w^s_j}{w^l_j}$ depends on the sector level endowment ratio $\frac{\bar{L}_j}{\bar{S}_j}$ and sector specific ratio of skilled to unskilled cost share in the production function $\frac{\eta_j}{1-\eta_j}$ and equilibrium migration cost cutoffs $\bar{\varepsilon}^s$ and $\bar{\varepsilon}^l$ for skilled and unskilled rural workers, which are shown above.

Second, urban to rural wage inequality does not depend on depends on η_j, but only depends on $\frac{1-\alpha}{\alpha}$, endowments $\bar{L}_{na}, \bar{L}_{ag}, \bar{S}_{na}, \bar{S}_{ag}$ and cutoffs $\bar{\varepsilon}^s, \bar{\varepsilon}^l$, as the following:

$$\frac{w_{na}}{w_{ag}} = \frac{1-\alpha}{\alpha} \frac{\bar{L}_{ag}\left(\bar{\varepsilon}^l\right)^{-k} + \bar{S}_{ag}\left(\bar{\varepsilon}^l\right)^{-k}}{\bar{L}_{na} + \bar{S}_{na} + \left(\left(1-\left(\bar{\varepsilon}^l\right)^{-k}\right)\bar{L}_{ag} + \left(1-\left(\bar{\varepsilon}^s\right)^{-k}\right)\bar{S}_{ag}\right)}.$$

Third, country level skill premium is:

$$\frac{w^s}{w^l} = \left(\frac{\eta_{na}\frac{1-\alpha}{\alpha} + \eta_{ag}}{\left(1-\eta_{na}\right)\frac{1-\alpha}{\alpha} + \left(1-\eta_{ag}\right)}\right)\frac{\bar{L}}{\bar{S}}.$$

This means that in the steady state, country level skill premium is pinned down by only the unskilled to skilled endowment ratio $\frac{\bar{L}_t}{\bar{S}_t}$, cost share in the production function η_{na}, η_{ag} and relative share of non-agricultural good to agricultural good in the aggregate consumption basket $\frac{1-\alpha}{\alpha}$.

3.3.2 Calibration

This section describes the parametrization of the model that I use for numerical simulations. Following the practice of Ghironi and Melitz (2005), each period is interpreted as a quarter. The household discount rate set to 0.99, which is the standard value for business cycle models at quarterly frequency. The parameters of the Pareto distribution are set to $\varepsilon_{min} = 1$ and $k = 2$, respectively. Share of domestic non-agricultural good in total non-agricultural consumption in Home and Foreign are $\omega = 0.75$ and $\omega^* = 0.85$, allowing for slightly more trade openness for the foreign economy than home. Share of non-agricultural consumption in total consumption basket is $\alpha = 0.6$.

Iceberg trade costs are calibrated to deliver an average share of US manufacturing trade with China in US manufacturing value added of 6% during 1988-2000 (the pre-liberalization period) and 25% during 2001-20013 (the post-liberalization period). Assuming symmetric trade costs, this share implies trade costs of $\tau = \tau^* = 1.5$ before liberalization and $\tau = \tau^* = 1.1$ after that. The policy-controlled migration cost X_t is also calibrated to match with a share of migrant workers in rural workers from 6% to 27.8% from 1995 to 2007. Productivity shock in the non-agricultural sector is modeled as an AR(1) process with persistence parameter $\rho = 0.9$.

Using the CHIP surveys in rural households and urban households, during the whole sample period of 1988-2013, the share of endowed skilled workers in total endowed workers $\bar{S}^j / \left(\bar{S}^j + \bar{L}^j\right)$ is roughly 4.572% in the rural area and 38.6% in the urban area. In the U.S., the share of skilled to total workers is 31%, according to Burstein and Vogel (2017). Because there is no rural to urban migration modeled in the foreign country, I assume the rural area and the urban area has the same share of skilled workers endowment.

3.3.3 Dynamic adjustment, impulse responses

Migration cost shock Fig.3.4 plots the impulse responses of macroeconomics and labor market variables following a negative migration cost shock. Migration cost cutoffs increase, leading to increase in both skilled and unskilled migration. Unskilled workers' wage in the non-agricultural sector $w^l_{na,t}$ goes down as there are more unskilled workers working the urban non-agricultural sector. Increase of unskilled migration exceeds that of skilled migration. Since $p_{na,h,t} = \frac{1}{Z_{na,t}(1-\eta_{na})} w^l_{na,t} \left(\frac{\bar{L}_{na}+L_{m,t}}{\bar{S}_{na}+S_{m,t}} \right)^{\eta_{na}}$, price of domestic non-agricultural good decreases, giving rise to more exports. On the contrary, both skilled and unskilled wage in the rural area increases due to a lower level of total labor remaining there. As a consequence, price of agricultural good increases as $p_{ag,t} = \frac{1}{Z_{ag,t}(1-\eta_{ag})} w^l_{ag,t} \left(\frac{\bar{L}_{ag}-L_{m,t}}{\bar{S}_{ag}-S_{m,t}} \right)^{\eta_{ag}}$. Exports and imports both increase. The share of sectoral goods in the home aggregate consumption basket changes due to lowering of $p_{na,h,t}$ and rise of $p_{ag,t}$: consumption of agricultural good $C_{ag,t}$ shrinks whereas consumption of non-agricultural good $C_{na,t}$ expands. In terms of wage inequality, with more workers reallocating from the rural area to the urban area increasing the relative labor supply in the urban area, urban to rural wage inequality decreases. However, skill premium in both the urban area and the rural area, as well as the aggregate level increase. In the urban area, skill premium increases as urban skilled wage rises but urban unskilled wage decreases. Skill premium in the rural area escalates because the rise of rural skilled wage far exceeds that of rural unskilled wage. Real exchange rate depreciates as the price of home non-agricultural good decreases and the price of foreign non-agricultural good increases.

Trade cost shock Fig.3.4 shows the effect of trade cost reduction on the labor market and macroeconomic dimension. A decline in the trade cost of home exports τ^* lowers the price of exports $p_{na,h,t}\tau^*/Q_t$, boosting foreign demand for home non-agricultural exports. Real exchange rate depreciates. As the demand for labor in the non-agricultural sector builds up, wages of skilled and unskilled workers in that sector climb up too. Therefore, migration cost cutoffs increase, generating larger migration flow into the non-agricultural sector. Meanwhile, with diminished labor supply in the agricultural sector, skilled and unskilled wage in the rural area also go up, putting upward pressure on the price of agricultural good as well. Thus, wages of skilled and unskilled workers in both the urban area and the rural area increase. Urban to rural wage inequality expands because wage increments in the urban area more than offsets that in the rural area. Sectoral skill premium and country-level skill premium widen.

Productivity shock in the non-agricultural sector As described in section3.3.2, productivity shock in the non-agricultural sector follows an autoregressive process with degree 1: $logZ_{na,t+1} = \rho logZ_{na,t} + \xi_t$, where $\rho = 0.9$. Fig.3.4 plots the impulse responses of variables following a positive productivity shock. A positive non-agricultural sector productivity shock increases migration cutoffs for rural skilled and unskilled workers through increasing wages in the non-agricultural sector, making migration more rewarding. All three measures of wage inequality rises. Urban-rural wage gap broadens because productivity growth in the urban area boosts the relative wages compared to the rural area. Skill premium in the sector level and aggregate level all go up. Productivity growth in the non-agricultural sector lowers the marginal cost of production, tapering price of the non-agricultural good produced at home $p_{na,h,t}$. Meanwhile, it contracts the agricultural sector, leading to less demand of labor in production of the agricultural good and thus a downward pressure on wages in the agricultural sector. Therefore, there will be a fall in the price $p_{ag,t}$. Both agricultural consumption and non-agricultural consumption increase due to a double lowering of the prices $p_{na,h,t}$ and $p_{ag,t}$. Rural skilled wage climbs up because the effect of a weakened labor supply on wage outweighs that of a suppressed labor demand. However, the opposite is true for rural unskilled wage, leading to a reduction in rural unskilled wage.

3.4 Conclusion

This paper examines the effects of China's domestic migration policy change and trade liberalization on wage inequality in China using a dynamic general equilibrium model of international trade and internal migration across regions. Calibrating the changes in policy-generated migration cost reduction and trade cost decline, as well as productivity increase in the tradable sector, this paper analyzes the responses of different measures of wage inequality and other macroeconomics variables following these shocks.

All these three exogenous changes are associated with rise in urban to rural wage inequality, sectoral skill premium and aggregate-level skill premium, with the exception that easing of migration restriction lead to lowering of urban-rural wage inequality. However, the channels leading to the outcomes are different across the three scenarios. Under all of these scenarios, there is simultaneous rise in migration and exports. Curtailing migration cost affects variables by changing the relative payoffs across sectors, increases migration cost cutoff for both unskilled and skilled rural workers. Price of domestic non-agricultural good decreases due to lower cost of production, giving rise to more exports. Trade cost reduction affects wages by lowering the price of home exports and thus boosting demand for home non-agricultural exports. As wages of skilled and unskilled workers in that sector climb up, migration cost cutoffs increase, generating larger migration flow into the non-agricultural sector. A positive non-agricultural sector productivity shock increases migration cutoffs for rural skilled and unskilled workers through increasing wages in the non-agricultural sector, making migration more rewarding. Meanwhile, productivity growth in the non-agricultural sector lowers the marginal cost of production, contributing to lower price of exports.

The findings in this paper has important policy implications. It shows that easing of migration restriction and trade barriers both encourage rural to urban migration and help with export surge. However, both of these two policies, one domestic one international, have distributional consequences on the skill premium as they broaden skill premium in both the non-agricultural sector and the agricultural sector.

Table 3.1: Employment and wage in China, 1995-2007

	1995	2007	%1995-2007	% per annum
Millions				
Rural areas labor force	490	476	-2.9	-0.03
Urban areas labor force	196	325	66.8	4.43
Rural-urban migrants stock	30	132	340	13.14
Yuan per annum, average (1995 prices)				
Urban real wage	5,348	19,904	272.2	11.16
Rural real income per capita	1,578	3,289	108.4	6.31

Source: China's National Bureau of Statistics

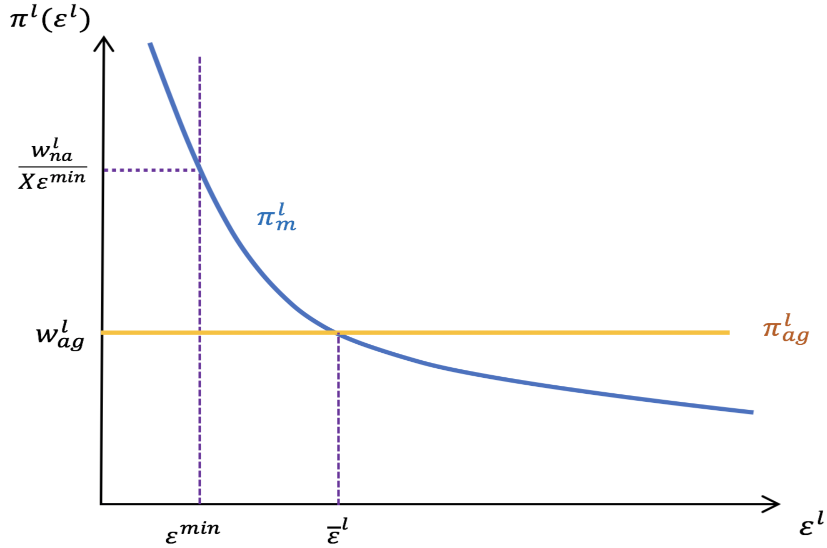


Figure 3.1: Existence of the migration cost cutoff.

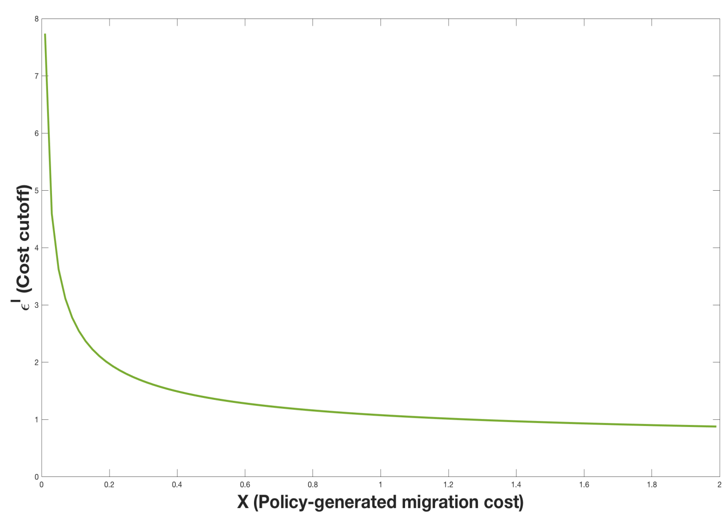


Figure 3.2: Migration cost cutoff as a function of common cost shock.

Table 3.2: Summary of model equations, financial autarky

$1 = \beta\left(1 + r_{t+1}\right) E_t \left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}$
$1 + \xi B_{*,t+1} = \beta^* \left(1 + r^*_{t+1}\right) E_t \left[\left(\frac{Q_{t+1}}{Q_t}\right)\left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\gamma}\right]$
$1 = \omega\left(p_{na,h,t}\right)^{1-\mu} + (1-\omega)\left(p_{na,f,t}\right)^{1-\mu}$
$1 = \omega^*\left(p_{na,f,t}\right)^{1-\mu^*} + (1-\omega^*)\left(p_{na,h,t}/Q_t\right)^{1-\mu^*}$
$P_t = \left(\frac{P_{ag,t}}{\alpha}\right)^{\alpha}\left(\frac{P_{na,t}}{1-\alpha}\right)^{1-\alpha}$
$P^*_t = \left(\frac{P^*_{ag,t}}{\alpha}\right)^{\alpha}\left(\frac{P^*_{na,t}}{1-\alpha}\right)^{1-\alpha}$
$C_t = (C_{ag,t})^{\alpha}(C_{na,t})^{1-\alpha}$
$C_{na,t} = \left[\omega^{\frac{1}{\mu}}\left(Y_{na,h,t}\right)^{\frac{\mu-1}{\mu}} + (1-\omega)^{\frac{1}{\mu}}\left(Y_{na,f,t}\right)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}}$
$C_{ag,t} = Y_{ag,t}$
$C^*_t = (C^*_{ag,t})^{\alpha}(C^*_{na,t})^{1-\alpha}$
$C^*_{ag,t} = Y^*_{ag,t}$
$C^*_{na,t} = \left[\omega^{\frac{1}{\mu}}\left(Y^*_{na,f,t}\right)^{\frac{\mu-1}{\mu}} + (1-\omega)^{\frac{1}{\mu}}\left(Y^*_{na,h,t}\right)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}}$
$Y_{na,h,t} = \omega\left(p_{na,h,t}\right)^{-\mu} C_{na,t} \qquad Y_{na,f,t} = (1-\omega)\left(p_{na,f,t}Q_t\right)^{-\mu} C_{na,t}$
$\tilde{\pi}^l_t = \frac{\bar{L}_{na,t}}{\bar{L}_t} w^l_{na,t} + \frac{\bar{L}_{ag,t}}{\bar{L}_t}\left(1 - \left(\bar{\varepsilon}^l_{m,t}\right)^{-k}\right)\tilde{v}^l_{m,t} + \frac{\bar{L}_{ag,t}}{\bar{L}_t}\left(\bar{\varepsilon}^l_{m,t}\right)^{-k} w^l_{ag,t}$
$\tilde{\pi}^s_t = \frac{\bar{S}_{na,t}}{\bar{S}_t} w^s_{na,t} + \frac{\bar{S}_{ag,t}}{\bar{S}_t}\left(1 - \left(\bar{\varepsilon}^s_{m,t}\right)^{-k}\right)\tilde{v}^s_{m,t} + \frac{\bar{S}_{ag,t}}{\bar{S}_t}\left(\bar{\varepsilon}^s_{m,t}\right)^{-k} w^s_{ag,t}$
$\tilde{\pi}^l_t \bar{L}_t + \tilde{\pi}^s_t \bar{S}_t + (1+r_t)B_t = C_t + B_{t+1}$
$\tilde{\pi}^{l*}_t \bar{L}^*_t + \tilde{\pi}^{s*}_t \bar{S}^*_t + (1+r^*_t)B^*_{*,t} = C^*_t + B^*_{*,t+1}$
$p^*_{na,h,t}\tau^* Y^*_{na,h,t} - p_{na,f,t}\tau Q_t Y_{na,f,t}$
$\tilde{\varepsilon}^l_t = \frac{k}{k+1}\left(\varepsilon_{min}\bar{\varepsilon}^l\right)^{-1}\frac{\left(\bar{\varepsilon}^l\right)^k - (\varepsilon_{min})^k}{\left(\bar{\varepsilon}^l\right)^{k+1} - (\varepsilon_{min})^{k+1}}$
$\tilde{\varepsilon}^s_t = \frac{k}{k+1}\left(\varepsilon_{min}\bar{\varepsilon}^s\right)^{-1}\frac{(\bar{\varepsilon}^s)^k - (\varepsilon_{min})^k}{(\bar{\varepsilon}^s)^{k+1} - (\varepsilon_{min})^{k+1}}$

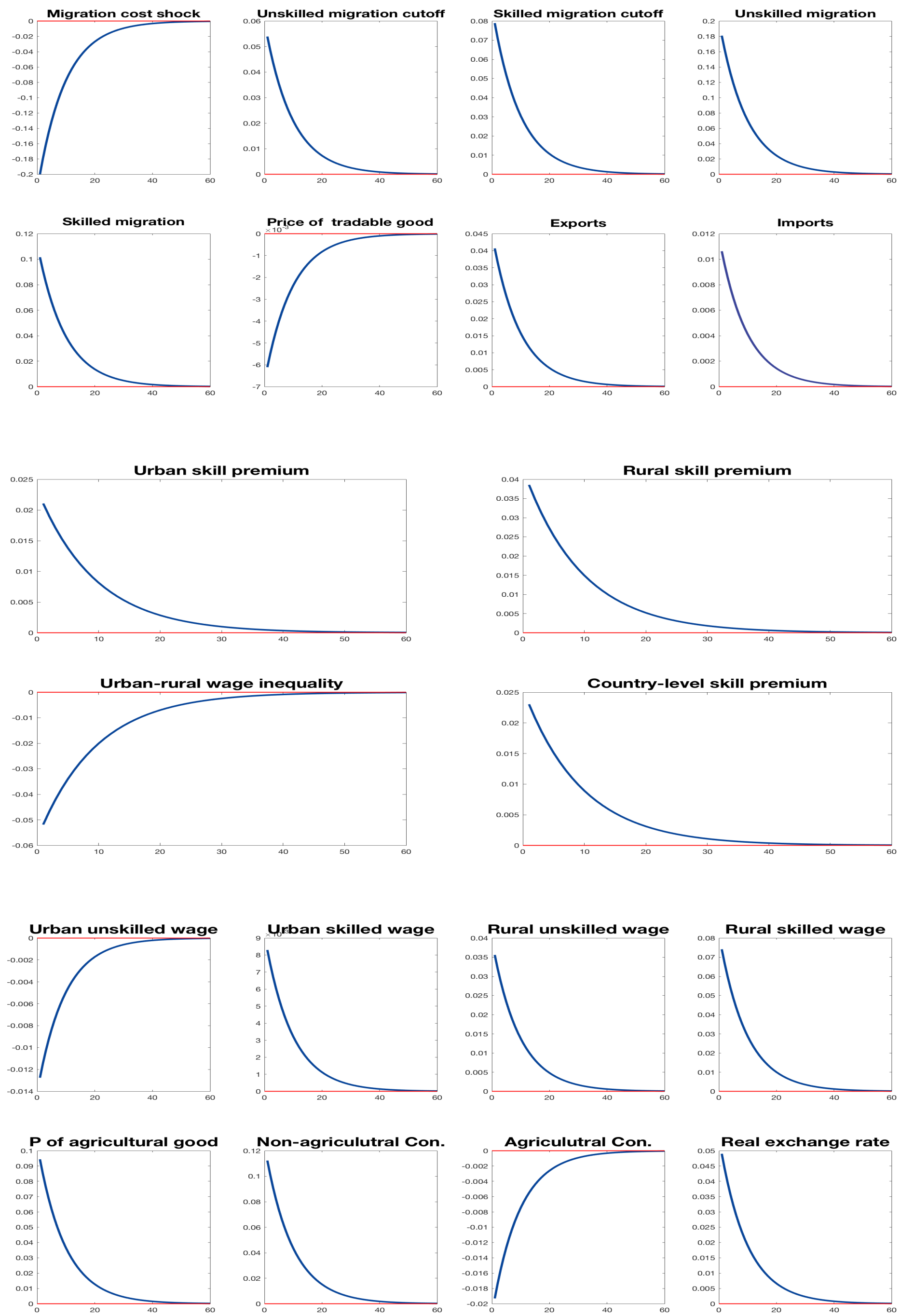


Fig 3.3: This figure shows the impulse response functions of variables following a reduction in common migration cost X_t under financial autarky.. Variables are in percentage deviations from the steady state.

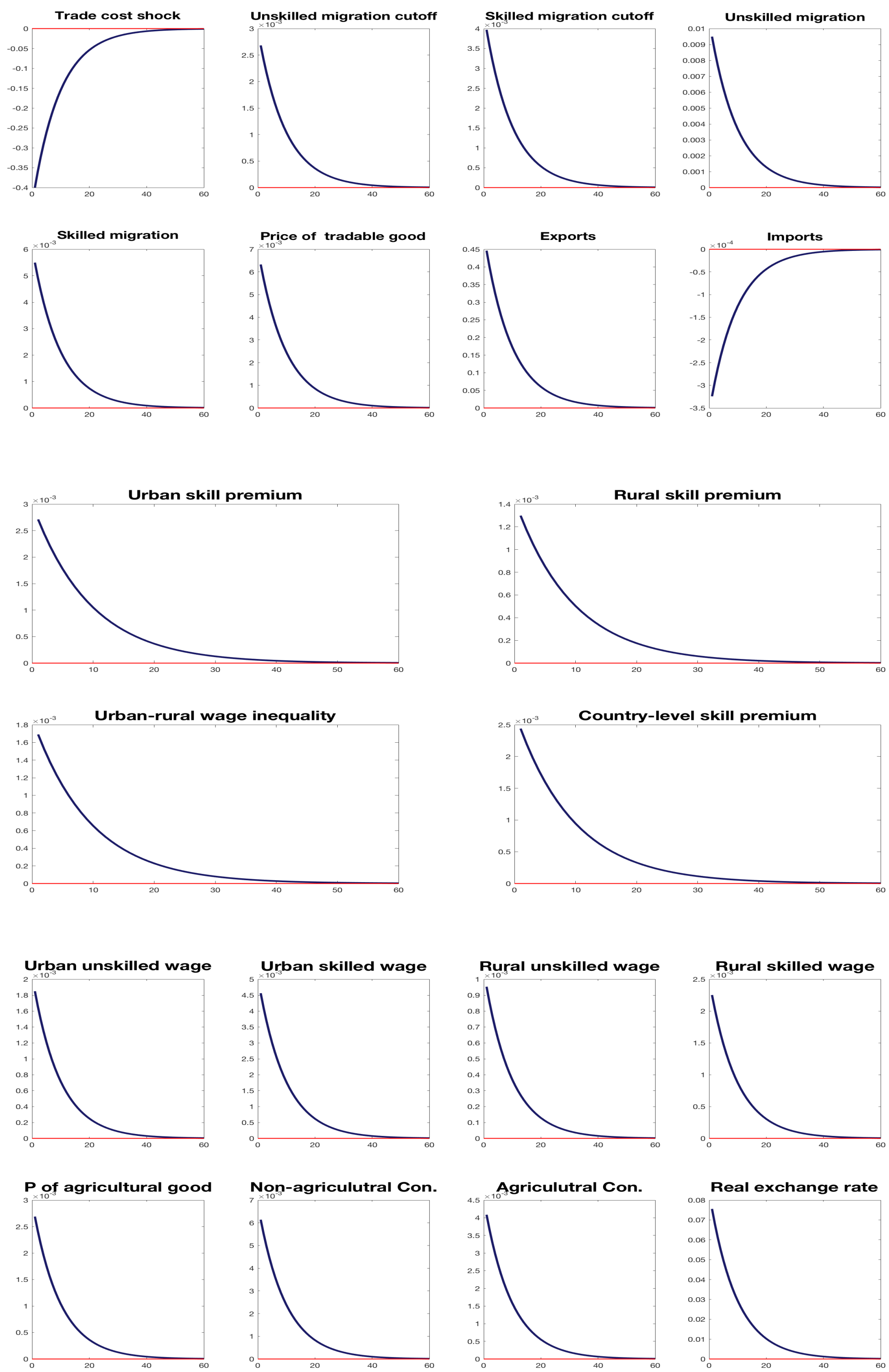


Fig 3.4: This figure shows the impulse response functions of variables in the home country following a negative trade cost shock τ_t^*, under financial autarky.

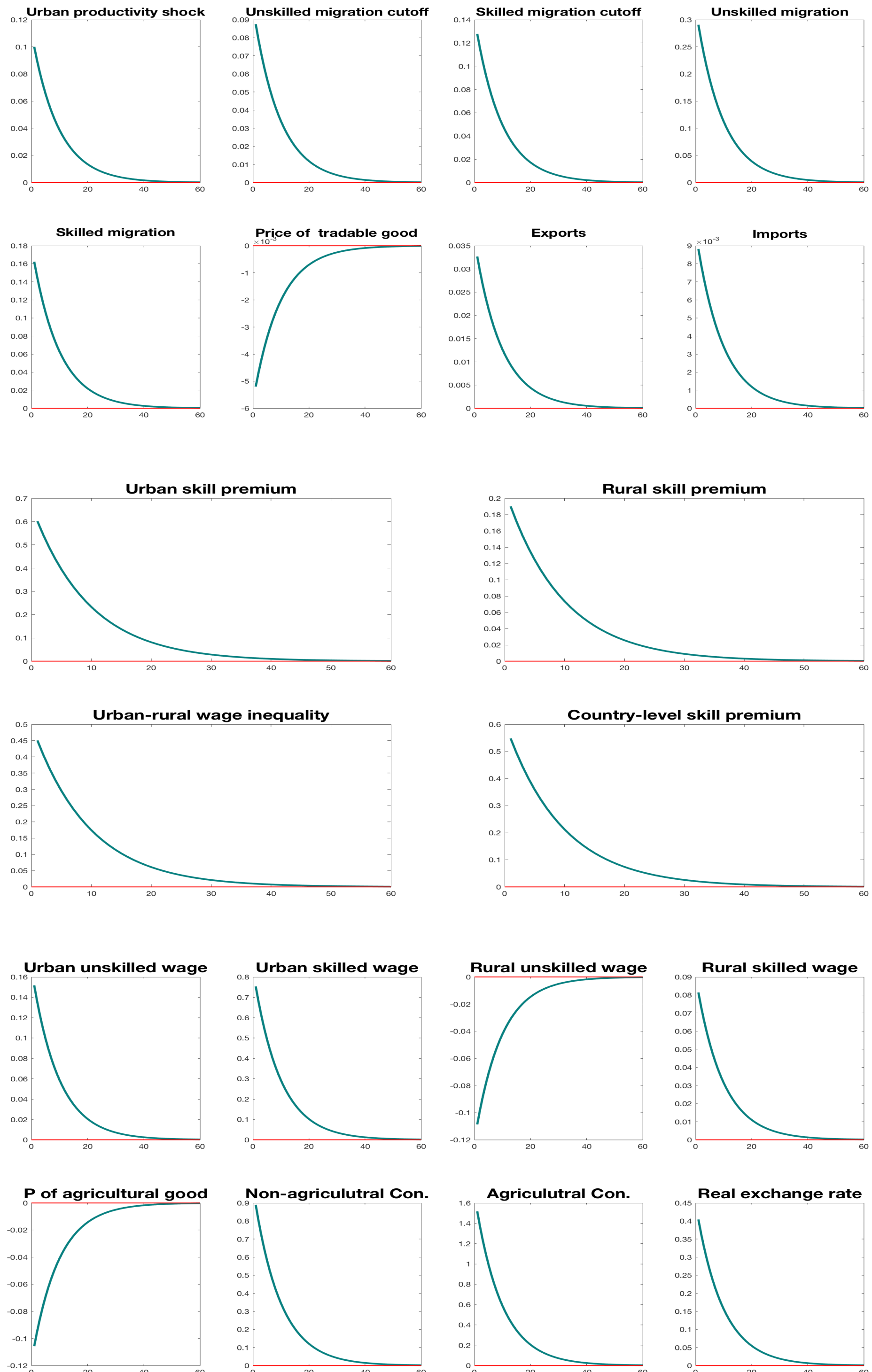


Fig 3.5: This figure shows the impulse response functions of variables in the home country following a positive productivity shock in the non-agricultural sector in the urban area under financial autarky.

BIBLIOGRAPHY

Daron Acemoglu. Patterns of skill premia. *The Review of Economic Studies*, 70(2):199–230, 2003.

Daron Acemoglu and David Autor. Skills, tasks and technologies: Implications for employment and earnings. In *Handbook of labor economics*, volume 4, pages 1043–1171. Elsevier, 2011.

Daron Acemoglu and Pascual Restrepo. Artificial intelligence, automation and work. Technical report, National Bureau of Economic Research, 2018a.

Daron Acemoglu and Pascual Restrepo. Low-skill and high-skill automation. *Journal of Human Capital*, 12(2):204–232, 2018b.

Daron Acemoglu and Pascual Restrepo. Automation and new tasks: how technology displaces and reinstates labor. *Journal of Economic Perspectives*, 33(2):3–30, 2019.

Daron Acemoglu, Gino Gancia, and Fabrizio Zilibotti. Offshoring and directed technical change. *American Economic Journal: Macroeconomics*, 7(3):84–122, 2015.

Daron Acemoglu, David Autor, David Dorn, Gordon H Hanson, and Brendan Price. Import competition and the great us employment sag of the 2000s. *Journal of Labor Economics*, 34(S1):S141–S198, 2016.

Ernesto Aguayo-Tellez, Marc-Andreas Muendler, and Jennifer P Poole. Globalization and formal sector migration in brazil. *World development*, 38(6):840–856, 2010.

George Alessandria and Horag Choi. Establishment heterogeneity, exporter dynamics, and the effects of trade liberalization. *Journal of International Economics*, 94(2):207–223, 2014.

James E Anderson and Eric Van Wincoop. Trade costs. *Journal of Economic literature*, 42 (3):691–751, 2004.

David Andolfatto. Business cycles and labor-market search. *The american economic review*, pages 112–132, 1996.

Pol Antras and Elhanan Helpman. Global sourcing. *Journal of political Economy*, 112(3): 552–580, 2004.

Pol Antràs and Stephen R Yeaple. Multinational firms and the structure of international trade. In *Handbook of international economics*, volume 4, pages 55–130. Elsevier, 2014.

Pol Antras, Teresa C Fort, and Felix Tintelnot. The margins of global sourcing: Theory and evidence from us firms. *American Economic Review*, 107(9):2514–64, 2017.

David M Arseneau. The welfare costs of skill-mismatch employment. FEDS Working Paper, 2014.

Brian Asquith, Sanjana Goswami, David Neumark, and Antonio Rodriguez-Lopez. Us job flows and the china shock. *Journal of International Economics*, 118:123–137, 2019.

David Autor. Skills, education, and the rise of earnings inequality among the" other 99 percent". *Science*, 344(6186):843–51, 2014.

David H. Autor, David Dorn, and Gordon H. Hanson. The china syndrome: Local labor market effects of import competition in the united states. *American Economic Review*, 103(6):2121–68, October 2013.

David H Autor, David Dorn, and Gordon H Hanson. The china shock: Learning from labor-market adjustment to large changes in trade. *Annual Review of Economics*, 8:205–240, 2016.

Richard Baldwin and Frédéric Robert-Nicoud. Trade-in-goods and trade-in-tasks: An integrating framework. *Journal of international Economics*, 92(1):51–62, 2014.

Alessandro Barattieri, Matteo Cacciatore, and Fabio Ghironi. Protectionism and the business cycle. Technical report, National Bureau of Economic Research, 2018.

Daniel Baumgarten, Ingo Geishecker, and Holger Görg. Offshoring, tasks, and the skill-wage pattern. *European Economic Review*, 61:132–152, 2013.

Sascha O Becker, Karolina Ekholm, and Marc-Andreas Muendler. Offshoring and the onshore composition of tasks and skills. *Journal of International Economics*, 90(1):91–106, 2013.

Andrew B Bernard, Stephen J Redding, and Peter K Schott. Comparative advantage and heterogeneous firms. *The Review of Economic Studies*, 74(1):31–66, 2007.

Olivier Blanchard and Peter Diamond. nthe aggregate matching function. Technical report, o NBER Working Papers 3175, National Bureau of Economic Research, Inc, 1991.

Nicholas Bloom, Kyle Handley, Andre Kurman, and Phillip Luck. The impact of chinese trade on us employment: The good, the bad, and the debatable. 2019.

Christoph E Boehm, Aaron Flaaen, and Nitya Pandalai-Nayar. Multinationals, offshoring and the decline of us manufacturing. Technical report, National Bureau of Economic Research, 2019.

Loren Brandt, Johannes Van Biesebroeck, Luhang Wang, and Yifan Zhang. Wto accession and performance of chinese manufacturing firms. *American Economic Review*, 107(9): 2784–2820, 2017.

Ariel Burstein and Marc J Melitz. Trade liberalization and firm dynamics. In *Advances in Economics and Econometrics Tenth World Congress. Applied Economics*, volume 2, pages 283–328, 2013.

Ariel Burstein and Jonathan Vogel. International trade, technology, and the skill premium. *Journal of Political Economy*, 125(5):1356–1412, 2017.

Sónia Cabral, Pedro S Martins, João Pereira dos Santos, and Mariana Tavares. Collateral damage? labour market effects of competing with china–at home and abroad. IZA Discussion Paper, 2018.

Matteo Cacciatore. International trade and macroeconomic dynamics with labor market frictions. *Journal of International Economics*, 93(1):17–30, 2014.

Matteo Cacciatore and Giuseppe Fiori. The macroeconomic effects of goods and labor markets deregulation. *Review of Economic Dynamics*, 20:1–24, 2016.

Matteo Cacciatore and Fabio Ghironi. Trade, unemployment, and monetary policy. mimeo, HEC Montréal and University of Washington, 2014.

Silvio Contessi. Multinational firms entry and productivity: Some aggregate implications of firm-level heterogeneity. *Journal of Economic Dynamics and Control*, 61:61–80, 2015.

Gregory Corcos, Delphine M Irac, Giordano Mion, and Thierry Verdier. The determinants of intrafirm trade: Evidence from french firms. *Review of Economics and Statistics*, 95(3): 825–838, 2013.

A Kerem Coşar, Nezih Guner, and James Tybout. Firm dynamics, job turnover, and wage distributions in an open economy. *American Economic Review*, 106(3):625–63, 2016.

James Costantini and Marc Melitz. The dynamics of firm-level adjustment to trade liberalization. *The organization of firms in a global economy*, 4:107–141, 2008.

Rosario Crino. Service offshoring and white-collar employment. *The Review of Economic Studies*, 77(2):595–632, 2010.

Rosario Crinò. Service offshoring and the skill composition of labour demand. *Oxford Bulletin of Economics and Statistics*, 74(1):20–57, 2012.

Chiara Criscuolo and Luis Garicano. Offshoring and wage inequality: Using occupational licensing as a shifter of offshoring costs. *American Economic Review*, 100(2):439–43, 2010.

Carl Davidson and Steven Joseph Matusz. *International trade and labor markets: Theory, evidence, and policy implications*. WE Upjohn Institute, 2004.

Carl Davidson, Lawrence Martin, and Steven Matusz. Trade and search generated unemployment. *Journal of International Economics*, 48(2):271–299, 1999.

Carl Davidson, Steven J Matusz, and Andrei Shevchenko. Globalization and firm level adjustment with imperfect labor markets. *Journal of international Economics*, 75(2): 295–309, 2008.

Rafael Dix-Carneiro. Trade liberalization and labor market dynamics. *Econometrica*, 82(3): 825–885, 2014.

Rafael Dix-Carneiro and Brian K Kovak. Trade liberalization and the skill premium: A local labor markets approach. *American Economic Review*, 105(5):551–57, 2015.

Avraham Ebenstein, Ann Harrison, Margaret McMillan, and Shannon Phillips. *Estimating the impact of trade and offshoring on American workers using the current population surveys*. The World Bank, 2011.

Avraham Ebenstein, Ann Harrison, and Margaret McMillan. Why are american workers getting poorer? china, trade and offshoring. Technical report, National Bureau of Economic Research, 2015.

Hartmut Egger, Udo Kreickemeier, and Jens Wrona. Offshoring domestic jobs. *Journal of International Economics*, 97(1):112–125, 2015.

Katherine Eriksson, Katheryn Russ, Jay C Shambaugh, and Minfei Xu. Trade shocks and the shifting landscape of us manufacturing. National Bureau of Economic Research, 2019.

Shenggen Fan, Ravi Kanbur, Shang-Jin Wei, and Xiaobo Zhang. *The Oxford companion to the economics of China*. OUP Oxford, 2014.

Robert C Feenstra. Offshoring to china: the local and global impacts of processing trade. *Lectures presented at the University of International Business and Economics, Beijing*, 2011.

Robert C Feenstra. Statistics to measure offshoring and its impact. Technical report, National Bureau of Economic Research, 2017.

Robert C Feenstra and Gordon H Hanson. Globalization, outsourcing, and wage inequality. Technical report, National Bureau of Economic Research, 1996.

Robert C Feenstra and Gordon H Hanson. Foreign direct investment and relative wages: Evidence from mexico's maquiladoras. *Journal of international economics*, 42(3-4):371–393, 1997.

Robert C Feenstra and Gordon H Hanson. The impact of outsourcing and high-technology capital on wages: estimates for the united states, 1979–1990. *The Quarterly Journal of Economics*, 114(3):907–940, 1999.

Robert C Feenstra and Akira Sasahara. The 'china shock,'exports and us employment: A global input–output analysis. *Review of International Economics*, 26(5):1053–1083, 2018.

Robert C Feenstra, Hong Ma, and Yuan Xu. Us exports and employment. *Journal of International Economics*, 2019.

Gabriel Felbermayr and Julien Prat. Product market regulation, firm selection, and unemployment. *Journal of the European Economic Association*, 9(2):278–317, 2011.

Christopher J Flinn. Minimum wage effects on labor market outcomes under search, matching, and endogenous contact rates. *Econometrica*, 74(4):1013–1062, 2006.

Fabio Ghironi and Marc J Melitz. International trade and macroeconomic dynamics with heterogeneous firms. *The Quarterly Journal of Economics*, 120(3):865–915, 2005.

Manisha Goel. Offshoring–effects on technology and implications for the labor market. *European Economic Review*, 98:217–239, 2017.

Jose L Groizard, Priya Ranjan, and Antonio Rodriguez-Lopez. Offshoring and jobs: The myriad channels of influence. *European Economic Review*, 72:221–239, 2014.

Gene M Grossman and Esteban Rossi-Hansberg. Trading tasks: A simple theory of offshoring. *American Economic Review*, 98(5):1978–97, 2008.

Ann Harrison and Margaret McMillan. Offshoring jobs? multinationals and us manufacturing employment. *Review of Economics and Statistics*, 93(3):857–875, 2011.

Matthias Helble, Trinh Q Long, and Trang T Le. The impact of increased import competition from the people's republic of china on income inequality and household welfare in viet nam. Asian Development Bank, 2018.

Elhanan Helpman and Oleg Itskhoki. Labour market rigidities, trade and unemployment. *The Review of Economic Studies*, 77(3):1100–1137, 2010.

Elhanan Helpman, Oleg Itskhoki, and Stephen Redding. Inequality and unemployment in a global economy. *Econometrica*, 78(4):1239–1283, 2010.

Laura Hering and Rodrigo Paillacar. Does access to foreign markets shape internal migration? evidence from brazil. *The World Bank Economic Review*, 30(1):78–103, 2016.

David Hummels, Rasmus Jørgensen, Jakob Munch, and Chong Xiang. The wage effects of offshoring: Evidence from danish matched worker-firm data. *American Economic Review*, 104(6):1597–1629, 2014.

Roberto N Fattal Jaef and Jose Ignacio Lopez. Entry, trade costs, and international business cycles. *Journal of International Economics*, 94(2):224–238, 2014.

Ronald W Jones, Henryk Kierzkowski, et al. The role of services in production and international trade: A theoretical framework. *World Scientific Book Chapters*, pages 233–253, 2018.

Gueorgui Kambourov. Labour market regulations and the sectoral reallocation of workers: The case of trade reforms. *The Review of Economic Studies*, 76(4):1321–1358, 2009.

Wilhelm Kohler. Aspects of international fragmentation. *Review of International Economics*, 12(5):793–816, 2004.

Brian K Kovak, Lindsay Oldenski, and Nicholas Sly. The labor market effects of offshoring by us multinational firms. Technical report, National Bureau of Economic Research, 2017.

Finn E Kydland and Edward C Prescott. Time to build and aggregate fluctuations. *Econometrica: Journal of the Econometric Society*, pages 1345–1370, 1982.

Wolfgang Lechthaler and Mariya Mileva. Smoothing the adjustment to trade liberalization. Technical report, WWWforEurope Working Paper, 2014a.

Wolfgang Lechthaler and Mariya Mileva. Trade liberalization and wage inequality: New insights from a dynamic trade model with heterogeneous firms and comparative advantage. *Review of World Economics*, pages 1–51, 2014b.

Wolfgang Lechthaler and Mariya Mileva. Trade liberalization and wage inequality: new insights from a dynamic trade model with heterogeneous firms and comparative advantage. *Review of World Economics*, 155(3):407–457, 2019.

Eunhee Lee. Trade, inequality, and the endogenous sorting of heterogeneous workers. 2017.

Shi Li, Hiroshi Sato, and Terry Sicular. *Rising inequality in China: Challenges to a harmonious society*. Cambridge University Press, 2013.

Federico Mandelman and Andrei Zlate. Offshoring, low-skilled immigration, and labor market polarization. FRB Boston Risk and Policy Analysis Unit Paper, 2016.

Federico S Mandelman. Labor market polarization and international macroeconomic dynamics. *Journal of Monetary Economics*, 79:1–16, 2016.

Federico S Mandelman and Andrei Zlate. Immigration, remittances and business cycles. *Journal of Monetary Economics*, 59(2):196–213, 2012.

Brian McCaig and Nina Pavcnik. Export markets and labor allocation in a low-income country. *American Economic Review*, 108(7):1899–1941, 2018.

Marc J Melitz. The impact of trade on intra-industry reallocations and aggregate industry productivity. *econometrica*, 71(6):1695–1725, 2003.

Monika Merz. Search in the labor market and the real business cycle. *Journal of monetary Economics*, 36(2):269–300, 1995.

Giordano Mion and Linke Zhu. Import competition from and offshoring to china: A curse or blessing for firms? *Journal of International Economics*, 89(1):202–215, 2013.

Devashish Mitra and Priya Ranjan. Offshoring and unemployment: The role of search frictions labor mobility. *Journal of International Economics*, 81(2):219–229, 2010.

Mark P Moore and Priya Ranjan. Globalisation vs skill-biased technological change: Implications for unemployment and wage inequality. *The Economic Journal*, 115(503):391–422, 2005.

Melanie Morten and Jaqueline Oliveira. The effects of roads on trade and migration: Evidence from a planned capital city. NBER Working Paper, 22158, 2018.

Dennis Novy. Gravity redux: measuring international trade costs with panel data. *Economic inquiry*, 51(1):101–121, 2013.

OECD. Employment outlook, 2004.

Gianmarco IP Ottaviano, Giovanni Peri, and Greg C Wright. Immigration, offshoring, and american jobs. *American Economic Review*, 103(5):1925–59, 2013.

Justin R Pierce and Peter K Schott. A concordance between ten-digit us harmonized system codes and sic/naics product classes and industries. *Journal of Economic and Social Measurement*, 37(1, 2):61–96, 2012.

Justin R Pierce and Peter K Schott. The surprisingly swift decline of us manufacturing employment. *American Economic Review*, 106(7):1632–62, 2016.

Christopher A Pissarides. *Equilibrium unemployment theory*. MIT press, 2000.

Priya Ranjan. Offshoring, unemployment, and wages: The role of labor market institutions. *Journal of International Economics*, 89(1):172–186, 2013.

Andrés Rodríguez-Clare. Offshoring in a ricardian world. *American Economic Journal: Macroeconomics*, 2(2):227–58, 2010.

Antonio Rodriguez-Lopez and Miaojie Yu. All-around table liberalization and firm-level employment: Theory and evidence from china. CESifo Working Paper Series, 2017.

Guru Sethupathy. Offshoring, wages, and employment: Theory and evidence. *European Economic Review*, 62:73–97, 2013.

Trevor Tombe and Xiaodong Zhu. Trade, migration, and productivity: A quantitative analysis of china. *American Economic Review*, 109(5):1843–72, 2019.

Stephen J Turnovsky. Domestic and foreign disturbances in an optimizing model of exchange-rate determination. *Journal of International Money and Finance*, 4(1):151–171, 1985.

Greg C Wright. Revisiting the employment impact of offshoring. *European Economic Review*, 66:63–83, 2014.

Andrei Zlate. Offshore production and business cycle dynamics with heterogeneous firms. *Journal of International Economics*, 100:34–49, 2016.

Appendix A

MULTINATIONAL FIRMS' SOURCING DECISION AND WAGE INEQUALITY: A DYNAMIC ANALYSIS

1.Autarky equilibrium

From the entry condition,

$$\tilde{v} = fe(\frac{w_l}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha}.$$

According to the Euler Equation for stocks, in the steady state, the following expression also holds:

$$\tilde{v} = \frac{\beta(1-\delta)}{1-\beta(1-\delta)}\tilde{d}.$$

Combining these two conditions, the average firm profit can be written as:

$$\tilde{d} = fe\left(\frac{w_l}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_h}{\alpha}\right)^{\alpha}\frac{\beta(1-\delta)}{1-\beta(1-\delta)} \tag{A.1}$$

Meanwhile, from the aggregate price index equation:

$$\tilde{\rho} = N^{\frac{1}{\theta-1}}.$$

According to the average profit expression $\tilde{d} = \frac{1}{\theta}\tilde{\rho}^{1-\theta}C$ and average productivity $\tilde{z}_D = \left(\frac{k}{k-\theta+1}\right)^{\frac{1}{\theta-1}}$,

$$\tilde{d} = \frac{1}{\theta}\left(\frac{\theta}{\theta-1}\right)^{1-\theta}\left(\frac{k}{k-\theta+1}\right)\left(\frac{w_l}{1-\alpha}\right)^{(1-\alpha)(1-\theta)}\left(\frac{w_h}{\alpha}\right)^{\alpha(1-\theta)}C. \tag{A.2}$$

Combining Eq. (A.1) and Eq. (A.2), the following equation can be derived:

$$\left(\frac{w_l}{1-\alpha}\right)^{(1-\alpha)\theta}\left(\frac{w_h}{\alpha}\right)^{\alpha\theta} = \frac{1}{f_e\theta}\left(\frac{\theta}{\theta-1}\right)^{1-\theta}\left(\frac{k}{k-\theta+1}\right)\frac{\beta(1-\delta)}{1-\beta(1-\delta)}C.$$

Meanwhile, the average number of high-skilled workers hired by firms is the following:

$$\tilde{h}_D = \left(\frac{k-\theta+1}{k}\right)^{\frac{1}{\theta-1}} \left(\frac{\alpha}{1-\alpha}\frac{w_l}{w_h}\right)^{1-\alpha} \tilde{\rho}^{-\theta} C.$$

The labor market clearing condition for high-skilled labor follows as:

$$H = \left(\frac{\theta}{\theta-1}\right)^{\theta-1} \left(\frac{k-\theta+1}{k}\right) \left(\frac{w_l}{1-\alpha}\right)^{(1-\alpha)\theta} \left(\frac{w_h}{\alpha}\right)^{\alpha\theta-1} f_e \left[(\theta-1)\frac{\beta(1-\delta)}{1-\beta(1-\delta)} + \frac{\delta}{1-\delta}\right].$$

Rearranging the equation above,

$$\frac{w_l}{1-\alpha} = \frac{\theta-1}{\theta} \left(\frac{k-\theta+1}{k}\right)^{\frac{1}{1-\theta}} \left(\frac{L}{H}\right)^{\frac{\alpha\theta}{1-\theta}} L^{\frac{1}{\theta-1}} f_e^{\frac{1}{1-\theta}} \left[(\theta-1)(\frac{1-\beta(1-\delta)}{\beta(1-\delta)}) + \frac{\delta}{1-\delta}\right]^{\frac{1}{1-\theta}}.$$

Therefore,

$$w_l = (1-\alpha) \left\{\frac{\theta-1}{\theta} \left(\frac{k-\theta+1}{k}\right)^{\frac{1}{1-\theta}} \left(\frac{L}{H}\right)^{\frac{\alpha\theta}{1-\theta}} L^{\frac{1}{\theta-1}} f_e^{\frac{1}{1-\theta}} \left[(\theta-1)(\frac{1-\beta(1-\delta)}{\beta(1-\delta)}) + \frac{\delta}{1-\delta}\right]^{\frac{1}{1-\theta}}\right\}, \text{ and}$$

$$w_h = \alpha \left\{\frac{\theta-1}{\theta} \left(\frac{k-\theta+1}{k}\right)^{\frac{1}{1-\theta}} \left(\frac{L}{H}\right)^{\frac{\alpha\theta+1-\theta}{1-\theta}} L^{\frac{1}{\theta-1}} f_e^{\frac{1}{1-\theta}} \left[(\theta-1)(\frac{1-\beta(1-\delta)}{\beta(1-\delta)}) + \frac{\delta}{1-\delta}\right]^{\frac{1}{1-\theta}}\right\}.$$

Besides the factor endowment, only f_e changes wage. If f_e decreases, both low-skilled and high-skilled wage w_l, w_h increase.

The following part derives the wage ratio of home low-skilled over foreign low-skilled. The average number of low-skilled workers hired by firms is the following:

$$l_D = \left(\frac{k-\theta+1}{k}\right)^{\frac{1}{1-\theta}} \left(\frac{\alpha}{1-\alpha}\frac{w_l}{w_h}\right)^{-\alpha} \tilde{\rho}^{-\theta} C.$$

Labor market clearing for low-skilled endowment is:

$$L = \left(\frac{\theta}{\theta-1}\right)^{\theta-1} \left(\frac{k-\theta+1}{k}\right) \left(\frac{w_l}{1-\alpha}\right)^{(1-\alpha)\theta-1} \left(\frac{w_h}{\alpha}\right)^{\alpha\theta} f_e \left[(\theta-1)\frac{\beta(1-\delta)}{1-\beta(1-\delta)} + \frac{\delta}{1-\delta}\right]$$

Let $\mu = (\theta-1)\frac{\beta(1-\delta)}{1-\beta(1-\delta)} + \frac{\delta}{1-\delta}$, it follows that

$$\tilde{\rho} = \frac{\theta}{\theta-1} \left(\frac{k-\theta+1}{k}\right)^{\frac{1}{\theta-1}} \left(\frac{w_l}{1-\alpha}\right) \left(\frac{L}{H}\right)^{\alpha} = \left(\frac{H}{L}\right)^{\frac{\alpha}{\theta-1}} L^{\frac{1}{\theta-1}} \left(\frac{1}{\mu f_e}\right)^{\frac{1}{\theta-1}} = H^{\frac{\alpha}{\theta-1}} L^{\frac{1-\alpha}{\theta-1}} \left(\frac{1}{\mu f_e}\right)^{\frac{1}{\theta-1}}.$$

Combining the equation of $N = \tilde{\rho}^{\theta-1}$, the number of firms can be written as:

$$N = \left(\frac{H}{L}\right)^{\alpha} L \left(\frac{1}{\mu f_e}\right) = L^{1-\alpha} H^{\alpha} \left(\frac{1}{\mu f_e}\right).$$

Consumption can be expressed as:

$$C = (\theta - 1)\left(\frac{k-\theta+1}{k}\right)^{\frac{1}{1-\theta}}\left(\frac{H}{L}\right)^{\frac{\alpha\theta}{\theta-1}} L^{\frac{\theta}{\theta-1}} \frac{1}{f_e}^{\frac{1}{\theta-1}} \frac{1}{\mu}^{\frac{\theta}{\theta-1}} \frac{1-\beta(1-\delta)}{\beta(1-\delta)}.$$

Combining with the equation $\tilde{d} = \frac{1}{\theta}\frac{C}{N}$, the following expression for average profit can be derived:

$$\tilde{d} = \frac{\theta-1}{\theta}(\frac{H}{L})^{\frac{\alpha}{\theta-1}} L^{\frac{1}{\theta-1}}(\frac{k}{k-\theta+1})^{\frac{1}{\theta}} f_e^{\frac{\theta-2}{\theta-1}} \mu^{\frac{1}{\theta-1}} \frac{1-\beta(1-\delta)}{\beta(1-\delta)}.$$

Using the equation $\tilde{v} = \frac{\beta(1-\delta)}{1-\beta(1-\delta)}\tilde{d}$, the average firm value $\tilde{v}$ follows as :

$$\tilde{v} = \frac{\theta-1}{\theta}\left(\frac{k}{k-\theta+1}\right)^{\frac{1}{\theta-1}}\left(\frac{H}{L}\right)^{\frac{\alpha}{\theta-1}} L^{\frac{1}{\theta-1}}\left(\frac{1}{f_e}\right)^{\frac{\theta-2}{\theta}} \mu^{\frac{1}{\theta-1}}.$$

Since the ratio of endowments are proportional to wage ratios as $\frac{H}{L} = \frac{w_l}{w_h}\frac{\alpha}{1-\alpha}$ and $\frac{H^*}{L^*} = \frac{w_l^*}{w_h^*}\frac{\alpha}{1-\alpha}$, the wage ratio for low-skilled workers across home and foreign country is the following:

$$\frac{w_l}{w_l^*} = (\frac{L}{L^*}\frac{H^*}{H})^{\frac{\alpha\theta}{1-\theta}}(\frac{L^*}{L}\frac{fe}{fe^*})^{\frac{1}{1-\theta}} = (\frac{L^*}{L})^{\frac{\alpha\theta-1}{\theta-1}}(\frac{H^*}{H})^{\frac{\alpha\theta}{\theta-1}}(\frac{fe^*}{fe})^{\frac{1}{\theta-1}}$$

2. Offshoring equilibrium

Denote the average firm profit under the offshoring scenario as $\tilde{d}^{OFF}$,

$$\begin{aligned} \tilde{d}^{OFF} &= \frac{N_D}{N}\tilde{d}_D + \frac{N_V}{N}\tilde{d}_V \\ &= (1 - z_o^{-k})\tilde{d}_D + (z_o^{-k})\tilde{d}_V. \end{aligned}$$

It follows that

$$\tilde{d}^{OFF} = \frac{1}{\theta}(\frac{\theta}{\theta-1})^{1-\theta}\frac{k}{k-(\theta-1)}(\frac{w_l}{1-\alpha})^{(1-\alpha)(1-\theta)}(\frac{w_h}{\alpha})^{\alpha(1-\theta)}c + \frac{z_o^{-k}(\theta-1)}{k-(\theta-1)} f_v(\frac{w_l^*}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha},$$

which yields the following relationship between average firm profit under offshoring and that under autarky:

$$\tilde{d}^{OFF} = \tilde{d}^{AUT} + \frac{z_o^{-k}(\theta-1)}{k-(\theta-1)} f_v(\frac{w_l^*}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha}.$$

In the steady state, $N_e = \frac{\delta}{1-\delta}N$ and $\tilde{v} = f_e(\frac{w_l}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha}$, which implies that:

$$\tilde{v} = \beta(1-\delta)(\tilde{d} + \tilde{v}) = \frac{\beta(1-\delta)}{1-\beta(1-\delta)}\tilde{d}.$$

Since $N\tilde{d} = N_D\tilde{d_D} + N_v\tilde{d_v}$, it follows that

$$\begin{aligned}\frac{1-\beta(1-\delta)}{\beta(1-\delta)}f_e &= \frac{1}{(\frac{w_l}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha}}[\frac{N_D}{N}\tilde{d_D} + \frac{N_v}{N}\tilde{d_v}] \\ &= \frac{1}{(\frac{w_l}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha}}[(1-(\frac{1}{z_v})^k)\tilde{d_D} + ((\frac{1}{z_v})^k)\tilde{d_v}]\end{aligned}$$

The existence of offshoring cutoff The offshoring productivity cutoff is defined by setting $d_D(z_o) = d_v(z_o)$, which is:

$$\frac{1}{\theta}[\frac{\theta}{\theta-1}\frac{1}{z_o}(\frac{w_l}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha}]^{1-\theta}C = \frac{1}{\theta}[\frac{\theta}{\theta-1}\frac{1}{z_o}(\frac{\tau w_l^*}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha}]^{1-\theta}C - f_v(\frac{w_l^*}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha}.$$

The cutoff z_o can then be expressed as the following:

$$z_o = (\frac{f_v\theta}{C})^{\frac{1}{\theta-1}}\frac{\theta}{\theta-1}(\frac{w_h}{\alpha})^{\frac{\alpha\theta}{\theta-1}}(\frac{w_l^*}{1-\alpha})^{\frac{1-\alpha}{\theta-1}}[\frac{(\tau w_l^*)^{(1-\alpha)(1-\theta)} - {w_l}^{(1-\alpha)(1-\theta)}}{(1-\alpha)^{(1-\alpha)(1-\theta)}}]^{\frac{1}{1-\theta}}$$

In order for $z_o > 0$ to hold, the condition $(\tau w_l^*)^{(1-\alpha)(1-\theta)} - {w_l}^{(1-\alpha)(1-\theta)} > 0$ needs to be satisfied, which implies $\tau w_l^* < w_l$. From this equation, it is easy to observe that both a decrease in f_v and τ lowers the productivity cutoff z_o.

Slope of profits for a firm with productivity z The profit for domestically producing the low-skilled task and that for offshoring the low-skilled task for firm with productivity level z are expressed as the following two equations:

$$d_D(z) = \frac{1}{\theta}(\frac{\theta}{\theta-1}(\frac{w_l}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha})^{1-\theta}z^{\theta-1}C\frac{k}{k-\theta+1}[\frac{z_o^{k-\theta+1}-1}{z_o^k-1}], \text{ and}$$

$$d_v(z) = \frac{1}{\theta}(\frac{\theta}{\theta-1}(\frac{\tau w_l^*}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha})^{1-\theta}z^{\theta-1}C\frac{k}{k-\theta+1} - f_v(\frac{w_l^*}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha}$$

The slope of $d_v(z)$ is steeper than $d_D(z)$ since $(\tau w_l^*)^{1-\theta} > w_l^{1-\theta}$.

Average profits of domestic production and offshoring

$$\tilde{d_D} = \frac{1}{\theta}(\frac{\theta}{\theta-1}(\frac{w_l}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha})^{1-\theta}\tilde{z_D}^{\theta-1}C\frac{k}{k-\theta+1}[\frac{z_o^{k-\theta+1}-1}{z_o^k-1}], \text{ and}$$

$$\tilde{d_v} = \frac{1}{\theta}(\frac{\theta}{\theta-1}(\frac{\tau w_l^*}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha})^{1-\theta}\tilde{z_v}^{\theta-1}C\frac{k}{k-\theta+1} - f_v(\frac{w_l^*}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha}.$$

The linkage between profits of the two production strategies thus follows:

$$\tilde{d_v} = \frac{z_o^k - 1}{z_v^{k-\theta+1} - 1}\tilde{d_D} + \frac{\theta - 1}{k - \theta + 1} f_v(\frac{w_l^*}{1-\alpha})^{1-\alpha}(\frac{w_h}{\alpha})^{\alpha}.$$

It is easy to note that $\tilde{d_v} > \tilde{d_D}$.

Decline in fixed offshoring cost

A decline in fixed offshoring cost has very similar effects as the decline in iceberg trade cost. They both serve as cost savings for offshoring firms on the one hand and offshoring cutoff lowering on the other. From firms' profit side, a lowering of the fixed offshoring cost increases their profits, encouraging more firms to offshore (shifting down the OFE-schedule). Since firms pay the fixed offshoring cost in terns of effective labor units – $f_v(\frac{w_l}{1-\alpha})^{\alpha}$, the fixed cost of offshoring also show up in the factor market clearing equations. Lowering of the f_v also shifts down the FMC-schedule the same way as the iceberg trade cost does.

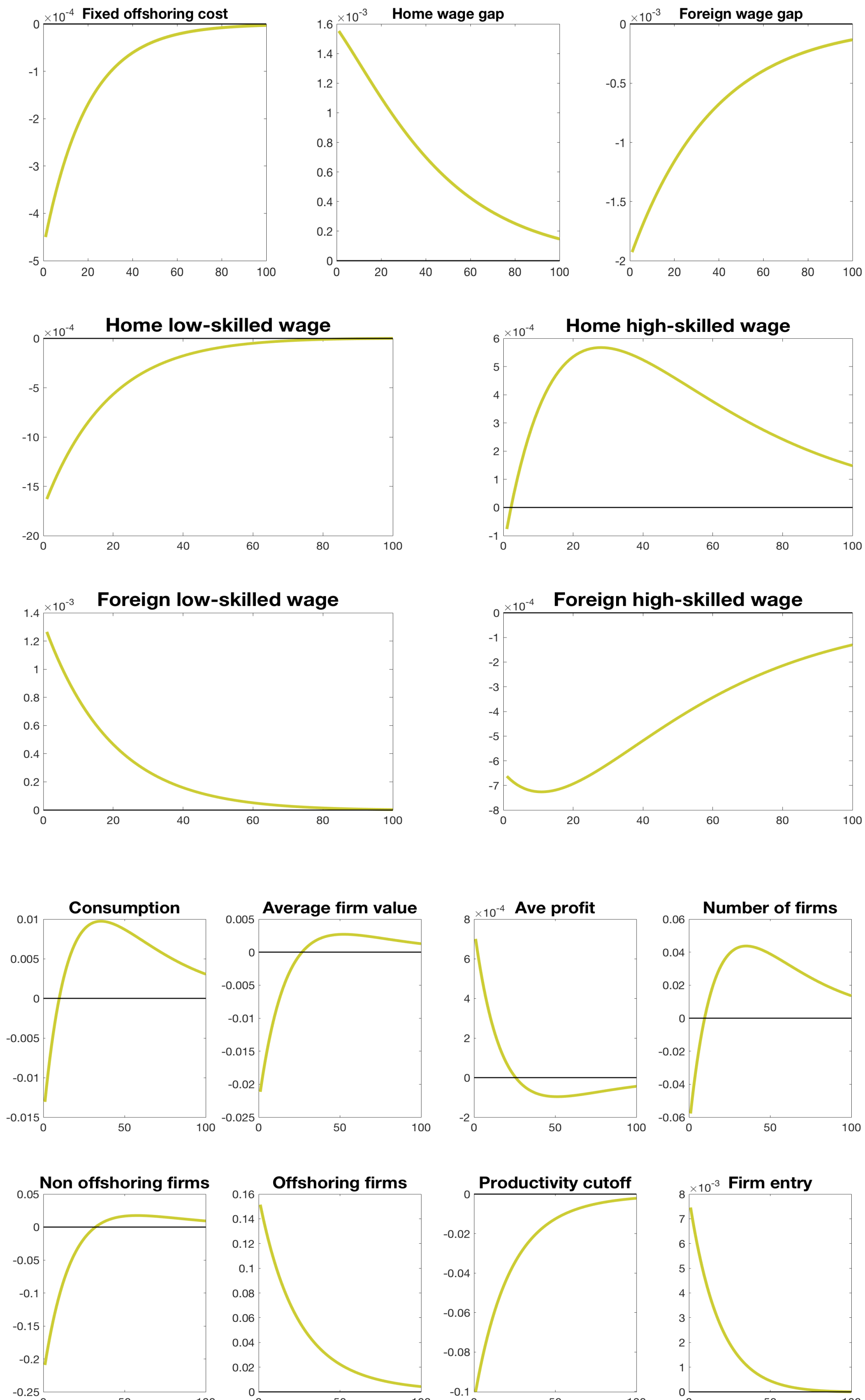


Figure A.1: Impulse responses of key variables following a reduction in fixed offshoring cost in the home country.

Appendix B

OFFSHORING, FIRM-LEVEL ADJUSTMENT, AND LABOR MARKET OUTCOMES

B.1 Data Description

Here we describe in detail the variables used in the VAR part of the main paper.

Tariffs.

In the VAR, I use tariff data from the World Bank WDI (World Development Indicator) Database as the baseline measure of trade cost reduction that allows for easier offshoring in China.

UN-WITS Database as the baseline measure of trade cost reduction that allows for easier offshoring in China. We aggregate HS-2 product-level applied tariff rates using an import-weighted average of tariffs for . In our baseline specification, we use constant weights (using imports data for the year 1999). We linearly detrend the tariff measure.

Unemployment Rates.

The seasonally adjusted monthly unemployment rates for high-skilled and low-skilled workers are from U.S. Bureau of Labor Statistics (BLS), which provides unemployment rates according to education attainment starting year 1992. Following much of the definition in the literature, I define the high-skilled groups as workers with some college degree and above and the low-skilled groups as workers with high school diploma and below.

Wages Gap.

The *annual* wage data for high-skilled and low-skilled workers in 1992-2007 is from Acemoglu and Autor (2011) (AA11 thereafter), in which the log hourly wages by years of education are provided. Wage data at the *quarterly* frequency is taken from Weekly and hourly earnings data from the Current Population Survey in BLS, which gives detailed information on earnings for workers with different levels of educational attainment starting from year 2000. Although the earliest available year for workers with different skills is much later than the annual data, the quarterly frequency gives us a larger sample for analysis.

Other measures of China shock used:

(i) the measure of Autor et al. (2016)(ADDHP), which captures the change in Chinese import penetration, and (ii) the measure of China's PNTR status granted by U.S. Pierce and Schott (2016) (iii) the measure of Antras et al. (2017), which looks at the growth of China's sourcing capacity. (iv) the measure calculated in Asquith et al. (2019), which focuses on the import exposure and acts as a robustness check for the VAR results. The first two measures both cover 392 manufacturing industries whereas the last one covers both 392 manufacturing industries and 87 non-manufacturing industries. More specifically, the first measure– Chinese import penetration from ADDHP is the annualized change of Chinese import penetration, which is calculated by U.S. imports from China in industry j at year t divided by real domestic absorption of U.S. industry j (the industry's real output, plus real imports, less real exports) in 1991, the starting year of the analysis. The second measure- permanent normal trade relations in PS is represented by the "NTR gap", which is defined as the difference between the non-NTR rates to which tariffs would have risen without successful annual renewal (37 percent on average in 1999) and the NTR tariff rates under PNTR (4 percent on average in 1999). In terms of the last measure used in the VAR analysis, Asquith et al. (2019) create a version of the NETS database that matches AADHP's industry classification from the County Business Patterns (CBP) of the Census Bureau. In total, there are 392 industries at the four-digit Standard Industry Classification (SIC) level, and 87 non-manufacturing industries covered in the calculation of exposure to Chinese imports.

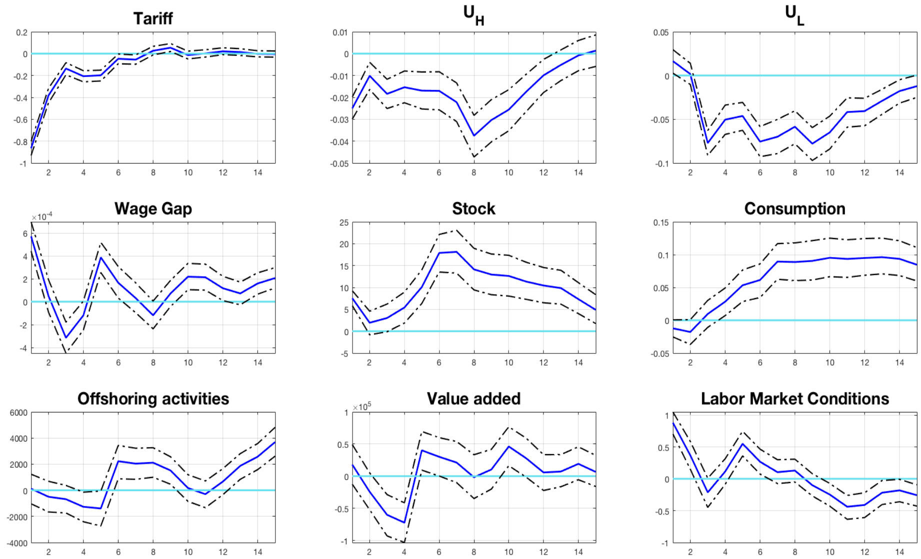


Figure B.1: VAR robustness check.

Figure B.2: Impulse response functions with a set of control variables following a negative trade cost shock.

B.2 VAR Robustness

B.3 Equations

B.3.1 Wage Equation

I assume wage is the solution of an individual Nash bargaining between a firm and a worker. The solution splits the surplus of the match with shares determined by the bargaining weight η in the following sharing rule:

$$\eta S_{i,t}^{F}(z) = (1-\eta)\, S_{i,t}^{W}(z),$$

where $S_{i,t}^{F}(z)$ is the value of the match with the type i worker to the firm with productivity level z and $S_{i,t}^{W}(z)$ is worker's surplus from the job. The value of the match to the firm is the marginal profit brought about by the worker, which is the marginal revenue product minus wage, plus the expected savings from posting the job next period

$$S^F_{i,t}(z) = \varphi^i_{z,t} z Z_t + (1-(1-\delta)(1-\lambda))\, E_t \frac{\kappa^i}{q^i_{t+1}} - w_{i,t}(z) = \frac{\kappa^i}{q^i_t}.$$

The surplus of the worker is given by:

$$S^W_{i,t}(z) = w_{i,t}(z) - \bar{\omega}_{i,t} + \left(1-\bar{\lambda}\right) E_t \beta_{t,t+1} S^W_{i,t+1},$$

where $\bar{\omega}_t$ is the worker outside option, defined as:

$$\bar{\omega}_{i,t} = \nu^i C^\gamma_t + b + (1-\bar{\lambda}) E_t \beta_{t,t+1} \iota_{t+1} S^W_{i,t+1}.$$

Meanwhile, using the equilibrium sharing rule, the following can be written:

$$S^W_{i.t} = \frac{\eta}{1-\eta}\frac{\kappa^i}{q^i_t},$$

which yields:

$$\begin{aligned} &\eta\left[\varphi^i_{z,t} z Z_t + (1-(1-\delta)(1-\lambda))\, E_t \beta_{t,t+1} \frac{\kappa^i}{q^i_{t+1}} - w_{i,t}(z)\right] \\ =&(1-\eta)\left[w_{i,t}(z) - \bar{\omega}_{it} + \left(1-\bar{\lambda}\right) E_t \beta_{t,t+1} S^W_{i,t+1}\right] \\ =&(1-\eta)\left[w_{i,t}(z) - \bar{\omega}_{it} + \left(1-\bar{\lambda}\right) E_t \beta_{t,t+1} \frac{\eta}{1-\eta}\frac{\kappa^i}{q^i_{t+1}}\right]. \end{aligned}$$

The above expression implies that the wage of a worker of type i employed at firm z is equal to:

$$w_{i,t}(z) = \eta \varphi^i_{z,t} z Z_t + (1-\eta)\, \bar{\omega}_{i,t}.$$

It follows that all firms pay the same wage $w_{i,t}(z) = w_t(z)$ for type i worker, which also leads to the equation of $S^W_{i,t+1} = S^{\tilde{W}}_{i,t+1}$. As a result, the worker's outside option becomes:

$$\begin{aligned} \bar{\omega}_t &= \nu^i C^\gamma_t + b + (1-\bar{\lambda}) E_t \beta_{t,t+1} \iota_{t+1} S^W_{i,t+1} \\ &= \nu^i C^\gamma_t + b + (1-\bar{\lambda}) E_t \left[\beta_{t,t+1} q^i_{t+1} \vartheta_{i,t+1} \frac{\eta}{1-\eta}\frac{\kappa^i}{q^i_{t+1}}\right] \\ &= \nu^i C^\gamma_t + b + (1-\bar{\lambda}) \frac{\eta}{1-\eta} E_t\left[\beta_{t,t+1} \kappa^i \vartheta_{i,t+1}\right]. \end{aligned}$$

Combining with the equilibrium value of $\bar{\omega}_{i,t}$, wage for a type i worker becomes:

$$w_{i,t} = \eta\left[\varphi^i_{z,t} z Z_t + (1-\bar{\lambda}) E_t \beta_{t,t+1} \kappa^i \vartheta_{i,t+1}\right] + (1-\eta)\left(\nu^i C^\gamma_t + b\right).$$

B.3.2 Steady State Analysis

Unemployment Rate

1. Home high-skilled unemployment:

The assumption here is that the number of vacancies an entrant posts is the same as what an incumbent does: $v_{e,t}^{\tilde{h}} = \frac{\tilde{h}_t}{q_t^h}$ where $\tilde{h}_t = \frac{N_{d,t}\tilde{h_{d,t}} + N_{v,t}\tilde{h_{v,t}}}{N_t}$.

$$\begin{aligned} H_t &= H_t^I + H_t^E \\ &= N_t\tilde{h}_t + N_{e,t}\tilde{h}_t \\ &= (N_t + N_{e,t})\,\tilde{h}_t \\ &= \frac{N_t + N_{e,t}}{N_t} H_t^I. \end{aligned} \tag{B.1}$$

The law of motion of the high-skilled for a firm z (regardless of production strategy) is the following:

$$h_{z,t} = \left(1 - \bar{\lambda}\right) h_{z,t-1} + q_t^h v_{z,t}^h,$$

which implies:

$$\tilde{h}_t = \left(1 - \bar{\lambda}\right) \tilde{h_{t-1}} + q_t^h \tilde{v_t^h}.$$

The total number of high-skilled employed is:

$$H_t = \left(1 - \bar{\lambda}\right) \frac{H_{t-1}}{N_{t-1}} N_t + q_t^h N_t \tilde{v_t^h},$$

and the total high-skilled employed at the incumbent firms follows the following equation:

$$H_t = \left(1 - \bar{\lambda}\right) \frac{N_t}{N_{t-1}} H_{t-1}^I + q_t^h V_t^{h,I}. \tag{B.2}$$

Combining Eq.(B.1) and Eq.(B.2),

$$H_t = \left(1 - \bar{\lambda}\right) \frac{N_t}{N_{t-1}} \left(1 + \frac{N_{e,t}}{N_t}\right) H_{t-1}^I + q_t^h \left(1 + \frac{N_{e,t}}{N_t}\right) V_t^{h,I}. \tag{B.3}$$

For entrants, the number of total vacancies posted is equal to

$$V_t^{h,E} = N_{e,t} v_{e,t}^{\tilde{h}} = N_{e,t} \frac{\tilde{h}_t}{q_t^h} = \frac{N_{e,t}}{N_t} \frac{H_t^I}{q_t^h}.$$

The second part of Eq.(B.3) is

$$\begin{aligned} q_t^h\left(1+\frac{N_{e,t}}{N_t}\right)V_t^{h,I} \\ &= q_t^h\left(1+\frac{N_{e,t}}{N_t}\right)\left[V_t^h - V_t^{h,E}\right] \\ &= q_t^h\left(1+\frac{N_{e,t}}{N_t}\right)\left[V_t^h - \frac{N_{e,t}}{N_t}\frac{H_t^I}{q_t^h}\right] \\ &= q_t^h\left(1+\frac{N_{e,t}}{N_t}\right)V_t^H - \left(1+\frac{N_{e,t}}{N_t}\right)\frac{N_{e,t}}{N_t}H_t^I. \end{aligned} \quad \text{(B.4)}$$

Plug Eq.(B.1) into the first part of Eq.(B.3) and use the result of Eq.(B.4),

$$H_t = \left(1-\bar{\lambda}\right)\frac{N_t}{N_{t-1}}\left(\frac{N_t}{N_t+N_{e,t}}\right)\left(\frac{N_t+N_{e,t}}{N_t}\right)H_{t-1}^I + q_t^h\left(1+\frac{N_{e,t}}{N_t}\right)V_t^H - \left(\frac{N_t+N_{e,t}}{N_t}\right)\frac{N_{e,t}}{N_t}\frac{N_t}{N_t+N_{e,t}}H_t.$$

The law of motion of total high-skilled employment can be expressed as:

$$H_t = \left(1-\bar{\lambda}\right)\frac{N_t}{N_{t-1}}\left(\frac{N_t}{N_t+N_{e,t}}\right)H_{t-1}^I + q_t^h V_t^h.$$

The steady state of high-skilled employment is thus:

$$\begin{aligned} H &= (1-\lambda)(1-\delta)H + \chi^h \vartheta_h^{1-\epsilon} U_h \\ &= (1-\lambda)(1-\delta)H + M^h. \end{aligned}$$

Therefore, high-skilled unemployment follows as:

$$U_h = \frac{1-(1-\lambda)(1-\delta)}{\chi^h \vartheta_h^{1-\epsilon}}H \quad \text{(B.5)}$$

. Meanwhile,

$$H = M^h + \bar{H} - U^h.$$

Therefore,

$$\begin{aligned} H &= \left[1-(1-\lambda)(1-\delta)\right]H + \bar{H} - U^h \\ &= \frac{\bar{H} - U^h}{(1-\lambda)(1-\delta)}. \end{aligned} \quad \text{(B.6)}$$

Plug Eq.(B.6) into Eq.(B.5):

$$u^h = \frac{1}{1+\frac{\chi^h \vartheta_h^{1-\epsilon}}{\lambda^{h,TOT}}},$$

where $\lambda^{h,TOT} = \frac{1-(1-\lambda)(1-\delta)}{(1-\lambda)(1-\delta)}$ and $u^h = \frac{U^h}{\bar{H}}$.

2. Home Low-skilled:

The assumption here is that the number of vacancies an entrant posts is the same as what an incumbent does: $v_{e,t}^{\tilde{l}} = \frac{\tilde{l}_t}{q_t^l}$ where $\tilde{l}_t = \tilde{l_{d,t}}$. Thus, $\tilde{l_{d,t}} = \tilde{l}_t = \frac{L_t^I}{N_{d,t}}$.

$$\begin{aligned} L_t &= L_t^I + L_t^E \\ &= N_{d,t}\tilde{l_{d,t}} + N_{e,t}\tilde{l_{d,t}} \\ &= (N_{d,t} + N_{e,t})\,\tilde{l_{d,t}} \\ &= \frac{N_{d,t} + N_{e,t}}{N_{d,t}} L_t^I. \end{aligned}$$

Since the law of motion of a low-skilled worker for a domestically producing firm with productivity level z follows:

$$l_{z,t} = \left(1 - \bar{\lambda}\right) l_{z,t-1} + q_t^l v_{z,t}^l,$$

taking the average and multiplied by the number of domestically producing firms, the total number of low-skilled employment can be expressed as :

$$L_t = \left(1 - \bar{\lambda}\right) \frac{L_{t-1}}{N_{d,t-1}} N_{d,t} + q_t^l N_{d,t} v_{z,t}^l.$$

The law of motion of the total low-skilled employed at an incumbent firm is:

$$L_t^I = \left(1 - \bar{\lambda}\right) \frac{N_{d,t}}{N_{d,t-1}} L_{t-1}^I + q_t^l V_t^l,$$

Therefore, the law of motion for aggregate low-skilled workers follows:

$$L_t = \left(1 - \bar{\lambda}\right) \frac{N_{d,t}}{N_{d,t-1}} \left(\frac{N_{d,.t}}{N_{d,t} + N_{e,t}}\right) H_{t-1}^I + q_t^h V_t^h.$$

Since firms

$$\begin{aligned} \frac{N_d}{N_d + N_e} &= \frac{\left(1 - z_o^{-k}\right) N}{\left(1 - z_o^{-k}\right) N + \frac{\delta}{1-\delta} N} \\ &= \frac{1 - \delta}{1 - \delta + \delta \left(1 - z_o^{-k}\right)^{-1}}, \end{aligned}$$

$$L = (1 - \lambda)(1 - \delta) \frac{1}{1 - \delta + \delta \left(1 - z_o^{-k}\right)^{-1}} L + \chi^l \vartheta_l^{1-\epsilon} u^l.$$

Therefore,

$$U^l = \frac{1 - \frac{(1-\lambda)(1-\delta)}{1-\delta+\delta\left(1-z_o^{-k}\right)^{-1}}}{\chi^l \vartheta_l^{1-\epsilon}} L.$$

Meanwhile,

$$L = M^l + \bar{L} - U^l$$

. As a result,

$$L = \frac{\bar{L} - U^l}{(1-\lambda)(1-\delta)}.$$

$$u^l = \frac{\frac{1-\frac{(1-\lambda)(1-\delta)}{1-\delta+\delta\left(1-z_o^{-k}\right)^{-1}}}{(1-\lambda)(1-\delta)}}{\chi^l \vartheta_l^{1-\epsilon} + \frac{1-\frac{(1-\lambda)(1-\delta)}{1-\delta+\delta\left(1-z_o^{-k}\right)^{-1}}}{(1-\lambda)(1-\delta)}},$$

and $u^l = \frac{U^l}{\bar{L}}$.

3. Foreign low-skilled:

The assumption regarding the number of vacancies an average entrant posts is $v_{e,t}^{l*} = \frac{\tilde{l}_t^*}{q_t^{l*}}$ where

$$\begin{aligned} \tilde{l}_t^* &= \frac{L_t^{*I}}{N_t^{L*}} \\ &= \frac{N^* \tilde{l}^* + N_v \tilde{l}_v}{N_t^{L*}}, \end{aligned}$$

with the total number of foreign low-skilled labor expressed as $N_t^{L*} = N_t^* + N_{v,t}$. The total foreign low-skilled labor follows:

$$\begin{aligned} L_t^* &= L_t^{*I} + L_t^{*E} \\ &= \left(N_t^{L*} + N_{e,t}^*\right) \tilde{l}_t^* \\ &= L_t^{*I} \frac{N_t^{L*} + N_{e,t}^*}{N_t^{L*}}. \end{aligned}$$

Therefore,

$$L_t^* = (1-\lambda) \frac{N_t^{L*}}{N_{t-1}^{L*}} L_{t-1}^{*I} + q_t^{l*} V_t^{l*,I},$$

and

$$L_t^* = (1-\lambda)\frac{N_t^{L*}}{N_{t-1}^{L*}}\left(1+\frac{N_{e,t}^*}{N_{t-1}^{L*}}\right)L_{t-1}^{*I} + q_t^{l*}\left(1+\frac{N_{e,t}^*}{N_t^{L*}}\right)V_t^{l*,I}.$$

Thus,

$$L_t^* = (1-\lambda)\frac{N_t^*+N_{v,t}}{N_{t-1}^*+N_{v,t-1}}\left(1+\frac{N_{e,t}^*}{N_{t-1}^*+N_{v,t-1}}\right)L_{t-1}^{*I} + q_t^{l*}\left(1+\frac{N_{e,t}^*}{N_{t-1}^*+N_{v,t-1}}\right)V_t^{l*,I},$$

generating the following equation:

$$L_t^* = (1-\lambda)\frac{N_t^*+N_{v,t}}{N_{t-1}^*+N_{v,t-1}}\left(1+\frac{N_t^*+N_{v,t}}{N_t^*+N_{e,t}^*}.\right)L_{t-1}^* + M_t^{l*}.$$

In the teady state:

$$\begin{aligned} L^* &= (1-\lambda)\frac{1+\frac{N_v}{N^*}}{1+\frac{\delta}{1-\delta}}L + M^{l*} \\ &= (1-\lambda)(1-\delta)\left(1+\frac{N_v}{N^*}\right)L^* + M^{l*}. \end{aligned}$$

What is the ratio of offshoring firms to foreign firms? From the price index equations for the two countries, the following equation can be written out:

$$\begin{aligned} &\left(1-z_o^{-k}\right)\left[\left(\frac{\varphi_l}{1-\alpha}\right)^{1-\alpha}\left(\frac{\varphi_h}{\alpha}\right)^{\alpha}\right]^{1-\theta} + \left(z_o^{-k}\right)\left[\left(\frac{\varphi_l^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{\varphi_h}{\alpha}\right)^{\alpha}\right]^{1-\theta} \\ &= \frac{N^*}{N}\left(1-z_o^{-k}\right)\left[\left(\frac{\varphi_l^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{\varphi_h}{\alpha}\right)^{\alpha}\right]^{1-\theta}. \end{aligned}$$

Thus,

$$\begin{aligned} \frac{N^*}{N} &= \left(1-z_o^{-k}\right)\left[\left(\frac{\varphi_l}{\varphi_l^*(1-\alpha)}\right)^{1-\alpha}\left(\frac{\varphi_h}{\varphi_h^*\alpha}\right)^{\alpha}\right]^{1-\theta} + z_o^{-k}\left(\frac{\varphi_h}{\varphi_h^*\alpha}\right)^{\alpha(1-\theta)} \\ &= \left(\frac{\varphi_h}{\varphi_h^*\alpha}\right)^{\alpha(1-\theta)}\left[\left(1-z_o^{-k}\right)\left(\frac{\varphi_l}{\varphi_l^*(1-\alpha)}\right)^{(1-\alpha)(1-\theta)} + z_o^{-k}\right]. \end{aligned}$$

Combining with $\frac{N}{N_v} = z_o^k$,

$$\begin{aligned} \frac{N^*}{N_v} &= \frac{N^*}{N}\frac{N}{N_v} \\ &= \left(\frac{\varphi_h}{\varphi_h^*\alpha}\right)^{\alpha(1-\theta)}\left[\left(z_o^k-1\right)\left(\frac{\varphi_l}{\varphi_l^*(1-\alpha)}\right)^{(1-\alpha)(1-\theta)} + 1\right], \end{aligned}$$

the following equation can be derived:

$$L^{*}=(1-\lambda)(1-\delta)\left(1+\frac{\left(\frac{\varphi_{h}}{\varphi_{h}^{*}\alpha}\right)^{\alpha(1-\theta)}}{\left(z_{o}^{k}-1\right)\left(\frac{\varphi_{l}}{\varphi_{l}^{*}(1-\alpha)}\right)^{(1-\alpha)(1-\theta)}+1}\right)L^{*}+\chi^{l*}\vartheta_{l*}^{1-\epsilon}U^{l*}.$$

Combining with

$$L^{*}=\frac{1-U^{l*}}{(1-\lambda)(1-\delta)},$$

the foreign low-skilled unemployment rate can be expressed as:

$$u^{l*}=\frac{1}{1+\frac{\chi_{l*}^{1-\epsilon}}{\lambda^{l*TOT}}},$$

where

$$\lambda^{l*TOT}=\frac{1-(1-\lambda)(1-\delta)\left[1+\frac{\left(\frac{\varphi_{h}}{\varphi_{h}^{*}\alpha}\right)^{\alpha(1-\theta)}}{\left(z_{o}^{k}-1\right)\left(\frac{\varphi_{l}}{\varphi_{l}^{*}(1-\alpha)}\right)^{(1-\alpha)(1-\theta)}+1}\right]}{(1-\lambda)(1-\delta)}.$$

Appendix C

TRADE, MIGRATION, AND INEQUALITY: AN ANALYSIS OF CHINA

C.1 Derivation of equations

C.1.1 Wage inequality equations

Within-sector skill premium

$$\frac{w^s_{ag,t}}{w^l_{ag,t}} = \frac{\eta_{ag}}{1-\eta_{ag}}\frac{L_{ag,t}}{S_{ag,t}} \quad \text{and} \quad \frac{w^s_{na,t}}{w^l_{na,t}}=\frac{\eta_{na}}{1-\eta_{na}}\frac{L_{na,t}}{S_{na,t}}$$

Country level skill premium Country-level skill premium is by definition $\frac{w^s_t}{w^l_t}$, the ratio between skilled wage and unskilled wage at the aggregate level.

$$w^s_t = \frac{S_{na,t}}{\bar{S}_t}w^s_{na,t} + \frac{S_{ag,t}}{\bar{S}_t}w^s_{ag,t}, \text{and}$$

$$w^l_t = \frac{L_{na,t}}{\bar{L}_t}w^l_{na,t} + \frac{L_{ag,t}}{\bar{L}_t}w^l_{ag,t}.$$

Substituting relative labor demand, skill wage and unskilled wage can be written as:

$$\begin{aligned} w^s_t &= \left[S_{na,t} * \eta_{na} Z_{na,t} S^{\eta_{na}-1}_{na,t} L^{1-\eta_{na}}_{na,t} + S_{ag,t} * \eta_{ag} Z_{ag,t} S^{\eta_{ag}-1}_{ag,t} L^{1-\eta_{ag}}_{ag,t}\right] / \left(S_{na,t} + S_{ag,t}\right) \\ &= \eta_{na} Z_{na,t} L^{1-\eta_{na}}_{na,t} \frac{S^{\eta_{na}}_{na,t}}{\bar{S}_t} + \eta_{ag} Z_{ag,t} L^{1-\eta_{ag}}_{ag,t} \frac{S^{\eta_{ag}}_{ag,t}}{\bar{S}_t}. \end{aligned}$$

$$\begin{aligned} w^l_t &= \left[L_{na,t} * \left(1-\eta_{na}\right) Z_{na,t} S^{\eta_{na}}_{na,t} L^{-\eta_{na}}_{na,t} + L_{ag,t} * \left(1-\eta_{ag}\right) Z_{ag,t} S^{\eta_{ag}}_{ag,t} L^{-\eta_{ag}}_{ag,t}\right] / \left(L_{na,t} + L_{ag,t}\right) \\ &= \left(1-\eta_{na}\right) Z_{na,t} S^{1-\eta_{na}}_{na,t} \frac{L^{\eta_{na}}_{na,t}}{\bar{L}_t} + \left(1-\eta_{ag}\right) Z_{ag,t} S^{1-\eta_{ag}}_{ag,t} \frac{L^{\eta_{ag}}_{ag,t}}{\bar{L}_t}. \end{aligned}$$

Therefore, the country-level skill premium follows:

$$\begin{aligned}
\frac{w_t^s}{w_t^l} &= \left[\frac{\eta_{na} Z_{na,t} L_{na,t}^{1-\eta_{na}} S_{na,t}^{\eta_{na}} + \eta_{ag} Z_{ag,t} L_{ag,t}^{1-\eta_{ag}} S_{ag,t}^{\eta_{ag}}}{\left(1-\eta_{na}\right) Z_{na,t} L_{na,t}^{\eta_{na}} S_{na,t}^{1-\eta_{na}} + \left(1-\eta_{ag}\right) Z_{ag,t} L_{ag,t}^{\eta_{ag}} S_{ag,t}^{1-\eta_{ag}}}\right] \frac{\bar{L}_t}{\bar{S}_t} \\
&= \left[\frac{\eta_{na} p_{na,h,t} \tilde{Y}_{na,t} + \eta_{ag} p_{ag,t} Y_{ag,t}}{\left(1-\eta_{na}\right) p_{na,h,t} \tilde{Y}_{na,t} + \left(1-\eta_{ag}\right) p_{ag,t} Y_{ag,t}}\right] \frac{\bar{L}_t}{\bar{S}_t} \\
&= \left[\frac{\eta_{na} \frac{p_{na,h,t} \tilde{Y}_{na,t}}{p_{ag,t} Y_{ag,t}} + \eta_{ag}}{\left(1-\eta_{na}\right) \frac{p_{na,h,t} \tilde{Y}_{na,t}}{p_{ag,t} Y_{ag,t}} + \left(1-\eta_{ag}\right)}\right] \frac{\bar{L}_t}{\bar{S}_t}
\end{aligned}$$

Urban-rural wage inequality Urban-rural wage inequality is defined as $\frac{w_{na,t}}{w_{ag,t}}$.

Since $w_{na,t}$ is the average wage of the unskilled non-agricultural wage and the skilled non-agricultural wage,

$$\begin{aligned}
w_{na,t} &= \frac{L_{na,t}}{L_{na,t} + S_{na,t}} w_{na,t}^l + \frac{S_{na,t}}{L_{na,t} + S_{na,t}} w_{na,t}^s \\
&= Z_{na,t} p_{na,h,t} \left[(1-\eta)_{na} S_{na,t}^{\eta_{na}} L_{na,t}^{1-\eta_{na}} + \eta_{na} S_{na,t}^{\eta_{na}} L_{na,t}^{1-\eta_{na}}\right] / \left(L_{na,t} + S_{na.t}\right) \\
&= \frac{Z_{na,t} p_{na,h,t} S_{na,t}^{\eta_{na}} L_{na,t}^{\eta_{na}}}{L_{na,t} + S_{na,t}} \\
&= \frac{p_{na,h,t} Y_{na,t}}{L_{na,t} + S_{na,t}}.
\end{aligned}$$

Similarly, $w_{ag,t}$, which is the average wage of the unskilled wage and the skilled wage in the agricultural sector can be written as:

$$\begin{aligned}
w_{ag,t} &= \frac{L_{ag,t}}{L_{ag,t} + S_{ag,t}} w_{ag,t}^l + \frac{S_{ag,t}}{L_{ag,t} + S_{ag,t}} w_{ag,t}^s \\
&= \frac{Z_{ag,t} p_{ag,t} S_{ag,t}^{\eta_{ag}} L_{ag,t}^{\eta_{ag}}}{L_{ag,t} + S_{ag,t}} \\
&= \frac{p_{ag,t} Y_{ag,t}}{L_{ag,t} + S_{ag,t}}.
\end{aligned}$$

Therefore, urban-rural wage inequality, which is the wage ratio between the average wage at the non-agricultural sector and that at the agricultural sector is the following:

$$\begin{aligned}
\frac{w_{na,t}}{w_{ag,t}} &= \frac{p_{na,h,t} Y_{na,t}}{p_{ag,t} Y_{ag,t}} \frac{L_{ag,t} + S_{ag,t}}{L_{na,t} + S_{na,t}} \\
&= \frac{p_{na,h,t} Y_{na,t}}{p_{ag,t} Y_{ag,t}} \frac{\bar{L}_{ag,t} + \bar{S}_{ag,t} - \left(L_{m,t} + S_{m,t}\right)}{\bar{L}_{na,t} + \bar{S}_{na,t} + \left(L_{m,t} + S_{m,t}\right)}.
\end{aligned}$$

This implies that urban-rural wage inequality is pinned down by two forces: ratio of output in these two areas $\frac{Y_{na,t}}{Y_{ag,t}}$ and the ratio of total labor working in the rural area over the total mass of labor working in the urban area $\frac{L_{ag,t}+S_{ag,t}}{L_{na,t}+S_{na,t}}$. These two forces work in opposite directions.

C.1.2 Steady state equations

The price indexes for the composite good of each country are:

$$1 = \omega \left(p_{na,h,t}\right)^{1-\mu} + (1-\omega)\left(p_{na,f,t}\tau Q_t\right)^{1-\mu},$$

$$1 = \omega^* \left(p_{na,f,t}\right)^{1-\mu^*} + (1-\omega^*)\left(p_{na,h,t}\tau^*/Q_t\right)^{1-\mu^*}.$$

The relationship between $p_{na,h}$ and $p_{na,f}$ are obtained:

$$p_{na,f} = \left[\frac{1-\omega\left(p_{na,h}\right)^{1-\mu}}{1-\omega}\right]^{\frac{1}{1-\mu}} \frac{1}{\tau Q},$$

$$p_{na,h} = \left[\frac{1-\omega^*\left(p_{na,f}\right)^{1-\mu^*}}{1-\omega^*}\right]^{\frac{1}{1-\mu^*}} \frac{Q}{\tau^*}.$$

Assuming $\mu = \mu^*$, price of the Home non-agricultural good $p_{na,h}$ is a function of $Q, \tau, \tau^*, \omega, \omega^*, \mu$ and μ^*:

$$\omega^* \left(\frac{1-\omega\left(p_{na,h}\right)^{1-\mu}}{1-\omega}\right)\tau^{\mu-1} + (1-\omega^*)\left(p_{na,h}\right)^{1-\mu}\left(\tau^*\right)^{1-\mu} = Q^{1-\mu}.$$

From the balanced trade equation:

$$p_{na,h}\tau^* Y^*_{na,h} = p_{na,f}\tau Q Y_{na,f}.$$

Substitute price ratios of $p_{na,h}$ to $p_{na,f}$ and that $Y^*_{na,h} = (1-\omega^*)\left(p_{na,h}\tau^*/Q\right)^{-\mu*} C^*_{na}$ and $Y_{na,f} = (1-\omega)\left(p_{na,f}\tau Q\right)^{-\mu} C_{na}$ into the above equation and assume $\mu = \mu^*$, it follows that:

$$C^*_{na} = \frac{\left(p_{na,h}\right)^{\mu-1} - \omega}{1-\omega^*} C_{na} Q^{\mu} \left(\tau^*\right)^{\mu-1}.$$

Thus, the consumption ratio in units of the same consumption basket is:

$$\frac{C_{na}}{C_{na}^{*}Q}=Q^{1-\mu}\tau^{1-\mu}\frac{1-\omega^{*}}{\left(p_{na,h}\right)^{\mu-1}-\omega}.$$

Since $p_{na,h}=\left(Z_{na}\left(1-\eta_{na}\right)\right)^{-1}w_{na}^{l}\left(\frac{\bar{L}_{na}+L_{m}}{\bar{S}_{na}+S_{m}}\right)^{\eta_{na}}$, the consumption ratio in units of the same consumption basket can also be written as:

$$\frac{C_{na}}{C_{na}^{*}Q}=Q^{\mu-1}\left(1-\omega^{*}\right)\left[\left(\frac{w_{na}^{l}}{Z_{na}\left(1-\eta_{na}\right)}\right)^{\mu-1}\left(\frac{\bar{L}_{na}+L_{m}}{\bar{S}_{na}+S_{m}}\right)^{\eta_{na}(\mu-1)}-\omega\right]^{-1}.$$

From the relative demand equation, price of home non-agricultural good and agricultural good are:

$$p_{na,h}=\left(Z_{na}\left(1-\eta_{na}\right)\right)^{-1}w_{na}^{l}\left(\frac{\bar{L}_{na}+L_{m}}{\bar{S}_{na}+S_{m}}\right)^{\eta_{na}},$$

$$p_{ag}=\left(Z_{ag}\left(1-\eta_{ag}\right)\right)^{-1}w_{ag}^{l}\left(\frac{\bar{L}_{ag}-L_{m}}{\bar{S}_{ag}-S_{m}}\right)^{\eta_{ag}}.$$

The expression for the real exchange rate in steady state is:

$$\begin{aligned}
Q^{u} &= \frac{1-\omega p_{na,h}^{1-\mu}}{\left(1-\omega^{*}\right)p_{na,h}^{1-\mu}}\frac{\tilde{\pi}^{l}\bar{L}+\tilde{\pi}^{s}\bar{S}}{\tilde{\pi}^{l*}\bar{L}^{*}+\tilde{\pi}^{s*}\bar{S}^{*}} \\
&= \frac{p_{na,h}^{\mu-1}-\omega}{\left(1-\omega^{*}\right)}\frac{w_{na}^{l}\left[\bar{L}_{na}+L_{m}\left(\frac{1}{X\bar{\varepsilon}^{l}}+\frac{\left(\bar{\varepsilon}^{l}\right)^{k}-1}{X\bar{\varepsilon}^{l}}\right)\right]+w_{na}^{s}\left[\bar{S}_{na}+S_{m}\left(\frac{1}{X\bar{\varepsilon}^{s}}+\frac{\left(\bar{\varepsilon}^{s}\right)^{k}-1}{X\bar{\varepsilon}^{s}}\right)\right]}{w_{na}^{l*}\bar{L}_{na}^{*}+w_{na}^{s*}\bar{S}_{na}^{*}+w_{ag}^{l*}\bar{L}_{ag}^{*}+w_{ag}^{s*}\bar{S}_{ag}^{*}} \\
&= \frac{p_{na,h}^{\mu-1}-\omega}{\left(1-\omega^{*}\right)}\frac{w_{na}^{l}\left[\bar{L}_{na}+\bar{L}_{ag}\left(\frac{1}{X\bar{\varepsilon}^{l}}+\frac{\left(\bar{\varepsilon}^{l}\right)^{-k}}{X\bar{\varepsilon}^{l}}+\frac{\left(\bar{\varepsilon}^{l}\right)^{-k}}{X\bar{\varepsilon}^{l}}\right)\right]+w_{na}^{s}\left[\bar{S}_{na}+\bar{S}_{ag}\left(\frac{1}{X\bar{\varepsilon}^{s}}+\frac{\left(\bar{\varepsilon}^{s}\right)^{-k}}{X\bar{\varepsilon}^{s}}+\frac{\left(\bar{\varepsilon}^{s}\right)^{-k}}{X\bar{\varepsilon}^{s}}\right)\right]}{w_{na}^{l*}\bar{L}_{na}^{*}+w_{na}^{s*}\bar{S}_{na}^{*}+w_{ag}^{l*}\bar{L}_{ag}^{*}+w_{ag}^{s*}\bar{S}_{ag}^{*}} \\
&= \frac{\left(Z_{na}\left(1-\eta_{na}\right)\right)^{1-\mu}\left(w_{na}^{l}\right)^{\mu-1}\left(\frac{\bar{L}_{na}+L_{m}}{\bar{S}_{na}+S_{m}}\right)^{\eta_{na}(\mu-1)}-\omega}{\left(1-\omega^{*}\right)} * \\
&\quad \frac{w_{na}^{l}\left[\bar{L}_{na}+\bar{L}_{ag}\left(\frac{1}{X\bar{\varepsilon}^{l}}+\frac{\left(\bar{\varepsilon}^{l}\right)^{-k}}{X\bar{\varepsilon}^{l}}+\frac{\left(\bar{\varepsilon}^{l}\right)^{-k}}{X\bar{\varepsilon}^{l}}\right)\right]+w_{na}^{s}\left[\bar{S}_{na}+\bar{S}_{ag}\left(\frac{1}{X\bar{\varepsilon}^{s}}+\frac{\left(\bar{\varepsilon}^{s}\right)^{-k}}{X\bar{\varepsilon}^{s}}+\frac{\left(\bar{\varepsilon}^{s}\right)^{-k}}{X\bar{\varepsilon}^{s}}\right)\right]}{w_{na}^{l*}\bar{L}_{na}^{*}+w_{na}^{s*}\bar{S}_{na}^{*}+w_{ag}^{l*}\bar{L}_{ag}^{*}+w_{ag}^{s*}\bar{S}_{ag}^{*}}.
\end{aligned}$$

Derivation of migration cost cutoffs:

Take skilled workers' urban and rural wage link as an example: $w_{na}^{s}/w_{ag}^{s}=X\bar{\varepsilon}^{l}$. Using $w_{na}^{s}=p_{na,h}\eta_{na}\tilde{Y}_{na}/S_{na}$, $w_{ag}^{s}=p_{ag,h}\eta_{ag}Y_{ag}/S_{ag}$, $C_{na}/C_{ag}=\left(1-\alpha\right)P_{ag}/\alpha P_{na}$, $P_{ag}Y_{ag}=P_{ag}C_{ag}$ as well as $p_{na,h}\tilde{Y}_{na}=C_{na}$ in equilibrium,

$$\begin{aligned}
\bar{\varepsilon}^s &= \frac{1}{X}\frac{p_{na,h}}{P_{ag}}\frac{\eta_{na}}{\eta_{ag}}\frac{\tilde{Y}_{na}}{Y_{ag}}\frac{S_{ag}}{S_{na}} \\
&= \frac{1}{X}\frac{C_{na}}{P_{ag}C_{ag}}\frac{\eta_{na}}{\eta_{ag}}\frac{\bar{S}_{ag}-S_m}{\bar{S}_{na}+S_m} \\
&= \frac{1}{X}\frac{\eta_{na}(1-\alpha)}{\eta_{ag}\alpha}\frac{\bar{S}_{ag}-\left(1-(\bar{\varepsilon}^s)^{-k}\right)\bar{S}_{ag}}{\bar{S}_{na}+\left(1-(\bar{\varepsilon}^s)^{-k}\right)\bar{S}_{ag}}.
\end{aligned}$$

Therefore, migration cost cutoffs satisfy:

$$\bar{\varepsilon}^l = \frac{1}{X}\frac{(1-\eta_{na})(1-\alpha)}{(1-\eta_{ag})\alpha}\frac{\left(\bar{\varepsilon}^l\right)^{-k}}{\frac{\bar{L}_{na}}{\bar{L}_{ag}}+1-(\bar{\varepsilon}^l)^{-k}},$$

$$\bar{\varepsilon}^s = \frac{1}{X}\frac{\eta_{na}(1-\alpha)}{\eta_{ag}\alpha}\frac{(\bar{\varepsilon}^s)^{-k}}{\frac{\bar{S}_{na}}{\bar{S}_{ag}}+1-(\bar{\varepsilon}^s)^{-k}}.$$

These imply that in the steady state, migration cost cutoff for unskilled workers $\bar{\varepsilon}^l$ depends only on common migration cost shock X, ratio of non-agricultural to agricultural good's share in the consumption basket $\frac{(1-\alpha)}{\alpha}$, ratio of skilled cost share in production $\frac{\eta_{na}}{\eta_{ag}}$ and ratio of urban to rural unskilled endowment $\frac{\bar{L}_{na}}{\bar{L}_{ag}}$. Similarly, migration cost cutoff for skilled workers $\bar{\varepsilon}^s$ depends only on common migration cost shock X, ratio of skilled cost share in production $\frac{\eta_{na}}{\eta_{ag}}$ and ratio of urban to rural unskilled endowment $\frac{\bar{S}_{na}}{\bar{S}_{ag}}$. Once we obtain $\bar{\varepsilon}^s$ and $\bar{\varepsilon}^l$, migration flow L_m and S_m are also derived.

From the budget constraint, $PC = w^l_{ag}\left(\bar{L}_{ag}-L_m\right) + w^s_{ag}\left(\bar{S}_{ag}-S_m\right) + w^l_{na}\left(\bar{L}_{na}+L_m\frac{1}{X\tilde{\varepsilon}^l}\right) + w^s_{na}\left(\bar{S}_{na}+S_m\frac{1}{X\tilde{\varepsilon}^s}\right)$. Since $C_{na} = \tilde{Y}_{na}p_{na,h} = w^l_{na}L_{na} + w^s_{na}S_{na}$ and $PC = \frac{C_{na}}{1-\alpha}$,

$$w^l_{na}\left[\left(\frac{1-\left(\bar{\varepsilon}^l\right)^{-k}}{X\tilde{\varepsilon}^l}+\frac{\left(\bar{\varepsilon}^l\right)^{-k}}{X\bar{\varepsilon}^l}-\frac{1-\left(\bar{\varepsilon}^l\right)^{-k}}{1-\alpha}\right)\bar{L}_{ag}-\frac{\alpha}{1-\alpha}\bar{L}_{na}\right] = \\
w^s_{na}\left[\frac{\alpha}{1-\alpha}\bar{S}_{na}-\left(\frac{1-(\bar{\varepsilon}^s)^{-k}}{X\tilde{\varepsilon}^s}+\frac{(\bar{\varepsilon}^s)^{-k}}{X\bar{\varepsilon}^s}-\frac{1-(\bar{\varepsilon}^s)^{-k}}{1-\alpha}\right)\bar{S}_{ag}\right].$$

Substitute $w^s_{na} = w^l_{na}\frac{\eta_{na}}{1-\eta_{na}}\frac{\bar{L}_{na}+L_m}{\bar{S}_{na}+S_m}$ into the above equation,

$$\frac{\left(\frac{1-\left(\bar{\varepsilon}^l\right)^{-k}}{X\bar{\varepsilon}^l}+\frac{\left(\bar{\varepsilon}^l\right)^{-k}}{X\bar{\varepsilon}^l}-\frac{1-\left(\bar{\varepsilon}^l\right)^{-k}}{1-\alpha}\right)\bar{L}_{ag}-\frac{\alpha}{1-\alpha}\bar{L}_{na}}{\frac{\alpha}{1-\alpha}\bar{S}_{na}-\left(\frac{1-(\bar{\varepsilon}^s)^{-k}}{X\bar{\varepsilon}^s}+\frac{(\bar{\varepsilon}^s)^{-k}}{X\bar{\varepsilon}^s}-\frac{1-(\bar{\varepsilon}^s)^{-k}}{1-\alpha}\right)\bar{S}_{ag}}=\frac{\eta_{na}}{1-\eta_{na}}\frac{\bar{L}_{na}+\left(\bar{\varepsilon}^l\right)^{-k}\bar{L}_{ag}}{\bar{S}_{na}+(\bar{\varepsilon}^s)^{-k}\bar{S}_{ag}}.$$

From the expression of $p_{na,h}$, which depends on Q, ω, ω^*, μ, and expressions of $\bar{\varepsilon}^s$ and $\bar{\varepsilon}^l$, combined with $w^l_{na} = p_{na,h}Z_{na}\left(1-\eta_{na}\right)\left(\frac{\bar{S}_{na}+\left(1-(\bar{\varepsilon}^s)^{-k}\right)\bar{S}_{ag}}{\bar{L}_{na}+\left(1-\left(\bar{\varepsilon}^l\right)^{-k}\right)\bar{L}_{ag}}\right)^{\eta_{na}}$, w^l_{na} can be obtained as a function of $Q, \omega, \omega^*, \mu, Z_{na}, \eta_{na}, \eta_{ag}, \bar{S}_{na}, \bar{L}_{na}, \bar{S}_{ag}, \bar{L}_{ag}$. Once w^l_{na} is pinned down, w^l_{ag} can be obtained as $w^l_{ag} = \frac{w^l_{na}}{X\bar{\varepsilon}^l}$. w^s_{na} can also be derived as $w^s_{na} = w^l_{na}\frac{\eta_{na}}{1-\eta_{na}}\frac{\bar{L}_{na}+\left(1-\left(\bar{\varepsilon}^l\right)^{-k}\right)\bar{L}_{ag}}{\bar{S}_{na}+\left(1-(\bar{\varepsilon}^s)^{-k}\right)\bar{S}_{ag}}$, and w^s_{ag} follows as $w^s_{ag} = \frac{w^s_{na}}{X\bar{\varepsilon}^s}$.