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Essays on Economic Development

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by

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ABSTRACT OF THE DISSERTATION

Essays on Economic Development

by

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Doctor of Philosophy in Economics
University of California, Los Angeles, 2020
Professor Lee Ohanian, Chair

My thesis consists of three chapters on economic development.

Chapter 1:

The research on the catch-up process of a developing economy focuses on the role of foreign technology transfer and the importance of domestic technology transfer lacks study. We study the trends of expenditures on innovation, foreign technology transfer, and domestic technology transfer. During the transition period of China from 1998 to 2007, the expenditures on innovation and domestic technology transfer of Chinese firms in the manufacturing sector grow two times faster than the expenditure on foreign technology transfer.Furthermore, the estimated productivity at the firm level shows the rapid productivity growth is accompanied by a decreasing productivity dispersion. The productivity dispersion has decreased by 39% in the same period. I document several empirical facts at the level of industry. First, the innovation is positively correlated with the relative productivity. Second,the expenditure on domestic technology transfer increases in the relative productivity and the growth rate of relative productivity is positively correlated to the expenditure on domestic technology transfer.

Chapter 2:

I develop a theory in which firms endogenously choose one of three mutually exclusive methods to increase productivity: innovation, foreign technology transfer, and domestic technology transfer. Domestic technology transfer offers firms with low productivity a chance to become highly productive by meeting highly productive domestic peers. Domestic technology transfer leads to faster growth of productivity and greater number

of firms with high productivity. The productivity growth in China makes more Chinese firms choose to innovate or learn from domestic peers in a dynamic environment. Thus, the expenditures on innovation and domestic technology transfer increase faster. In our model, firms with low productivity adopt foreign or domestic technology and grow faster than highly productive firms. This results in the decreasing productivity observed in the data. We use the simulated method of moments to estimate key parameter values of the transition model. Our model fits data well. After checking the model fit, we conduct two experiments to answer the two questions mentioned at the beginning of our talk. In one experiment, domestic technology transfer is not allowed, and I find that the domestic technology transfer contributes 30% of productivity growth and 31% of relative innovation expenditure growth. In the other experiment, we improve the domestic intellectual property and the policy changes significantly reduce both productivity growth and expenditure on innovation.

Chapter 3:

Our economic geography model features cross-country productivity, human capital, amenity and population differences, international trade, migration cost, and heterogeneous working and entrepreneurial skills. We compare welfare under baseline parameterization with a migration autarky counterfactual and the welfare gains of the US native residents from migration reform. The gains from migration are substantial, as high as trade gains, and natives in countries that received a lot of migration are much better off, at about 5% to 15% . Both the native entrepreneurs and workers benefit from migration while the entrepreneurs tend to gain twice as large as the workers. The welfare of the US native entrepreneurs and workers can increase by 5.1% and 1.6% by optimizing migration frictions and the population of the US increases by 14.7% under optimization.

The dissertation of Nan Wu is approved.

Nico Voigtlaender

Francois Geerolf

Gary Hansen

Lee Ohanian, Committee Chair

University of California, Los Angeles

2020

To my parents,

who gave me so many things.

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CHAPTER 1

The transition of Chinese Manufacturing in Technology Development

1.1 Introduction

In the past decades, China's economy and real per capita income grew at a high rate. Some economists argue that the future growth in China relies on innovation and technology upgrading[WXZ17]. The literature discusses how expenditure on innovation rises with the boom of patent applications and patents granted[WXZ17, XZ15].Another strand of literature, which focuses on the transition from imitation to innovation, emphasizes the tradeoff between imitating foreign firms (foreign technology transfer) and innovation (R&D)[Ace03a, MB95].This reveals the force behind productivity growth and innovation expenditure increase in the transition of a developing country. However, recent work on the tradeoff between imitation and innovation shows both learning from other domestic firms (domestic technology transfer) and innovation are vital to the economy growth in the long run. Motivated by the literature, this paper explores how domestic technology transfer affects productivity growth and innovation expenditure increases in the transition.

To answer the question, we have constructed a dynamic model in which domestic firms are heterogeneous in productivity and adopt different ways to improve productivity. They can attempt to use technology employed by other foreign and domestic firms or increase productivity by innovation (R&D). The decision of a firm on productivity depends on relative domestic productivity to foreign productivity and the relative productivity of the domestic firm to other domestic firms. Domestic firms tend to imitate foreign technology when relative domestic productivity is low. Otherwise, domestic firms are less willing to pay for foreign technology. Whether to imitate technology used by other domestic firms depends on how far the firm is behind other domestic firms in productivity. In our model, the highly productive firms innovate and transfer technology to other domestic firms. These firms cannot get more productive technology from other domestic and foreign firms and have to rely on innovation to improve productivity. Firms with low productivity tend to adopt technology from other domestic firms, and middle firms prefer technology transfer from foreign firms. Compared with foreign technology transfer, adopting domestic technology induces lower costs but improvement of technology depends on the average domestic productivity. Unproductive firms could obtain technology improvement from other domestic firms and benefit from the lower costs. However, middle firms are not very likely to meet more productive domestic firms and increase their productivity. As a consequence, they would rather spend more and obtain greater technology from foreign firms.

Our paper emphasizes two channels through which domestic technology transfer can affect innovation in the transition. The first and direct channel is that domestic technology transfer encourages firms to do more innovation as a subsidy. We assume the firm that adopts domestic technology meets another domestic firm after a random search and pays a share of surplus generated by the transfer as a result of Nash bargaining. Due to the random search, heterogeneous firms that transfer technology would meet firms with the same expected productivity. Thus the payment received by a firm transferring technology is proportional to its own productivity. To some extent, transferring technology to less productive firms provides extra incentives to innovative firms and encourages them to spend more on innovation.

The other channel works indirectly. Domestic technology transfer offers a probability for a unproductive firm to gain a large increase in productivity and to become a highly productive firm. The greater the share of productive firms due to domestic technology transfer, the greater the share of innovative firms in the future and thus the more firms spend on innovation. The literature on imitation and innovation in the long run steady state shows that imitation is a alternative way to improve productivity other than innovation and that the existence of imitation can help long run growth but discourage firms to innovate[BPT17]. However, domestic technology transfer in our paper is different from imitation in the literature in two aspects. First, domestic technology transfer provides extra incentives for innovation. Second, adopting domestic technology does not crowd out innovation during the transition. In our model, unproductive middle firms would choose between adopting domestic technology and foreign technology while productive middle firms decide whether to innovate or adopt foreign technology. Thus only foreign technology transfer is able to crowd out innovation during the transition.

The paper is part of the literature on the tradeoff between innovation and the transfer of foreign technology in developing countries[AAZ06, CCG14, MB95, Ace03b, BPT14].In the literature, [MB95] were the first to discuss the mechanism by which a poor country chooses to copy foreign technology rather than innovation. The cost of copying foreign cost gradually rises as the poor country catches up with the foreign country. [BPT14] explore the catch-up of poor country and how the cost of technology diffusion determines convergence and fall-back of the poor country in the long run. [Ace03b] and [AAZ06] focus on the firm strategy of innovation and imitation as the economy approaches the world technology frontier and whether the economy can converge with the frontier. In [Ace03b], the key factor that determines convergence is outsourcing of production, while [AAZ06] show how the tradeoff between the skill of a manager and capital plays a vital role. Our paper's contribution to the literature is twofold. First, we model heterogeneous firms in the transition. Firms in our economy adopt different strategies of development during the same period. Second, we focus on the interaction between domestic technology imitation and innovation although the tradeoff between foreign technology imitation and innovation is important as well. [CCG14] is the only paper that incorporates the three strategies discussed in our paper. However, the transfer of foreign technology in their paper is limited to foreign directed investment firms, and the rest can either innovate or imitate other firms. The other difference is that the firm that adopts technology in our model will apply the technology to a different variety while the firm in their paper will steal the market owned by the firm it imitates.

Our paper also relates to another strand of literature that explores the role of domestic imitation in growth [ABL08, LM14, Lut07, KLZ16, PT14, BPT17, KSS18]. In the literature, domestic imitation contributes to the long run growth of the economy and the growth effect of imitation depends on the support and tail thickness of productivity distribution. Following the tradition of the literature, we model the domestic technology transfer as the result of a random search . Domestic technology transfer is featured with payment from the imitator to the imitatee, while imitation in the literature is free. Motivated by [ACG16], the payment in transfer is determined by Nash Bargaining. [BPT17] and [KSS18] provide analysis on the interaction between imitation and innovation with discrete and continuous productivity distribution. Our paper incorporates foreign technology adoption other than domestic technology transfer , and innovation and adopting foreign technology is taken as an important source of growth for developing countries such as China[WXZ17]. We apply the theory to the case of the Chinese transition economy and quantify the effect of domestic technology transfer on growth and innovation. [KSS18] provides a model incorporating domestic imitation and innovation of Chinese firms. But they emphasize the distortion on innovation faced by Chinese firms and explain why innovation investments are less productive in China.

The main contribution of the paper is to estimate the importance of domestic technology transfer to innovation and productivity growth based on the theory: we use a Simulated Method of Moments approach to estimate a dynamic transition equilibrium model that incorporates the interactions between domestic technology transfer and innovation.We estimate the model using data of Chinese firms in manufacturing from 1998 to 2007 and targeting aggregate expenditure on innovation, domestic and foreign technology transfer and productivity distribution. According to the Chinese Statistics Yearbook of Science and Technology, the expenditure of Chinese manufacturing firms on domestic technology transfer and innovation rose dramatically over the past ten years. Domestic technology transfer payments increased from 1.82 billion Yuan to 12.96 billion Yuan, and innovation expenditure surged from 19.71 billion Yuan to 211.25 billion Yuan. Compared with the trend of expenditure on foreign technology transfer, which only went up from 21.48 to 45.25 billion, relative domestic technology payment surged from 8.5% to 28.5% and innovation from 91% to 466%. The transition during this period also features increasing average productivity and decreasing distance to frontier. The average productivity of manufacturing in China relative to the US surged from 4.6% to 12.4% . And the distance to frontier within industry, which measures the log difference between the most and least productive firms within the same industry, dropped from 3.92 to 3.53.

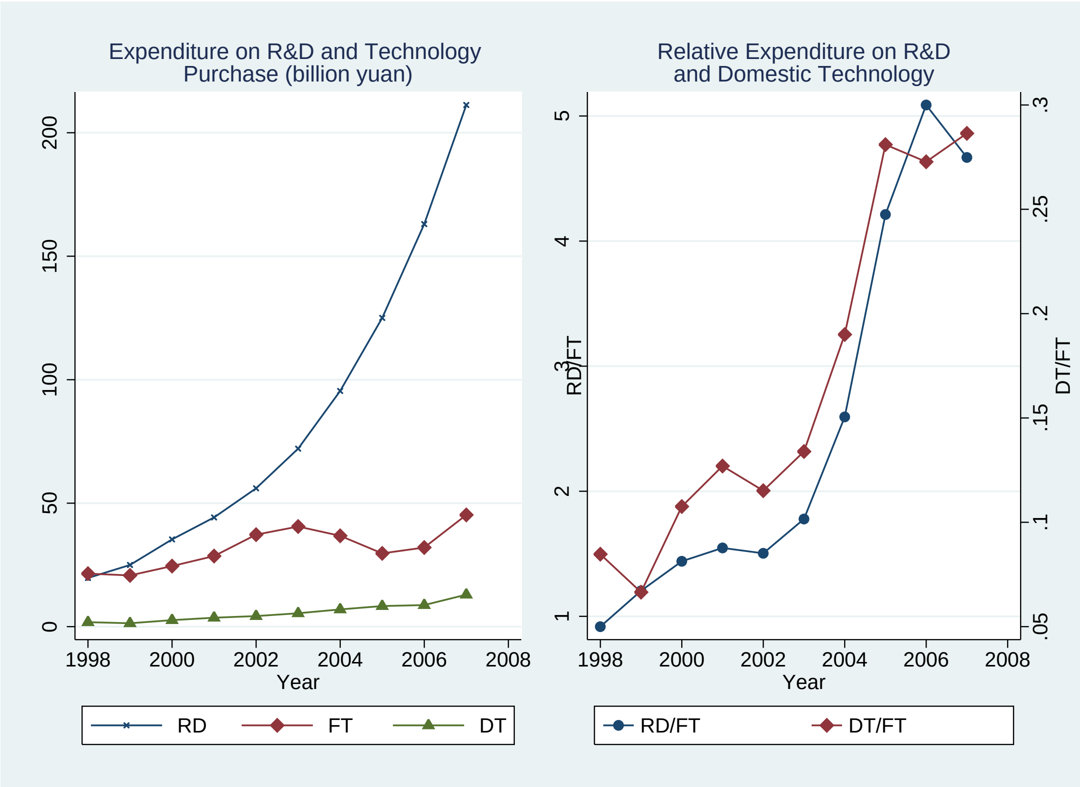
Our model fits the trends of productivity growth and innovation expenditure. The average productivity of manufacturing in China relative to the US surged to 10.68%, and relative innovation expenditure increased to 239%. In other words, the model accounts for 79.8% of productivity growth and 46.4% of innovation expenditure increase. The first experiment is conducted to figure out the importance of domestic technology transfer to productivity growth and innovation increase. In the first experiment, we increase the cost of domestic technology transfer such that no firms adopt domestic technology, which results in reductions of productivity growth and innovation increase by 57% and 64% , respectively. The second experiment examines the effects of intellectual property rights(IPR) protection on growth and innovation in transition. Increasing the strength of IPR protection would result in greater bargaining power of the imitatee in our model. When we increase the share of surplus gained by the imitatee from 0.6% to 1.2%, the growth of productivity decreases by 35% and expenditure on innovation by 48% in the period.

1.2 Empirical Facts

Since the reform in 1978, the Chinese economy has experienced a great transition. [Zhu12] argues 1998-2007 is an important phase during the transition. In 2007, China's government started to legalize the development of private enterprises. Between 1998 and 2007, the average annual total factor productivity growth rates of the state and non-state sectors were 5.50 percent and 3.67 percent, respectively. The manufacturing sector grows even faster during the same period. [BVZ12] estimate that, for the manufacturing sector, the total factor productivity growth rate is 13.4 percent a year.

Our paper focuses on the manufacturing sector between 1998 and 2007. Adopting foreign technology, domestic technology transfer, and innovation are three ways for Chinese manufacturing firms to improve their productivity. Using industry level data from the Chinese Science and Technology Yearbook, we find Chinese firms spend most on adopting foreign technology in 1998 while the expenditure on innovation becomes the greatest in 2007 (Figure 1). The spending on domestic technology transfer and innovation is 8.5%, and 91% of this on foreign technology transfer in 1991. During the ten years, expenditures on domestic technology and innovation grow rapidly and the growth rate of foreign technology expenditure is moderate. In the year 2007, the ratios of expenditures on domestic technology transfer and innovation to foreign technology transfer increase to 0.29 and 4.66 respectively.

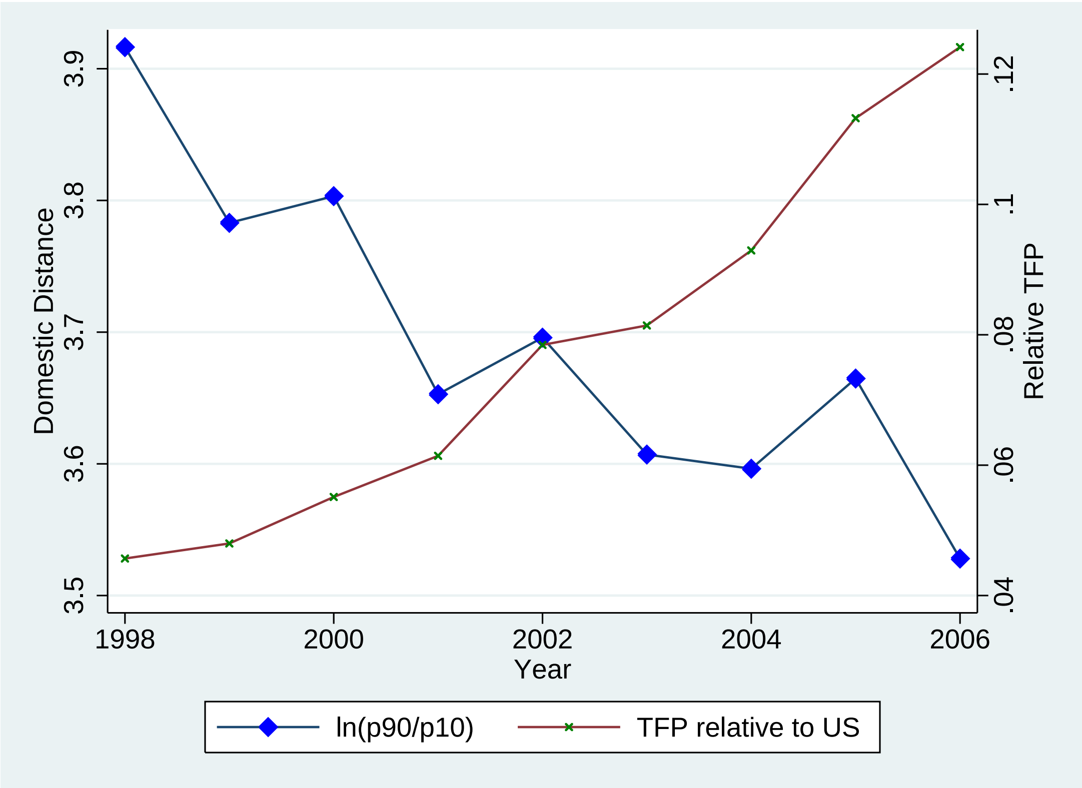
Figure 1.1: Expenditure on Technology Transfer and Innovation



Notes: The first graph shows the trends of expenditures on innovation, and foreign and domestic technology. The second graph shows the relative expenditure on R&D and domestic transfer. The relative expenditure is defined as the expenditure divided by the expenditure on foreign technology transfer.The left axis in the second graph shows value for relative R&D expenditure and the right shows value for relative domestic technology transfer expenditure. *Source*: Chinese Science and Technology Yearbook

Another important trend is the distance to frontier of productivity distribution. Using the Annual Survey of Above Scale Industrial Firms from 1998-2007, we calculate firm productivity according to [BVZ12] and [HK09]. The distance to frontier in an industry is defined as the productivity log difference between the 90th and 10th percentile firms in the industry. The average distance to frontier of manufacturing, which is weighted by value added, dropped from 3.92 to 3.53 in the period. This fact means the annual growth rate of the 10th percentile firm is approximately 4% greater than that of 90th percentile firm on average. Consistent with [Zhu12] and [BVZ12], we observe the rapid growth of relative productivity of Chinese manufacturing. The average growth rate of Chinese manufacturing productivity relative to the US is as high as 12.7% . This results in relative productivity increase from 4.6% to 12.4% in ten years.

Figure 1.2: Distance to Domestic Frontier and Relative Productivity



Notes: The left axis shows values for the distance to frontier and the right shows values for relative productivity. The decreasing trend of distance to frontier is robust for other measures such as simple average and other sample such as a sample without SOE.
Source: Annual Survey of Above Scale Industrial Firms and NBER-CES Manufacturing Industry Database

Controlling value added, exporting share of products, capital per worker, number of firms, and year dummy, we find one percent point increases of relative productivity and distance to frontier are associated with a 0.26 and 0.29 percent point domestic technology transfer payment (Table 2). We explore the correlation between domestic technology transfer and relative productivity growth rate as well. The correlation coefficient is 0.05

Table 1.1: Domestic Technology Expenditure

	$ln(DE)$			$TFP\,Growth$
Dependent Variable	(1)	(2)	(3)	(4)
$ln(TFP)$	$.3336^{**}$		$.2629^{*}$	$-.3067^{***}$
	(.1509)		(.1516)	(.0467)
$ln(Dist)$		$.3289^{***}$	$.2965^{***}$	$-.0594^{*}$
		(.0638)	(.1130)	(.0336)
$ln(DE)$				$.0512^{***}$
				(.0193)
Controls	Yes	Yes	Yes	Yes
Year Dummy	Yes	Yes	Yes	Yes
Observations	260	260	260	231
R^2	0.5866	0.5933	0.5966	0.1859

Notes: The dependent variables are the log of domestic expenditure for column (1) (2) (3) and the productivity growth rate for column (4). Productivity is the relative productivity of the Chinese manufacturing industry to the US. *Dist* represents the distance to frontier in the industry. $ln(.)$ indicates the variable is the log value of the variable in the brackets. Robust standard errors are in brackets.

$***$Significant at the 1 percent level. $**$Significant at the 5 percent level. $*$Significant at the 10 percent level

and significant at the1 percent confidence level.

1.3 Conclusions

This chapter investigates the empirical facts on the transition of China from 1998 to 2007. It shows Chinese firms changed their ways to develop productivity during the transition and they spent more on innovation and domestic technology transfer compared with foreign technology transfer. The industry level evidence indicates the expenditure on domestic technology transfer is positively correlated with the growth rate of productivity in the industry and the growth productivity would increase the expenditure on innovation and domestic technology transfer payment.

CHAPTER 2

The Contributions of Domestic Technology Transfer to Innovation and Productivity Growth

2.1 The Transition Dynamic Model

In this section, we develop a theory of transition economy that is consistent with previous evidence and featured with the endogenous choice of innovation and technology transfer.

A. Demography and Preference

The model economy is a small open economy, and the interest rate is R. Time is discrete and infinite, $t = 1, 2, 3....$ The economy is populated by overlapping generations of agents who live for two periods. In the first period, the agents own one unit of labor and earn a wage as workers. They save or borrow money to consume at the end of the period. In the second period, the agents become old and lose their ability to work. But they inherit the firm from their parents. They claim the profits from the firm and consume the saving and income in the second period. Preferences of agents are the following time separable utility function.

$$U_t = \frac{c_{1,t}^{1-\frac{1}{\theta}} - 1}{1 - \frac{1}{\theta}} + \delta \frac{c_{2,t}^{1-\frac{1}{\theta}} - 1}{1 - \frac{1}{\theta}} \tag{2.1}$$
$$s.t.\, c_{1,t} + \frac{c_{2,t}}{R} = w_t + \frac{\pi_{1,t+1}}{R}$$

,where β is the discount factor and θ is the intertemporal elasticity of substitution in consumption. The agent born at time t consumes $c_{1,t}$ and $c_{2,t}$ in the first and second periods of his life, w_t is his wage earning in period t ,and $\pi_{1,t+1}$is the firm profit that he claims in period $t + 1$.

B. Production

There are two sectors in production: the intermediate sector and the final sector. The final sector consists of competitive firms. These firms use intermediate goods, and labor to produce final goods, and the production technology is

$$Y_t = \frac{1}{1-\alpha} L_{ft}^{\alpha} \int_0^1 q_{jt}^{\alpha} k_{jt}^{1-\alpha} dj \tag{2.2}$$

, where Y_t is the output of final goods. L_{ft} is the labor used to produce final goods. The intermediate good is continuous and indexed by $j \in [0, 1]$, q_{jt} represents the quality of intermediate j in period t, and k_{jt} represents the quantity. In the final good production function, $\sigma < 1$. The marginal return of intermediate goods in production is decreasing in quantities. The final firm tends to use various intermediate goods as inputs in the production.

Final firms maximize profits by choosing an optimal amount of labor and varieties of intermediate goods. Given the production technology of the final sector, the problem is

$$\max_{k_{jt}, L_{ft}} \frac{1}{1-\alpha} L_{ft}^{\alpha} \int_0^1 q_{jt}^{\alpha} k_{jt}^{1-\alpha} dj - \int_0^1 p_{jt} k_{jt} dj - w_t L_{ft} \tag{2.3}$$

, where p_{jt} is the price of intermediate good j and w_t is the wage rate of workers in the labor market. We derive the inverse demand functions for intermediate goods and labor from first order conditions,

$$p_{jt} = L_{ft}^{\alpha} q_{jt}^{\alpha} k_{jt}^{\alpha-1} \tag{2.4}$$

$$w_t = \frac{\alpha}{1-\alpha} L_{ft}^{\alpha-1} \int_0^1 q_{jt}^{\alpha} k_{jt}^{1-\alpha} dj \tag{2.5}$$

The final firms produce more final goods using the intermediate good with higher quality and thus the price of the intermediate good with greater quality is higher. The quality of intermediate goods also affects the wage rate of the economy. The wage rate increases in intermediate good quality because labor and intermediate goods are complementary in production.

The firms in the intermediate sector are monopolistic, and the only input of intermediate goods is labor. The production technology of the intermediate firm is

$$k_{jt} = \bar{q} l_{jt} \tag{2.6}$$

, where $\bar{q}_t = \int_0^1 q_{jt} dj$ is the average quality of intermediate goods in the sector. In other words, the quantity of intermediate good production is independent of its quality, but the firm's profits increase in its quality. We calculate productivity using the value of output in the empirical section, and the measured productivity is equivalent to quality in our model. Workers in the labor market are employed either by intermediate or by final sector. In the production sectors,

(1)the profits of the intermediate firms are linear in their productivity;

(2)the wage rate is proportional to the average productivity of the intermediate sector;

(2)the share of labor employed by the intermediate sector is invariant over time

Proof. Appendix

B. Productivity of the Intermediate Firms

The intermediate Firms are heterogeneous in productivity, and the productivity is q_t. In period t, the productivity distribution is $G_t(q_t)$ and the support is $q_t \in [q_t^M, \infty)$. We assume foreign firms are homogeneous in productivity and their productivity is $\bar{A}$, which is constant over time. We have derived that the profits of the intermediate firms are linear in their productivity. The domestic firm owners make an optimal decision on productivity to maximize the firm profits. We assume that the measure of intermediate firms is 1 and each old agent owns one firm. When the old agent dies, the firm is inherited by a young agent. For simplicity, we assume the old receives no compensation from giving the firm to the young. Therefore, the old does not consider the profits of the firm in the future when he makes decisions on technology development. When the firm is taken over by the young, the productivity of the firm does not change.

We focus on innovation and technology adoption and ignore the selection in the transition. In other words, we do not consider firm entry and exit. The reason our model does not incorporate the explicit firm entry and exit is that the firm selection is a form of imitation [Lut07] . In our model, the least productive firms adopt technology from other domestic firms , and their productivity increases to the level of the firm they meet. The process is similar to that in which the least productive firms exit and new firms enter with productivity drawn from the productivity distribution of incumbent firm. The literature on innovation and imitation also does not model the entry and exit [BPT17, KSS18].

We assume firm innovation, foreign and domestic technology transfer are mutually exclusive. Firm owners choose one of the three ways to maximize the profit of the current period

$$\pi_t(q_{t-1}) = \max\{\pi_t^R(q_{t-1}), \pi_t^F(q_{t-1}), \pi_t^D(q_{t-1})\} \tag{2.7}$$

, where q_{t-1} is the productivity of the firm at the beginning of period t. The profits from innovation, and foreign and domestic technology transfer are denoted as $\pi_t^R(q_{t-1}), \pi_t^F(q_{t-1})$,and

$$\pi_t^D(q_{t-1})$$

, respectively.

If the firm owner decides to innovate, he faces the following problem,

$$\pi_t^R(q_{t-1}) = \max_{\gamma_t} \pi^*(1+\gamma_t)q_{t-1} - (\chi^R\gamma_t^\psi q_{t-1} + \eta^R q_{t-1}) + \tau^D((1+\gamma_t)q_{t-1}, \theta^D) \tag{2.8}$$

, where γ_t is the growth rate of productivity in period t and productivity at the end of period t is $(1+\gamma_t)q_{t-1}$. The profits of the firm by innovation are determined by three components: profit from sales, cost of innovation, and gain from transferring technology. $\pi^*(1+\gamma_t)q_{t-1}$ represents the profits from sales and π^* is the constant coefficient. The cost of innovation has two parts: the variable cost , $\chi^R\gamma_t^\psi q_{t-1}$, and the fixed cost, $\eta^R q_{t-1}$. The variable innovation cost increases in the growth rate of productivity and $\eta^R q_{t-1}$ is linear in the productivity. χ^R governs the variable cost of innovation and affects the average growth rate of innovative firms. ψ is the convexity of innovation cost with respect to the growth rate and affects the changes in the innovation growth rate over time and the distribution of innovation growth rate. η^R is the cost parameter of fixed cost and determines the share of firms choosing innovation. At last, $\tau^D((1+\gamma_t)q_{t-1}, \theta^D)$ represents the gain from transferring technology. The expression of the gain will be spelled out below.

If the firm adopts foreign technology, the owner will decide the amount of foreign technology to purchase,

$$\pi_t^F(q_{t-1}) = \max_{\lambda_t} \pi^*(q_{t-1} + \lambda_t \bar{A}) - \chi^F \lambda_t^\beta \bar{A} - \tilde{\tau^F}(\theta^F) + \tau^D(q_{t-1} + \lambda_t \bar{A}, \theta^D) \tag{2.9}$$

, where $\lambda_t \bar{A}$ represents the amount of foreign technology that the firm decides to adopt and $\bar{A}$ is the level of foreign technology. At the end of the period, the productivity increases to $q_{t-1}+\lambda_t \bar{A}$. The variable cost of adopting foreign technology ,$\chi^F \lambda_t^\beta \bar{A}$, increases in how much the domestic firm learns from foreign firms. The domestic firm need to make a payment to foreign firms as well, and the payment is denoted by $\tilde{\tau^F}(\theta^F)$. The domestic firm that adopts foreign technology can transfer its technology to these firms that adopt domestic technology and gain the revenue, $\tau^D(q_{t-1} + \lambda_t \bar{A}, \theta^D)$.

The last way that domestic firms can develop their productivity is through domestic technology transfer. The problem of domestic technology transfer is

$$\pi_t^D(q_{t-1}) = \int (\pi^* q - \tilde{\tau}^D(q, q_{t-1}, \theta^D)) dG_t(q | q \in \Phi^R \cup \Phi^F) - \eta^D q_{t-1} \tag{2.10}$$

The timing of innovation and technology adoption is important. At the beginning of period t, the firm decides to innovate or adopt technology. It takes one period for the firm to innovate or digest the foreign technology. However, the domestic firm (imitator) needs one period to randomly search other domestic firms (imitatee) and meet the firm and purchase technology at the end of the period. Since the domestic technology transfer occurs at the end of the period, imitatees have increased their productivity through innovation and foreign technology transfer and the productivity distribution is denoted by $G_t(q | q \in \Phi^R \cup \Phi^F)$, ,where Φ^R and Φ^F are the sets of firms doing innovation and adopting foreign technology. When the imitator meets an imitatee with productivity q, the imitator's productivity jumps to q and the imitator pays $\tilde{\tau}^D(q, q_{t-1}, \theta^D)$. To search the imitatee, the imitator bears the search cost, $\eta^D q_{t-1}$. The search cost is linear in the firm's productivity, which is the same as in [BPT17]. One important assumption we make here is that the imitator will not meet other imitators.This assumption yields a clean truncation of the distribution, with no mass of firms perpetually left behind. [PT14] have the same assumption on imitation.

Different from pure imitation, the imitatee has IPR on their technology and can prevent others from learning their technology. We assume the payment of technology transfer is the result of Nash Bargaining. The bargaining powers of the domestic imitator against a foreign and domestic imitatee are θ^F and θ^D, respectively. Thus the domestic imitator keeps the share ,$\theta^F(\theta^D)$, of surplus generated by the foreign (domestic) technology transfer, and the rest of the surplus is the payment of technology transfer. The matching function between imitators and imitatees is

$$H = M(s_t^D, s_t^R + s_t^F) = (s_t^D)^{\mu}(s_t^R + s_t^F)^{1-\mu} \tag{2.11}$$

We assume the probability that the imitator finds an imitatee is always 1 and thus $\mu = 1$. Then the measure of imitators that an imitatee can meet is $\frac{H}{s_t^R+s_t^F} = \frac{s_t^D}{s_t^R+s_t^F}$. If $\frac{s_t^D}{s_t^R+s_t^F} > 1$, this means that the imitatee sells its technology to several imitators. If $\frac{s_t^D}{s_t^R+s_t^F} < 1$, some imitatees at the end of the period may fail to meet any imitator.

The payment of a imitator, q_{t-1} ,that adopt technology from a domestic firm, q , is

$$\tau(q, q_{t-1}, \theta^D) = (1 - \theta^D)\pi^*(q - q_{t-1}) \tag{2.12}$$

We derive the expression of payment received by domestic firms,

$$\tau^D(q, \theta^D) = \frac{s_t^D}{s_t^R + s_t^F}(1 - \theta^D)\pi^*(q - E_j(q_j|G_{t-1}^D)) \tag{2.13}$$

, where s_t^D,s_t^F , and s_t^R are shares of firms that adopt domestic and foreign technology and conduct innovation and $s_t^D + s_t^F + s_t^R = 1$. G_{t-1}^D is the productivity distribution of imitator firms at the beginning of period t. At the end of the period, the imitatee firm meets heterogeneous imitator firms.The measure of imitators is $\frac{s_t^D}{s_t^R+s_t^F}$, and their expected productivity is $E_j(q_j|G_{t-1}^D)$. On average the productivity of an imitator jumps from $E_j(q_j|G_{t-1}^D)$ to q and the difference $q - E_j(q_j|G_{t-1}^D)$ represents the surplus of technology transfer.

The payment that a domestic firm makes to the foreign firm for technology transfer has the following expression,

$$\tilde{\tau^F} = (1 - \theta^F)(\pi^*\lambda_t\bar{A} + \frac{s_t^D}{s_t^R + s_t^F}(1 - \theta^D)\pi^*\lambda_t\bar{A}) \tag{2.14}$$

The productivity increase from the foreign technology transfer is $\lambda_t \bar{A}$. The imitator gains additional output $\lambda_t \bar{A}$ and the domestic imitator's payment $\frac{s_t^D}{s_t^R + s_t^F}(1-\theta^D)\pi^* \lambda_t \bar{A}$. The foreign firm shares both the additional output and the domestic imitator's payment.

C. Equilibrium during Transition

When adopting technology from foreign firms, the domestic firm bears the cost of digesting foreign technology and the cost increases in the amount of foreign technology they adopt. When the firms spend money on innovation, the innovation expenditure increases in the growth rate of firms as well. Therefore, the firm owners make decisions on the optimal rates of both innovation and foreign technology adoption. Plugging equation 2.12 into equation 2.8 and equation 2.14 into equation 2.9, we can derive optimal rates from the first order conditions. There exists the optimal growth rate of the innovative firm and the optimal rate of foreign technology adoption,

$$\gamma_t^* = ((1 + \frac{s_t^D}{s_t^R + s_t^F}(1-\theta^D))\frac{\pi^*}{\psi \chi^R})^{\frac{1}{\psi - 1}} \tag{2.15}$$

$$\lambda_t^* = ((1 + \frac{s_t^D}{s_t^R + s_t^F}(1-\theta^D))\frac{\pi^* \theta^F}{\beta \chi^F})^{\frac{1}{\beta - 1}} \tag{2.16}$$

Proof. See Appendix

Other than the optimal rates, we find the way that firms choose to develop productivity depends on the productivity of the firm. Given several regularity conditions, there exist two thresholds in the productivity distribution q_{t-1}^{RF} and q_{t-1}^{DF} in period t such that

(1)firms innovate if their productivity $q > q_{t-1}^{RF}$;

(2)firms adopt foreign technology if their productivity $q \in [q_{t-1}^{DF}, q_{t-1}^{RF}]$;

(3)firms adopt domestic technology if their productivity $q < q_{t-1}^{DF}$

, where q_{t-1}^{RF} and q_{t-1}^{DF} are determined by

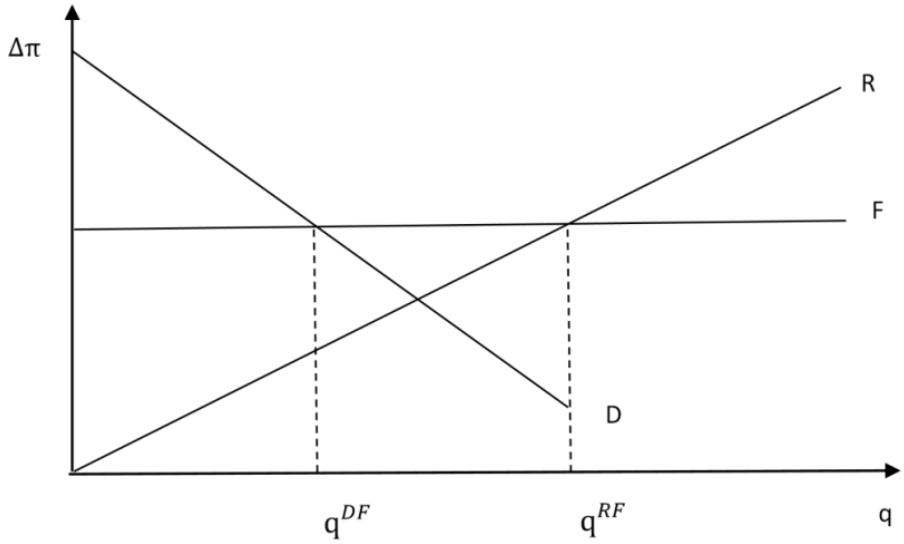
$$\pi_t^D(q_{t-1}^{DF}) = \pi_t^F(q_{t-1}^{DF}) \tag{2.17}$$

$$\pi_t^R(q_{t-1}^{RF}) = \pi_t^F(q_{t-1}^{RF}) \tag{2.18}$$

Proof. See Appendix

Figure

Figure 2.1: gains after technology development



Notes: This figure shows the gains, of firms that develop productivity through innovation, foreign and domestic technology transfer, $\Delta\pi$, against firm productivity q. The three lines R, F, and D represent the profit gains from innovation,foreign and domestic technology transfer, respectively.

Given the thresholds in the productivity distribution, we have the shares of firms innovating and adopting technology in period t,

$$s_t^R = 1 - G_{t-1}(q_{t-1}^{RF}) \tag{2.19}$$

$$s_t^F = G_{t-1}(q_{t-1}^{RF}) - G_{t-1}(q_{t-1}^{DF}) \tag{2.20}$$

$$s_t^D = G_{t-1}(q_{t-1}^{DF}) \tag{2.21}$$

The distribution of productivity evolves as domestic firms develop their productivity. We assume the support of the initial productivity is $[q_0^M, \infty)$. During the transition, the lower bound of distribution support is

$$q_t^M = q_{t-1}^{DF} + \lambda_t \bar{A} \tag{2.22}$$

As we have shown in proposition 2.1, the firms whose productivity is less than q_{t-1}^{DF} choose to search other domestic firms and copy their technology. At the end of period t, the least productive firms that adopt foreign technology increase their productivity from q_{t-1}^{DF} to $q_{t-1}^{DF} + \lambda_t \bar{A}$. These firms are the least productive firms that domestic imitator firms can meet. Thus the minimum productivity of all firms at the end of period t is $q_{t-1}^{DF} + \lambda_t \bar{A}$. The productivity distribution has the following evolution,

$$g_t(q) = \begin{cases} \frac{1}{1-G_{t-1}(q_{t-1}^{DF})} \frac{1}{1+\gamma_t} g_{t-1}(\frac{q}{1+\gamma_t}) & q > q_t^u \\ \frac{1}{1-G_{t-1}(q_{t-1}^{DF})} g_{t-1}(q - \lambda_t \bar{A}) & q < q_t^l \\ \frac{\frac{1}{1+\gamma_t} g_{t-1}(\frac{q}{1+\gamma_t}) + g_{t-1}(q-\lambda_t \bar{A})}{1-G_{t-1}(q_{t-1}^{DF})} & q_t^l < q < q_t^u \, and \, q_{t-1}^{RF} < \frac{\lambda_t \bar{A}}{\gamma_t} \end{cases} \tag{2.23}$$

, where q_t^l and q_t^u are minimum and maximum between $q_{t-1}^{RF}(1+\gamma_t)$ and $q_{t-1}^{RF} + \lambda_t \bar{A}$. The firms with productivity q_{t-1}^{RF} gain the same profits from adopting foreign technology. However, the productivity of these firms would be $q_{t-1}^{RF} + \lambda_t \bar{A}$ if they adopt foreign technology and $q_{t-1}^{RF}(1+\gamma_t)$ if they innovate. Because time is discrete in our model, it is possible that these firms whose productivity is less than q_{t-1}^{RF} adopt foreign technology and end up with productivity higher than those innovative firms.

The first line of the productivity evolution equation describes the tail of productivity distribution. Two types of firms make up of the tail firms at the end of period: the productive firms that choose innovation and the firms that adopt domestic technology and meet the first type of firms. For the first type of firm with productivity q at the end of the period, their productivity is $\frac{q}{1+\gamma_t}$ in the last period and the density of these firms is reduced to $\frac{1}{1+\gamma_t} g_{t-1}(\frac{q}{1+\gamma_t})$. The second type of firm increases the density of productivity distribution and the density of the second type of firm is linear in the density of the first type of firms, $\frac{s_t^D}{1-s_t^D} \frac{1}{1+\gamma_t} g_{t-1}(\frac{q}{1+\gamma_t})$.

The second line is the expression of the productivity density function of less productive firms. The firms described by this line consist of two types of firms as well. The first type of firms is the firm that adopts foreign technology and the second type is the domestic imitator that meets them. The density of the first type is $g_{t-1}(q-\lambda_t \bar{A})$, and the second type contributes the same multiplier $\frac{1}{1-G_{t-1}(q_{t-1}^{DF})}$.

The third line provides the density function for the case in which the innovative firms grow faster than those firms purchasing foreign technology. And the density in the overlapping area of support is the sum of densities in the first and second lines. Given an initial distribution $G_0(q)$, the value of $\bar{A}$ and the sequence $\{R_t\}_{t\geq 0}$, the transition equilibrium is a sequence of firm-specific variables $\{p_{jt}, k_{jt}, q_{jt+1}\}_{j\in[0,1],t\geq 0}$ and a sequence of aggregate variables $\{w_t, L_{ft}, s_t^D, s_t^F, s_t^D, q_t^{DF}, q_t^{RF}, G_t\}_{t\geq}$ such that

(1) firm owners decide optimal price and quantity$\{p_{jt}, k_{jt}\}_{t\geq 0}$ to maximize the intermediate firm's profits;

(2) labor wage$\{w_t\}_{t\geq 0}$ clears labor market, $L(t)+\int l_{jt}dj = 1$;

(3) firm owners choose the optimal way to increase $\{q_{jt}\}_{j\in[0,1],t\geq 0}$ to $\{q_{jt+1}\}_{j\in[0,1],t\geq 0}$ in order to maximize the firm owner's income;

(4) the productivity distribution$\{G_t(q)\}_{t\geq 0}$ evolves as equations 2.22 and 2.23;

(5) the shares of firms adopting technology and innovating $\{s_t^D, s_t^F, s_t^D\}_{t\geq 0}$ are defined by equations 2.19,2.21, and 2.20;

(6) two thresholds in the productivity distribution $\{q_t^{DF}, q_t^{RF}\}$ are determined by the indifference equations 2.17 and 2.18. We observe the surge of expenditure on innovation, and foreign and domestic technology transfer during the transition, The aggregate expenditures on innovation, and the aggregate foreign and domestic technology transfer payments in our model are

$$T_t^R = (\frac{1}{\psi}\gamma_t + \eta^R)\int_{q_{t-1}^{RF}}^{\infty} q dG_{t-1}(q) \tag{2.24}$$

$$T_t^F = (1-\theta^F)(\lambda_t \bar{A} + \frac{s_t^D}{s_t^R + s_t^F}(1-\theta^D)\lambda\bar{A})s_t^F \tag{2.25}$$

$$T_t^D = (1-\theta^D)\int_{q_{t-1}^M}^{q_{t-1}^{DF}}\int_{q_{t-1}^{DF}+\lambda_t\bar{A}}^{\infty}(q-q')dG_{t-1}(q)dG_{t-1}(q') \tag{2.26}$$

Innovation expenditure T_t^R includes both variable and fixed costs of innovation. The innovation expenditure of a firm depends on its productivity. Therefore, the aggregate expenditure is the integral of firm expenditure over innovative firms. The aggregate foreign technology transfer payment is the product of firm payment and the measure of firms adopting foreign technology. The costs of adopting domestic technology consist of search cost and transfer payment. The empirical part corresponds to the transfer payment. We aggregate firm transfer payment over the support of domestic imitators and imitatees with heterogeneous productivity.

The transition is featured with the rapid growth of productivity and decreasing distance to frontier within the domestic industry. In the model, the productivity and distance to frontier are measured by

$$TFP_t = \int_{q_t^M}^{\infty} q dG_t(q) \tag{2.27}$$

$$Cr_t = \frac{q_t^M}{q_{t-1}^M} - \gamma_t \tag{2.28}$$

The final goods production function is linear in the average productivity of intermediate firms and thus the expression 2.27 measures the average productivity of both intermediate and final sectors. The expression 2.28 reflects how fast the firms at the lower bound catch up with the frontier firms. The frontier firms always choose to innovate, and the growth rate is γ_t.

2.2 Structural Estimation and Experiments

In this section, we estimate the model laid out in section 3. The estimation focuses on matching empirical moments during 1998-2006, which is covered by the dataset we have. Some parameters are calibrated and the rest are estimated by the Simulated Method of Moments [Blo09]. The results are summarized in Table **??**.

The parameters we calibrate include the initial distribution G_0, the foreign firm productivity,$\bar{A}$, innovation cost η^R,ψ and the bargaining power against foreign firms, θ^F.

We assume the initial distribution is a Pareto distribution, $P(q_0^M, b)$, in which q_0^M determines the average productivity of firms and b determines the shape of the productivity tail. We normalize the value of q_0^M to 1. The year 1998 is set as the initial period. In 1998, the average ratio of mean to median over the productivity distributions of different

Parameters	Value	Target/Source	Data	Model
q_0^m	1	Normalization		
b	1.16	Productivity Distribution in 1998	7.25	7.25
$\bar{A}$	149	Relative Productivity in 1998	4.6%	4.9%
ψ	8	R&D intensity in 2005	0.08%	0.08%
η^R	0.06	Share of R&D firms in 2005	9.6%	10.2%
θ^F	0.4	Relative R&D Expenditure in 1998	0.92	0.88
β	2.90	SMM		
θ^D	0.994			
η^D	5.74			

Table 2.1: Parameter Values and Targets

industries is 7.25. We let $b = 1.16$ such that the ratio of the Pareto distribution equals the value in 1998. Foreign firm productivity, $\bar{A}$, is set so that the relative productivity of Chinese firms in 1998 is 4.6% of that of US firms. This yields $\bar{A} = 149$.

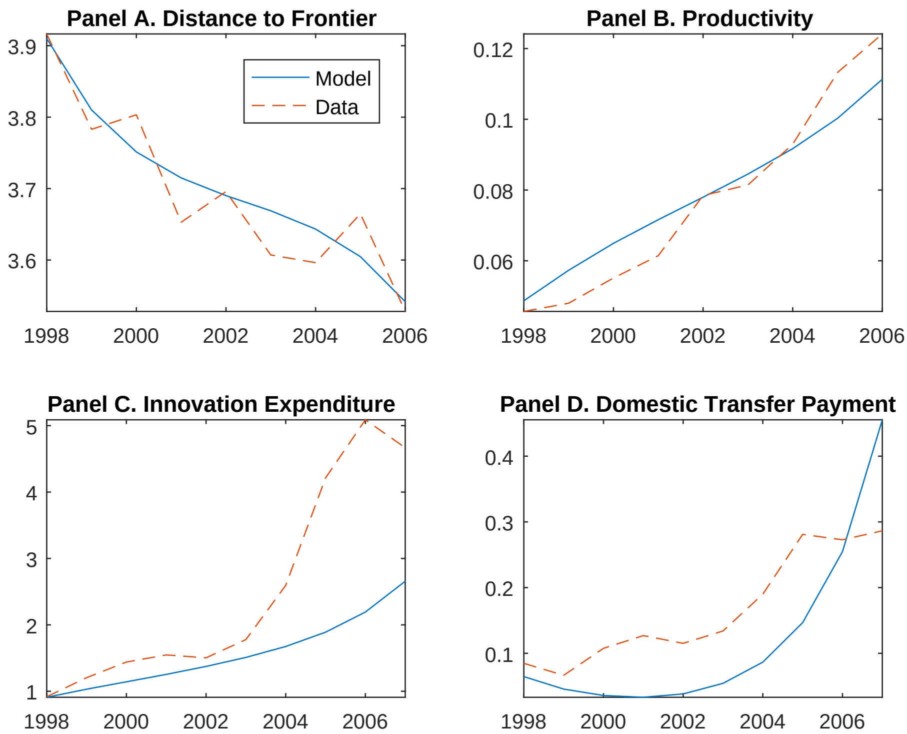
The parameters that are related to innovation cost, η^R and ψ, are set to match two empirical moments: (1) the share of firms innovating and (2) the innovation expenditure intensity in the Annual Survey of Above Scale Industrial Firms 2005. The innovation expenditure intensity is the innovation expenditure divided by total sales. η^R governs the fixed cost of innovation, and ψ measures the curvature of variable cost. There are 9.6% of firms doing innovation in 2005 and the average intensity is 0.08%. We let $\eta^R = 0.06$ and $\psi = 8$ such that the share of innovative firms is 10.2% and the innovation intensity is 0.08% in 2005. The parameter θ^F measures the bargaining power of domestic imitators, and the domestic imitator can grab more surplus generated by foreign technology transfer if the parameter is larger. The target of this parameter is the ratio of innovation expenditure over foreign technology transfer payment in 1998. We set the parameter $\theta^F = 0.4$ such that the ratio is 0.88, slightly lower than the ratio in the data (0.92).

We have the remaining three parameters $\omega = \{\theta^D, \eta^D, \beta\}$ to be estimated. The vector of moments $y = \{Cr_t, (\frac{T_t^D}{T_t^F})\}_{t=1998-2006}$ includes the catch-up rates and the ratios of domestic transfer payment over foreign transfer payment from 1998 to 2006 and we minimize the objective function

$$\hat{\omega} = \arg\min_{\omega \in \Omega} [\Lambda(\omega) - \Lambda(y)] W [\Lambda(\omega) - \Lambda(y)]'$$

,where W is a weighted diagonal matrix and the diagonal elements are $W_{ii} = \frac{1}{\Lambda_i(y)^2}$. $\Lambda(\omega) - \Lambda(y)$ represents the differences between moments in the data and moments in our model.

Figure 2.2: Transition in the Model Economy



Notes: The figure shows the transition of key variables during the transition in the model economy. The solid and dashed lines refer to variables in the model economy and data.

The dynamics of the transition in our model economy are illustrated in Figure 5. Panels A-D display various macroeconomic trends of the model against the data. The values of moments in the data and these generated by the model are available in Appendix B.2.

First of all, the estimated model economy generates almost the same speed catch-up rate as its empirical counterpart (Panel A). The catch-up rate is determined by three factors: the innovation growth rate, the amount of foreign technology transfer, and the share of domestic imitators. The growth of innovative tail firms increases the distance to frontier, while the adoption of foreign and domestic technology decrease it. During the transition of our model economy, the growth rate of innovative firms is stable (6.7 percent). The amount of foreign technology transfer is stable as well, but the effect of foreign technology on the distance to frontier is decreasing over time because the productivity of bottom firms grows rapidly. However, the share of domestic imitator rises (7.24% to 12.73%), which compensates for the reduced effect of foreign technology. Therefore, the distance to frontier in our model economy exhibits a high decreasing rate during the transition period.

The other trend is on the growth of relative domestic transfer payment (Panel D). The relative domestic transfer payment is the domestic technology payment divided by the payment of foreign technology transfer. The trend in our model economy has a slight U shape because of the growing productivity. In the first half of the period, the bottom firms grow faster than the tail firms and more and more firms prefer to adopt foreign technology. In the second half of the period, adopting foreign technology is no longer as profitable as before because of the faster productivity growth of both bottom and tail firms.

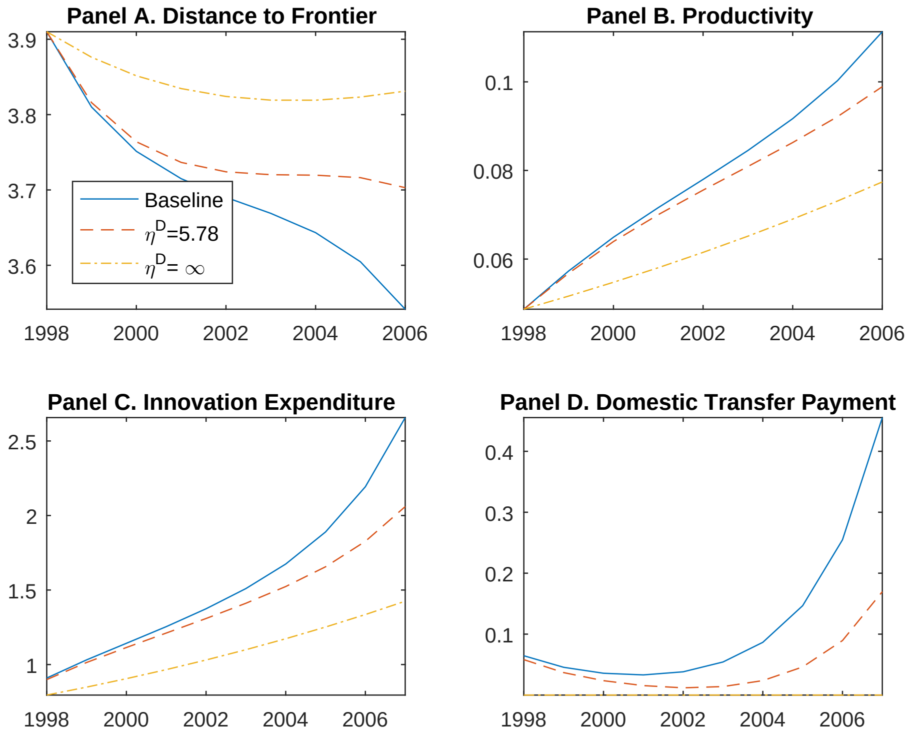
Third, the average productivity trend during the transition tracks remarkably well with the growth rate of Chinese manufacturing productivity (Panel B). Recall that we do not target the moments of productivity when we estimate the parameters. The relative productivity in our model accounts for 79.8% of productivity growth. The productivity relative to the US increases from 4.87% to 11.13%, and the productivity in our data surges from 4.57% to 12.41%. The contribution of adopting foreign technology to productivity is decreasing and the contribution of domestic technology is growing. Thus the growth of productivity in our model keeps a high rate in the transition. Last, our model generates a sizable increase in relative innovation expenditure growth. The relative innovation expenditure to foreign technology adoption payment is 91.76% in 1998 and 466.85% in 2007. In our model, the relative innovation expenditure grows from 90.94% to 265.69% (Panel C). The growth in our model accounts for 46.4% of the empirical counterpart.

B. Experiments

We have two experiments in the section. The first experiment changes the fixed cost parameter of domestic technology adoption,η^D. We first increase the value of the fixed cost from 5.74 to 5.78 to figure out the changes caused by the greater cost of adopting domestic technology. The increased cost of domestic technology transfer leads to a smaller catch-up rate. We find the catch-up rate in the first half of the period is not affected very much, but the effects due to the change become significant in the second half of the period. The foreign and domestic technology transfers are two forces that drive the bottom firms to catch up with the frontier. In the first half of the period, the force of adopting foreign technology dominates the force of domestic technology transfer. The greater cost in the experiment discourages firms from adopting domestic technology. Instead, these firms turn to adopting foreign technology, which enhances the catch-up rate to some extent. However, the force from adopting domestic technology dominates the other force in the second half of the period, and the catch-up rate of the bottom firms is reduced much more than before.

The increase in fixed cost decreases the growth of productivity and innovation expenditure as well. The greater cost of adopting domestic technology makes more firms turn to adopting foreign technology and thus firms with low productivity are less likely to be productive. This diminishes the growth of productivity in the period. Because the only most productive firms innovate and the mobility of firms with low productivity is harmed by greater cost, less firms spend money on innovation and the growth of innovation expenditure is slowed. In a dynamic environment, a thinner tail of productivity distribution further reduces the technology transfer from productive firms to less productive firms in the domestic industry. This explains why the differences in productivity and innovation expenditure between the baseline model and the experiment become greater over time.

Figure 2.3: Effects of Domestic Technology Transfer



Notes: The figure shows the effects of domestic technology transfer on the distance to frontier, and relative productivity, relative expenditure on foreign and domestic technology transfer.

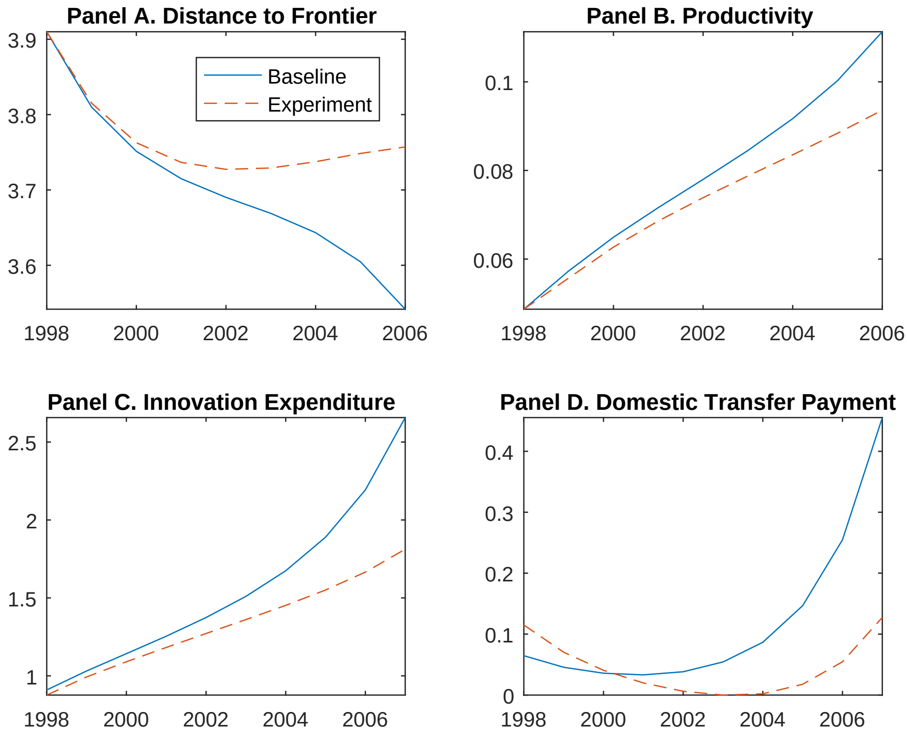
We increase the cost of adopting domestic technology to infinity such that we can quantify the contributions of adopting domestic technology to the growth of productivity and innovation (Figure 2.3). Clearly, the relative expenditure on domestic technology transfer is zero in Panel D. The differences between the baseline model (solid line) and the experiment with infinity cost of adopting domestic technology (dashed-dot line) indicate that the domestic technology transfer contributes to 57% of the productivity growth and 64% of the innovation expenditure increase.

The other experiment we conduct is to test whether stronger IPR protection helps the growth. [CCG14] finds a positive correlation between the strength of IPR protection and relative productivity and they argue the optimal strength of the IPR protection depends on the stage of development. At the early stage of development, the country has weak protection to facilitate technology imitation. And the country imposes strong protection to encourage innovation. In our model, the bargaining power of the imitator in domestic technology transfer, θ^D, determines the profits that the imitatees obtain from selling technology. When the bargaining power of imitator goes up, the profit of the imitatee decreases. Therefore, we decreases the value of θ^D in our second experiment to figure out the consequences of stronger IPR protection on productivity growth and innovation expenditure.

Stronger IPR protection has several effects on the technology development of firms. First, it discourages firms from adopting domestic technology, so these firms turn to adopting foreign technology, thus reducing the share of firms adopting domestic technology. Second, stronger IPR protection leads to greater profits from selling technology to a certain imitator. But it also decreases the measure of imitators that an imitatee can meet because of fewer domestic imitator and more firms adopting foreign technology. Third, the change of IPR protection also induces a change in the share of innovative firms. Because the experiment affects the optimal growth rate of innovation and the optimal rate of foreign technology adoption, the returns to these two ways of developing technology are different and the shares of the two types of firms are changed.

In the experiment, we change the share of profits obtained by the imitatee from 0.6% to 1.2% (Figure 2.4). We find that the effects on the optimal rates of innovation and foreign technology transfer are trivial. Because the share obtained by the imitatee is so low, it changes the optimal decisions of imitatees by less 1 percent. Therefore, the catch-up rate slows down in the second half of the transition for the same reason as in the first experiment (Panel A). In the transition, stronger IPR protection decreases the share of firms adopting domestic technology and productivity growth rate. Productivity growth has decreased by 35% in the year of 2006 (Panel B). Due to the slowdown of productivity growth, fewer firms choose to do innovation and the innovation expenditure drops by 46% (Panel C). Relative domestic transfer expenditure shows a different trend compared with that in the first experiment. Due to greater IPR protection, domestic imitator has to pay more at the beginning of the transition. However, there would be fewer domestic imitators and the technology that domestic imitators can purchase would be less advanced compared with the case of the baseline model. That is why domestic transfer payment is less than that in the baseline model after 2001(Panel D).

Figure 2.4: Effects of Stronger IPR Protection



Notes: The figure shows the effects of stronger IPR protection on the distance to frontier, and relative productivity, relative expenditure on foreign and domestic technology transfer.

2.3 Conclusion

In this paper, we construct a dynamic transition model featureing an endogenous choice between innovation and technology adoption. We model the technology transfer payment as the result of Nash Bargaining. The cost of domestic technology adoption and the bargaining power of the domestic imitator affect productivity growth and expenditure on innovation in the transition. The theory is based on the significantly positive correlation between innovation expenditure and relative productivity. The expenditure on domestic technology increases in both distance to domestic technology frontier and relative productivity level. Expenditure on domestic technology is positively correlated with the productivity growth rate in the industry. The empirical evidence on the level of industry supports the theory as well. Our model is consistent with the trends of productivity growth, decreasing dispersion of the productivity distribution, and rising expenditures on innovation and domestic technology transfer. The estimated baseline model is shown to match with the data very well.

We impose several simplifications on the model for the sake of tractability, and we may relax the simplifications in future research. First, we assume overlapping generation agents who live only for two periods and simplify the dynamic problem to a static problem. Compared with the length of the period we study, this assumption may not be adequate in the quantitative exercise. The other simplification is the market structure and demand function for the intermediate goods. That China joined in the WTO is an important event in the period we study, and the accession to WTO expands the market for productive exporters and induces greater competition, which may encourage these productive firms to spend more on innovation. Our model does not take the change of market into consideration and thus the relative innovation expenditure in our model does not match the data very well after 2002.

Despite our model having the limitations above, we believe our paper casts some light on the catch-up of developing countries. The literature emphasizes the role of foreign technology transfer in the developing country. We realize the importance of domestic technology transfer among domestic firms, although most domestic firms have much lower productivity than the world frontier. In this paper we tell a story including both the traditional mechanism and the new mechanism involving the domestic technology transfer. We find domestic technology transfer contributes most to productivity growth and the rise of innovation expenditure. The economic transition for developing countries would be facilitated if policymakers take the mechanism into consideration.

CHAPTER 3

Immigration and Gains from Openness

3.1 Introduction

The United States is the largest immigrant country of the world. Over last three decades, immigrants fraction of the total employment in the United States has risen 6.9% to 17.2%. During the same period, immigrant entrepreneurs who receive great attentions account for a much larger share of the total entrepreneur population, from 7.2% to 20.8%. Although immigrant entrepreneurs are frequently discussed , most work doesn't involve quantitative examination on their effects. Some papers are descriptive [Fai12, FL15, Hun11, KK16]. Some researchers focus specially on high-tech sector [Sax00, WSR07]. We quantify how immigration to the United States and the rest countries of the world affects the welfare of the US natives and people in the rest of the world. We further explore the interaction between immigration and international trade.

In this paper, we construct a general equilibrium multi-country model of immigration and trade in which the agents endogenously decide whether to be entrepreneurs or workers and make decisions on the places they live in. The agents have heterogeneous abilities in working and entrepreneurship in different countries. The immigrants face country-specific immigration frictions. These frictions reduce the welfare of the immigrants but do not affect the productivity and the income of the immigrants.

immigration affects the native entrepreneurs and workers in the destination country. The immigrant entrepreneurs establish more firms and create job opportunities, which benefits workers but induces stronger competition with existing native entrepreneurs. Workers are heterogeneous in skill and perfect substitutes no matter they are natives or immigrants.Thus, immigrant workers reduce relatively working income and crowd out native workers. Instead of being unemployment workers crowded out run their own business. The crowd-out loss is mitigated because of alternative occupational choice. immigrants increase the varieties of destination economy by running business or crowding out would-be native workers to produce new products. The native entrepreneurs and workers benefit equally from the increases number of varieties. The other occupation-neutral effect of immigration on the natives is congestion. Following fixed amenity framework [HMR08, RS08, AA14], we assume the increase of population causes congestion externality. One interpretation of congestion externality is that individuals demand for housing with fixed supply and the inflow of immigrants increases local housing price.

The immigration affects the origin countries of immigrants as well. The immigrant entrepreneurs produce different varieties in the destination country and sell them to the markets of the destination and origin countries and the rest of the world under monopolistic competition [Mel03]. An immigrant entrepreneur could be more productive after moving to the destination country , which lowers the cost of the variety. However, the price of the variety faced by people living in his origin country includes the international trade cost between the origin and the destination countries. The welfare of people living in the origin country relies on the change of the immigrant entrepreneur's productivity and the international trade cost.

We contribute to the literature on estimating welfare impacts of migration. The literature focuses on labor productivity differences across countries and gains generated by labor moving to more productive countries [KV07, KV09, BJ12, DW02, Ken13]. Without considering congestion effect, they find huge welfare gains of the world economy but immigration reduces welfare of native individuals who are workers in the destination country. Two exceptions that emphasize the endogenous variety are [IP09] and [GLO14]. In their papers, immigrants are only working labors. More firms enter the market due to labor increase and provide more varieties. For [IP09], workers are heterogeneous in skills and employed in different sectors. Depending on skills of immigrants, workers in different sectors receive different shocks. However, production technology doesn't change with inflow of people and firms in the same sector are homogeneous. In [GLO14], firm productivity is Pareto distributed and those entrants after the inflow of labor have relatively lower productivity. My paper differs from the literature and it is possible that immigrant entrepreneurs improve average productivity of destination if they are of high entrepreneurship, which echoes recent report on successful immigrant entrepreneurs such as Arianna Huffington, Elon Musk, and Sergey Brin. Whether the immigrant entrepreneurs could increase the productivity of the destination country depends on the immigration friction between the origin and the destination countries. The productivity of the immigrant entrepreneurs would be high enough to increase the productivity if the immigrant entrepreneurs face high friction.

To quantify the welfare effects of immigration to the United States, one counterfactual experiment is conducted in which the United States closes it border while international immigration still exists among other countries. Provided the current skill and occupation composition of immigrants in the United States, native entrepreneurs welfare is improved by 3.95% and native workers are worse off moderately by 0.98%. The immigration of the United States also contributes to world welfare by 0.43%. We further compare the worldwide international immigration and trade autarky with the baseline model, and figure out the welfare effects of the international immigration and trade. The welfare gains from immigration is substantial and as high as the gains from international trade. The gains of different countries range from 5% to 15% and the entrepreneurs gain more than workers in most countries.

Second, we explore marginal contribution of immigrants to the United States by origin country and the optimal scheme for immigration frictions. immigrants in the United States come from all over the world and face immigration country-dependent frictions. For example, the United States immigration system sets a per country limit. No more than 7 percent of the visas may be issued to natives of any one independent country in a fiscal year. Empirical evidence shows great variances in their shares of the United States population (quantity) and relative incomes (quality) as worker and entrepreneur. For example, Mexican immigrants account for 3.38% of workers and 5.19% of entrepreneurs while the average population of Mexico over 1980 to 2015 is 98.10 millions. On contrary, immigrants from China and India accounts for less than one percent of workers and entrepreneurs. In terms of income, Mexican immigrants only receive about half income as their American cohorts, while Indian earn 43% more income as workers and 46% as entrepreneurs than American natives (Appendix 5). We measure the marginal contribution of immigrants by origin country to the United States as the increase of average welfare of the US natives for a marginal increase of immigrant population from the origin country. We assume the US government can change country-specific immigration frictions and implement an optimal scheme to maximize the welfare of the US natives. Under the optimal scheme, the welfare of native entrepreneurs and workers increase by 5.06% and 1.65% relative to those in our baseline parameterization and the total population in the US increases by 14.7%.

The rest of the chapter is organized as follows. Section 2 presents the multi-country model. Section 3 provides the calibration and parameter values. Section 4 shows the results of experiments. Section 5 concludes.

3.2 Model

Our framework extends the model of trade in [Mel03] to incorporate occupation and immigration decisions. Our model is a monopolistic model with a continuum of endogenous tradable varieties . Following [GLO14], individuals choose one country to live in and make occupational choice between entrepreneur and worker.

A. Preferences and Welfare

The world consists of I countries indexed by $i, j = 1, ..., I$ with N_i^0 units of population. Individuals in different economies have identical preferences. Individuals consume final good Q_i. The final good Q_i represents a CES aggregator over a continuum of varieties from domestic and foreign producers,

$$Q_i = (\sum_j \int_{\Omega_j} q_{ji}(\omega_j)^{\frac{\sigma-1}{\sigma}} d\omega_j)^{\frac{\sigma}{\sigma-1}} \tag{3.1}$$

,where $q_{ji}(\omega_j)$ is the consumption of variety $\omega_j \in \Omega_j$ produced in country j . $\sigma > 1$ is an elasticity of substitution between any two goods. Given the aggregate consumption, the demand for each variety of goods ,q_{ji}, and expenditure, r_{ji}, are

$$q_{ji} = Q_i(\frac{p_{ji}}{P_i})^{-\sigma} \quad r_{ji} = P_i Q_i(\frac{p_{ji}}{P_i})^{1-\sigma} \tag{3.2}$$

,where $P_i = [\sum_j \int p_i(\omega_j)^{1-\sigma} d\omega_j]^{1/(1-\sigma)}$ is the overall price index in country i. The aggregate income is $R_i = P_i Q_i$.

Welfare in country i depends on utility derived from consumption Q_i and amenity a_i^0 which is one unique characteristics of the country. Thus the welfare of a native individual with income y_i is

$$U_i(y_i) = \frac{a_i^0}{(N_i)^\lambda} Q_i = \frac{a_i^0}{(N_i)^\lambda} \frac{y_i}{P_i} \tag{3.3}$$

,where N^i is the population of country i including immigrants from the rest of world and λ captures the congestion effect of population. A key implication of this assumption is that preferences exhibit love of variety: given one's income and goods, the individual's utility increases when the set of goods Ω_j increases. Thus, immigrant entrepreneurs affect the equilibrium set of varieties and have a welfare effect through this channel.

B. Production

There is a continuum of firms run by entrepreneurs, and each chooses to produce a different variety $\omega \in \Omega$. Production requires only labor which is inelastically supplied by workers. Firm production technology is a product of firm specific and sector productivity. The output exhibits increasing return to scale with respect to labor used: $q_i(\omega) = A\phi(\omega)l_i^\gamma$, $\gamma > 1$, where A and $\phi(\omega)$ represent sector and firm specific productivity. A firm with productivity ϕ in country i maximizes its profits by making decisions on sales in every market,

$$\pi_i(\phi) = \max_{p_{ij}} \sum p_{ij} q_{ij} - w_i l_i \tag{3.4}$$

$$\begin{aligned} s.t. \ \sum_j \tau_{ij} q_{ij} &= A_i \phi l_i^\gamma \\ q_{ij} &= R_j P_j^{\sigma-1} p_{ij}^{-\sigma} \end{aligned}$$

,where τ_{ij} is iceberg trade cost of variety exporting to country j and q_{ij} is the quantity of the variety. Varieties are tradable but the final goods are not. Trade is subject to the iceberg costs: $\tau_{ij} \geq 1$ units of any variety must be shipped from country i for one unit to arrive in country j. We assume $\tau_{ii} = 1$ for all I countries and the triangle inequality holds: $\tau_{ij} \leq \tau_{ik}\tau_{kj}$ for all $i, j, k \in I$. We exclude multinational production and thus labor used in production only consists of immigrant and native residents. First order condition reveals the pricing rule of a firm over markets in different countries, $p_{ij} = \tau_{ij} p_{ii}$. Given the simple pricing rule, producer's problem becomes choosing optimal domestic price, p_{ii},

$$\pi_i(\phi) = \max_{p_{ii}} D_i p_{ii}^{1-\sigma} - \frac{w_i}{\phi A_i} D_i^{\frac{1}{\gamma}} p_{ii}^{-\frac{\sigma}{\gamma}}$$

,where $D_i = \sum_j \tau_{ij}^{1-\sigma} R_j P_j^{\sigma-1}$ measures the world market demand for goods produced in country i .The optimal domestic price, revenue, and profits can be expressed as

$$p_{ii}(\phi) = [\frac{\sigma}{(\sigma-1)\gamma}\frac{w_i}{A_i\phi}D_i^{\frac{1-\gamma}{\gamma}}]^{\frac{\gamma}{\sigma+\gamma-\sigma\gamma}}$$

$$r_i(\phi) = (\frac{(\sigma-1)\gamma}{\sigma})^{\frac{(\sigma-1)\gamma}{\sigma+\gamma-\sigma\gamma}}(D_i(\frac{A_i\phi}{w_i})^{(\sigma-1)\gamma})^{\frac{1}{\sigma+\gamma-\sigma\gamma}}$$

$$\pi_i(\phi) = \frac{\sigma+\gamma-\sigma\gamma}{\sigma} r_i(\phi)$$

. A special case when $\gamma = 1$ has same results of pricing and profits as [Mel03]. When $\gamma > 1$, the markup of firms is constant as well, $\frac{\sigma}{(\sigma-1)\gamma}$. The markup is lower than that in the case where $\gamma = 1$. To have these results requires $(\sigma-1)(\gamma-1) < 1$. This means the effect of increasing return to scale is still dominated by substitution effect between varieties and thus there exist many producers in an economy.

C. Immigration and Occupation

An individual born in country i has entrepreneurship, $\mathbf{z}$, and working ability, $\mathbf{l}$, over countries. He can choose to be an entrepreneur who runs a firm and claims profits or a worker employed by others. These abilities are drawn and realized before immigration and occupation decisions are made. Assume the abilities follow a multivariate Fréchet distribution

$$G_i(\mathbf{z}, \mathbf{l}) = exp\{-\sum_o \sum_j T_{ij}^o (o_{ij})^{-\theta}\},\ i, j = 1, ...I,\ o = z, l \tag{3.5}$$

, where $o_{ij} = z_{ij}$ and $o_{ij} = l_{ij}$ are entrepreneurship and working ability if the individual born in country i works in country j. The parameter θ governs the dispersion of abilities and a higher θ corresponds to smaller dispersion. The parameter T_{ij}^o governs the average ability of the group of people who migrate from country i to j and have occupation o. According to $T_{ij}^o = h_i \epsilon_{ij}^o$, the average ability depends on the human capital improvement of origin country, h_i, and productivity shock ϵ_{ij}^o.The immigrants may receive more education with higher quality in their home country, this is captured by the factor

h_j. The human capital should be affected by destination country as well. However, we cannot differentiate the human capital contribution from destination country and productivity of destination country. Every factor of destination country would be attributed to productivity. On the other hand, productivity shock ϵ_{ij}^o is generated but not limited by language and culture differences between the pair of origin and destination economy. To have tractability with Fréchet distribution, we assume the relationship between firm owner's entrepreneurship and the productivity of the firm can be described by the function $z = \phi^{\frac{(\sigma-1)\gamma}{\sigma+\gamma-\sigma\gamma}}$ and thus the profits of a firm are linear in its owner's entrepreneurship, $\pi_i(z) = \frac{\sigma+\gamma-\sigma\gamma}{\sigma}(D_i(\frac{A_i}{w_i})^{(\sigma-1)\gamma})^{\frac{1}{\sigma+\gamma-\sigma\gamma}} z$. Henceforth, firm productivity and entrepreneurship are used interchangeably. The individual makes decision on where to live and work. He also chooses to be an entrepreneur who claims the profits of his firm or earns wages for being employed. The problem faced by the individual born in country i and having abilities $\{\mathbf{z}, \mathbf{l}\}$is

$$U_{ij}(\mathbf{z}, \mathbf{l}) = \max_{j,o\in\{z,l\},} \{U_{ij}(\pi_j(z_{ij})f_{ij}),\, U_{ij}(w_j l_{ij} f_{ij})\} \tag{3.6}$$

$$= \max_{j,o\in\{z,l\}} \{u_{ij}^z f_{ij} z_{ij}, u_{ij}^l f_{ij} l_{ij}\}$$

, where the utility of an entrepreneur with unit entrepreneurship and a worker with unit working ability are expressed by

$$u_{ij}^z = \frac{\sigma+\gamma-\sigma\gamma}{\sigma} \frac{a_i^0}{(N_i)^\lambda} \frac{(D_i(\frac{A_i}{w_i})^{(\sigma-1)\gamma})^{\frac{1}{\sigma+\gamma-\sigma\gamma}}}{P_i} \tag{3.7}$$

$$u_{ij}^l = \frac{a_i^0}{(N_i)^\lambda} \frac{w_i}{P_i} \tag{3.8}$$

. f_{ij} measures the friction one individual faces when he migrates from country i to country j. The friction mainly reflects non-pecuniary costs the immigrants have to undertake. We assume it is proportional to the income of immigrant and independent of occupational choice, capturing the time used to migrate and the probability of failure. The domestic friction $f_{ii} = 1$ means individuals do not have any cost if they live in the country where they are born. If $f_{ij} = 0$, the friction is so high that the immigration is forbidden.

D. Aggregation

An equilibrium of a country i will be characterized by over $(0, \infty)$ in each country. In the equilibrium, the aggregate price P_i is then given by

$$P_i = [\sum_j \int_0^\infty p_{ji}(z)^{1-\sigma} M_j \mu_j(z) dz]^{\frac{1}{1-\sigma}}. \tag{3.9}$$

Using the pricing rule, this expression can be written $P_i = [\sum_j (\frac{\sigma}{(\sigma-1)\gamma} \frac{\tau_{ji} w_j}{A_j} D_j^{\frac{1-\gamma}{\gamma}})^{\frac{\gamma(1-\sigma)}{\sigma+\gamma-\sigma\gamma}} M_j \bar{z}_j]^{\frac{1}{1-\sigma}}$, where $\bar{z}_j = \int_0^\infty z \mu_j(z) dz$. $\bar{z}_j$ is the weighted average of firm productivity z and is independent of the mass of firms M_j. The average productivity $\bar{z}$ also summarizes other aggregate variables:

$$R_i = (\frac{(\sigma-1)\gamma}{\sigma})^{\frac{(\sigma-1)\gamma}{\sigma+\gamma-\sigma\gamma}} M_i (D_i (\frac{A_i}{w_i})^{(\sigma-1)\gamma})^{\frac{1}{\sigma+\gamma-\sigma\gamma}} \bar{z}_i \tag{3.10}$$

$$L_i = \frac{(\sigma-1)\gamma}{\sigma} \frac{R_i}{w_i} \tag{3.11}$$

,where R_i denotes the sum of all firms revenue and total output. L_i is immigrant and native efficiency labor used in production. Given the assumption on the ability distribution, we can derive occupation and immigration share , $\bar{p}_{ji}^o$, denoting the share of immigrant moving from country j to i and choosing occupation o in the population of origin country. Aggregating across people, the solution to the individual's choice problem leads to the share

$$\bar{p}_{ji}^o = \frac{T_{ji}^o (u_{ji}^o f_{ji})^\theta}{\sum_s \sum_j T_{ji}^s (u_{ji}^s f_{ji})^\theta}. \tag{3.12}$$

Occupational choice and immigration decision depend on the overall reward that one born in country j with mean ability can obtain by migrating to country j and working in occupation o relative to power mean of people born in country j over all choices. This expression shows reasons of immigration and occupational choice. The fraction of people born in country j and working in occupation o is low when human capital is negatively affected (T_{ji}^o is low) , the destination country has poor amenity and low income (u_{ji}^o is low) , or when those immigrants face a barrier in migrating to country i (f_{ji} is low). We can also derive the average entrepreneurship, $\bar{z}$, and working ability, $\bar{l}$. The average quality of immigrants from country j to country i who choose occupation o is

$$\bar{o}_{ji} = \Gamma(1 - \frac{1}{\theta}) \frac{(\sum_s \sum_j T_{ji}^s (u_{ji}^s f_{ji})^\theta)^{\frac{1}{\theta}}}{u_{ji}^o f_{ji}} \tag{3.13}$$

,where $\Gamma(1-\frac{1}{\theta})$ is related to the mean of the Frechet distribution for ability. The relationship between the share of immigrant, $\bar{p}^o_{ji}$, and the average quality, $\bar{o}_{ji}$ is ambiguous. When the share of immigrant increases due to human capital improvement, average quality increases as a result. However, average quality in inversely related to the share when the change comes from greater income, better amenity, or smaller immigration friction. Since each entrepreneur only runs one firm, the measure of firms equal the measure of entrepreneurs,

$$M_i = \sum_j \bar{p}^z_{ji} N^j_0 \tag{3.14}$$

Aggregating each firm's export, we find gravity equation, the share of trade flow from i to j in $i's$ total output,

$$X_{ij} = \frac{\int p_{ij} q_{ij} d\omega_i}{\sum_j \int p_{ij} q_{ij} d\omega_i} = \frac{R^j (P^j/\tau^{ij})^{\sigma-1}}{\sum_j R^j (P^j/\tau^{ij})^{\sigma-1}} \tag{3.15}$$

(Equilibrium) Given a set of countries ,I, and initial amenity, population, productivity, and human capital $(a^i_0, N^i_0, A, h^i) : I \rightarrow R_+$ and immigration productivity shock, bilateral trade and immigration frictions, $(\tau_{ij}, \epsilon^o_{ij}, f_{ij}) : I \times I \rightarrow R_{++}$, a competitive equilibrium in the world economy consists of choices $\{j, o\}$ of individuals in every country, a immigration decision and an occupational choice, immigrant and native efficiency wage w_i such that

1. Each individual chooses the destination country and his occupation that maximizes his utility $U_{ij}(\mathbf{z}, \mathbf{l})$ in equation 3.3, taking his draw of abilities $\{\mathbf{z}, \mathbf{l}\}$ as given.

2. Entrepreneurs maximize profits by hiring optimal amount of workers and deciding pricing of goods in different markets as equation 3.4.

3. Given the country a consumer resides in, he maximizes his utility derived from consumption as results in equation 3.2.

4. w_i clears labor markets of immigrant and native workers in every country. And the general equilibrium of the model can be solved by following equations:

1. The population of country i after immigration is

$$N_i = \sum_o \sum_j \bar{p}^o_{ji} N^j_0 \tag{3.16}$$

2.The share and average quality of native and immigrant people are described by equations 3.13 and 3.12. The measure of firms is indicated by equation 3.14.

3. The utility of individual is determined by equations 3.7 and 3.8.

4.Market clearing conditions for immigrant and native workers are

$$\frac{(\sigma-1)\gamma}{\sigma}\frac{R_i}{w_i} = \sum_j \bar{l}_{ji}\bar{p}^l_{ji}N^j_0 \tag{3.17}$$

5. The aggregate price, income level, and world market demand are

$$P_j^{1-\sigma} = \sum_i \left(\frac{(\sigma-1)\gamma}{\sigma}\frac{A_i}{\tau_{ij}w_i}D_i^{1-\frac{1}{\gamma}}\right)^{\frac{(\sigma-1)\gamma}{\sigma+\gamma-\sigma\gamma}} M_i\bar{z}_i \tag{3.18}$$

$$R_i = \left(\frac{(\sigma-1)\gamma}{\sigma}\right)^{\frac{(\sigma-1)\gamma}{\sigma+\gamma-\sigma\gamma}} \left(D_i\left(\frac{A_i}{w_i}\right)^{(\sigma-1)\gamma}\right)^{\frac{1}{\sigma+\gamma-\sigma\gamma}} M_i\bar{z}_i \tag{3.19}$$

$$D_i = \sum_j \tau_{ij}^{1-\sigma} R_j P_j^{\sigma-1} \tag{3.20}$$

3.3 Calibration

A. Data Description

We restrict our analysis to a set of 57 countries including most OECD countries, populous developing countries and countries as important source of immigrants to the United States.We use 1996 CEPII trade data on bilateral trade flow from country i to country j, π_{ij}. We use 2000 UN international immigrant stock data on bilateral immigration flow from i to j , N_{ij}. Since the data only has immigration flows but doesn't have the population of people residing their home country, we use 2000 World Bank total population data to generate the initial population of people born in country i, $N_0^i = N_i + \sum_j N_{ij} - \sum_j N_{ji}$, where N_i and N_0^i represent population in country i with and without migration. We complement the bilateral immigration data with data on the occupational choice and income of immigrant in the United States. These data are available for the United States from 2000 Census and 2001, 2002 American Community Survey (ACS). All data are averaged over the period, 2000-2002, where possible.

B. Calibration Procedure

Our general calibration strategy is as follows. First, we can assign values to these parameters without solving the model: the elasticity of substitution,σ, the variance parameter of skill distribution ,θ, the congestion parameter λ.Then we calibrate parameters such that the outcomes of the model match certain features of the data: the parameter of increasing return of production γ , each country human capital, h_i, and shock to immigrant's human capital, ϵ_{ij}, the population of people born in country i, N_0^i, local productivity of each country, A_i, immigration frictions, f_{ij}, and the trade iceberg cost τ_{ij} for countries $i, j = 1, ..., I$.

The values of the first group of parameters are showed in Table (3.1). [BW06] estimate the elasticity of substitution between differentiated varieties which corresponds to σ. We choose $\sigma = 4$ as the baseline value. The parameter λ represents congestion effects including housing ,traffic and public service. [DNR18] use 192 metropolitan data in the United States and find the elasticity of amenities to population is -0.32. Given the skill distribution is multivariate Frechet distribution, the distribution of income of immigrants from the same origin country follows Frechet distribution with same shape parameter. Using the US census and ACS data, we calibrate the shape parameter from the equation

$$\frac{Variance + Mean^2}{Mean^2} = \frac{\Gamma(1 - \frac{2}{\theta})}{\Gamma(1 - \frac{1}{\theta})^2} \tag{3.21}$$

. It turns out that each group by occupation and origin country in the United States has similar shape parameter. We choose the value of θ which determines the right hand side to minimize the difference between observed left hand side and right hand side and get the value $\theta = 2.35$.

We then estimate the trade iceberg cost parameter τ_{ij} according to [Wau10]. Based on trade share equation 3.15, we derive the following relationship between home trade share, bilateral trade share, aggregate price, total income, and trade costs:

$$\frac{X_{ij}}{X_{ii}} = \frac{R^j(P^j)^{\sigma-1}}{R^i(P^i)^{\sigma-1}}\tau_{ij}^{1-\sigma} \tag{3.22}$$

.Taking logs yields $I - 1$ equations for each country i:

$$\log(\frac{X_{ij}}{X_{ii}}) = S_j - S_i - (\sigma - 1)\log\tau_{ij} \tag{3.23}$$

Table 3.1: Baseline Parameter Values and Variable Normalization

Parameter	Definition	Determination	Value
σ	Elasticity of Substitution	[BW06]	4
λ	Congestion	[DNR18]	0.32
θ	Frechet shape	Income distribution	2.35
γ	Increasing return	US Share of entrepreneur	1.23
a_0^i	Amenity	[JK16]	Appendix
A_i	Productivity	Output	
N_0^i	Initial Population	Population	

Notes: A_i, N_0^i and a_0^i are productivity, initial population, and amenity of country i in our sample. The calibrated values of these countries are presented in the Appendix 5.

,in which $S_j = \log(R^j(P^j)^{\sigma-1})$ represents the market size of the country. To solve the under-identification problem, we make restrictions on the parameter space and assume that trade costs take the following functional form:

$$\log(\tau_{ij}) = \alpha ln(\text{dist}_{ij}) + b_{ij}^{\tau} + l_{ij}^{\tau} + ex_i + \varepsilon_{ij} \tag{3.24}$$

, where dist_{ij} is the distance between country i and j. The variable b_{ij}^{τ} equals one if countries share a border and l_{ij}^{τ} equals one if people speak same language in those countries. Otherwise these variables are zero. The variable ex_i represents an exporter fixed effect. A country with smaller exporter fixed effect can attract more entrepreneurs since the trade costs to get access to all rest countries are low. Table (3.2) shows the estimates of coefficients and exporter fixed effects of the US, Canada, and China. Since the data is year 1996 and China joined in the WTO in 2001, it is reasonable that China has larger fixed effects than other two countries.

The average quality of the group of people who immigration from i to j and have occupation o is determined by the mean parameter $T_{ij}^o = h_i^o \epsilon_{ij}^o$. We assume the human capital contributed by origin country is directly related to the average years of education from [BL13], $\log(h_i^o) = \beta^o \text{edu}_i$. Similar with [RR13], we reduce the number of parameters to calibrate by assuming that immigration shocks are a function of distance, whether countries share a border and a language, and whether these two countries have ever had

Table 3.2: Estimation Results of Trade Costs

	Estimate	Standard Error
Geographic Barriers		
Dist	0.905	.018
Shared Border	-0.783	.112
Common Language	-0.952	.080
Fixed Exporter Effects		
United States	-4.724	.276
Canada	-2.641	.275
China	-2.409	.276

Notes: We used the data from CEPII Geodist and CEPII Trade (1996). All parameters were estimated by the OLS regressions according to [Wau10]. We list the fixed exporter effects of the United States, Canada, and China as examples in the table.

a colonial relationship, respectively,

$$\log(\epsilon_{ij}^{o}) = \delta^{o}\text{dist}_{ij} + l_{ij}^{o} + b_{ij}^{o} + col_{ij}^{o},\ o = z, l$$

,where l_{ij}^{o},b_{ij}^{o}, and col_{ij}^{o} are language, border, and colonial dummies. All these variables depend on occupation. The variable $l_{ij}^{\delta}(b_{ij}^{o}, col_{ij}^{o})$ equals zero if countries share a border (language, colonial relationship). Then $\epsilon_{ii}^{o} = 1$ for any i, and o, people residing in their home country don't receive human capital shock. We only have income and occupation choice of immigrants and natives in the United States and calculate the relative income,$\frac{inc_{i,US}^{o}}{inc_{US,US}^{o}}$, and relative population,$\frac{N_{i,US}^{o}}{N_{i,US}^{o}}$, of each immigrant group to the native group. We find the relationship between human capital, immigration shocks, relative income, and population,

$$(\frac{h_i\hat{\epsilon_{i,US}^{o}}}{h_{US}\epsilon_{US,US}^{o}}) = \frac{N_{i,US}^{o}}{N_{US,US}^{o}}\frac{N_0^{US}}{N_0^{i}}(\frac{inc_{i,US}^{o}}{inc_{US,US}^{o}})^{\theta} \tag{3.25}$$

Based on the assumptions, we also derive the expression,

$$\log(\frac{h_i\epsilon_{i,US}^{o}}{h_{US}\epsilon_{US,US}^{o}}) = \beta^{o}(\text{edu}_i - \text{edu}_{US}) + \delta^{o}\text{dist}_{ij} + l_{iUS}^{o} + b_{iUS}^{o} + col_{iUS}^{o} \tag{3.26}$$

. We choose values of ten variables $\beta^{o}, \delta^{o}, l_{iUS}^{o}, b_{iUS}^{o}, col_{iUS}^{o}$ to minimize the difference between the observed $(\frac{h_i\hat{\epsilon_{i,US}^{o}}}{h_{US}\epsilon_{US,US}^{o}})$ and $(\frac{h_i\epsilon_{i,US}^{o}}{h_{US}\epsilon_{US,US}^{o}})$ and the number of observations between

Table 3.3: Calibration Results of Migration, Amenity, and Productivity

Panel.A. Immigration shock and human capital					
	β	δ^o	l_{ij}^o	b_{ij}^o	col_{ij}^o
Entrepreneur	1.23	-1.14	1.09	-1.86	-1.20
Worker	1.32	-0.80	0.99	-0.82	-0.55

Panel.B. Immigration Friction, Amenity, and Productivity			
Country	$1 - f_{i,US}$	a_0^i	A^i
Mexico	0.80	1.02	0.19
Canada	0.74	1.13	0.44
China	0.99	0.72	0.04

Source: US Census 2000; CEPII Geodist; Barron-Lee Education Attainment Dataset; UN Population Division's Global Migration; [JK16].

Notes: $1 - f_{i,US}$ denotes the immigration friction faced by immigrants from country i to the US. We list the country-specific parameter values of Mexico, Canada, and China as examples in Panel B. The values of migration frictions of all the countries in our sample are provided in Appendix 5 : immigration frictions

2000-2002 is 573 = 171. The results are showed in panel A in table 3. R^2 in the last column of panel.A illustrates how the model matches the features of the data. These value are high, indicating that our model captures a large fraction of variance of the observed income and immigration flows.

Finally we calibrate the rest parameters: productivity,A_i, amenity,a_0^i,immigration frictions, f_{ij}, and the parameter of increasing return to scale, γ. We set productivity A_i such that real GDP in the model matches those in the data.[JK16] propose a summary statistic for the economic welfare of people in a country, we set amenity,a_0^i, such that the average welfare of residents in one country is same as their index. The country-pair specific immigration friction is set to match bilateral immigration flows. And the parameter of increasing return to scale γ matches the share of US native entrepreneurs in the population of the United States, 9.46%. Panel B in table 3 displays the location characteristics of three countries: Mexico, Canada, and China. Since China has largest population but relatively small number of immigrant in the United States, this indicates Chinese immigrants face extremely high level of friction compared with Mexicans and Canadians.

3.4 Counterfactuals

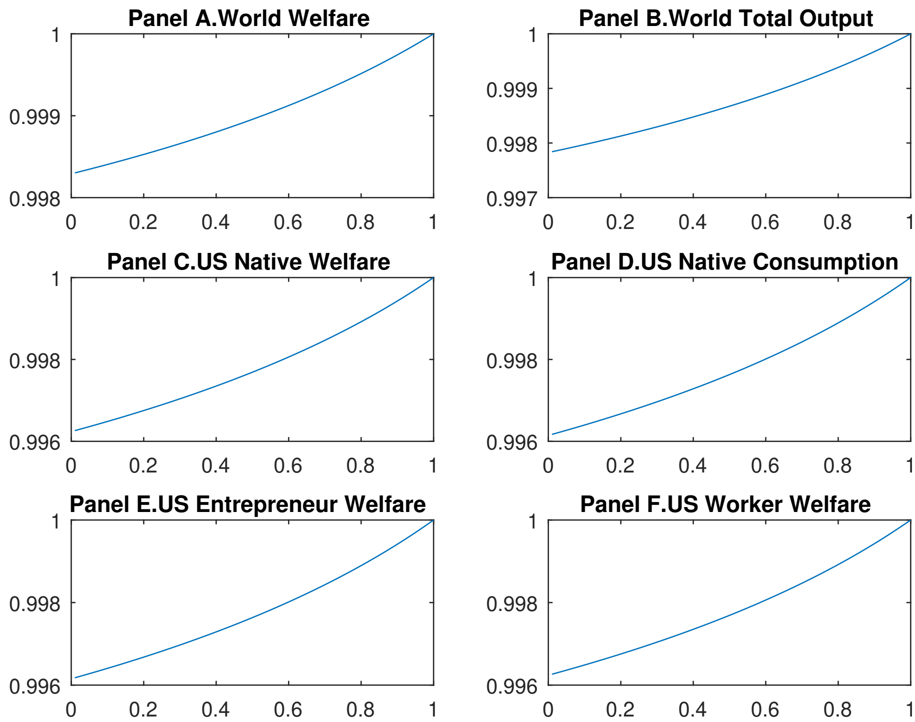
We use the parameterized model to conduct a series of counterfactuals in which we vary trade costs and immigration frictions. First, we show the effects of immigration to the US by conducting an experiment in which the immigration to the US is allowed. Then we consider changes in trade costs and immigration frictions such that countries move from autarky to the baseline 2000 parameterization. Last we figure out the scheme of frictions to the United Sates which maximizes the average welfare of native residents.

3.4.1 Effects of immigration to the US

In this part we examine the effects of immigration to the US on the welfare and output of the US and the world. In the experiment, we increase the immigration friction faced by immigrants moving from other countries to the US to 1 such that no agents born in other countries would move to the US.

We compare the case in which immigrants can not move to the US with our baseline parameterization. We find the world welfare increases by 1.7% and the world total output increases by 2.2% (Panel A and B in Figure 3.1). When the US opens its border to immigrants from the rest countries in the world, these immigrants would become more productive after they move to the US. However, the welfare effects are impaired by two factors negatively: congestion and immigration friction. These factors account for why the welfare gain is less than the increase of output.

Figure 3.1: Effects of immigration to the US



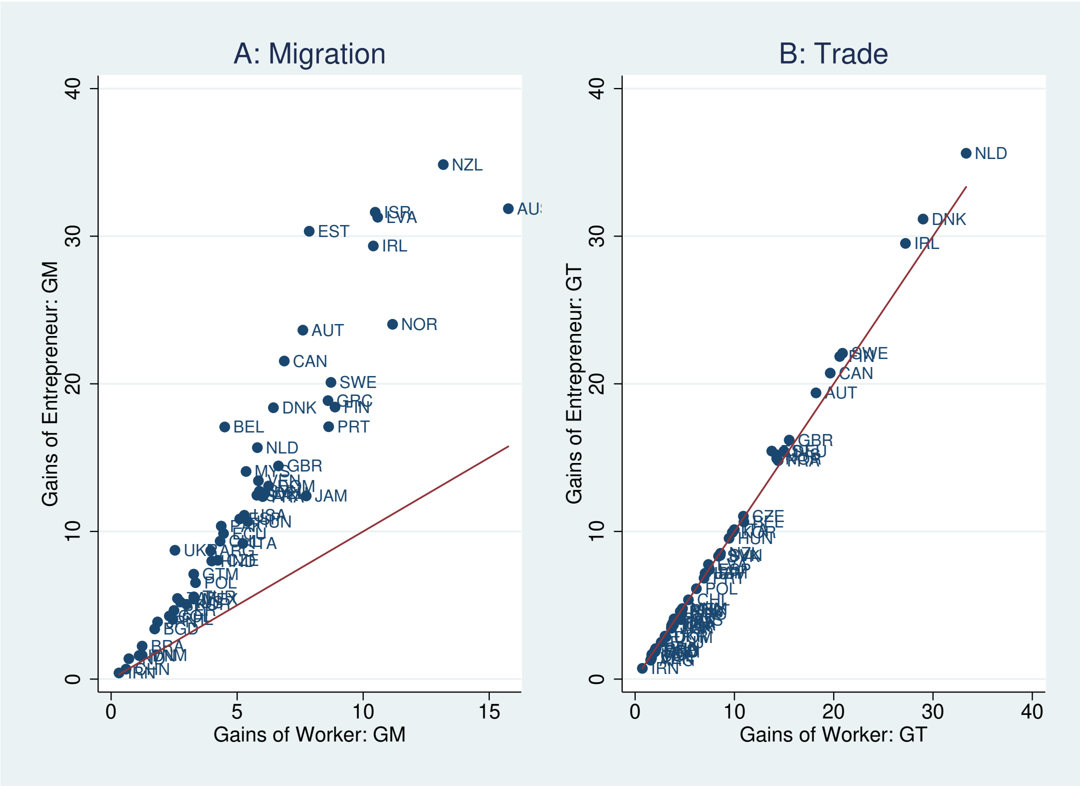
Notes: The figure shows how each variable changes with respect to the friction of migrating to the US. The horizontal axis corresponds to the immigration friction and the vertical axis corresponds to the relative value of the variable when we normalize the values of the variables in the baseline parameterization to 1.

The immigrants from the rest of the world to the US improve the welfare and consumption of US natives. The welfare of US natives is increased by 3.7% and the consumption by 3.8%, respectively (Panel C and D in Figure 3.1). Due to the change of immigration friction, it changes the population of people who are born and live in the US. The welfare and consumption refer to the average values of the welfare and consumption of people who are born and live in the US. And the immigration contributes to the welfare of US native entrepreneurs and workers similarly. The welfare of native entrepreneurs and workers increases by 3.8% and 3.7%, respectively.

3.4.2 Immigration and Trade Autarky to Baseline Parameterization

We consider a reduction in immigration frictions and trade costs, moving each country from autarky to baseline parameterization. When we have immigration autarky, trade costs are same as the values in the baseline and vice versa.

Figure 3.2: Immigration and Trade Autarky



Notes: Panel A shows the gains of entrepreneurs and workers from immigration autarky to the baseline model. Panel B shows the gains of entrepreneurs and workers from trade autarky to the baseline model. The lines in two panels are 45 degree lines. The axes represent the percentage gains relative to the corresponding autarky cases.

Panel A (B) of Figure 3.2 plots 100× the log change in welfare in the baseline parameterization relative to migration(trade) autarky for entrepreneur's welfare plotted against worker welfare for each country in our model. Since each country has endogenous population of entrepreneurs and workers, we define the welfare as the average welfare of native residents. Because the welfare of individuals in each group is linear in their ability, the average welfare measures the improvement of welfare of every individual. For instance,the worker welfare of China doesn't reflect the welfare change of a Chinese immigrant working in the United States.

Panel A of Figure 3.2 highlights that the gains from immigration liberalization are unevenly distributed across countries in our model. For instance, the worker's and entrepreneur's welfare increases by 13% and 35% in New Zealand and 16% and 32% in Australia while that in China rises by 0.7% and 0.6%. The graph also demonstrates that entrepreneur gains have highly positive correlation with worker gains ($R^2 = 0.75$) and the gains of entrepreneur is as twice large as the gains of worker in the same country. The intuition behind the correlation is that immigration liberalization increases labor efficiency in every country and lowers the price level. The variance can be accounted by for relative increase of the efficiency wage and market size. On average the market size increases greater than the increase of efficiency wage , therefore entrepreneurs benefit more than worker from the liberalization. And the variance of access to market leads to the variances of entrepreneur gains relative to worker gains.

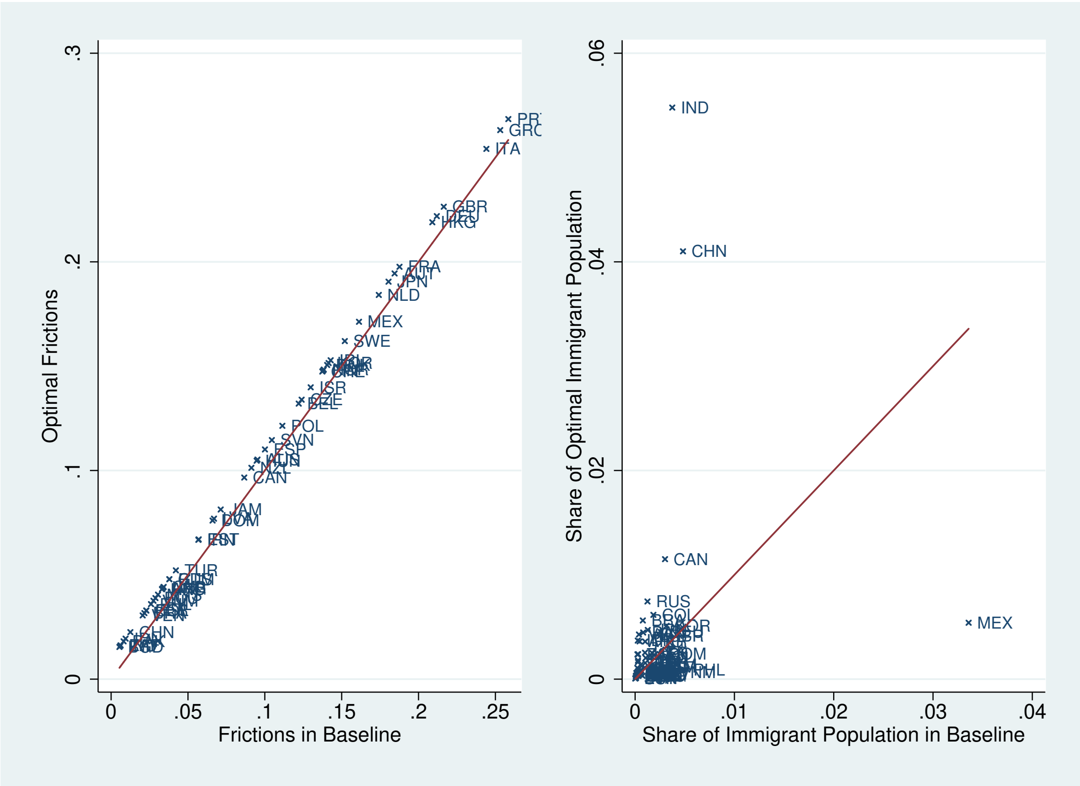
Panel B of Figure 3.2 shows even greater correlation between gains of entrepreneur and worker($R^2 = 0.99$). Intuitively, reducing trade costs is equivalent to increase productivity, resulting in proportional increases of firm profits and efficiency wage. The gains from trade liberalization are of great variation across countries. The gain of worker rises by as much as 33% in Netherlands, 29% in Denmark and by as little as 1.9% in Bangladesh and 1.7% in India.

In summary, reductions in immigration frictions and trade costs tend to raise welfare of entrepreneur and worker. Reducing trade costs increase welfare of entrepreneur and worker equally while elimination of immigration frictions improves the welfare of entrepreneur more.

3.4.3 Optimal Immigration Frictions of the US

We now aim to illustrate the welfare gain of the US from changing immigration friction. We assume the United States can change immigration frictions from all other countries to the United States as long as those frictions are smaller than one and assume the change of immigration friction is costless for the US government. We derive optimal immigration friction for each origin country, which maximizes the aggregate welfare of native US residents. Under optimal migration, welfare of entrepreneur and worker increase by 5.06% and 1.65% relative to those in baseline parameterization and the total population increases by 14.7%. The policy implication is that the US should relax immigration barrier and have more immigrants overall.

Figure 3.3: Optimal Immigration Frictions



Notes: Panel A compares the optimal frictions of countries in our sample with the estimated frictions. Panel B shows the shares of immigrant population in the counterfactual and the baseline model. The solid lines are 45 degree lines. The values of optimal frictions are shown in Appendix 5.

Panel A of Figure 3.3 demonstrates values of the optimal immigration frictions and their values in the baseline parameterization. Panel B show the optimal share of immigrant population by origin in total US population. Most countries in panel A are below the red line, which indicates immigration friction for most countries should be relaxed. For instance the friction faced by immigrants from Belgium drops 0.59 to 0.17 and it drops from 0.99 to 0.97 for Chinese immigrants. immigration frictions of all countries except for Slovenia are still smaller than one under optimal scenario, which means immigration still needs regulation and restriction. Changing immigration frictions also changes the population composition. The shares of Chinese and Indian immigrants in total population rise from 0.48% to 4.1% and from 0.37% to 5.5% ,respectively. The share accounted for by Mexican immigrant would decrease from 3.4% to 0.54%.

3.5 Conclusion

International trade is treated as the main economic activity that benefits countries through their interactions with the rest of the world. We argue that immigration as another channel should not be ignored. Our paper develops a quantitative multicountry model that incorporates country-specific immigration friction and trade cost. We allow countries to differ from another in terms of their amenities, access to the world market, population, and productivity of natives. The difference of immigrants in terms of their occupations are considered and immigrants as entrepreneurs could improve the productivity of the destination country and produce more varieties. The calibration of our model reveals that the immigration to the US increases the welfare of the US natives by 3.7% and improves the welfare of the world by about 1.7%. The worldwide immigration contributes more to the welfare of the world and the contribution is no less than that from openness to trade. We further explore how a country could benefit from a proper immigration policy. By implementing proper immigration policy, the United States could increase the welfare of native entrepreneurs and workers by 5.1% and 1.6%.

CHAPTER 4

Appendix 1

4.1 Appendix A.Theoretical proofs

A. Lemma 2.1

In this part, we will prove the properties in Lemma 2.1. The profits maximization problem of final firms is

$$Y_t = \max_{k_{jt}, L_{ft}} \frac{1}{1-\alpha} L_{ft}^{\alpha} \int_0^1 q_{jt}^{\alpha} k_{jt}^{1-\alpha} dj - \int_0^1 p_{jt} k_{jt} dj - w_t L_{ft} \tag{4.1}$$

Using first order conditions, we derive the demand functions for intermediate goods and labor are

$$p_{jt} = L_{ft}^{\alpha} q_{jt}^{\alpha} k_{jt}^{\alpha-1} \tag{4.2}$$

$$w_t = \frac{\alpha}{1-\alpha} L_{ft}^{\alpha-1} \int_0^1 q_{jt}^{\alpha} k_{jt}^{1-\alpha} dj \tag{4.3}$$

The problem of the intermediate producer is

$$\pi_{jt} = \max_{k_{jt}} p_{jt} k_{jt} - w_t k_{jt} / \bar{q}_t \tag{4.4}$$

We plug equation 4.2 in the problem 4.4 and derive the first order condition of the optimal quantity,

$$k_{jt} = ((1-\alpha)\frac{\bar{q}_t}{w_t})^{\frac{1}{\alpha}} L_{ft} q_{jt} \tag{4.5}$$

Thus the profit of the intermediate firm is

$$\pi_{jt} = \alpha((1-\alpha)\frac{\bar{q}_t}{w_t})^{\frac{1-\alpha}{\alpha}} L_{ft} q_{jt} \tag{4.6}$$

We plug the equations of different intermediate firms 4.2 and 4.5 into the equation 4.1, and we have a simplified profit function of final firm,

$$Y_t = \max_{L_{ft}} \frac{\alpha}{1-\alpha} L_{ft}((1-\alpha)\frac{\bar{q}_t}{w_t})^{\frac{1-\alpha}{\alpha}} \bar{q}_t - w_t L_{ft} \tag{4.7}$$

The first order condition of labor input in the final sector indicates

$$\frac{\alpha}{1-\alpha}((1-\alpha)\frac{\bar{q}_t}{w_t})^{\frac{1-\alpha}{\alpha}} \bar{q}_t = w_t \tag{4.8}$$

Therefore, we can solve the wage rate,

$$w_t = \alpha^\alpha (1-\alpha)^{1-2\alpha} \bar{q}_t \tag{4.9}$$

This means the wage rate is proportional to the average productivity of the intermediate sector. Plugging equation 4.9 into the profit function of the intermediate firm 4.6, we have

$$\pi_{jt} = \alpha^\alpha (1-\alpha)^{2(1-\alpha)} L_{ft} q_{jt} \tag{4.10}$$

Given the wage rate 4.9, the optimal quantity of the intermediate good 4.5, and the production technology, we obtain the labor demand in the intermediate sector,

$$l_{jt} = \frac{(1-\alpha)^2}{\alpha} \frac{q_{jt}}{\bar{q}_t} L_{ft} \tag{4.11}$$

The aggregation of labor over intermediate firms is

$$\int_0^1 l_{jt} dj = \frac{(1-\alpha)^2}{\alpha} L_{ft}$$

The labor market clear equation is

$$L_{ft} + \int_0^1 l_{jt} dj = \bar{L}$$

,where $\bar{L}$ is a constant labor supply. And thus the labor employed by the final sector is

$$L_{ft} = (1 + \frac{(1-\alpha)^2}{\alpha})^{-1} \bar{L} \tag{4.12}$$

This equation indicates that the share of labor employed by the final sector is constant over time. Last, we apply equation 4.12 to equation 4.10 and have

$$\pi_{jt} = \alpha^\alpha (1-\alpha)^{2(1-\alpha)} (1 + \frac{(1-\alpha)^2}{\alpha})^{-1} \bar{L} q_{jt} = \pi^* q_{jt}$$

Given the constant labor supply, the profits of intermediate firms are linear in their productivity and the coefficient is invariant over time.

A. Proposition 2.1

In this part, we derive the optimal growth rate of innovation and the optimal rate of foreign technology adoption. We plug equation 2.12 into equation 2.8 and obtain

$$\begin{aligned}\pi_t^R(q_{t-1}) &= \max_{\gamma_t} \pi^*(1+\gamma_t)q_{t-1} - (\chi^R\gamma_t^{\psi}q_{t-1} + \eta^R q_{t-1}) + \tau^D((1+\gamma_t)q_{t-1}, \theta^D) \\ &= \max_{\gamma_t} \pi^*(1+\frac{s_t^D}{s_t^R+s_t^F}(1-\theta^D))(1+\gamma_t)q_{t-1} - (\chi^R\gamma_t^{\psi}q_{t-1} + \eta^R q_{t-1}) \\ &\quad - \frac{s_t^D}{s_t^R+s_t^F}(1-\theta^D)\pi^* E_j(q_j|G_{t-1}^D)\end{aligned} \tag{4.13}$$

The first order condition of γ_t indicates the optimal value is

$$\gamma_t^* = ((1+\frac{s_t^D}{s_t^R+s_t^F}(1-\theta^D))\frac{\pi^*}{\psi\chi^R})^{\frac{1}{\psi-1}}$$

Given the optimal growth rate, we have the maximum of profits is

$$\pi_t^R(q_{t-1}) = \pi^*(1+\frac{s_t^D}{s_t^R+s_t^F}(1-\theta^D))(1+\frac{\psi-1}{\psi}\gamma_t^*)q_{t-1} - \eta^R q_{t-1} - \frac{s_t^D}{s_t^R+s_t^F}(1-\theta^D)\pi^* E_j(q_j|G_{t-1}^D)$$

Similarly, we combine equation 2.9 with equation 2.14 and 2.13, and we have

$$\begin{aligned}\pi_t^F(q_{t-1}) &= \max_{\lambda_t} \pi^*(q_{t-1}+\lambda_t\bar{A}) - \chi^F\lambda_t^{\beta}\bar{A} - \tilde{\tau^F}(\theta^F) + \tau^D(q_{t-1}+\lambda_t\bar{A}, \theta^D) \\ &= \max_{\lambda_t} \pi^*(q_{t-1}+\lambda_t\bar{A}) - \chi^F\lambda_t^{\beta}\bar{A} - (1-\theta^F)(\pi^*\lambda_t\bar{A} + \frac{s_t^D}{s_t^R+s_t^F}(1-\theta^D)\pi^*\lambda_t\bar{A}) \\ &\quad + \frac{s_t^D}{s_t^R+s_t^F}(1-\theta^D)\pi^*(q_{t-1}+\lambda_t\bar{A} - E_j(q_j|G_{t-1}^D)) \\ &= \max_{\lambda_t} \pi^*(1+\frac{s_t^D}{s_t^R+s_t^F}(1-\theta^D))(q_{t-1}+\theta^F\lambda_t\bar{A}) - \chi^F\lambda_t^{\beta}\bar{A} - \frac{s_t^D}{s_t^R+s_t^F}(1-\theta^D)\pi^* E_j(q_j)\end{aligned}$$

Using the first order condition, we derive the optimal rate of foreign technology adoption,

$$\lambda_t^* = ((1+\frac{s_t^D}{s_t^R+s_t^F}(1-\theta^D))\frac{\pi^*\theta^F}{\beta\chi^F})^{\frac{1}{\beta-1}}$$

If the firm adopts foreign technology with the optimal rate, the profit is

$$\pi_t^F(q_{t-1}) = \pi^*(1+\frac{s_t^D}{s_t^R+s_t^F}(1-\theta^D))(q_{t-1}+\frac{\beta-1}{\beta}\theta^F\lambda_t\bar{A}) - \frac{s_t^D}{s_t^R+s_t^F}(1-\theta^D)\pi^* E_j(q_j|G_{t-1}^D)$$

A. Proposition 2

In this part, we derive the thresholds in the support and the regularity conditions that make the proposition hold. We first derive the threshold between innovation and adoption of foreign technology. The difference between these two developments is

$$\begin{aligned}\pi_t^R(q_{t-1}) - \pi_t^F(q_{t-1}) =&(1 + \frac{s_t^D}{s_t^R + s_t^F}(1-\theta^D))(\frac{\psi-1}{\psi}\gamma_t^* q_{t-1} - \frac{\beta-1}{\beta}\theta^F \lambda_t^* \bar{A}) - \eta^R q_{t-1} \\ =&(1+s_t^*)(\frac{\psi-1}{\psi}\gamma_t^* q_{t-1} - \frac{\beta-1}{\beta}\theta^F\lambda_t^*\bar{A}) - \eta^R q_{t-1}\end{aligned}$$

,where $s_t^* = \frac{s_t^D}{s_t^R+s_t^F}(1-\theta^D)$ for simplicity. If $(1+s_t^*)\frac{\psi-1}{\psi}\gamma_t^* > \eta^R$, then the difference increases in productivity and the productivity that makes the firm indifferent between innovation and foreign technology adoption is

$$q_{t-1}^{RF} = \frac{(1+s_t^*)\frac{\beta-1}{\beta}\theta^F\lambda_t^*\bar{A}}{(1+s_t^*)\frac{\psi-1}{\psi}\gamma_t^* - \eta^R} \tag{4.14}$$

The difference between the adoption of foreign and domestic technology is

$$\pi_t^F(q_{t-1}) - \pi_t^D(q_{t-1}) =(s_t^* + \theta^D + \eta^D)q_{t-1} \quad - s_t^* E_j(q_j|G_{t-1}^D) - \theta^D \int q dG_t(q|q \in \Phi^R \cup \Phi^F)$$

The difference increases in the productivity of the firm as well, and the threshold is

$$q_{t-1}^{DF} = \frac{s_t^* E_j(q_j|G_{t-1}^D) + \theta^D \int q dG_t(q|q\in\Phi^R\cup\Phi^F)}{s_t^* + \theta^D + \eta^D} \tag{4.15}$$

Equation 4.14 and 4.15 shows that given the distribution of productivity and other firms' choice, the differences between innovation and foreign technology adoption and between foreign and domestic technology adoption increase in productivity. Given the distribution of productivity, these two equations are two implicit equations for q_{t-1}^{DF} and q_{t-1}^{RF}. To guarantee the existence of these two thresholds, we require

$$q_{t-1}^{DF} > q_t^M \tag{4.16}$$

$$q_{t-1}^{RF} > q_{t-1}^{DF} \tag{4.17}$$

The first condition means that the threshold between foreign and domestic technology adoptions is greater than the lower bound of the support. If the condition is violated, there will be no firm adopting domestic technology. The second condition shows the inequality between two thresholds and no firm will choose to adopt foreign technology if this condition is violated. To prove the existence of the thresholds during the transition, we only need to show the existence of the threshold in the initial period. In the section of parameter estimation, we assume the initial distribution is Pareto distribution and the distribution is $G_0(q) = 1 - (\frac{q_0^M}{q})^b$.

We first derive a sufficient condition for the existence of the threshold between firms adopting domestic and foreign technology. We assume that there is no firm adopting domestic technology in the initial period such that $s_0^* = 0$. In this case, the optimal rates of growth are

$$\gamma_0^* = (\frac{\pi^*}{\psi\chi^R})^{\frac{1}{\psi-1}}$$

$$\lambda_0^* = (\frac{\pi^*\theta^F}{\beta\chi^F})^{\frac{1}{\beta-1}}$$

And the threshold is

$$q_0^{DF} = \frac{\theta^D \int_{q_0^M}^{\infty} q dG_1(q)}{\theta^D + \eta^D} \geq \frac{\theta^D \int_{q_0^M}^{\infty} q dG_0(q)}{\theta^D + \eta^D} = \frac{\theta^D}{\theta^D + \eta^D}\frac{b}{b-1}q_0^M \tag{4.18}$$

Therefore the threshold exists if

$$\frac{\theta^D}{\theta^D + \eta^D}\frac{b}{b-1} > 1 \Leftrightarrow \frac{\theta^D}{\eta^D} > b - 1 \tag{4.19}$$

We show the sufficient condition for the existence of the threshold between firms adopting foreign technology and innovating. We assume the measure of firms adopting foreign technology is close to 0 in the initial period and thus the sum of shares of firms doing innovation and adopting domestic technology is 1,

$$s_0^D = 1 - s_0^R \tag{4.20}$$

And

$$s_0^* = 1 + \frac{s_0^D}{s_0^R}(1 - \theta^D) \tag{4.21}$$

Given the Pareto distribution, the share of innovative firms is

$$s_0^R = (\frac{q_0^M}{q_0^{RF}})^b \tag{4.22}$$

Plugging equation 4.22 into 4.20 and 4.21, we obtain

$$s_0^D = 1 - (\frac{q_0^M}{q_0^{RF}})^b \tag{4.23}$$

$$s_0^* = \frac{(q_0^{RF})^b - (q_0^M)^b}{(q_0^M)^b}(1 - \theta^D) \tag{4.24}$$

We further get the expressions of the optimal rates,

$$\lambda_0^* = (\frac{(1-\theta^D)(q_0^{RF})^b + \theta^D(q_0^M)^b}{(q_0^M)^b}\frac{\pi^*\theta^F}{\beta\chi^F})^{\frac{1}{\beta-1}} \tag{4.25}$$

$$\gamma_0^* = (\frac{(1-\theta^D)(q_0^{RF})^b + \theta^D(q_0^M)^b}{(q_0^M)^b}\frac{\pi^*}{\psi\chi^R})^{\frac{1}{\psi-1}} \tag{4.26}$$

Plugging these equations into equation 4.14, we have

$$q_0^{RF} = \frac{\frac{\beta-1}{\beta}\theta^F(\frac{\pi^*\theta^F}{\beta\chi^F})^{\frac{1}{\beta-1}}(\frac{(1-\theta^D)(q_0^{RF})^b+\theta^D(q_0^M)^b}{(q_0^M)^b})^{\frac{\beta}{\beta-1}}}{\frac{\psi-1}{\psi}(\frac{(1-\theta^D)(q_0^{RF})^b+\theta^D(q_0^M)^b}{(q_0^M)^b})^{\frac{\psi}{\psi-1}} - \eta^R}\bar{A} \tag{4.27}$$

We find the only unknown in the equation 4.27 is q_0^{RF}, which means the value of q_0^{RF} can be solved from the equation.

Plugging these equations into equation 4.15, we have

$$\begin{aligned} q_0^{DF} =& \frac{s_t^* E_j(q_j|G_0^D) + \theta^D \int q dG_1(q|q \in \Phi^R)}{s_t^* + \theta^D + \eta^D} \\ =& \frac{s_t^*(\frac{b}{b-1}(q_0^M - \frac{(q_0^M)^b}{(q_0^{RF})^b})) + \theta^D(1+\gamma_0^*)}{s_t^* + \theta^D + \eta^D} \end{aligned} \tag{4.28}$$

And the last condition is $q_0^{RF} > q_0^{DF}$.

Appendix B Empirical Appendix

B Productivity

In this paper, we introduce the methods we used to measure productivity [BVZ12]. Productivity is measured by the following equation

$$ln(TFP_{it}) = q_{it} - \tilde{s}_{it} l_{it} - (1 - \tilde{s}_{it}) k_{it}$$

Table 4.1: Changes in Productivity

Year	Number of Firms	TFP	US TFP	Weighted Average Distance
1998	63488	222	4609	3.91
1999	64739	235	4668	3.78
2000	65739	263	4579	3.80
2001	65401	305	4694	3.65
2002	72766	436	4400	3.69
2003	78304	415	4445	3.60
2004	118778	418	4260	3.59
2005	104932	547	4597	3.66
2006	114659	565	4562	3.52

,where q_{it}, l_{it}, and k_{it} are the log value of output (value added), labor (wage bill) and capital stock, and $\tilde{s}_{it}$ is the average wage bill in value added. The capital stock is constructed as [BVZ12]. After calculating the productivity of each firm, we take the average of firm productivity in the same industry, compare the values with those of the US counterparts and derive the relative productivity. The calculation of US productivity uses the NBER-CES manufacturing data. The NBER-CES manufacturing data provides industry-level information on value added, capital stock, and wage bills. Using the same productivity equation, we obtain the productivity of the US industry. Given the purchase power parity conversion factor from the World Bank, we convert the Chinese data and make the productivity of Chinese firms comparable to the US productivity. Then we derive the measurement of distance to frontier as the log difference between the 90th and 10th percentile firms in term of productivity. We report the results of the calculations in Table **??**.

We find two features of manufacturing during the transition: the rapid growth of the relative TFP and the decreasing distance to frontier. The rapid growth is well known in the literature. But the other feature is newly documented. We check the robustness of the second feature based on two aspects. We first report the average distances to frontier calculated in different ways based on different samples. The average of the distances to frontier at the industry level is calculated in two ways: an arithmetic average and an

Table 4.2: Distance to Frontier

Year	W. Average	Average	W. Average/Private	Average/Private
1998	3.91	4.08	2.82	2.79
1999	3.78	3.84	2.81	2.75
2000	3.80	3.89	2.70	2.66
2001	3.65	3.71	2.58	2.60
2002	3.69	3.54	2.61	2.52
2003	3.60	3.42	2.54	2.43
2004	3.59	3.48	2.53	2.45
2005	3.66	3.30	2.54	2.45
2006	3.52	3.27	2.56	2.43

Notes: W. Average is the weighted average of distances in different industries of the full sample. Average represents the arithmetic mean of distance in different industries of the full sample. Columns with /Private are values from the sample of private firms.

average weighted by value added. We calculate the distances of two samples as well: one sample consists of all firms covered by the dataset and the other sample is full of private firms. A private firm is defined as a firm whose share is owned by private owners is greater than 50%. Table **??** shows various measurements of the distances in different samples.

We can find that the trend that the distance to frontier is decreasing is robust no matter which sample and method we use to calculate the values.No matter which method we use, the distance to frontier of the full sample decreases faster than that of the sample of private-owned firms. The difference can be explained by the reform on state-owned enterprises (SOE). During the transition, the inefficient SOEs gradually exit and private-owned firms with greater productivity enter the market. The full sample that includes the entry and exit of SOE exhibits a greater rate of catch-up. Moreover, the decreases of the weighted values are smaller than those of the arithmetic ones in both samples. This means that the industry with greater value added changes less dramatically than other industries. To verify the robustness of the trends, we further provide data on the changes of different industries in Table **??**. We notice that most of industries have decreasing distance to frontier during the transition except for two industries: Printing, Reproduction of Recording Media and Manufacture of Special Purpose Machinery. We can draw the conclusion that the manufacturing sector in China witnesses the decreasing distance to frontier in the short period.

B.2 Algorithm and Model Fit

To simulate the process of transition, we randomly draw one million of firms with heterogeneous productivity from the initial distribution. First, we create a grid of different parameter values. Given one set of estimated parameters, we solve the growth rate and the thresholds between innovation and technology transfer $\{\lambda_t, \gamma_t, q_{t-1}^{DF}, q_{t-1}^{RF}\}$ given the distribution, $G_{t-1}(q)$. Then we update the productivity of each firm and derive the distribution of these firms in the next period, $G_t(q)$, given the optimal decisions of these firms. Iterating the steps before would generate the distributions of productivity in the transition and We calculate the value of the SMM objective function. We can find the minimum of the objective function values under the parameters on the grid. Table 7 provides moments in the data and moments generated by the estimated parameters in the model.

Table 4.3: Distance to Frontier across Industries

Code	Industry Name	Dist. 1998	Dist. 2006
15	Beverage	3.60	2.97
16	Tobacco	4.12	2.22
17	Textile	2.58	2.21
18	Textile Wearing Apparel Footware and Caps	2.30	1.88
19	Leather Fur Feather and Its Products	2.52	2.35
20	Wood Bamboo Rattan Palm Straw	2.68	2.15
21	Furniture	2.79	2.22
22	Paper and Paper Products	2.40	2.22
23	Printing Reproduction of Recording Media	2.99	3.11
24	Articles for Culture Education and Sport Activity	2.90	2.89
25	Petroleum Coking Processing of Nucleus Fuel	2.52	2.18
26	Chemical Raw Material and Chemical Products	2.83	2.74
27	Medicines	2.85	2.57
28	Chemical Fiber	2.58	2.32
29	Rubber	2.67	2.16
30	Plastic	2.82	2.64
31	Non-metallic Mineral Products	2.66	2.52
32	Ferrous Metals	3.13	2.43
33	Nonferrous Metals	2.86	2.59
34	Metal Products	2.54	2.25
35	General Purpose Machinery	2.76	2.30
36	Special Purpose Machinery	2.35	2.48

Notes: The industry names are cited from the table of Industrial classification for national economic activities published by National Bureau of Statistics of China without alteration.

Table 4.4: Moments in the data and model

	Distance to Frontier		Domestic Transfer Payment	
Year	Data	Model	Data	Model
1998	3.91	3.91	8.47%	6.45%
1999	3.78	3.81	6.65%	4.56%
2000	3.80	3.75	10.76%	3.58%
2001	3.65	3.71	12.70%	3.31%
2002	3.69	3.69	11.52%	3.82%
2003	3.61	3.67	13.39%	5.43%
2004	3.60	3.64	19.00%	8.66%
2005	3.66	3.60	28.10%	14.67%
2006	3.52	3.54	27.28%	25.48%

Notes: The table shows the trends of distance to frontier and domestic transfer payment based on the data and generated in the model from 1998-2006.

CHAPTER 5

Appendix 2

Appendix A. Empirical Appendix

A.Population and Income of Immigrant

In this part of appendix, we provide the immigrant from several countries in the United State and this part shows the variances in population and income. Table **??** tabulates shares of immigrant workers and entrepreneurs by origin country. Mexican immigrants account for 3.38% of workers and 5.19% of entrepreneurs while the average population of Mexico over 1980 to 2015 is 98.10 millions. This indicates about 10% of Mexican population migrated to the United States. A contrast happens to Chinese and Indian immigrants. Both countries have more than one billion population during the period while immigrants from those two countries accounts for less than one percent of workers and entrepreneurs. Compared with natives, immigrants are more likely to be entrepreneurs. Although that more immigrants tend to be self-employed works for every origin country, huge heterogeneity still exists in occupational choice. Take India and Korea as examples. The probability of becoming entrepreneurs for Indian immigrants is moderately higher than the one for natives while the probability for Korean immigrants is more than doubled likely to be entrepreneurs. Combining with the analysis on the effect of occupational choice on natives, the contribution of immigrants from different countries can be various.

Table **??**gf further demonstrates the heterogeneity of relative incomes in terms of origin country. Mexican immigrants, the largest group among all immigrants, are much less productive than the natives. They receive about half income as their American cohorts. In contrast, Indian immigrants do much better. They earn 43% more income as workers and 46% as entrepreneurs than American natives.

Table 5.1: Average Share of Immigrants by Occupation and Origin Country, 1980-2015

Origin Country	Worker %	Entrepreneur %	Population millions
U.S.	85.26	83.20	273.6
Mexico	3.38	5.19	98.10
Canada	0.34	0.52	30.06
Germany	0.45	0.51	80.63
U.K.	0.18	0.26	59.24
India	0.81	0.87	1006
China	0.73	0.82	1210
Korea	0.33	0.81	45.40

Notes: The data used in the table consists of IPUMS USA U.S. Census 1980, 1990, 2000; American Community Survey 2001-2015; United Nations Population Division data.

Table 5.2: Average Relative Income of Immigrants by Occupation and Origin Country, 1980-2015

Origin Country	Worker	Entrepreneur	RGDP per capita
U.S.	1	1	1
Mexico	0.48	0.58	0.17
Canada	1.26	1.47	0.82
Germany	1.06	1.15	0.83
U.K.	1.27	1.95	0.81
India	1.43	1.46	0.02
China	0.97	1.20	0.06
Korea	0.93	1.04	0.37

Notes: The data used in the table consists of IPUMS USA U.S. Census 1980, 1990, 2000; American Community Survey 2001-2015; United Nations Population Division data.

A.Population, Productivity, and Amenity

In this part, we provide values of population, productivity, and amenity of every country in our sample. The variable values of the United States are normalized to 1 for the conveniecce of comparision. The country names are world bank country codes.

Country	Population	Amenity	TFP	Country	Population	Amenity	TFP
ARG	0.13	0.72	0.22	IRL	0.01	0.84	0.70
AUS	0.07	1.15	0.91	IRN	0.23	1.02	0.16
AUT	0.03	1.05	0.85	ISL	0.001	1.33	1.12
BEL	0.04	1.13	0.83	ISR	0.02	0.99	0.63
BGD	0.48	0.52	0.02	ITA	0.20	1.12	0.78
BRA	0.64	0.54	0.12	JAM	0.01	0.66	0.13
CAN	0.11	1.08	0.82	JPN	0.47	1.15	0.83
CHE	0.02	0.98	0.87	KOR	0.17	0.88	0.45
CHL	0.06	0.56	0.20	LVA	0.01	1.22	0.25
CHN	4.63	0.61	0.07	MEX	0.38	0.96	0.23
COL	0.15	0.60	0.09	MYS	0.08	0.43	0.15
CZE	0.04	1.22	0.48	NLD	0.06	1.02	0.86
DEU	0.29	1.03	0.77	NOR	0.02	0.83	0.81
DNK	0.02	0.98	0.76	NZL	0.01	1.16	0.71
DOM	0.03	0.88	0.16	PAK	0.50	0.58	0.04
ECU	0.05	0.74	0.09	PER	0.10	0.78	0.10
ESP	0.15	1.24	0.77	PHL	0.29	0.48	0.05
EST	0.01	1.04	0.30	POL	0.14	1.22	0.31
FIN	0.02	1.07	0.74	PRT	0.04	1.05	0.51
FRA	0.21	1.29	0.91	RUS	0.51	0.96	0.21
GBR	0.21	1.27	0.90	AVK	0.02	1.40	0.42
GRC	0.04	1.31	0.70	SVN	0.01	1.18	0.60
GTM	0.04	0.60	0.07	SWE	0.03	1.20	0.91
HKG	0.02	0.58	0.59	TUR	0.23	1.34	0.22
HND	0.02	0.91	0.07	UKR	0.17	0.88	0.13
HUN	0.04	1.02	0.34	VEN	0.09	0.81	0.15
IDN	0.78	0.49	0.06	VNM	0.28	0.62	0.04
IND	3.86	0.64	0.04	ZAF	0.16	0.20	0.05

A. Immigration Frictions

In this part, we show the immigration frictions we calibrated based on our model and the optimal immigration frictions that maximize the welfare of US natives.

Country	Calibrated Fric.	Optimal Fric.	Country	Calibrated Fric.	Optimal Fric.
ARG	0.10	0.26	IRL	0.51	0.65
AUS	0.19	0.39	IRN	0.28	0.35
AUT	0.64	0.79	ISL	0.98	0.99
BEL	0.41	0.83	ISR	0.45	0.55
BGD	0.01	0.01	ITA	0.36	0.44
BRA	0.03	0.07	JAM	0.36	0.30
CAN	0.20	0.42	JPN	0.22	0.40
CHE	0.53	0.77	KOR	0.17	0.22
CHL	0.06	0.14	LVA	0.34	0.38
CHN	0.01	0.03	MEX	0.26	0.12
COL	0.08	0.14	MYS	0.03	0.05
CZE	0.47	0.73	NLD	0.31	0.50
DEU	0.27	0.36	NOR	0.42	0.66
DNK	0.39	0.64	NZL	0.21	0.39
DOM	0.27	0.28	PAK	0.02	0.04
ECU	0.10	0.14	PER	0.05	0.09
ESP	0.18	0.46	PHL	0.04	0.02
EST	0.24	0.37	POL	0.32	0.37
FIN	0.36	0.62	PRT	0.78	0.53
FRA	0.32	0.49	RUS	0.06	0.13
GBR	0.32	0.42	SVK	0.01	0.01
GRC	0.83	0.74	SVN	0.64	0.99
GTM	0.20	0.19	SWE	0.31	0.51
HKG	0.33	0.24	TUR	0.08	0.18
HND	0.18	0.20	UKR	0.11	0.16
HUN	0.28	0.38	VEN	0.08	0.24
IDN	0.01	0.03	VNM	0.04	0.02
IND	0.01	0.03	ZAF	0.01	0.03

REFERENCES

[AA14] T. Allen and C. Arkolakis. “Trade and the Topography of the Spatial Economy.” *The Quarterly Journal of Economics*, **129**(3):1085–1140, may 2014.

[AAZ06] Daron Acemoglu, Philippe Aghion, and Fabrizio Zilibotti. “Distance to frontier, selection, and economic growth.” *Journal of the European Economic association*, **4**(1):37–74, 2006.

[ABL08] Fernando E Alvarez, Francisco J Buera, and Robert E Lucas Jr. “Models of idea flows.” Technical report, National Bureau of Economic Research, 2008.

[Ace03a] Daron Acemoglu. “Labor- And Capital-Augmenting Technical Change.” *Journal of the European Economic Association*, **1**(1):1–37, mar 2003.

[Ace03b] Daron Acemoglu. “Patterns of Skill Premia.” *Review of Economic Studies*, **70**(2):199–230, apr 2003.

[ACG16] Ufuk Akcigit, Murat Alp Celik, and Jeremy Greenwood. “Buy, keep, or sell: Economic growth and the market for ideas.” *Econometrica*, **84**(3):943–984, 2016.

[BJ12] Jess Benhabib and Boyan Jovanovic. “OPTIMAL MIGRATION: A WORLD PERSPECTIVE$*.''$ $International Economic Review, 53(2) : 321 - -348, may 2012$.

[BL13] Robert J Barro and Jong Wha Lee. “A new data set of educational attainment in the world, 1950–2010.” *Journal of development economics*, **104**:184–198, 2013.

[Blo09] Nicholas Bloom. “The impact of uncertainty shocks.” *econometrica*, **77**(3):623–685, 2009.

[BPT14] Jess Benhabib, Jesse Perla, and Christopher Tonetti. “Catch-up and fall-back through innovation and imitation.” *Journal of Economic Growth*, **19**(1):1–35, 2014.

[BPT17] Jess Benhabib, Jesse Perla, and Christopher Tonetti. “Reconciling models of diffusion and innovation: a theory of the productivity distribution and technology frontier.” Technical report, National Bureau of Economic Research, 2017.

[BVZ12] Loren Brandt, Johannes Van Biesebroeck, and Yifan Zhang. “Creative accounting or creative destruction? Firm-level productivity growth in Chinese manufacturing.” *Journal of development economics*, **97**(2):339–351, 2012.

[BW06] Christian Broda and David E Weinstein. “Globalization and the Gains from Variety.” *The Quarterly journal of economics*, **121**(2):541–585, 2006.

[CCG14] Angus C Chu, Guido Cozzi, and Silvia Galli. “Stage-dependent intellectual property rights.” *Journal of Development Economics*, **106**:239–249, 2014.

[DNR18] Klaus Desmet, Dávid Krisztián Nagy, and Esteban Rossi-Hansberg. "The geography of development." *Journal of Political Economy*, **126**(3):903–983, 2018.

[DW02] Donald R Davis and David E Weinstein. "Bones, bombs, and break points: the geography of economic activity." *American Economic Review*, **92**(5):1269–1289, 2002.

[Fai12] Robert W Fairlie et al. "Immigrant entrepreneurs and small business owners, and their access to financial capital." *Small Business Administration*, (396):1–46, 2012.

[FL15] Robert W Fairlie and Magnus Lofstrom. "Immigration and entrepreneurship." In *Handbook of the economics of international migration*, volume 1, pp. 877–911. Elsevier, 2015.

[GLO14] Julian di Giovanni, Andrei A. Levchenko, and Francesc Ortega. "A GLOBAL VIEW OF CROSS-BORDER MIGRATION." *Journal of the European Economic Association*, **13**(1):168–202, oct 2014.

[HK09] Chang-Tai Hsieh and Peter J. Klenow. "Misallocation and Manufacturing TFP in China and India∗." $QuarterlyJournalofEconomics, 124(4) : 1403 - -1448, nov 2009$.

[HMR08] Elhanan Helpman, Marc Melitz, and Yona Rubinstein. "Estimating Trade Flows: Trading Partners and Trading Volumes∗." $QuarterlyJournalofEconomics, 123(2) : 441 - -487, may 2008$.

[Hun11] Jennifer Hunt. "Which immigrants are most innovative and entrepreneurial? Distinctions by entry visa." *Journal of Labor Economics*, **29**(3):417–457, 2011.

[IP09] Susana Iranzo and Giovanni Peri. "Migration and trade: Theory with an application to the Eastern–Western European integration." *Journal of International Economics*, **79**(1):1–19, sep 2009.

[JK16] Charles I. Jones and Peter J. Klenow. "Beyond GDP? Welfare across Countries and Time." *American Economic Review*, **106**(9):2426–2457, sep 2016.

[Ken13] John Kennan. "Open borders." *Review of Economic Dynamics*, **16**(2):L1–L13, apr 2013.

[KK16] William R. Kerr and Sari Pekkala Kerr. *Immigrant Entrepreneurship*, chapter 11. Chicago: University of Chicago Press, 2016.

[KLZ16] Michael D König, Jan Lorenz, and Fabrizio Zilibotti. "Innovation vs. imitation and the evolution of productivity distributions." *Theoretical Economics*, **11**(3):1053–1102, 2016.

[KSS18] Michael König, Kjetil Storesletten, Zheng Song, and Fabrizio Zilibotti. "From Imitation to Innovation? Where Is All That Chinese R&D. Going?" Technical report, Working Paper, 2018.

[KV07] Paul Klein and Gustavo J Ventura. "TFP differences and the aggregate effects of labor mobility in the long run." *The BE Journal of Macroeconomics*, **7**(1), 2007.

[KV09] Paul Klein and Gustavo Ventura. “Productivity differences and the dynamic effects of labor movements.” *Journal of Monetary Economics*, **56**(8):1059–1073, nov 2009.

[LM14] Robert E Lucas Jr and Benjamin Moll. “Knowledge growth and the allocation of time.” *Journal of Political Economy*, **122**(1):1–51, 2014.

[Lut07] Erzo GJ Luttmer. “Selection, growth, and the size distribution of firms.” *The Quarterly Journal of Economics*, **122**(3):1103–1144, 2007.

[MB95] Xavier X Sala-i Martin and Robert Joseph Barro. “Technological diffusion, convergence, and growth.” Technical report, Center Discussion Paper, 1995.

[Mel03] Marc J Melitz. “The impact of trade on intra-industry reallocations and aggregate industry productivity.” *econometrica*, **71**(6):1695–1725, 2003.

[PT14] Jesse Perla and Christopher Tonetti. “Equilibrium Imitation and Growth.” *Journal of Political Economy*, **122**(1):52–76, feb 2014.

[RR13] Natalia Ramondo and Andrés Rodríguez-Clare. “Trade, Multinational Production, and the Gains from Openness.” *Journal of Political Economy*, **121**(2):273–322, apr 2013.

[RS08] Stephen J Redding and Daniel M Sturm. “The Costs of Remoteness: Evidence from German Division and Reunification.” *American Economic Review*, **98**(5):1766–1797, nov 2008.

[Sax00] AnnaLee Saxenian. “Silicon Valley’s new immigrant entrepreneurs.” 2000.

[Wau10] Michael E Waugh. “International Trade and Income Differences.” *American Economic Review*, **100**(5):2093–2124, dec 2010.

[WSR07] Vivek Wadhwa, AnnaLee Saxenian, Ben Rissing, and Gary Gereffi. “America’s new immigrant entrepreneurs.” *Kauffman Foundation report*, 2007.

[WXZ17] Shang-Jin Wei, Zhuan Xie, and Xiaobo Zhang. “From” Made in China” to” Innovated in China”: Necessity, prospect, and challenges.” *Journal of Economic Perspectives*, **31**(1):49–70, 2017.

[XZ15] Zhuan Xie and Xiaobo Zhang. “The patterns of patents in China.” *China Economic Journal*, **8**(2):122–142, may 2015.

[Zhu12] Xiaodong Zhu. “Understanding China’s growth: Past, present, and future.” *Journal of Economic Perspectives*, **26**(4):103–24, 2012.