**Title**
Essays on Immigration and Frictional Labor Markets



**Author**
Zhang, Shiyun

**Publication Date**
2019

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA
RIVERSIDE

# Essays on Immigration and Frictional Labor Markets

A Dissertation submitted in partial satisfaction
of the requirements for the degree of

Doctor of Philosophy

in

Economics

by

Shiyun Zhang

September 2019

Dissertation Committee:

Professor Jang-Ting Guo, Co-Chairperson
Professor Victor Ortego-Marti, Co-Chairperson
Professor Guillaume Rocheteau
Professor David Malueg

The Dissertation of Shiyun Zhang is approved:

Committee Co-Chairperson

Committee Co-Chairperson

University of California, Riverside

## Acknowledgments

I am truely grateful to my advisors, Dr. Jang-Ting Guo and Dr. Victor Ortego-Marti, for their patience and their continued support during the last five years. I espectially appreciate the time and effort that they put into helping me to become a researcher; all their help with my writing, communication, and presentation skills; all their thoughtful comments and suggestions on my research. It is impossible to achieve what I have without their generous guidance, mentorship, and encouragement.

I am deeply grateful to my dissertation committee members for their helpful comments and guidance on my research. Their help has been invaluable. In particular, I am thankful to:

Dr. Guillaume Rocheteau, especially for his profound suggestions and comments during our meetings and presentations. It is greatly helpful for me to become a researcher.

Dr. Matthew Lang, especially for his helpful suggestions and advices on my research and presentation.

Dr. David Malueg, especially for his thoughtful comments and suggestions on my research. I am thankful that he continues being in my dissertation committee even after his retirement.

I am grateful to my classmates and friends at the Department of Economics at UC Riverside and at the Department of Economics at UC Irvine for their help and support during the last five years. In particular, to Yoon Jae Ro, I greatly appreciate for her generous help and supports during my graduate school life.

I am thankful to all my family and friends. Their encouragement and support made me to be where I am today.

Lastly, I would love to thank my parents Hongbo Zhang and Guimei Zhou. Their love and support encourage me to complete the journey as a Ph.D. student.

To my parents for all the support.

ABSTRACT OF THE DISSERTATION

Essays on Immigration and Frictional Labor Markets

by

Shiyun Zhang

Doctor of Philosophy, Graduate Program in Economics
University of California, Riverside, September 2019
Professor Jang-Ting Guo, Co-Chairperson
Professor Victor Ortego-Marti, Co-Chairperson

This dissertation consists of three essays which rationalize the effects of immigration on labor market outcomes. Chapter 2 provides an explanation of impact of immigration on labor market outcomes and crime. Chapter 3 discusses how immigration behavior of workers affect the population of immigrants and labor market outcomes between developed and developing countries. Chapter 4 studies the impact of skilled immigrants on the measure of overeducation in the United States.

The relationship between immigration and crime is one of the important issues on immigration that people are concerned about. In chapter 2, I construct a model that can explain the relationship between immigration and crime and tracks worker's criminal behavior. This model allows all workers to meet criminal opportunities and commit the opportunity that they meet if its value is sufficiently high. This criminal behavior is determined by the value that workers have in the legal sector. The model predicts that crime rate decreases by 0.156 per 1000 population with the increase in the population of immigrants in the 2000s. Particularly, the crime rate decreases by 0.226 with an increase in the

population of skilled immigrants only but increases by 0.061 with an increase in unskilled immigrants.

Chapter 3 studies the migration behavior of workers and the impact of immigration polices on labor market outcomes. The migration behavior is highly related to labor market conditions and the direction of flows can be inverted. Chapter 3 models the migration behavior with two skilled bias frictional labor markets between two countries. The model captures the double-direction flows of skilled workers between the United States and Mexico and shows that unskilled immigrants flow only from Mexico to the United States. The model also discusses the immigration policy effects on controlling the population of immigrants.

Chapter 4 focus on the impact of immigration on overeducation in the United States. Since the 1990s, the population of immigrants, especially skilled foreign workers. I apply the mismatch measure model from Şahin et al. (2014). With the CES production function, when there are more skilled workers in the labor market, the marginal price of skilled labor decreases and the skilled jobs become less valuable. This effect may push skilled workers to search in the unskilled labor market and increase the measure of mismatch in the United States.

# Contents

# List of Figures

# List of Tables

# Chapter 1

# Introduction

Immigration is an important issue in host countries, like the United States. The immigrant population increased from about 5 million in the 1970s to over 40 million in 2015 in the United States. The share of immigrants in the total population in the United States has become significant over that time, increasing from 5% to 14% of the population. There has been a lot of empirical research on the consequences of immigration but there is not a consensus. The three essays in my dissertation address the effects of immigration on labor market outcomes using a frictional labor market framework.

The second chapter studies the immigration effects on labor market outcomes and the crime rate. Many empirical studies have recently examined the effects of immigration on labor market outcomes and crimes (Basso and Peri (2015); Bianchi et al. (2012); Borjas (2005); Butcher and Piehl (2007); Borjas (2003a), etc.) and the results appear to depend on which countries and which immigrant groups are being studied. To the best of my knowledge, I am the first one to study the frictional labor market outcomes through both the crime and immigration channel. In theory people discuss effects on labor market outcomes through crime channel or immigration channel (Chassamboulli and Palivos (2014); Engelhardt et al. (2008); Engelhardt (2010); Dai et al. (2013)etc.). Previous research has examined each of these channels separately, but not simultaneously.

I extend the Engelhardt-Rocheteau-Rupert (Engelhardt et al. (2008)) crime model with skill heterogeneity and immigration to analyze the effects of immigration on labor market outcomes and crime rate. With the calibration of United States data, the model finds that an increase in immigrants can make the overall labor market better off, but raises property crime rates. I also introduce a labor market policy to increase unemployment benefits for immigrants. This policy amplifies the immigration effects on labor market and crime rates.

Chapter 3 studies the immigration behavior of workers in developed and developing countries. Existing literature assumes that the population of immigrants in developed countries is exogenous or that all immigrants only come from developing countries. However, the data shows that double-direction labor mobility exists between developed and developing countries. A model is developed with endogenous migration behavior and shows that this double-direction labor mobility exists in the skilled labor market. The labor in the unskilled labor market only moves in a single direction and goes from the developing country to the developed country. The model is calibrated with the labor market data in the US and Mexico and used to predict effects of immigration policies. A subsidy to firms who hire native workers in the US attracts more Mexicans to move to the US, since the US labor markets become stronger. The tax to firms who hire Mexican workers decreases the labor mobility between the US and Mexico, because the labor market tightness in the US goes down. A tax to Mexicans who move to the US discourages Mexicans to move to US as the migration cost goes up. Subsidies to US-born workers searching for work in Mexico attracts US-born workers move to Mexico.

Chapter 4 discusses the effect of skilled immigration on overeducation in the United States. Skilled workers are able to search in both the skilled or unskilled labor market. There are two equilibria in this model. When the population of skilled workers are small, no skilled workers search in the unskilled labor market. As a result, there is no overeducation. When the number of workers with high education are too large and there are not enough vacancies for them, they are indifferent between searching the skilled and unskilled labor market, causing the overeducation.

When the population of skilled immigrants increases in the US, it affects the overeducation in two channels. The first channel is the price channel. The more skilled workers in the market, the lower price of skilled labor, causing skilled workers search in the unskilled labor market, leading to an increase in the overeducation. The second channel is the cost channel. Skilled immigrants ask for lower wages and encourage firms to post more vacancies in the skilled labor market. Therefore, unemployed skilled workers can find jobs quickly and are less likely to search in the unskilled labor market. In this case, the overeducation decreases when there is an increase in skilled immigrants.

# Chapter 2

# Immigration and crime in frictional labor markets

This paper studies the relationship between immigration and crime by applying the Engelhardt et al. (2008) crime model. The relationship between immigration and crime has been debated widely, but there is no theoretical explanation that can well define the effects of immigration on crime. This model constructs two channels through which immigrants affect the crime rate in the host country: a composition (direct) channel and labor market (indirect) channel. These two channels provide explanations of the ambiguity of immigration effects on the crime rate. An extension of the model with skill bias and imperfect substitution between skilled and unskilled labor has more sophisticated numerical results based on the U.S. labor market and immigration. A more generous unemployment insurance system for immigrants increases both the unemployment and crime rates. An extended duration of incarceration and a deportation policy reduce crime rates but have no significant impact on labor market outcomes.

## 2.1 Introduction

Since the 1970s, immigrants have moved continuously to the United States (U.S.). The most significant wave of immigrants was between 1990 to 2010, increasing the population of immigrants from 19.8 million to 40 million. Research on the impact of this wave of immigrants on crime rates is not conclusive. Alonso-Borrego et al. (2012) find that immigration has a positive correlation with crime rates, whereas Wadsworth (2010) argues that immigrants reduce crime rates. Bell et al. (2013) provide evidence that asylum waves in the United Kingdom increased the property crime rate but that waves of immigrants from A8 countries have opposite effects.[1] Neither wave had any effect on rates of violent crimes. Bianchi et al. (2012) and Spenkuch (2014) find that immigration is positively correlated only with property crimes. However, this literature is not able to explain how immigrants affect crime rates.

This paper studies the effects of immigration on crime rates theoretically. By using the Pissarides labor search model and Engelhardt et al. (2008) criminal behavior model, there are two channels through which immigrants affect crime rates. The first channel is called the composition channel. An increase in immigrants directly affects the composition of the labor force in the host country. The propensity to commit crimes for immigrants and native workers are different: compared with native workers, unemployed immigrants

[1] The A8 countries are eight countries that joined the E.U. in 2004: Poland, Hungary, Czechia, Slovakia, Slovenia, Latvia, Lithuania, and Estonia.

have more difficulties when they search in the labor market, but employed immigrants have a higher value of employment in the labor market. As a result, unemployed immigrants are most likely to commit crimes while employed immigrants are the least likely to commit crimes among all workers. When the share of immigrants goes up, employed immigrants drive the crime rate down while unemployed immigrants increase the crime rate directly. The second channel is called the labor market channel because this channel operates through frictions in labor markets. Firms' expected profits increase when more immigrants search for work in labor markets. Such a compositional change in the labor force leads firms to create more jobs, which benefits both native and immigrant workers in terms of employment and wages. The incentive of committing a crime for unemployed workers — regardless of immigration status — decreases because they can get hired faster in labor markets with more vacancies. However, employed workers are more likely to commit crimes because the value of employment in labor markets decreases. Thus, the overall effect of immigration on the crime rate is analytically ambiguous.

The existing literature concludes that workers' criminal behavior regarding property crimes is highly related to labor market outcomes. Burdett et al. (2003) and Burdett et al. (2004) document that low-wage workers commit more crimes than those with higher wages, and a high unemployment rate leads to high crime rates. Engelhardt (2010) states that workers with fewer unemployment benefits commit more crimes. Therefore, it is reasonable to link immigration and criminal behavior via labor markets.

The main difference between immigrants and native workers are their unemployment utility. I assume immigrants earn less than native workers. It is reasonable to consider that this wage gap comes from the low unemployment value of immigrants for two reasons. First, immigrants have limited access to the social security system, so they cannot have the same unemployment income and benefits as natives. Second, immigrants lack social networks and communication skills, and can have culture conflicts in the host country. Given these difficulties, immigrants must search more intensively for work than do natives and, as a result, enjoy less leisure when they are unemployed. A lower value of unemployment leads to higher profits for firms, as in the baseline Diamond-Mortensen-Pissarides (DMP) model. Immigrants have a lower unemployment value than do natives, so unemployed immigrants are more likely to commit crimes. Employed immigrants receive a higher surplus from employment than do natives. Therefore, employed immigrants are pickier than employed natives when they encounter criminal opportunities. Among all types of workers, employed immigrants are the least likely to commit crimes, while unemployed immigrants are the most likely to commit crimes. An increase in immigrants directly affects the composition of the workforce. The increase in employed immigrants decreases the crime rate, but the increase in unemployed immigrants drives up the crime rate directly.

The crime rate is also affected by the criminal behavior of workers. Criminal behavior in this paper follows the model of Engelhardt et al. (2008). As immigration changes the workers' distribution directly, these changes also affect labor markets and criminal behavior of workers via labor markets. Workers encounter criminal opportunities at random, but they commit a crime only when the payoff is sufficiently high. An increase in immigrants does not change the criminal behavior of workers explicitly, but it leads to the creation of more jobs in the labor markets. Employed and unemployed workers respond differently to the job creation resulting from immigration. With more jobs in the markets, unemployed workers prefer remaining unemployed instead of getting involved in criminal activity because they can find jobs faster, which increases the value of unemployment. Employed workers, however, commit more crimes because their jobs become less valuable. These opposite effects of an increase in immigration on the criminal behavior of employed and unemployed workers may explain the ambiguity of the effect of immigration on crime observed in empirical studies.

This paper calibrates the model to the U.S. labor market data and crime report data in the 1990s. The model predicts that, with the wave of immigrants in the 2000s, the overall unemployment rate decreases by 0.3288 percentage points and the wage of skilled native workers increases by 0.13%, the wage of unskilled native workers increases by 0.23%. The overall crime rate decreases by 0.156 per 1,000 population, which means the nationwide total number of criminal offences decreases by by approximately 45,988. In particular, with the wave of skilled immigrants only in the 2000s, the overall crime rate decreases by 0.226 per 1,000 and the overall unemployment rate decreases by 0.1137 percentage points. With the wave of unskilled immigrants only, the overall unemployment rate will decrease by 0.2248 percentage points but the overall crime rate increases by 0.061 per 1,000. For the numerical exercise, I also extend the model with imperfect substitution between skilled and unskilled labor. The crime rate decreases by 0.139 offenses per 1,000 with the increase in immigrants. In particular, the crime rate decreases by 0.193 per 1,000 with an increase in skilled immigrants but increases by 0.053 offenses per 1,000, respectively, with the increase in unskilled immigrants.

Finally, this paper studies several relevant public policies. First, I consider the effect of giving immigrants access to a more generous unemployment insurance system, so that they receive the same unemployment benefits as natives. This policy raises the unemployment rate of natives by 0.89 percentage points and lowers the skilled native wage by 0.31%, unskilled native wage by 0.65%, while increasing the overall crime rate by 0.235 offenses per 1,000. Second, an extended duration of incarceration and deportation policies reduce the crime rate by increasing the opportunity cost of committing a crime. The longer duration of incarceration affects the criminal behavior of both natives and immigrants. The crime rate declines by 20.48 offenses per 1,000 when the average jail sentence is extended from 16 months to 48 months. The difference with a change in deportation policy is that deportation only affects immigrant criminals. With this policy, the crime rate drops by 1.61 offenses to 4.48 offenses per 1,000, depending on country of origin. Both incarceration and deportation policy have little effect on labor market outcomes.

This paper is the first to study the effects of immigration on labor market outcomes and crime jointly in a search and matching framework. I extend the Engelhardt et al. (2008) criminal behavior model with skill bias and the population of immigrants. The most closely related paper on immigration is Chassamboulli and Palivos (2014). Their paper studies a model with two frictional labor markets with skill bias and imperfect substitution between skilled and unskilled labor. The authors show that an increase in immigrants can raise natives' wages and reduce unemployment. Compared to their work, the main contribution of this paper is discussing the effect of immigration on crime rates. Criminal behavior of workers in this paper follows Engelhardt et al. (2008). As immigration changes the workers' distribution directly, these changes also affect labor markets and criminal behavior of workers via labor markets. As the paper shows, this novel mechanism is important for understanding the effects of migration policy on the labor market and crime rates.

Other related literature is as follows. Dai et al. (2013) also look at the relationship between immigration and crime. There are two main differences between their paper and this paper. Firstly, they do not have search framework so there is no unemployment in Dai et al. (2013). Secondly, they show that the overall effect of immigration on crimes is ambiguous analytically but do not do a numerical exercise to show which effect dominates. The numerical exercise in this paper shows the dominating channel given different group of immigrants. Chassamboulli and Palivos (2013a) introduce unskilled immigrants only. Immigrants only show up in the unskilled labor market in the host country and compete with unskilled natives, while there are only native workers in the skilled labor market. Skilled native workers benefit from unskilled immigrants in terms of wages and employment, while the impact of unskilled immigrants on the unskilled labor market outcomes is ambiguous. Chassamboulli and Peri (2015a) focus on the effects of illegal immigrants on labor market outcomes with a two-country model. They endogenize the migration behavior of legal and illegal immigrants from Mexico, i.e., Mexican immigrants can choose either to stay in Mexico or to migrate to the U.S.. In their paper, the presence of illegal immigrants encourages firms to create more jobs, so the unemployment rate in the U.S. decreases, and the wages of natives increase. Ortega (2000) and Liu (2010) also study the impact of immigration in a search and matching framework. Ortega (2000) constructs a two-country model in which workers decide whether to either search for employment in their own country or migrate. He proves that the migration equilibria Pareto dominates the non-migration equilibrium. Liu (2010) finds that illegal immigrants lower the job-finding rate in the labor market and force native workers to accept lower wages.

In section 2, this paper describes frictional labor markets with skilled and unskilled immigrants. The steady state equilibrium of the model is solved in section 3. In steady state equilibrium, an increase in the number of immigrants affects the composition of the labor force. The effects of immigration on labor market outcomes and crimes, respectively, are discussed in section 4. In section 5, the model is calibrated to the U.S. labor market data and crime report data in the 1990s. The simulation with an increase in the numbers of immigrants and the comparison to the data are reported in section 6. Section 7 discusses policy effects. Section 8 extends the model with skill bias and imperfect substitution between skilled and unskilled labor. Section 9 concludes.

## 2.2 Model

In the model, time is continuous, with an infinite horizon. There is a large measure of firms. Both firms and workers are risk neutral and discount their future value at a constant rate $r$. The productivity of workers depends on their skills; there are two skill levels of workers in this economy: high and low. Workers who have college degrees or above are considered high-skill workers with productivity $y_H$. Workers without college degrees are defined as low-skill workers with productivity $y_L$, where $y_L < y_H$.[2] Workers are either native workers ($N$) who were born in the host country, or immigrant workers ($I$) who were

[2] In the baseline model, I assume that high-skill and low-skill workers are perfectly substituted. A model with imperfect substitution between skilled and unskilled labor is showed in section 2.8.

born outside the host country, regardless of their skills.[3] The measure of total native workers is normalized to 1, the measure of skilled natives is denoted $\lambda$. The exogenous measure of immigrants is denoted as $I_i$, given the skill level $i$, normalized to the native population.

There are two labor markets, high-skill and low-skill labor markets.[4] Only unemployed workers search in the labor market conditionally on their skills. Unemployment exists because of search frictions in these labor markets. Immigrants search legally for jobs in the host country, and firms that hire immigrants do not get fined or punished.[5] Immigrants earn less than native workers.[6] This wage gap comes from the different unemployment utility flows between immigrants and native workers. Because immigrants lack social security and social networks and can have communication difficulties and other hardships, they receive lower unemployment income and have to search for employment more intensively to compete with native workers. Therefore, unemployed immigrants receive a lower flow of utility

[3] The superscript/subscript variable $i$ represents the skill level of workers, high-skilled ($H$) and low-skilled ($L$); $s$ represents the labor market status, employed ($E$), unemployed ($U$), or in prison ($P$); $j$ represents the immigration status, native ($N$) or immigrant ($I$).

[4] In some cases, skilled workers can work an unskilled job. I relax this segmented market assumption in appendix A.4, by using a model with random search in a single labor market. I thank an anonymous referee for this issue.

[5] All immigrants considered in this model are legal immigrants, including naturalized citizens and permanent residents.

[6] Using CPS in the 1990s, the 2000s and the 2010s and standard Mincerias regression (for example, Ortego-Marti (2016) and Ortego-Marti (2017)), immigrants earn less wage than native workers, even conditional on observables. I run the following regression of log wage,

$$log\ wage = \beta_I I_{immigration} + \beta_X X + \epsilon$$

where $I_{immigration}$ is the dummy variable represents the immigration status of the sample. It equals one if the sample is a native-born worker. The variable $X$ is a vector of variables includes year, education, age, and occupation of the sample. The coefficient of $I_{immigration}$ is 0.075 (standard error: 0.0008) when vector $X$ includes occupation. It means native workers earn native workers earn 7.5% more than immigrants conditionally on education, age, and occupation. The coefficient of $I_{immigration}$ is 0.108 (standard error: 0.0008) when the vector $X$ does not include occupation. It means that native workers earn 10.8% more than immigrants without conditional on occupation. These two coefficients are statistically significant. The results also consistent with empirical literature (Peri et al. (2015), Borjas (1987), etc.).The results of regression is available upon request.

than do natives, even some of immigrants are permanent residents or naturalized citizens.[7] More specifically, when a worker is unemployed, she receives an exogenous flow of utility $B_i^j$, which depends on her immigration status and skill, $j \in \{N, I\}$, $i \in \{H, L\}$ and $B_i^N > B_i^I$. The variable $M_i$ is the number of matches that are made in skilled-$i$ market, following a matching function of the number of vacancies $V_i$ and the measure of unemployment $U_i$,

$$M_i \equiv m(V_i, U_i).$$

The matching function is continuous, strictly increasing, and concave with respect to each of its arguments, and it displays a constant return to scale. The worker matches a firm at a Poisson rate $f(\theta_i) \equiv M_i/U_i$. The variable $\theta_i$ is defined as the market tightness in the skilled-$i$ labor market, which is a vacancy-unemployment ratio. When the worker matches with a firm, she starts producing with productivity $y_i$. Exogenous job separation shocks arrive at a Poisson rate $\delta_i$.

Every worker in the economy is both a potential victim and a potential criminal. All workers encounter criminal opportunities at an exogenous Poisson rate $\mu$. The rate $\mu$ also equals to the fraction of workers who may commit crimes. The probability of meeting a type-$ij$ unemployed criminal is $\mu U_i^j$ and the probability of meeting a type-$ij$ employed criminal is $\mu E_i^j$. For all $s \in \{E, U\}$, let $\mathbb{E}_{s,i}(g)$ denote the expected (endogenous) crime value of type-$ij$ criminals with labor force status $s \in \{E, U\}$. Criminal activities are considered a

[7] According to CPS in the 1990s, about 40% of foreign-born workers have been in the U.S. fewer than 10 years. Some naturalized immigrants or permanent residents may have the same unemployment utility as natives, but on average, the unemployment utility of immigrants is still lower than natives. This assumption is also adopted in Chassamboulli and Palivos (2014), Chassamboulli and Palivos (2013a) and Chassamboulli and Peri (2015a).

wealth transfer from victims to criminals. Therefore, the worker's expected loss from crime is

$$\tau = \mu[\sum_i \sum_j U_i^j \mathbb{E}_U(g) + \sum_i \sum_j E_i^j \mathbb{E}_E(g)]. \tag{2.1}$$

When the worker encounters a criminal opportunity, she can observe the value of this criminal opportunity, $g$, i.e. how much she can get from this victim. This value is drawn randomly from a known distribution $F(g)$ with support $[0, g^{max})$. If the value $g$ is high enough, the worker commits this criminal opportunity. The criminal can be arrested by the police with an exogenous probability $\pi$. When the criminal is in jail, she receives a constant flow of utility $x$. Assume that workers value their freedom, so that $x < B_i^j - \tau$.[8] Incarcerated workers are released from jail and return to the labor market at an exogenous rate $\rho$, which is independent of the value of the crime.

Each firm has only one job in the market, either filled ($F$) or vacant ($V$). A firm enters the labor market freely by posting a job vacancy and pays a constant recruitment cost, $k_i > 0$, given the market that it enters. According to the free entry condition, firms are indifferent to post vacancies in the high-skilled or low-skilled labor market. A firm matches an unemployed worker randomly at rate $q(\theta_i) \equiv M_i/V_i$. The firm offers its employee an employment contract. This employment contract requires the worker to pay a one-time hiring fee $\phi_i^j$ when hired, and the firm pays a flow wage $w_i^j$ to the worker during the match. This employment contract $\{\phi_i^j, w_i^j\}$ is determined by some bargaining solution. Once production begins, the firm receives the productivity $y_i$ from the employee. The firm

[8] Assume that there is no criminal activity in jail. Workers value their freedom outside of jail, therefore, no one wants to go to jail for avoiding criminal activities.

loses its employee either when a separation shock arrives or when the employee commits a crime and is arrested.

### 2.2.1 Bellman Equations

Let $\Pi_{V,i}$ denote the value function of a vacancy and $\Pi_{F,i}$ denote the value function of a filled job. The firm expects the capital gain from the match, $\mathbb{E}(\Pi_{F,i} + \phi) - \Pi_{V,i}$, since the firm knows only the distribution of unemployed workers in the market before matching with a worker. Once the match is formed, the firm receives productivity $y_i$ from the worker and pays her the wage $w_i^j$, which is determined by the employment contract. The firm suffers the capital loss $\Pi_{F,i}^j - \Pi_{V,i}$ either when the separation shock occurs or when the employee commits a crime and gets caught. Firms have no explicit monetary loss from criminal activities. Thus, the asset equations of firms are

$$r\Pi_{V,i} = -k_i + q(\theta_i)[\mathbb{E}(\Pi_{F,i} + \phi) - \Pi_{V,i}] \tag{2.2}$$

$$r\Pi_{F,i}^j = y_i - w_i^j - [\delta_i + \mu\pi(1 - F(\bar{g}_{E,i}^j))](\Pi_{F,i}^j - \Pi_{V,i}), \tag{2.3}$$

where $\mathbb{E}(\Pi_{F,i} + \phi) = \sum_i \sum_j (U_i^j / U_i)(\Pi_{F,i}^j + \phi_i^j)$, for all $i \in H, L$ and $j \in \{I, N\}$.

Denote the value of individual of type $s$-$ij$ as $V_{s,i}^j$. Each individual can be in one of three states $s$: employed ($E$), unemployed ($U$) or in prison ($P$). Everyone has a burden $\tau$ that comes from the criminal activity. Employed workers earn wages $w_i^j$ from firms and suffer a capital loss $V_{E,i}^j - V_{U,i}^j$ when separation occurs. Unemployed workers receive a flow of utility $B_i^j$. They find a job at a rate $f(\theta_i) = \theta_i q(\theta_i)$, which yields a capital gain $V_{E,i}^j - V_{U,i}^j$. Upon finding a job, workers must pay the hiring fee $\phi_i^j$ determined by the employment contract. Both employed and unemployed workers encounter a criminal opportunity at a rate $\mu$ and commit a crime if the criminal payoff $K^j_{s,i}(g)$ is strictly greater than the value in the legal sector. The criminal payoff $K^j_{s,i}(g)$ is a function of the crime value $g$. Workers in jail receive a flow utility $x$. They are released from jail and return to the labor market as unemployed workers at a rate $\rho$, and obtain the capital gain $V^j_{U,i} - V^j_{P,i}$.[9] The value functions of workers satisfy the following Bellman equations

$$rV^j_{E,i} = w^j_i - \tau - \delta_i(V^j_{E,i} - V^j_{U,i}) + \mu \int_0^{g^m} \max\{K^j_{E,i}(g) - V^j_{E,i}, 0\} dF(g). \tag{2.4}$$

$$rV^j_{U,i} = B^j_i - \tau + \theta_i q(\theta_i)(V^j_{E,i} - V^j_{U,i} - \phi^j_i) + \mu \int_0^{g^m} \max\{K^j_{U,i}(g) - V^j_{U,i}, 0\} dF(g) \tag{2.5}$$

$$rV^j_{P,i} = x - \tau + \rho(V^j_{U,i} - V^j_{P,i}). \tag{2.6}$$

The criminal decision of a worker depends on the value of the criminal opportunity. A worker commits a crime if the criminal opportunity is of a sufficiently high value, i.e., the payoff from the crime should be greater than is her current value of either employment or unemployment. The criminal payoff is the net capital gain from the criminal activity. If the worker commits a crime, she gets the crime value $g$ from the victim. She keeps the value in the legal sector $V^j_{s,i}$ if she does not get arrested. If the criminal gets arrested, which happens with a probability $\pi$, she becomes a prisoner and suffers an expected capital loss $\pi(V^j_{P,i} - V^j_{s,i})$. The payoff of a crime is given as

$$K^j_{s,i}(g) = g + V^j_{s,i} + \pi(V^j_{P,i} - V^j_{s,i}), \tag{2.7}$$

[9]To simplify the analysis, I assume that criminals do not have a criminal record when they return to the labor market. The model can be extended to allow for criminal records, but the main mechanism will remain unchanged.

for all $i \in \{H, L\}$, $j \in \{N, I\}$ and $s \in \{E, U\}$. Since the worker commits a crime only when the crime payoff is higher than is the value of the current state, the reservation crime value determines her criminal behavior, i.e. whether to commit a crime. The endogenous reservation value is given as

$$\bar{g}^j_{s,i} = \pi(V^j_{s,i} - V^j_{P,i}) \tag{2.8}$$

for all $i \in \{H, L\}$ $j \in \{N, I\}$ and $s \in \{E, U\}$. When the worker meets a victim with a value $g$ that is strictly greater than the reservation crime value $\bar{g}^j_{s,i}$, she commits a crime.

### 2.2.2 Employment contract

I assume that there is free entry of firms in the market for vacancies, which implies that $\Pi_V = 0$. The total surplus of a match is defined by

$$S^j_i = V^j_{E,i} - V^j_{U,i} + \Pi^j_{F,i},$$

for type-$ij$ workers. From Equations (2.3) to (2.5), the total surplus can be rewritten as

$$rS^j_i = y_i - \tau - rV^j_{U,i} - \delta S^j_i + \mu \int_{\bar{g}^j_{E,i}}^{g^m} [g - \pi S^j_i + \pi(V^j_{P,i} - V^j_{U,i})] dF(g).$$

Suppose that workers and firms decide the reservation crime value together. When workers and firms match with each other, the value of the match is $V^j_{E,i} + \Pi^j_{F,i}$. When the employee commits a crime and gets arrested, the value of a prisoner is $V^j_P$ and the job becomes vacant with value $\Pi_{V,i} = 0$. Firms do not have an explicit monetary loss from workers' criminal activities, but they lose their employee and suffer the capital loss from this additional separation. Hence, the expected capital loss of a match caused by a criminal behavior is $\pi(V^j_{E,i}+\Pi^j_{F,i}-V^j_{P,i})$. However, the opportunity cost of a match is higher than the opportunity cost of employees. Employees do not consider the value of a filled job when they decide to commit a crime. Therefore, they commit more crimes than firms expect and the surplus cannot be maximized. The employment contract is determined by Nash Bargaining, with the bargaining power of workers given by $\beta \in [0,1]$, i.e.

$$(w^j_i, \phi^j_i) = \underset{w^j_i, \phi^j_i}{\text{argmax}} (V^j_{E,i} - V^j_{U,i} - \phi^j_i)^\beta (\Pi^j_{F,i} + \phi^j_i)^{1-\beta}. \tag{2.9}$$

**Lemma 1** *The optimal employment contract that solves equation (2.9) satisfies*

$$w^j_i = y_i,$$

$$\phi^j_i = (1-\beta)(V^j_{E,i} - V^j_{U,i}).$$

The proofs of all lemmas and propositions are in Appendix A.1. The intuition is as follows. According to the optimal contract, the wage of workers equals their productivity, which depends only on the workers' skill. Since the firm pays the productivity as a wage to its employee and has no profit from the match, the hiring fee is the only revenue of the firm. The match surplus in this case becomes $V^j_E - V^j_U$. The worker and the firm share the surplus based on the worker's bargaining power $\beta$, so that the optimal hiring fee equals to the firm's share of the match surplus. Since the hiring fee covers the firm's share of the surplus, the firm is not concerned about the inefficient separation that is caused by the worker's criminal activities. Firms transfer implicitly to workers their risk of losing employees, which is caused by employees' criminal behavior.

### 2.2.3 Discussion: optimal contract and Nash bargaining

According to Nash (1953), Nash efficiency requires convexity of the bargaining set. Shimer (2006) shows the on-the-job search violates the convexity of bargaining set. Similar to the on-the-job search, the criminal behavior in this model creates extra job separation by employees. In this case, the bargaining set with criminal behavior violates the Nash efficiency axiom.

Intuitively, risk-neutral firms and workers are only concerned about the match surplus. They are willing to have an employment contract that can maximize the match surplus. Similar to on-the-job search, the criminal behavior of employees generates inefficient job separations. The standard Nash bargaining share rule is not able to provide a Pareto-efficient outcome, since it does not consider the asymmetric information of criminal behavior between workers and firms. This situation may shorten the duration of the match, and, as a result, firms suffer an additional capital loss. Therefore, the model needs a contract that can transfer this loss to employees. Similar to Stevens (2004) and to follow Engelhardt et al. (2008) closely, I assume that firms offer their employees an employment contract with a hiring fee and a constant wage. According to Stevens (2004), this employment contract is the first best contract for on-the-job search. Assume that workers and employers can cooperate, they will deviate from the Nash bargaining to this employment contract and achieve Pareto optimum.

Appendix A.2 shows the version of the model with the standard Nash bargaining. A further comparison is also provided in appendix A.2.

## 2.3 Equilibrium

From equation (2.2) and $\Pi_{V,i} = 0$, the job creation condition (JC) is

$$\frac{k_i}{q(\theta_i)} = \mathbb{E}(\Pi_{F,i} + \phi_i). \tag{2.10}$$

In equilibrium, the average cost of posting a vacancy equals the expected revenue of firms. The left hand side of equation (2.10) represents the average cost of a match. The job filling rate $q(\theta_i)$ is defined as the ratio of matches to vacancies, i.e., $q(\theta_i) \equiv M_i/V_i$. Hence,

$$k_i/q(\theta_i) = k_i V_i/M_i. \tag{2.11}$$

The variable $k_i V_i$ is the total cost of all vacancies in the labor market $i$, and $M_i$ is the number of matches, so equation (2.11) represents the average cost of matches. The right hand side of equation (2.10) represents the expected revenue of a match. Given the zero profit condition of vacant and filled jobs ($\Pi_{V,i} = 0, \Pi^j_{F,i} = 0$), the hiring fee is the only source of firms' revenue. Firms know only the distribution of unemployed workers before matching with any unemployed workers. Therefore, the expected hiring fee is a weighted average of hiring fees, i.e., $\phi^e_i = \sum_i \sum_j (U^j_i/U)\phi^j_i$. Using (2.4) and (2.5), the hiring fee of type-$ij$ is

$$\begin{aligned}\phi_i^j &= (1-\beta)(V_{E,i}^j - V_{U,i}^j) \\ &= \frac{1-\beta}{r+\delta_i+\beta\theta_i q(\theta_i)}\left[y_i - B_i^j - \mu\int_{\bar{g}_{U,i}^j}^{\bar{g}_{E,i}^j}(1-F(g))dg\right]. \end{aligned} \tag{2.12}$$

Given equation (2.10) and lemma 1, the job creation condition is rewritten as

$$\begin{aligned}\frac{k_i}{q(\theta_i)} &= \phi_i^e \\ &= \frac{1-\beta}{r+\delta_i+\beta\theta_i q(\theta_i)}\mathbb{E}\left[y_i - B_i - \mu\int_{\bar{g}_{U,i}}^{\bar{g}_{E,i}}(1-F(g))dg\right]. \end{aligned} \tag{2.13}$$

The measures of type-$ij$ unemployed workers and total unemployed workers are given by workers' flows.

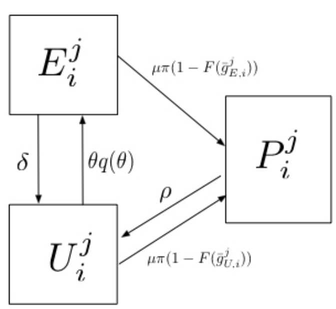


Figure 2.1: Worker flows

Figure 2.1 shows workers' flows. There are three states of workers: employed, unemployed, and in prison. At a steady state, the inflows of each pool are equal to its outflows. Equation (2.14) shows that flows into and flows out of unemployment must be equal. The flows out of unemployment are unemployed individuals who get hired, $\theta_i q(\theta_i)U_i^j$, and individuals who commit a crime and get arrested, $\eta^j_{U,i}U^j_i$. The variable $\eta^j_{s,i} \equiv \pi\mu(1 - F(\bar{g}^j_{s,i}))$ represents the probability that a worker commits a crime and gets caught. The flows into unemployment correspond to employed individuals who lose their jobs $\delta_i E^j_i$ and individuals who are released from jail $\rho P^j_i$. Equation (2.15) represents the flows into and out of employment. Similarly, the flows into employment include individuals that get hired $\theta q(\theta_i)U^j_i$. The flows out of employment are given by employees that suffer a job separation shock $\delta_i E^j_i$ and by employed workers who commit crimes and get arrested $\eta^j_{E,i}E^j_i$. The population of type-$ij$ workers is the sum of employed workers, unemployed workers, and prisoners.

$$\delta_i E^j_i + \rho P^j_i = [\theta_i q(\theta_i) + \eta^j_{U,i}]U^j_i, \tag{2.14}$$

$$(\delta_i + \eta^j_{E,i})E^j_i = \theta_i q(\theta_i)U^j_i, \tag{2.15}$$

$$\lambda = E^N_H + U^N_H + P^N_H, \tag{2.16}$$

$$1 - \lambda = E^N_L + U^N_L + P^N_L, \tag{2.17}$$

$$I_H = E^I_H + U^I_H + P^I_H, \tag{2.18}$$

$$I_L = E^I_L + U^I_L + P^I_L, \tag{2.19}$$

Using the above flow equations, the steady state measure of unemployment of each type of workers is as follows

$$U_H^N = \frac{\rho(\delta_H + \eta_{E,H}^N)\lambda}{\theta_H q(\theta_H)(\eta_{E,H}^N + \rho) + (\eta_{E,H}^N + \delta_H)(\eta_{U,H}^N + \rho)}, \tag{2.20}$$

$$U_H^I = \frac{\rho(\delta_H + \eta_{E,H}^I)I_H}{\theta_H q(\theta_H)(\eta_{E,H}^I + \rho) + (\eta_{E,H}^I + \delta_H)(\eta_{U,H}^I + \rho)}, \tag{2.21}$$

$$U_L^N = \frac{\rho(\delta_L + \eta_{E,L}^N)(1-\lambda)}{\theta_L q(\theta_L)(\eta_{E,L}^N + \rho) + (\eta_{E,L}^N + \delta_L)(\eta_{U,L}^N + \rho)}, \tag{2.22}$$

$$U_L^I = \frac{\rho(\delta_L + \eta_{E,L}^I)I_L}{\theta_L q(\theta_L)(\eta_{E,L}^I + \rho) + (\eta_{E,L}^I + \delta_L)(\eta_{U,L}^I + \rho)}. \tag{2.23}$$

Before solving for the equilibrium, the formal definition of the steady state equilibrium is the following.

**Definition 1** *The steady state equilibrium is a set of variables, $\{\theta_i, \bar{g}_{E,i}^j, \bar{g}_{U,i}^j, U_i^j, E_i^j, P_i^j, \tau\}$ for all $i \in \{H, L\}$, $j \in \{N, I\}$, such that: $\theta_i$ satisfies equation (2.13); $\{U_i^j, E_i^j, P_i^j\}$ satisfy equations (2.14) – (2.19); $\{\bar{g}_{E,i}^j, \bar{g}_{U,i}^j\}$ satisfy equation (2.8); and $\tau$ satisfies equation (2.1).*

The equilibrium is recursively solvable. Equations (2.14) to (2.19) determine the distribution of workers given any $\theta_i$. The pair of reservation crime values of employed and unemployed workers $\{\bar{g}_{E,i}^j, \bar{g}_{U,i}^j\}$ are solved jointly by equations (2.4) to (2.6) and (2.8). The expected revenue of a match is determined by equations (2.4) and (2.5). Finally, $\theta_i$ satisfies (2.13).

Figure 2.2 represents the equilibrium.[10] The equilibrium market tightness is determined by the equality of average recruitment cost, represented by the curve AC, and the expected hiring fee, represented by the curve HF; i.e., the equilibrium is the intersection of the AC and HF curves. With a higher market tightness, the firm needs to wait

[10]The concavity of the curves does not affect the determination of the equilibrium. The AC and HF curves are drawn as straight lines for simplification.

longer to hire a worker, so the average recruitment cost increases. Hence, the AC curve is upward-sloping. The slope of the curve HF depends on the workers' distribution and the match surplus. Unemployed workers get hired sooner when market tightness increases. It increases the value of unemployed workers and shrinks the difference between employed and unemployed workers. As a result, the match surplus decreases with market tightness. However, the effect on the workers' distribution is ambiguous. Given (2.20) and (2.21), the unemployment distribution depends on market tightness. When market tightness increases, the measure of unemployment of each type of workers decreases and so does the measure of total unemployment. Under a set of reasonable parameter values, the fraction of each type of unemployed worker $U_i^j/U_i$ barely changes. Therefore, the effect of market tightness on the match surplus dominates. The hiring fee is in constant proportion to the match surplus, so it also decreases with the market tightness as well. The slope of the curve HF is downward-sloping.

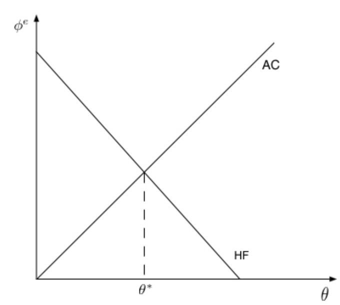


Figure 2.2: Equilibrium

**Lemma 2** *The expected hiring fee $\phi_i^e$ decreases with $\theta_i$.*

When $\theta_i$ goes to zero, there are too many unemployed workers and no vacancies in the labor market. The firm matches with a worker as soon as it posts a vacancy. Hence, the average recruitment cost goes to zero. When $\theta_i = 0$, the expected hiring fee is

$$\phi_i^e = (1-\beta)\mathbb{E}\left[\frac{y_i - B_i - \mu \int_{\bar{g}_{U,i}}^{\bar{g}_{E,i}} (1-F(g))dg}{r+\delta_i}\right].$$

If $\phi_i^e > 0$ at $\theta_i = 0$, the curve AC and the curve HF have an unique intersection on $(\theta_i, \phi_i^e)$ space and $\theta_i > 0$ at the equilibrium.

**Proposition 1** *An equilibrium with $\theta_i > 0$ exists and is unique if $\phi_i^e > 0$ when $\theta_i = 0$. In equilibrium, $\bar{g}_{E,i}^j > \bar{g}_{U,i}^j$.*

Proposition 1 also states that unemployed workers are more likely to commit a crime than are employed workers in equilibrium. If $\phi_i^e > 0$, then $V_{E,i}^j > V_{U,i}^j$. Employed workers have a higher value than when they are unemployed. As a consequence, employed workers have a higher reservation crime value and are pickier than unemployed workers when encountering criminal opportunities.

## 2.4 Effects of Immigration

This section discusses the effects of an increase in the number of immigrants on labor market outcomes and crime rates.

### 2.4.1 Composition (direct) effects

When the population of immigrants increases, the share of immigrants in the total labor force distribution increases directly. To see how this increase in immigrant population affect the overall crime rate, I compare the reservation value of committing crimes of immigrants with native workers. Employed immigrants, conditional on their skills, are less likely to commit crimes than employed native workers. Meanwhile, unemployed immigrants have more incentives to commit crimes compared with unemployed native workers, because of their lower unemployment utility.

**Lemma 3** *For all $i \in \{H, L\}$, the reservation value of crime of immigrants with skill $i$, $\bar{g}^I_{s,i}$,*

*i) $\bar{g}^I_{E,i} > \bar{g}^N_{E,i}$ if $\delta_i < \rho$;*

*ii) $\bar{g}^I_{U,i} < \bar{g}^N_{U,i}$.*

The reservation value of crime is also related to the skill level. Skilled workers are less likely to commit crimes, regardless of their labor market and immigration status.

**Lemma 4** *For all $s \in \{E, U\}$ and $j \in \{N, I\}$, the reservation value of crime for skilled workers is higher than unskilled workers, i.e. $\bar{g}^j_{s,H} > \bar{g}^j_{s,L}$.*

The crime rate is defined as

$$c = \frac{\sum_i \sum_j [(1 - F(\bar{g}^j_{E,i}))E^j_i + (1 - F(\bar{g}^j_{U,i}))U^j_i]}{\sum_i \sum_j (E^j_i + U^j_i)}, \tag{2.24}$$

which is the weighted average of crime rates of each type of worker. Employed and unemployed immigrants are less likely to commit crimes than all unskilled workers, regardless of unskilled native or immigrant workers. When the population of skilled immigrants increase, the crime rate drops directly. However, when the population of unskilled immigrants increases, the share of unskilled workers goes up and the share of skilled workers decreases—this composition change directly increases the overall crime rate.

**Proposition 2** *Given a certain market tightness, an increase in the population of skilled immigrants, $I_H$, decreases the overall crime rate.*

**Proposition 3** *Given a certain market tightness, an increase in the population of unskilled immigrants, $I_L$, increases the overall crime rate.*

### 2.4.2 Labor market (indirect) effects

In either the skilled or unskilled labor market, immigrants pay a higher hiring fee than native workers.

**Lemma 5** *The rank of hiring fee of each type of workers is: $\phi_i^I > \phi_i^N$ for all $i \in \{H, L\}$.*

The expected hiring fee is a weighted average of the hiring fees of all types of workers in both labor markets. With an increase in immigrants, the weight of unemployed immigrants ($U_i^I/U_i$) increases and the weight of unemployed natives ($U_i^N/U_i$) decreases. Since immigrants provide the greater surplus than native workers, the expected hiring fee increases when the weight of unemployed immigrants increases. Figure 2.3 shows that an increase in the number of immigrants shifts the curve HF to the right and increases market tightness.

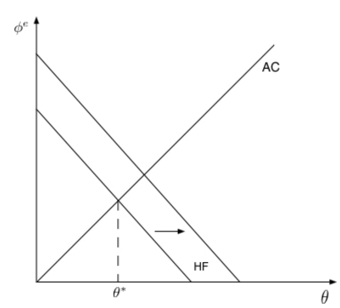


Figure 2.3: Effects of immigration on labor market

**Lemma 6** *The expected hiring fee in labor market $i$ increases with $I_i$.*

Intuitively, immigrants have a lower unemployment value than do natives, so they pay a higher hiring fee than do natives. Since the hiring fee is the only revenue of firms, a higher number of immigrants raises the expected revenue of firms, which encourages more firms to enter the labor market and post vacancies. The average cost of a match increases with the increase in the expected revenue to balance the equality of equation (2.13) and move to the new equilibrium. Intuitively, firms are able to wait longer to hire a worker with a higher expected revenue; therefore, market tightness goes up. Proposition 2 shows the effect of an increase in immigrants on labor market tightness. According to lemma 6, labor market tightness increases with the number of immigrants.

**Proposition 4** *In equilibrium, the market tightness in labor market $i$, $\theta_i$, increases when the number of skilled immigrants, $I_i$, increases.*

As shown in (2.4) to (2.6) and (2.8), the reservation crime value depends on the labor market tightness. When the market tightness goes up, unemployed workers can be hired quickly. The value of unemployed workers goes up so unemployed workers prefer to stay unemployed and wait for jobs instead of committing crime. The reservation crime value of unemployed workers falls with the market tightness.

When market tightness increases, the increase in unemployment value shrinks the employment premium, and the value of employment goes down. Employed workers eventually end up being unemployed because they either lose their jobs or are incarcerated. The transition rate from employment to unemployment is $\delta$, and the transition rate from prison to unemployment is $\rho$. If the incarceration duration is shorter than the duration of a job, which means that $\rho > \delta$, and the value of unemployment increases, the value of workers in jail goes up. Therefore, the opportunity cost of committing a crime for employed workers drops and employed workers have more incentive to commit crime.

**Lemma 7** *If the market tightness $\theta_i$ increases,*

*i) $\bar{g}^j_{E,i}$ decreases if $\rho > \delta$;*

*ii) $\bar{g}^j_{U,i}$ increases.*

According to composition and criminal behavior effect, the effect of immigration on the overall crime rate is ambiguous analytically. This is consistent with the ambiguity found in empirical studies of the effects of immigration on crime.

## 2.5 Calibration

I calibrate the parameter values of the model using U.S. data from 1990 to 1999. All the parameters are interpreted annually. As in Krusell et al. (2000b), I define skilled workers as those who have at least a college degree, and unskilled workers as those without any college degree. Using the empirical findings in Chassamboulli and Palivos (2014) in the 1990s, the measure of skilled immigrants $I_H$ is 0.036, and the measure of unskilled immigrants $I_L$ is 0.089. The measure of skilled native workers $\gamma$ is 0.274. The total native population is normalized to 1. The productivity of skilled workers $y_H$ is also normalized to 1. The relative productivity of unskilled workers to skilled workers $y_L$ is 0.62, which targets the wage premium between workers with college degrees and without college degrees. Based on the estimation in Petrongolo and Pissarides (2001), I assume the matching function is $m(V, U) = AU^{\alpha}V^{1-\alpha}$ and $\alpha$ to be 0.5. The bargaining power of workers $\beta$ is 0.5, satisfying

Hosios (1990a) condition. The average annual job separation rate is 0.228 and 0.408 in the skilled and unskilled labor markets respectively. They are drawn from Chassamboulli and Palivos (2014). The equilibrium market tightness $\theta$ and the constant recruitment cost $k_i$ can be determined using (2.13) with a given job finding rate. Market tightness is normalized to 1 without loss of generality; thus, the calibration of the matching efficiency $A$ equals to 6.7455, and the constant recruitment cost $k_H$ is 0.4260 and $k_L$ is 0.5283.[11]

Since the optimal employment contract requires that the wage equals to the productivity of workers, the implied wage can be recovered using

$$\tilde{w}_i^j = y_i - (r + \delta_i + \pi\mu(1 - F(\bar{g}_{E,i}^j)))\phi_i^j. \tag{2.25}$$

The implied wage is the difference between the productivity of workers and the flow hiring fee, which is the second term of (4.16). The one-time hiring fee can be considered as the present discounted value of a flow hiring fee at each point of time with the discount rate $r + s + \pi\mu(1 - F(\bar{g}_{E,i}^j))$ during the time of employment. Given (4.16), the implied wage of skilled native workers is 0.9829, and that of unskilled natives is 0.5958. Shimer (2005) estimates that the replacement ratio of unemployment and employment income is 0.4. The unemployment utilities of skilled and unskilled natives are 0.3932 and 0.2383, respectively. Following the estimation of Chassamboulli and Palivos (2014), the wage gap between skilled natives and immigrants is -18.8%, and the wage gap between unskilled natives and immigrants is -19%. Thus the unemployment utilities of skilled and unskilled immigrants are -1.7263 and -1.0703, respectively.

[11]The calibration strategy follows Pissarides (2009). Once the job finding rate and job separation rate match the data, the labor market tightness can be normalized to one without loss of generality.

I normalize all dollar figures in the data by the annualized earnings of workers over 25 years old with a bachelor's degree and above in the CPS from 1990 to 1999; the amount is \$33,708.16. In the crime sector, the overall property crime rate targets the average property crime rate from 1990 to 1999, which is 45.11 criminal offenses per 1,000 from the Uniform Crime Report (UCR). I assume that the crime value follows an exponential distribution.[12] The average property loss per offense is approximately \$1,318.8, so the mean of the exponential distribution is $g^e = \$1,318.8/\$33,708.6 = 0.0391$, which targets the average property loss per offense and is normalized by the wage. The Poisson rate of meeting a crime opportunity $\mu$ targets the crime rate, and equals to 0.0704. Since the loss of crime is a wealth transfer from victims to criminals, I set the expected loss $\tau$ equal to the mean of the crime value. The probability of getting caught is a ratio of the number of people that are sent to jail to the total number of offenses, which is 0.019 following Engelhardt et al. (2008). The mean length of incarceration of property crimes was 16 months in 2002, which is also from Engelhardt et al. (2008). Hence the rate of being released is $\rho = 0.75$. Because of lack of information on the utility flow in jail, I normalize this utility flow to $x = 0$.[13] The calibration is summarized in Table A.1.

## 2.6 Effects of Immigration: A Numerical Exercise

This section studies the quantitative impact of the immigration waves from 2000 to 2009. Using the findings in Chassamboulli and Palivos (2014), the skilled and unskilled

[12] According to the UCR in 2004, the distribution of property crime value has a shape similar to an exponential distribution.

[13] I also run numerical exercises with $x = -0.5$ and $x = -1$. The different flow utility values in jain do not change the quantitative results significantly.

immigrants increased by 0.026 and 0.051, respectively, in the 2000s. The simulation results are presented in table A.2. Since productivity in the model is constant, and I focus only on the long-run equilibrium, I de-trend the hourly real wage in the U.S. labor market. The de-trended wage increases by 0.6 percentage points from the 1990s to the 2000s. The model predicts that the implied wage of skilled natives increases by 0.21% and that of unskilled native workers increases by 0.148%, with the wave of immigrants. Compared with the de-trended wage, the impact of immigration on wages covers about 1/3 of the increase of de-trended wages from the 1990s to the 2000s.[14] Since immigrants create jobs for both of natives and immigrants, the overall unemployment rate decreases by 0.3288 percentage points.

Without effects from the labor market, the increase in immigrants in the 2000s decreases the overall crime rate by 0.2455 per 1,000 population. Table A.3 reports the respective crime rates of each type of worker in the 1990s. Skilled immigrants have lower incentives to commit a crime than do unskilled immigrants. Unemployed skilled immigrants are more willing to commit a crime than are employed skilled and unemployed natives, but are less likely to commit a crime than other types of workers. Unemployed unskilled immigrants have the lowest value in the legal sector, and, as a result, they are the most likely to commit a crime. Employed unskilled immigrants have a reservation crime value that is higher than that of unskilled natives and unskilled unemployed immigrants but lower than that of other types of workers. When there is a wave of only skilled immigrants, the

[14]The reason I de-trended the wage is because the growth of wages is mainly driven by productivity growth, which is absent in my model. According to CPS data, wage growth mainly follows productivity growth in the 1990s and the 2000s. Since productivity in this paper is exogenous, I tried to compare the model prediction with wage growth without productivity growth. Therefore, I use de-trended wages from the 1990s to the 2000s and compared the de-trended wage growth with the model prediction.

overall crime rate drops by 0.2724 per 1,000, and increases by 0.0148 when there is a wave of only unskilled immigrants.

Immigrants also affect the criminal behavior of workers through the labor market. According to propositions 4 and 5, employed workers commit more crimes because jobs become less valuable with increasing labor market tightness. The opportunity cost of committing a crime for employed workers goes down. Therefore, employed workers have more incentives to commit crimes. Meanwhile, unemployed workers commit fewer crimes. Unemployed workers are hired faster with increasing labor market tightness. The Survey of Inmates in State and Federal Correctional Facilities in 1997 and 2004 shows that the fraction of inmates who had a job before being arrested increased by 6.06%, whereas the fraction of inmates who did not have a job before being arrested decreases. These survey data support the model's prediction regarding the change in criminal behavior of employed and unemployed workers when the number of immigrants increases. Combining the composition and the criminal behavior effects, the overall crime rate decreases by 0.156 per 1,000, which is equivalent to 45,988 nation-wide criminal offenses.[15]

Column 3 of table A.2 reports the results with an increase in skilled immigrants only. Column 4 of table A.2 reports the results with an increase in unskilled immigrants only. When the economy gains only skilled immigrants, the skilled market tightness increases by 0.3291, which lowers the unemployment rate by 0.1137 percentage points and increases wages of skilled native workers by 0.13%. When there are more unskilled immigrants,

[15]The average population in the 2000s in the U.S. was 294,796,911. The estimated number of total criminal offenses was 13,295,340.69.

the unskilled labor market tightness increases by 0.1214. The overall unemployment rate decreases by 0.2248 percentage points.

In the crime sector, the model predicts that the overall crime rate decreases by 0.226 (-0.061) offenses per 1,000 with an increase in skilled (unskilled) immigrants. Compared to skilled immigrants, unskilled immigrants are more likely to commit crimes, since they have a lower reservation crime value than skilled immigrants. Bell et al. (2013) and Spenkuch (2014) provide empirical evidence that the crime rate in the host country increases with immigrants from less-developed countries and decreases with the immigrants from more developed countries.

## 2.7 Discussion: Policies

This section discusses three policies: an increase in unemployment income, an increase in the duration of incarceration, and deportation.

### 2.7.1 Unemployment income

Machin and Marie (2006) and Fougère et al. (2009) document that unemployment benefits affect workers' criminal behavior. Because the measure of unemployment value is the only difference between natives and immigrants, I introduce a more generous unemployment insurance system for immigrants. This unemployment insurance system increases the unemployment income of immigrants and makes the flow of the unemployment utility of immigrants equal to that of natives.

**Proposition 5** *For all $i \in \{H, L\}$ and $j \in \{N, I\}$, and $i' \neq i$, an increase in $B_i^I$ has the following effects:*

*i) $\theta_i$ decreases;*

*ii) $\bar{g}_{E,i}^N$ and $\bar{g}_{E,i'}^I$ increases if $\rho > \delta$;*

*iii) $\bar{g}_{U,i}^N$ and $\bar{g}_{U,i'}^I$ decreases;*

*iv) $\bar{g}_{E,i}^I$ decreases;*

*v) $\bar{g}_{U,i}^I$ increases.*

With this unemployment insurance system, natives and immigrants are now the same in the model. The increasing unemployment utility flow raises immigrants' unemployment value. The employment premium of immigrants decreases and lowers the expected revenue of firms. As a result, fewer firms enter the market and post vacancies. Since the unemployment value of immigrants goes up, immigrants are more patient and wait to find a job. More unemployed workers and fewer vacancies decrease the labor market tightness in equilibrium.

Quantitatively, the market tightness decreases by 0.558 for the skilled market and 0.2507 for the unskilled market. The overall unemployment rate increases by 0.8886 percentage points with this more generous unemployment insurance system. Because of the drop in market tightness, skilled natives' implied wage decreases by 0.31% and unskilled natives' implied wage decreases by 0.64%. The overall crime rate increases by 0.235 per 1,000 due to the mixed effects on different types of workers. With a less tight labor market, native employees have high employment value and care about their jobs. Their opportunity cost of committing a crime becomes higher, so they raise their reservation crime value and commit fewer crimes. The crime rates of employed skilled and unskilled natives drop by 0.264 and 0.169, respectively. With lower labor market tightness, unemployed native workers must wait longer to find a job. The native unemployment value and the reservation crime value of unemployed natives decline. Therefore, criminal offenses that are committed by unemployed natives increase. The crime rates of skilled and unskilled unemployed natives increase by 0.149 and 0.238, respectively.

Unemployed immigrants enjoy a higher unemployment utility, even though it is hard for them to get hired with low market tightness. They prefer to stay unemployed rather than commit crimes. The number of crimes that are committed by unemployed immigrants decreases. As a result, the crime rate of unemployed skilled (unskilled) immigrants decreases by 2.863 (5.17). Employed immigrants, by contrast, commit more crimes. A more generous social security system narrows the difference between employed and unemployed immigrants' value, even though the market tightness decreases, employed immigrants have a lower employment premium, so the opportunity cost of committing a crime drops. Therefore, the crime rate of skilled (unskilled) employed immigrants increases by 4.558 (3.35). The results are summarized in table A.4.

### 2.7.2 More severe jail sentences

The average duration of a jail sentence for property crimes is 16 months, which provides an exit rate of $\rho = 0.75$. I extend the jail sentence to 32 months and to 48 months, which implies exit rates $\rho$ of 0.375 and 0.25, respectively. Table A.5 reports the policy effects on labor market outcomes and crime rates.

**Proposition 6** *With a decrease in $\rho$,* *i)* $\theta_i$ *increases;*

*ii)* $\bar{g}^j_{E,i}$ *and* $\bar{g}^j_{U,i}$ *increase.*

A longer jail duration directly lowers prisoners' value. A worker needs to give up more value in the legal sector when she wants to commit a crime. With a longer duration of incarceration, many criminal opportunities are not of sufficiently high value to cover a worker's opportunity cost. Therefore, fewer workers get involved in criminal activities.

When the reservation crime value increases, workers' valuation of their illegal outside option decreases. The value in the legal sector goes up, and this results in an increase in the match surplus. There are fewer unemployed workers in the market when sentence lengths increase. Criminals have to stay in jail longer, so fewer criminals return back to the labor market. Also, employed workers commit fewer crimes, which lowers the transition rate from employed to unemployed through criminal activity. When there are fewer unemployed workers in the market, the number of vacancies per unemployed worker increases. Since this incarceration policy affects the criminal behavior of all workers, the workers' distribution barely changes. Therefore, it shifts the curve HF to the right and increases market tightness in equilibrium.

Quantitatively, there is no significant effect of more severe sentences on labor market outcomes, but this policy reduces crime rates significantly. With the sentence extended to 32 months and to 48 months, the overall crime rate decreases by 12.461 and 20.475 per 1,000, respectively.

### 2.7.3 Deportation

Under a deportation policy, immigrants who commit a crime and get arrested are sent back to their countries of origin. The assumption in this model is that some immigrants come from countries with worse labor markets than in the host country. Deportation increases the opportunity cost of committing a crime for immigrants, so the reservation crime value of immigrants rises.

I assume that the value of being deported is proportional to the value of being in prison, i.e., for all $i \in \{H, L\}$,

$$V^I_{D,i} = aV^I_{P,i},$$

where the variable $a \in [0, 1)$ is the proportion coefficient. Therefore, the criminal activity payoff of immigrants is $K^I_i = g + V^I_{s,i} + \pi(V^I_{D,i} - V^I_{s,i})$ and the reservation value of crime is

$$\bar{g}^I_{s,i} = \pi(V^I_{s,i} - V^I_{D,i}) = \pi(V^I_{s,i} - aV^I_{P,i}). \tag{2.26}$$

$$> \pi(V^I_{s,i} - V^j_{P,i})$$

which is higher than is that the one without deportation.

Since the deportation policy reduces the measure of immigrants over time, newly-arriving immigrants enter the host country to ensure a steady state distribution with immigrants. All newcomers are unemployed. In steady state, immigrant flows are given by

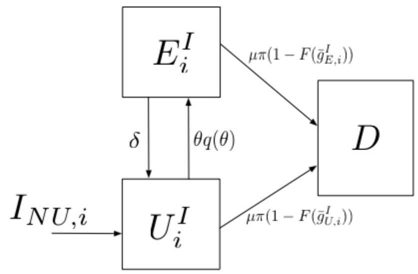


Figure 2.4: Immigrant flows

$$(\theta q(\theta) + \eta^I_{U,i})U_i^I = I_{N,i} + \delta E_i^I$$

$$(\delta + \eta^I_{E,i})E_i^I = \theta q(\theta)U_i^I$$

$$U_i^I + E_i^I = I_i$$

for all $i \in \{H, L\}$, where $I_{N,i}$ is the measure of newly arriving immigrants. Therefore, the measure of newcomers is

$$I_{N,i} = \frac{I_i[\theta q(\theta)\eta^I_{E,i} + \delta\eta^I_{U,i} + \eta^I_{E,i}\eta^I_{U,i}]}{\theta q(\theta) + \eta^I_{E,i} + \delta}$$

and the measure of unemployed immigrants is

$$U_i^I = \frac{I_i(\delta + \eta^I_{E,i})}{\theta q(\theta) + \eta^I_{E,i} + \delta}.$$

**Proposition 7** *With the deportation policy,*

*i)* $\theta_i$ *is ambiguous;*

*ii)* $\bar{g}^I_{s,i}$ *increases;*

*iii)* $\bar{g}^N_{U,i}$ *increases and* $\bar{g}^N_{E,i}$ *decreases if* $\rho > \delta$*.*

Deportation policy is aimed at the criminal behavior of immigrants— it increases the cost of committing a crime for immigrants only. The reservation crime value of immigrants increases, so the immigrants' value of illegal outside options decreases. With deportation, the value of the legal sector increases and the match surplus of immigrants increases. However, with deportation, there are fewer unemployed immigrants in the labor market than is the case without deportation. Without deportation, there are two flows into immigrant unemployment: employed workers who lose their jobs and prisoners who are released from jail. Only a proportion $\rho$ of total prisoners are released from jail and return to the labor market as unemployed workers. With deportation, there are also two flows into immigrant unemployment: employed workers who lose their jobs and newly arrived immigrants. The flows out of immigrant unemployment are the same with and without deportation. At the steady state, the number of newly-arriving immigrants equals the number of immigrants being deported. The reservation crime value of immigrants increases so the number of newcomers is less than the number of immigrants released from jail. Therefore, the number of unemployed immigrants decreases with deportation, and the share of unemployed immigrants goes down. Therefore, any changes in labor market tightness are ambiguous when the deportation policy is imposed.

There is not enough information to measure the deportation value of immigrants, so I set $a = 0.1$, 0.5, and 0.9 to represent three levels of immigrants' original countries. If an immigrant either comes from a country that has similar labor market conditions to the host country or she can re-enter the host country easily, then the coefficient $a = 0.9$. If an immigrant comes from a country with a worse labor market (such as a market with a high separation rate, low market tightness, or low wages) than that of the host country, the coefficient $a$ becomes 0.1. Table A.6 shows the effects of deportation on labor market outcomes and the crime rates. The effect of deportation on workers' distribution is limited. When the reservation crime value of immigrants goes up with deportation, the share of unemployed immigrants converges to that without deportation. The increase in the match surplus due to the deportation policy is also small. Therefore, market tightness increases by a small margin when the deportation policy is imposed. The reservation crime value of native workers depends only on labor market tightness in this case, so the effect of deportation on the criminal behavior of native workers is not significant. Comparing the case of immigrants from more developed countries ($a = 0.9$) to the case of those from less developed countries ($a = 0.1$), the effect on market tightness is almost the same, but the effect on the criminal behavior of immigrants from different countries varies. The crime rate decreases more when the coefficient $a$ is smaller. When immigrants come from less-developed countries, they pay a higher opportunity cost if they commit a crime. Fewer of these immigrants commit crimes under the deportation policy. Thus, for immigrants from a country with a labor market condition similar to that of the host country, the crime rate decreases by 1.606 per 1,000. In the case of immigrants from a country where labor market conditions are worse than in the host country, the deportation policy decreases the overall crime rate by 3.973 ($a = 0.5$) and 4.481 ($a = 0.1$).

## 2.8 Extension: imperfect substitution between skilled and unskilled labor

The model above assumes that skilled and unskilled labor substitutes perfectly. For a more realistic numerical exercise, this section extends the baseline model with imperfect substitution between skilled and unskilled labor.[16]

### 2.8.1 Production

There are two sectors in this extension, final and intermediate good sectors. Firms in the final good sector produce final goods by purchasing intermediate goods from competitive intermediate good markets. There are two intermediate goods, skilled and unskilled intermediate goods. They are produced by skilled/unskilled labor. Firms in the intermediate good sector hire workers from the skilled/unskilled labor market.

The output of the final good follows the CES production function with constant returns to scale,

$$Y = [\alpha Y_H^\sigma + (1-\alpha) Y_L^\sigma]^{1/\sigma}, \tag{2.27}$$

where variable $Y$ is the production of final good, $Y_H$ is the production of the skilled intermediate good, and $Y_L$ is the production of the unskilled intermediate good. The parameter $\alpha$ represents the importance of the skilled intermediate good. The parameter $\sigma$ represents

[16] I only show the extension with imperfect substitution between skilled and unskilled labor in the manuscript. I also have a numerical exercise with imperfect substitution between native and immigrant workers, and between skilled and unskilled labor and native and immigrant workers together. These two extensions do not significantly change the baseline results, so they are not in the manuscript. The numerical results of these two extensions are available upon request. I am grateful to an anonymous referee who suggested having imperfect substitution between different types of workers.

the elasticity of substitution, which is $1/(1-\sigma)$. One employed skilled/unskilled worker, regardless of their immigration status, produces one unit of the skilled/unskilled intermediate good, i.e.

$$Y_H = E_H^N + E_H^I, \tag{2.28}$$

$$Y_L = E_L^N + E_L^I. \tag{2.29}$$

Firms in the final good sector purchase intermediate goods in competitive markets. The prices of intermediate goods are the marginal product of skilled/unskilled intermediate goods, which are

$$p_H = \alpha[\alpha + (1-\alpha)(\frac{Y_L}{Y_H})^{\sigma}]^{\frac{1-\sigma}{\sigma}}, \tag{2.30}$$

$$p_L = (1-\alpha)[\alpha(\frac{Y_L}{Y_H})^{-\sigma} + (1-\alpha)]^{\frac{1-\sigma}{\sigma}}. \tag{2.31}$$

### 2.8.2 Effects of immigration

Firms in the intermediate good sector search and match workers in the labor markets. The matching mechanism is the same as in the baseline model. The equilibrium is determined by

$$
\begin{aligned}
\frac{k_i}{q(\theta_i)} &= \phi_i^e \\
&= \frac{1-\beta}{r+\delta_i+\beta\theta_i q(\theta_i)}\mathbb{E}\left[p_i - B_i^j - \mu\int_{\bar{g}_{U,i}}^{\bar{g}_{E,i}}(1-F(g))dg\right]. \qquad (2.32)
\end{aligned}
$$

The imperfect substitution between skilled and unskilled labor provides an additional channel for the effects of immigration. This channel is called the price channel. When the population of skilled/unskilled immigrants increase, there is more skilled/unskilled labor in the labor markets. As a result, the production of the skilled/unskilled intermediate good increases and the price of skilled/unskilled labor decreases, while the price of unskilled/skilled labor increases.

**Lemma 8** *When $I_i$ increases,*

*(i) $p_i$ decreases,*

*(ii) $p_{i'}$ increases for all $i' \in \{H, L\}$, and $i' \neq i$.*

According to lemma 8, the population of immigrants affects the reservation value of crime through the price channel.

**Lemma 9** *Given a certain $\theta_i$, when $I_i$ increases,*

*(i) $\bar{g}_{s,i}^j$ decreases,*

*(ii) $\bar{g}_{s,i'}^j$ increases,*

*for all $i, i' \in \{H, L\}, s \in \{E, U\}, j \in \{N, I\}$.*

The price channel also affects the labor market equilibrium. Differing from the baseline model, the price channel weakens the effect of immigration on the labor market outcomes. The equilibrium condition (2.33) can be rewritten as

$$\frac{k_i}{q(\theta_i)} + \frac{1-\beta}{r+\delta_i+\beta\theta_i q(\theta_i)}\mathbb{E}\left[B_i^j - \mu\int_{\bar{g}_{U,i}}^{\bar{g}_{E,i}}(1-F(g))dg\right] = \frac{1-\beta}{r+\delta_i+\beta\theta_i q(\theta_i)}p_i. \quad (2.33)$$

The left hand side of equation (2.33) can be considered the total cost of a match: an average cost from job posting and the expected value of workers' outside option. The right hand side represents the share of intermediate good price that firms can get. When the population of skilled-$i$ immigrants increases, the total cost of a match decreases while the price of the skilled-$i$ intermediate good decreases as well. The market tightness of labor market $i$ increases with skilled-$i$ immigrants only if the effect on the cost is greater than the effect on the price.

**Proposition 8** *When $I_i$ increases,*

*(i) $\theta_i$ increases if the cost effect dominates the price effect;*

*(ii) $\theta_{i'}$ increases for all $i' \in \{H, L\}, i' \neq i$.*

Imperfect substitution between skilled and unskilled labor contributes more ambiguity to the effects of immigration on labor market outputs and crime. Table A.7 shows the simulation results of the extended model.

## 2.9 Conclusion

This paper studies the joint impact of immigration on labor market outcomes and crime. A wave of immigrants encourages firms to create more jobs, since it reduces firms' labor costs. With this wave of immigrants, the unemployment rate of native workers decreases, and the wages of native workers increase. Immigration affects workers' criminal behavior by changing workers' distribution and raising labor market tightness. Compared to skilled immigrants, unskilled immigrants are more likely commit crimes because of their poor outside options. Therefore, the overall crime rate decreases with an increase in skilled immigrants, but increases with an increase in unskilled immigrants. Immigration also affects the criminal behavior of workers by raising labor market tightness. More employed workers commit a crime if the duration of incarceration is shorter than the duration of employment. With this increase in labor market tightness, unemployed workers prefer to wait for jobs rather than commit crimes. Therefore, the effect of immigration on the overall crime rate is ambiguous.

Quantitatively, with the increase in both skilled immigrants and unskilled immigrants observed in the 2000s, the unemployment rate decreased by 0.3288 percentage points, and the crime rate decreased by 0.156 per 1,000 population. The model also discusses policy effects. With a more generous unemployment insurance system for immigrants, the unemployment and the crime rates increase, and the wages of native workers decrease. Deportation and a longer incarceration duration lower the crime rate by increasing the opportunity cost of committing a crime. The former affects the criminal behavior of both native and immigrant workers, but the latter affects only the criminal behavior of immigrants. Thus, the magnitude of the effect of incarceration is larger than the deportation policy.

# Chapter 3

# Endogenous immigration behavior and effects of immigration policies

## 3.1 Introduction

Since the 2000s, the cost of relocation has become cheaper with increases in technology. The reduction of moving cost makes workers relocate more frequently than in the past. This increasing global labor mobility is an important topic as the public is concerned about how to control the increased labor movement, particularly as it pertains to the effect of immigrants on the local labor market. A lot of literature has talked about how immigrants affect the labor market in the host country but the results are not conclusive. For example, Borjas (2003b; 2005) finds that immigration reduces natives' wages, but Ottaviano and Peri (2012) and Peri et al. (2015) provide evidence of the opposite effect.

However, most literature assumes that labor mobility is exogenous and only moves with one direction. They focus on effects on local labor market when the exogenous stock of immigrant increases and provide some policy analysis. In fact, the stock of immigrants depends on the migration behavior of workers endogenously and highly related the labor market conditions, especially incomes and unemployment rates. Greenwood (1969) provides evidence that income and unemployment significantly affect people's migration. In addition, workers move with double direction between two countries. For example, there are about 363,000 US-born workers in Canada and about 1 million Canadians live in the US. There are about 1 million Mexicans in the United States and about 669,000 Americans in Mexico in 2015. The local labor market is affected by both population inflows and outflows.

This paper studies effects of immigration policy on labor market outcomes by modeling the migration behavior in frictional labor markets. There are two countries and two skill-bias labor markets. All workers are able to immigrate to the other country legally. Country 1 has more high skilled workers and better technology and social security system (e.g. the U.S.) and country 2 has more low skilled workers and lower technology and social security system (e.g. Mexico). When skilled workers stay in the country of origin, they are able to search in the skilled and unskilled labor market. Unskilled workers only can search in the unskilled labor market, since they cannot achieve the skill requirements of the skilled labor market, for example, the requirement of college degrees. Skilled and unskilled workers can also choose to emigrate to the other country when a migration opportunity arrives. The migration opportunity comes with a migration cost. This migration cost includes relocation costs, search cost in the foreign country and the benefit that workers give up in their country of origin. The reservation migration cost is determined by the comparison of the unemployment value in the country of origin and the foreign country of the worker. If the labor market in the foreign country compensates more than the reservation migration cost, workers search in the foreign country and relocate.

Theoretically, skilled workers from either country 1 or country 2 may emigrate to the other country while unskilled workers only emigrate from country 2 to country 1 at the steady state equilibrium. The model is calibrated to the labor market data in the U.S. and Mexico in 2010. The model shows that skilled U.S.-born and Mexican workers migrate to each other, while only Mexican unskilled workers migrate to the United States but no unskilled US-born workers move to Mexico. The model predicts that there are 2% of skilled workers in Mexico are US-born workers, 1.62% of skilled workers and 10% of unskilled workers in the US are Mexicans.

I introduce three immigration policies in the United States and one in Mexico that are able to apply in this model. The subsidy of firms in the United States that hire U.S.-born workers encourages more firms to enter the labor market in the United States. Therefore the market tightnesses in skilled and unskilled labor market in the United States increase. This policy increases the wages and decreases the unemployment rate in the United States. The labor markets in the US attract more workers from Mexico. Meanwhile, the market tightnesses in both skilled and unskilled labor markets in Mexico decrease and it leads a decrease in wages and an increase in unemployment rates. The taxation of firms in the United States that hire Mexicans decreases the labor market tightnesses in both skilled and unskilled labor markets. This taxation decreases wages and increases unemployment rates in the United States. The labor markets in the U.S. become less attractive to Mexicans so that fewer Mexicans move to the US. Mexican government tries to attract more US-born skilled workers to immigrate to Mexico because these workers have higher productivity. To attract these workers, Mexico subsidizes all U.S.-born workers who search in Mexico. The labor markets in Mexico become stronger, which means wages increase and unemployment rates decrease. Since the labor markets in Mexico become attractive, fewer Mexicans move to the US.

This paper is the first one that captures double-direction immigration flows between two countries. Chassamboulli and Peri (2015b) and Ortega (2000) endogenize migration behavior with two-country search and matching framework. Chassamboulli and Peri (2015b) studies the effects of illegal immigrants from Mexico on the labor market outcomes in the United States. They assume that there is only immigrants from Mexico and there is no migration opportunity for workers who were born in the US. All immigrants from Mexico are unskilled workers. The US-born workers cannot search across markets or countries. My paper releases these assumptions that US-born workers are allowed to search across market or countries with a heterogenous migration cost. Ortega (2000) assumes that all workers search in the other country when the job duration is longer in that country than their country of origin. My paper introduce heterogenous migration opportunities that workers can choose to emigrate or to stay in their own country. With the model in this paper, the effects of immigration polices on labor market outcomes and the population of immigrants are trackable.

Other papers that studies effects of immigration with frictional labor market assume that immigration is an exogenous variable. Chassamboulli and Palivos (2014) introduce imperfect substitution with skilled-bias labor markets to show that immigration benefit native workers from wages and employments. Liu (2010) shows that an increase in illegal immigrants generate a significant social welfare gain. Liu et al. (2017) introduces mismatch and imperfect transferability of foreign human capital in the search and matching labor market model with immigrants. They shows that with the increase of immigrants in 2000 to 2009 in the United States, all workers in the US gain in terms of income and employment.

The paper describes a frictional labor market with two countries and two labor markets. The steady state equilibrium of the model is recursively solved. In steady state equilibrium, the flows of immigrants from the U.S. and Mexico may occur simultaneously in the skilled labor market, while there is only Mexican immigrants come to the US in the unskilled labor market. The model is calibrated to the US and Mexico labor market data in 2010. Some immigration policy effects on labor market outcomes are discussed in section 7.

## 3.2 Model

Time is continuous. Firms and workers are risk neutral and discount the future value at a rate $r$. There are two countries and two skill level of workers. High skilled workers in both countries have higher productivity than low skilled workers. Country 1 has more high skilled workers while country 2 has fewer high skilled workers and more unskilled workers. Unemployed workers in country 1 has higher unemployment benefit than in country 2. Country 1 has more advanced technology and education than country 2. Therefore, the productivity of skilled and unskilled worker in country 1 is higher than in country 2, which is $y$Also, skilled workers emigrate from country 1 to country 2 have higher productivity than skilled workers who were born in country 2. Unskilled workers from country 1 that move to country 2 have the same productivity as unskilled workers who were born country 2. Skilled and unskilled workers from country 2 that move to country 1 have the same productivity. High skilled workers are free to search in either high skilled labor market or low skilled labor market, but low skilled workers are able to search in the low skilled labor market only. Meanwhile, unemployed workers can also consider searching in the other country, if the other country provide higher value in the labor market. If workers search in the other country, they cannot search across markets, i.e. high (low) skilled foreigners can only search in high (low) skilled labor market. All workers legally search across countries.

Unemployment exists because of the search frictions in the labor market. For all $i \in \{1, 2\}$, skilled unemployed workers who were born in country $i$ and search in country $i$ obtain a flow of unemployment benefit $b_{ii}^{H}$. The superscript $\kappa$ represents skill level of workers, where $H$ for high skill and $L$ for low skill. The subscript with two digits represents the country $i$ that workers were born and the country $j$ that workers search/work. If $i = j$, this worker was born in country $i$ and stays in country $i$. If $i \neq j$, this worker was born in country $i$ and emigrates to country $j$. If skilled workers stays in their country of origin, they search in the high skilled labor market and the low skilled market at the same time. Unskilled unemployed workers who were born in country $i$ and search in country $i$ obtain a flow of unemployment benefit $b_{ii}^L$. They are only able to search in the low skilled labor market because they lack skills that the high skilled labor market requires. An migration opportunity arrives at a Poisson rate $\mu_i$ to both skilled and unskilled unemployed workers. This migration opportunity requires that workers need to pay a one-time search cost $c$, to search in the other country $j$. This migration cost is randomly drawn from a given distribution $F(c)$ on support $[0, c^{max})$. The migration cost is one-time cost that includes the relocation cost, the present discounted cost of flows of search cost in the foreign country, and the benefit that the immigrant worker gives up when she was in her country of origin. All migrations are considered in this model is legal migration.

If these unemployed workers stay in their country of origin, they match with a firm in country $i$. The number of matches generates in high (low) skilled labor market in country $i$ follows a match function, $M_i^\kappa = m(V_i^\kappa, U_i^\kappa)$ where $V_i^\kappa$ is the number of vacancies and $U_i^\kappa$ is the number of unemployed workers in $\kappa$-skilled labor market in country $i$. As a result, an unemployed worker matches with a firm at a Poisson rate $f(\theta_i^\kappa) = M_i^\kappa / U_i^\kappa$, where tightness $\theta_i^\kappa$ is defined as the vacancy-unemployment ratio, i.e. $\theta_i^\kappa \equiv V_i^\kappa / U_i^\kappa$. Skilled unemployed workers match with a firm in skilled labor market at rate $f(\theta_i^H)$ or match with a firm in unskilled labor market at rate $f(\theta_i^L)$. Unskilled unemployed workers match with a firm in the unskilled labor market at rate $f(\theta_i^L)$. When the skilled (unskilled) worker matches in the skilled (unskilled) labor market, she earns wages $w_{ii}^H$ ($w_{ii}^L$) and suffers the capital loss when an exogenous separation shock, which arrives at rate $s^H$ ($s^L$). Similarly, if the skilled worker works in the unskilled labor market, she earns wages $w_{ii}^{HL}$ and suffers the capital loss of job separation in the unskilled labor market.

If the search in the foreign country is low, workers decide to search in the other country. If they search in the foreign country $j$ (workers were born in country $i \neq j$), they obtain a flow of unemployment benefit $b_{ij}^H$ or $b_{ij}^L$, according to their skills. High (low) skilled workers from country $i$ are only able to search in high (low) skilled labor market. Workers from country $i$ match with a firm in country $j$ with rate $f(\theta_j^\kappa)$. They earn wages $w_{ij}^\kappa$ and suffer the capital loss of job separation at rate $s^\kappa$. An exogenous departure shock arrives at rate $d$ such that all workers from country $i$ have to return to their country of origin and become unemployed.

All firms in this model are small firms and each of them only has one job, vacant or filled. They can post a vacant job freely in either skilled or unskilled labor market in the country $i$ that they locate. Firms are not able to move. When firms post a vacant job, they pay a constant recruitment cost $k^\kappa$. They match with a worker at a rate $q(\theta_i^\kappa) = M_i^\kappa / V_i^\kappa$. When firms and workers match with each other, they start producing. Firms receive $y_{ji}^\kappa$ units of production from the worker that they hire. Similar as the interpretation of the subscript of individual variables, the first digit represents the country that workers were born and the second digit represents the location of the firm. They pay wage $w_{ji}^\kappa$ to the worker. If firms in country $i$ hire a worker from country $j$, they lose their employee by either the separation shock or the departure shock. If employees are from country $i$, firms in country $i$ lose them only because of the separate shock.

## 3.3 Bellman equations

### 3.3.1 Workers

The value of employed workers with skilled $\kappa$ who were born in country $i$ and work in country $j$ is denoted as $\mathcal{W}_{ij}^{\kappa}$, the value of unemployed workers as $\mathcal{U}_{ij}^{\kappa}$. Skilled workers who were born and work in the same country can search in the skilled and unskilled labor market simultaneously. The value of a skilled worker that works in the unskilled labor market is denoted as $\mathcal{W}_{ii}^{HL}$. Equation (3.1) shows that employed skilled workers match with a firm in skilled labor market. Equation (3.2) shows that a skilled worker gets a job in the unskilled labor market. Equation (3.3) shows that the outside options of skilled workers. It includes the flow of unemployment benefit, the expected capital gain of getting a job, and the surplus value of migration. When the migration opportunity arrives, the worker compares the value of unemployment when she searches oversea with the cost of migration, and the value of unemployment when she stays in country $i$. The bellman equations of skilled workers who were born in country $i$ and work in country $j$ are

$$r\mathcal{W}_{ii}^{H} = w_{ii}^{H} - s^{H}(\mathcal{W}_{ii}^{H} - \mathcal{U}_{ii}^{H}) \tag{3.1}$$

$$r\mathcal{W}_{ii}^{HL} = w_{ii}^{HL} - s^{L}(\mathcal{W}_{ii}^{HL} - \mathcal{U}_{ii}^{H}) \tag{3.2}$$

$$r\mathcal{U}_{ii}^{H} = b_{ii}^{H} + f(\theta_{i}^{H})(\mathcal{W}_{ii}^{H} - \mathcal{U}_{ii}^{H}) + f(\theta_{i}^{L})(\mathcal{W}_{ii}^{HL} - \mathcal{U}_{ii}^{H}) + \mu_i \int_0^{\infty} \max\{\mathcal{U}_{ji}^{H} - \mathcal{U}_{ii}^{H} - c, 0\} dF(c) \tag{3.3}$$

If she decides to search in country $j$, she can only search in skilled market. The bellman equations when the worker decide to search and to work in country $j$ are following,

$$r\mathcal{W}_{ij}^{H} = w_{ij}^{H} - s^{H}(\mathcal{W}_{ij}^{H} - \mathcal{U}_{ij}^{H}) - d(\mathcal{W}_{ij}^{H} - \mathcal{U}_{ii}^{H}) \tag{3.4}$$

$$r\mathcal{U}_{ij}^{H} = b_{ij}^{H} + f(\theta_{j}^{H})(\mathcal{W}_{ij}^{H} - \mathcal{U}_{ij}^{H}) - d(\mathcal{U}_{ij}^{H} - \mathcal{U}_{ii}^{H}). \tag{3.5}$$

When the departure shock arrives, employed or unemployed skilled workers in country $j$ have to return to country $i$ and become unemployed. The capital loss of the departure shock is showed in the last term of equations (3.4) and (3.5).

The value functions of unskilled workers are similar. The only difference is that unskilled workers are only able to search in the unskilled labor market. Therefore, the bellman equations of unskilled workers who were born in country $i$ are

$$r\mathcal{W}_{ii}^{L} = w_{ii}^{L} - s^{L}(\mathcal{W}_{ii}^{L} - \mathcal{U}_{ii}^{L}) \tag{3.6}$$

$$r\mathcal{U}_{ii}^{L} = b_{ii}^{L} + f(\theta_{i}^{L})(\mathcal{W}_{ii}^{L} - \mathcal{U}_{ii}^{L}) + \mu_i \int_0^\infty \max\{\mathcal{U}_{ij}^{\kappa} - \mathcal{U}_{ii}^{\kappa} - c, 0\} dF(c) \tag{3.7}$$

$$r\mathcal{W}_{ij}^{L} = w_{ij}^{L} - s^{L}(\mathcal{W}_{ij}^{L} - \mathcal{U}_{ij}^{L}) - d(\mathcal{W}_{ij}^{L} - \mathcal{U}_{ii}^{L}) \tag{3.8}$$

$$r\mathcal{U}_{ij}^{L} = b_{ij}^{L} + f(\theta_{j}^{L})(\mathcal{W}_{ij}^{L} - \mathcal{U}_{ij}^{L}) - d(\mathcal{W}_{ij}^{L} - \mathcal{U}_{ij}^{L}). \tag{3.9}$$

### 3.3.2 Firms

Firms in country $i$ can post a vacancy and match with a worker in either the skilled labor market or the unskilled labor market. The value of a vacant job is denoted as $\mathcal{V}_{i}^{\kappa}$ and the value of a filled job as $\mathcal{J}_{ii}^{\kappa}$, where the first digit of the subscription represents the country that the employee was born and the second digit represents the location of the firm. If a firm posts a vacancy in the skilled labor market, its bellman equations are following,

$$r\mathcal{V}_i^H = -k^H + q(\theta_i^H)(\mathbb{E}\mathcal{J}_i^H - \mathcal{V}_i^H) \tag{3.10}$$

$$r\mathcal{J}_{ii}^H = y_{ii}^H - w_{ii}^H - s^H(\mathcal{J}_{ii}^H - \mathcal{V}_i^H) \tag{3.11}$$

$$r\mathcal{J}_{ji}^H = y_{ji}^H - w_{ji}^H - (s^H + d)(\mathcal{J}_{ji}^H - \mathcal{V}_i^H). \tag{3.12}$$

Firms do not know the types of workers, either from country $i$ or $j$, before they matches, but firms can observe the unemployed skilled workers' distribution in the market. Therefore, when a firm posts a vacancy, it has an expected capital gain of a match. The expected value of a filled job is $\mathbb{E}\mathcal{J}_i^H = (U_{ii}^H/U_i^H)\mathcal{J}_{ii}^H + (U_{ji}^H/U_i^H)\mathcal{J}_{ji}^H$, where the total unemployment in the skilled market in country $i$ is $U_i^H = U_{ii}^H + U_{ji}^H$, the sum of skilled unemployed workers from country $i$ and $j$. Similarly, the bellman equations of a firm that posts a vacancy in the unskilled labor market in country $i$ are

$$r\mathcal{V}_i^L = -k^L + q(\theta_i^L)(\mathbb{E}\mathcal{J}_i^L - \mathcal{V}_i^L) \tag{3.13}$$

$$r\mathcal{J}_{ii}^L = y_{ii}^L - w_{ii}^L - s^L(\mathcal{J}_{ii}^L - \mathcal{V}_i^L) \tag{3.14}$$

$$r\mathcal{J}_{ii}^{HL} = y_{ii}^{HL} - w_{ii}^{HL} - s^L(\mathcal{J}_{ii}^{HL} - \mathcal{V}_i^L) \tag{3.15}$$

$$r\mathcal{J}_{ji}^L = y_{ji}^L - w_{ji}^L - s^L(\mathcal{J}_{ji}^L - \mathcal{V}_i^L), \tag{3.16}$$

where the expected value of unskilled filled job is $\mathbb{E}\mathcal{J}_i^L = [U_{ii}^L/(U_i^L + U_{ii}^H)]\mathcal{J}_{ii}^L + [U_{ji}^L/(U_i^L + U_{ii}^H)]\mathcal{J}_{ji}^L + [U_{ii}^H/(U_i^L + U_{ii}^H)]\mathcal{J}_{ii}^{HL}$ and the total low skilled unemployment is $U_i^L = U_{ii}^L + U_{ji}^L$.

The wage are determined by Nash bargaining. The bargaining power of workers is denoted as $\beta$. Workers and firms devide the match surplus by their bargaining power. If workers stay in their country of origin and work in the market that match with their skill, the surplus of workers is $\mathcal{W}_{ii}^{\kappa} - \mathcal{U}_{ii}^{\kappa}$. If workers move to the other country, their surplus becomes $\mathcal{W}_{ij}^{\kappa} - \mathcal{U}_{ij}^{\kappa}$. Skilled workers can search in the unskilled labor market in their country of origin. Therefore the surplus of these mismatched workers is $\mathcal{W}_{ii}^{HL} - \mathcal{U}_{ii}^{HL}$. Similarly, firms' surplus in $\kappa$-skilled labor market in country $i$ is $\mathcal{J}_{ii}^{\kappa} - \mathcal{V}_{i}^{\kappa}$ if firms match with a worker who was born in the same country, $\mathcal{J}_{ji}^{\kappa} - \mathcal{V}_{i}^{\kappa}$ if they match with a worker comes from the other country. If firms are in the unskilled labor market, they may match with a skilled worker who was born in the same country as the firm. Hence the surplus of firms that mismatch with a skilled worker is $\mathcal{J}_{ii}^{HL} - \mathcal{V}_{i}^{H}$. The surplus maximization problems of skilled-$\kappa$ workers who were born in country $i$ or $j$ and work in country $i$ are written as following,

$$w_{ii}^{\kappa} = \arg\max(\mathcal{W}_{ii}^{\kappa} - \mathcal{U}_{ii}^{\kappa})^{\beta}(\mathcal{J}_{ii}^{\kappa} - \mathcal{V}_{i}^{\kappa})^{1-\beta} \tag{3.17}$$

$$w_{ji}^{\kappa} = \arg\max(\mathcal{W}_{ji}^{\kappa} - \mathcal{U}_{ji}^{\kappa})^{\beta}(\mathcal{J}_{ji}^{\kappa} - \mathcal{V}_{i}^{\kappa})^{1-\beta} \tag{3.18}$$

$$w_{ii}^{HL} = \arg\max(\mathcal{W}_{ii}^{HL} - \mathcal{U}_{ii}^{H})^{\beta}(\mathcal{J}_{ii}^{HL} - \mathcal{V}_{i}^{L})^{1-\beta}. \tag{3.19}$$

When skilled workers search in the unskilled labor market, their productivity is higher than unskilled workers but lower than when they work with a skilled job. If skilled workers work with an unskilled job, the value of this job should be at least the same as the unemployment value of skilled workers, i.e. $\mathcal{W}_{ii}^{HL} \geq \mathcal{U}_{ii}^{H}$. Otherwise, no skilled workers search in the unskilled labor market. Proposition 1 concludes the condition of the existence of mismatch.

**Proposition 9** *Mismatch of skilled workers in unskilled labor market exists if*

$$\frac{r+s^H+\beta f(\theta_i^H)}{r+s^H}y_{ii}^{HL} \geq \frac{\beta f(\theta_i^H)}{r+s^H}y_{ii}^H + b_{ii}^H + \mu_i \int_0^{\bar{c}_i^H} F(c)dc..$$

The proof of Proposition 1 is in the appendix.

### 3.3.3 Reservation migration cost

When the migration opportunity arrives, workers can accept the opportunity and pay the one-time cost of migration, or reject and stay in the country that they were born. This one-time cost of migration includes the cost of relocation, the opportunity cost of moving out of the original country, and the discounted present value of the flow of search cost in the foreign country. When the worker moves to the other country, she loses her benefit in her country of origin and suffers some hardship in the new country. Therefore when she moves, the new country needs to compensate her equal or more than her cost. If the cost of migration is equal to the compensation from the new country, this cost is the reservation cost of migration. If the cost of migration is higher than the reservation, workers reject the opportunity and stay in the country of origin. Otherwise, they migrate to the new country. The determination of this reservation cost is the comparison between the value of unemployment in the other country and in the country of origin. Intuitively, if migration costs more than the worker can gain, then she rejects the migration opportunity.

Therefore, the reservation migration cost is

$$\bar{c}_i^\kappa = \max\{\mathcal{U}_{ij}^\kappa - \mathcal{U}_{ii}^\kappa, 0\}. \tag{3.20}$$

The reservation cost is non-negative. When $\bar{c}_i^\kappa = 0$, there is no worker with skill $\kappa$ emigrates from country $i$.

## 3.4 Equilibrium

The equilibrium is determined by the equality between the average cost of a match and the expected revenue from a match. This equality is given by the job creation condition, according to the free entry condition of vacancy, $\mathcal{V}_i^\kappa = 0$. In the unskilled labor market in country $i$, the job creation condition is written as

$$\frac{k^L}{q(\theta_i^L)} = \frac{U_{ii}^H}{U_i^L + U_{ii}^H}\mathcal{J}_{ii}^{HL} + \frac{U_{ii}^L}{U_i^L + U_{ii}^H}\mathcal{J}_{ii}^L + \frac{U_{ji}^L}{U_i^L + U_{ii}^H}\mathcal{J}_{ji}^L. \tag{3.21}$$

According to the environment of the model, there are three types of workers search in the unskilled labor market: skilled and unskilled workers who were born in country $i$ and unskilled workers who were born in country $j$. Similarly, the job creation condition of the skilled labor market in country $i$ is

$$\frac{k^H}{q(\theta_i^H)} = \frac{U_{ii}^H}{U_i^H}\mathcal{J}_{ii}^H + \frac{U_{ji}^H}{U_i^H}\mathcal{J}_{ji}^H \tag{3.22}$$

At the steady state, the flows into and out of employment and unemployment are equal to each other.

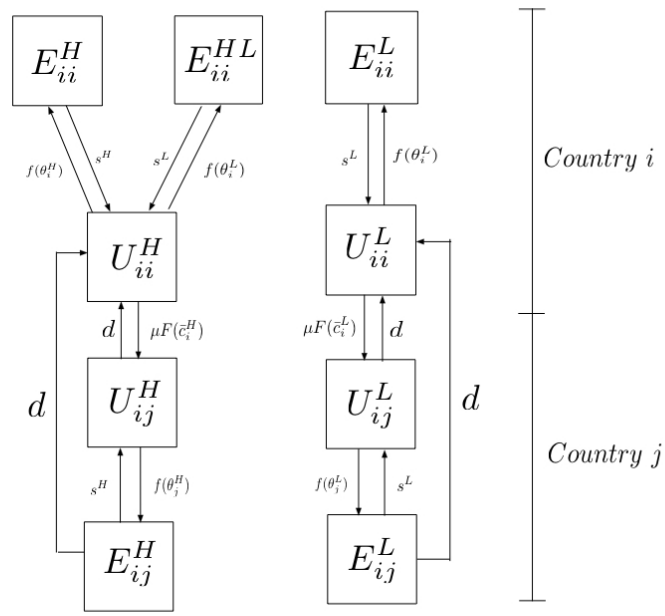


Figure 3.1: Workers flows

According to figure 1, the flows into and out of each country equal each other, i.e. $\mu F(\bar{c}_i^{\kappa})U_{ii}^{\kappa} = d(E_{ii}^{\kappa} + U_{ii}^{\kappa})$. In country $i$, the flows into skilled unemployment are employed workers lose their jobs in skilled and unskilled market, and the returned workers from country $j$. The flows out of skilled unemployed workers are workers who get a job in the skilled or unskilled labor market, and workers who decide to search in country $j$. For unskilled unemployment, the inflows are the unskilled employees who lose their jobs and the workers return from country $j$. The outflows of unskilled unemployment in country $i$ are workers who get a job and the ones who decide to search in the unskilled labor market in country $j$.

In country $j$, the flows into the skilled (unskilled) unemployment are workers coming from country $i$ and the ones who lose their jobs. The flows out of the skilled (unskilled) unemployment are workers who get a job and the ones who return to country $i$. The following equations show the equality of flows into and out of employment and unemployment,

$$H_i = E_{ii}^H + E_{ii}^{HL} + U_{ii}^H + E_{ij}^H + U_{ij}^H \tag{3.23}$$

$$1 - H_i = E_{ii}^L + U_{ii}^L + E_{ij}^L + U_{ij}^L \tag{3.24}$$

$$d(E_{ij}^\kappa + U_{ij}^\kappa) = \mu F(\bar{c}_i^\kappa) U_{ii}^\kappa \tag{3.25}$$

$$s^\kappa E_{ij}^\kappa = f(\theta_j^\kappa) U_{ij}^\kappa \tag{3.26}$$

$$[f(\theta_i^H) + f(\theta_i^L) + \mu F(\bar{c}_i^H))] U_{ii}^H = s^H E_{ii}^H + s^L E_{ii}^{HL} + d(E_{ij}^H + U_{ij}^H) \tag{3.27}$$

$$[f(\theta_i^L) + \mu F(\bar{c}_i^L)] U_{ii}^L = s^L E_{ii}^L + d(E_{ij}^L + U_{ij}^L). \tag{3.28}$$

With this system of equations, the steady state equilibrium is defined as a set of variables: the market tightness in skilled and unskilled labor market, the distribution of workers, and the reservation migration cost.

**Definition 2** *The steady state equilibrium in country i is a set of variables,* $\{\theta_i^H, \theta_i^L, U_{ii}^\kappa, E_{ii}^\kappa, U_{ji}^\kappa, E_{ji}^\kappa, E_{ii}^{HL}, \bar{c}$ *for all* $i \neq j \in \{1, 2\}$, $\kappa \in \{H, L\}$, *such that:* $\theta_i^H$ *satisfies (3.22);* $\theta_i^L$ *satisfies (3.21);* $\{U_{ii}^\kappa, E_{ii}^\kappa, U_{ji}^\kappa, E_{ji}^\kappa, E_{ii}^{HL}\}$ *satisfy (3.23) – (3.28);* $\bar{c}_i^\kappa$ *satisfies (3.20).*

The equilibrium in country $i$ is recursively solvable. Given any certain $\theta_i^\kappa$, the workers distribution at steady state is solved by equations (3.23) to (3.28). The wage is determined by equation (3.17) to (3.19). The reservation migration cost is given by (3.20).

At the end, (3.21) and (3.22) solve the equilibrium labor market tightness in $\kappa$-skilled labor market in country $i$. The solution of wages, unemployment and the reservation costs are presented in the appendix.

At the steady state, some of skilled workers in both country 1 and country 2 may migrate simultaneously but the flows of unskilled immigrants are only from country 2 to country 1. According to the assumption in this economy, skilled workers from country 1 have high productivity than skilled worker from country 2, even they are in country 2. When these skilled workers move to country 2, their unemployment benefit is relatively lower than when they are in country 1. Therefore, the surplus of a skilled job in country 2 with a skilled worker from country 1 can be high enough to compensate the migration cost of skilled workers from country 1. For unskilled workers from country 1, they have high productivity and unemployment benefit in country 1 so that there is no enough compensation to motivate them to relocate to country 2. Unskilled workers in country 2 benefit from the high productivity and unemployment benefit so that they are willing to move to country 1 and gain more from the match in country 1. Therefore, the match surplus of an unskilled job is always higher in country 1 than country 2.

**Proposition 10** *At steady state,*

*i)* $\bar{c}_1^H > 0$ *if*

$$\frac{\beta f(\theta_j^H) y_{ij}^H + (r + s^H + d) b_{ij}^H}{r + s^H + d + \beta f(\theta_j^H)} > \frac{b_{ii}^H + \beta f(\theta_i^H) y_{ii}^H/(r + s^H) + \beta f(\theta_i^L) y_{ii}^L/(r + s^L) + \mu_i \int_0^{\bar{c}_i^H} F(c)dc}{1 + \beta f(\theta_i^H)/(r + s^H) + \beta f(\theta_i^H)/(r + s^L)};$$

*ii)* $\bar{c}_2^H > 0$;

*iii)* $\bar{c}_1^L = 0$;

*iv)* $\bar{c}_2^L > 0$.

## 3.5 Calibration

The parameter value in the model is calibrated to the labor market data in the United States and Mexico. Assume that country 1 represents the U.S. and country 2 represents Mexico. All parameters are presented monthly. The population in the U.S. is normalized to 1 so that the population in Mexico is 1/3. According to Krusell et al. (2000a), skilled workers are defined as the ones who have at least a college degree and unskilled workers are defined as the ones who do not have any college education. According to IPUMS International 2010 in the U.S. and in Mexico, the measure of skilled worker is 0.3144 in the U.S. and 0.0265 in Mexico. The productivity gap between skilled and unskilled workers targets the wage premium of education. In the U.S., the productivity of skilled workers who were born in the U.S. is normalized to 1 and the productivity of U.S.-born unskilled workers is 0.4699. The productivity of mismatched U.S.-born skilled worker is 0.6833. The mismatch productivity targets to the wage gap between the skilled U.S.-born workers works with a unprofessional job and with a professional job in the U.S. There is also a productivity gap between workers who are from the U.S. and from Mexico. The productivity gap between two countries targets to the gap of the total factor productivity between two countries. Therefore, the productivity of Mexico-born skilled workers is 0.6944 and the productivity of unskilled Mexican is 0.1968. The productivity of mismatched skilled Mexican workers is 0.1240 that targets the wage gap between skilled Mexican workers with professional jobs and with unprofessional jobs. Because U.S. skilled workers have better education than Mexican skilled worker, the productivity of U.S.-born skilled workers works in Mexico is 0.9561, which targets the wage gap between U.S.-born and Mexican skilled workers. Mexican skilled and unskilled workers have the same productivity as U.S.-born skilled and unskilled workers when they work in the U.S. The U.S.-born unskilled workers also have the same productivity as Mexican unskilled workers. Since the productivity of skilled U.S. and Mexican workers in the the U.S. is the same, the wage gap between U.S. workers comes from the difference of the unemployment benefit. From IPUMS International U.S. data in 2010, the wage gap between skilled U.S. and Mexican workers is -0.4305. The unemployment benefit in the U.S. is 71% to the employment income from Hall (2005). Therefore, the unemployment benefit of U.S. skilled workers is 0.7345 and of Mexican skilled workers who work in the U.S. is 0.5134. The unemployment benefit in Mexico is 40% to the employment income, assuming that it is equal to the lower bound of the U.S. unemployment benefit from Shimer (2005). Therefore, the unemployment benefit of skilled and unskilled Mexicans are 0.2397 and 0.0774 respectively. The unemployment benefit of U.S.-born skilled and unskilled workers in Mexico targets to the wage gap between U.S. and Mexican unskilled workers in Mexican. As a result, the unemployment benefit of U.S.-born skilled and unskilled workers in Mexico is 0.2397 and 0.0774 respectively.

The matching function follows Petrongolo and Pissarides (2001), which is $m(V_i^H, U_i^H) = A(V_i^H)^{1-\alpha}(U_i^H)^{\alpha}$ for skilled labor market and $m(V_i^L, U_i^L + U_{ii}^H) = A(V_i^L)^{1-\alpha}(U_i^L + U_{ii}^H)^{\alpha}$. The unemployment elasticity of the matching function $\alpha$ is 0.5 from Petrongolo and Pissarides (2001). The bargaining power of workers $\beta$ is 0.5, which satisfies Hosios (1990b) condition. The value of the exogenous departure rate, separation rates in the skilled and unskilled labor market, and the labor market tightness in both country are from Chassamboulli and Peri (2015b), which are 0.0023, 0.024, 0.032, and 0.62 respectively. The matching technology $A$ targets the employment rate in the U.S., which is 0.9520 in the skilled labor market and 0.8743 in the unskilled labor market. As a result, the matching technology $A$ is equal to 0.3501. The constant recruitment cost in the skilled and unskilled labor market are 0.6906 and 0.0630, which are calibrated to the job creation conditions in the U.S. following equation (3.22) and (3.21) when $i = 1$. At the end, the arrival rate of migration opportunity $\mu$ is $1.0456 \times 10^{-4}$, which matches the flows of skilled workers from Mexico to the U.S.

## 3.6 Discussion: immigration policy examples

This section discusses three immigration policy examples that policy maker may be concerned about to attract or decrease immigrants.

### 3.6.1 Subsidy of firms

The US government can pay subsidy to encourage firms in the United States to hire more US-born workers. When firms in the United States match with a worker from the US, they can receive a one-time subsidy $\gamma$ from the government. Therefore the value of vacancies in the US becomes

$$r\mathcal{V}_1^H = -k^H + q(\theta_1^H)[\frac{U_{11}^H}{U_1^H}(\mathcal{J}_{11}^H + \gamma) + \frac{U_{21}^H}{U_1^H}\mathcal{J}_{21}^H] \tag{3.29}$$

$$r\mathcal{V}_1^L = -k^L + q(\theta_1^L)[\frac{U_{11}^L}{U_1^L + U_{11}^H}(\mathcal{J}_{11}^L + \gamma) + \frac{U_{11}^H}{U_1^L + U_{11}^H}(\mathcal{J}_{11}^{HL} + \gamma) + \frac{U_{21}^L}{U_1^L + U_{11}^H}\mathcal{J}_{21}^L]. \tag{3.30}$$

When firms receive the subsidy, the expected value of a match increases. The market tightness increases when more firms enter to the labor market in the United States. Therefore, the wages in the US increase and the unemployment in the US decreases. The U.S. labor markets become more attractive to Mexicans, both of skilled and unskilled workers. More Mexicans move to the US.

This policy also affects the labor markets in Mexico. When the labor market in the US is attractive, the reservation migration cost of Mexicans increases. This increase in the reservation migration cost drives the wage of both skilled and unskilled Mexicans increase and the unemployment rate of unskilled Mexicans decrease. According to equation (3.21), this increase in wages reduces the expected surplus of a filled job in Mexico. Therefore, the labor market tightnesses in Mexico decrease. The unemployment rate of skilled Mexicans increases because the effect of decreasing market tightnesses dominates the effect of the increasing reservation migration cost.

**Proposition 11** *With an increase in the subsidy $\gamma$, for all $\kappa \in \{H, L\}$,*

*i) the labor market tightness in the skilled-$\kappa$ market $\theta_1^\kappa$ in the U.S. increases;*

*ii) the wages of skilled-$\kappa$ in the U.S. increases;*

*iii) the unemployment rate in skilled-$\kappa$ in the U.S. decreases;*

*iv) the immigrants with skilled $\kappa$ from Mexico to the U.S. increases;*

*v) the skilled immigrants from the U.S. to Mexico increases.*

### 3.6.2 Taxation of firms

The US government taxes firms that hire foreign workers to reduce firms incentives to hire foreigners. When firms match with a Mexican, they need to pay a one-time tax $\phi$. Therefore the value of vacancies of firms in the US becomes

$$r\mathcal{V}_1^H = -k^H + q(\theta_1^H)[\frac{U_{11}^H}{U_1^H}\mathcal{J}_{11}^H + \frac{U_{21}^H}{U_1^H}(\mathcal{J}_{21}^H - \phi)] \tag{3.31}$$

$$r\mathcal{V}_1^L = -k^L + q(\theta_1^L)[\frac{U_{11}^L}{U_1^L + U_{11}^H}\mathcal{J}_{11}^L + \frac{U_{11}^H}{U_1^L + U_{11}^H}\mathcal{J}_{11}^{HL} + \frac{U_{21}^L}{U_1^L + U_{11}^H}(\mathcal{J}_{21}^L - \phi)]. \tag{3.32}$$

This tax makes the expected match value lower. Fewer firms enter the labor market in the U.S. therefore the labor market tightness decreases. The labor markets in the United States are less attractive to the Mexicans because the unemployment rate and wages in the United States decrease. As a result, the share of Mexicans in Mexico increases. Per the change in the labor markets in Mexico, the labor market tightnesses in Mexico decrease. The labor markets in Mexico are less attractive to US workers as well. Therefore, this taxation police decreases the labor mobility between Mexico and the US. Since the labor market tightness in skilled labor market in the US decreases, more skilled workers get a job in the unskilled labor market. Even though the unskilled labor market goes down with the tax as well, the mismatched workers from skilled labor market bring higher expected match surplus. This mismatch increases the market tightness in the unskilled labor market in the US.

**Proposition 12** *With an increase in $\phi$, or all $\kappa \in \{H, L\}$,*

*i) the labor market tightness of the skilled-$\kappa$ labor market in the U.S. decreases;*

*ii) the unemployment of skilled-$\kappa$ labor market in the U.S. increases;*

*iii) the wages of skilled-$\kappa$ workers in the U.S. decrease;*

*iv) the skilled-$\kappa$ immigrants from Mexico to the U.S. decrease;*

*v) the skilled immigrants from the U.S. to Mexico decreases.*

### 3.6.3 Taxation of Mexicans

Another way to control the Mexican immigrants move to the United States is to tax them and control their migration cost. If Mexicans decides to search in the labor market the U.S., they need to pay additional tax $\tau$, such like an application fee for the working permit. Therefore the value functions of unemployed Mexicans become

$$r\mathcal{U}_{22}^H = b_{22}^H + f(\theta_2^H)(\mathcal{W}_{22}^H - \mathcal{U}_{22}^H) + f(\theta_2^L)(\mathcal{W}_{22}^{HL} - \mathcal{U}_{22}^H) + \mu \int_0^\infty \max\{\mathcal{U}_{21}^H - \mathcal{U}_{22}^H - \tau - c, 0\} dF(c) \tag{3.33}$$

$$r\mathcal{U}_{22}^L = b_{22}^L + f(\theta_2^L)(\mathcal{W}_{22}^L - \mathcal{U}_{22}^L) + \mu \int_0^\infty \max\{\mathcal{U}_{21}^L - \mathcal{U}_{22}^L - \tau - c, 0\} dF(c). \tag{3.34}$$

The tax on Mexicans reduces the surplus of migration to the United States. This taxation discourages these Mexican workers immigrate to the United States. Therefore, the share of Mexicans in the labor force in the United States decreases. When the share of Mexicans decreases, the expected surplus of a match in the US decreases since Mexicans provide higher surplus in the US. When more Mexicans stay in Mexico and the surplus of migration decreases, the expected surplus

**Proposition 13** *With an increase in $\tau$, for all $\kappa \in \{H, L\}$,*

*i) the labor market tightness in the skilled labor market in the U.S. increases; the labor market tightness in the unskilled labor market in the U.S. decreases;*

*ii) the unemployment of the skilled labor market in the U.S. decreases; the unemployment of the unskilled labor market in the U.S. increases;*

*iii) the wages of skilled-$\kappa$ workers in the U.S. decrease;*

*iv) the immigrants with skill $\kappa$ from Mexico to the U.S. decrease;*

*v) the skilled immigrants from the U.S. to Mexico increase.*

The change on the worker distribution decreases the expected revenue of a match in the United States. The labor market tightness in the unskilled labor market in the United States decreases. However, the labor market tightness in the skilled labor market in the United States increases. More US-born workers move out of the US to Mexico.

## 3.7 Conclusion

This paper studies policy examples that can control the number of immigrants. I apply a search and matching framework to model the migration behavior with two skill-bias labor markets and two countries. In this model, all unemployed workers encounter with a migration opportunity with heterogenous migration cost. If the migration cost is low enough, workers search and work in the foreign country. The model is calibrated to the labor market data in the US and Mexico and captures the labor mobility between the US and Mexico.

The model is able to predict effects of immigration policies. The subsidy to firms who hire native workers in the US attracts more Mexicans to move to the US, since the US labor markets become better. The tax to firms who hire Mexico decreases the labor mobility between the US and Mexico, because the labor market in the US goes down. The tax to

Mexicans who move to the US discourage Mexicans to move to US as the migration cost goes up. The subsidy to the US-born workers search in Mexico attracts US-born workers move to Mexico.

# Chapter 4

# Immigration and overeducation in the US

## 4.1 Introduction

How do immigrants affect the labor market in the US? This question have been debated for a long time. Existing research focus on the impact of immigration on unemployment and wages of natives. Native workers benefit from immigrants in term of employment. However, do these native workers work for a job that match their skill? To answer this question, this paper constructs a model based on the Pissarides labor search and matching model. The model provides a theoretical explanation of the mismatch in the labor market in the US. Moreover, it also predicts a quantitative measure of mismatch with and without foreign workers.

Since the 1970s, people realize that the unemployment rate persists on a high rate and wage inequality become larger. These issues attract people's attention and they try to explain these problems. Şahin et al. (2014) provide three reason to explain this situation. First, there are no enough aggregate labor demand. Second, higher unemployment benefit keeps people being unemployed longer. The third reason is that mismatch becomes a severe issue in U.S. labor market. When people look at the wage differential, they believe that it happened only cross sections or skills, e.g. high school graduate and college graduate. However, recent empirical research shows that this wage inequality not only occurs across sections, but also occurs in the same section. People widely believe that workers obtain more education than they need for jobs. Freeman (1976) states that Americans are overeducated because of the falling college-high school wage differential.

Wage inequality caused by mismatch are even more severe among immigrants. Borjas (2005) indicates that high-skill immigrants increase 10% of labor supply but reduce 3% of earning of their cohort. Beckhusen et al. (2013) give empirical evidence that immigrants suffer much more overeducation than native workers in United States. Aleksynska and Tritah (2013) provide that 22% of immigrants are mismatched in Europe, compared with 13% overeducated native workers. Because immigrants have lower outside option, they are not only willing to accept lower wages of skilled jobs, but to accept unskilled jobs. The other reason that immigrants have higher overeducation rate is that they are imperfect for human capital transferability. Liu et al. (2014) mention that this imperfect transferability of human capital is caused by lack of language skills, cultural and economic difference, and occupational licensing requirement. Also, Nielsen (2011) points out that the human capital acquired in their original countries is costed less than the one acquired in the destination countries.

In this paper, I study the impacts of immigration with mismatch and imperfect substitution between unskilled native workers and immigrants, following search and matching approach. To introducing the imperfect substitution between unskilled native workers and immigrants, I apply the production function from Acemoglu (2001). There are two sectors in the production section, final good and intermediate good. Unskilled workers, either native workers or immigrants, produce intermediate good. Final good is produced by skilled labor input and intermediate good. Both labor markets and intermediate good market are competitive. The difference between native workers and immigrants are unemployment benefit, which is lower for immigrants. In this model, skilled workers choose to search in skilled or unskilled labor market. There are two equilibria. One equilibrium is that there is no mismatch exists. If the population of skilled workers is too limited, the price of skilled intermediate good is high enough such that the value of searching in the skilled labor market is greater than searching in the unskilled labor market. The other equilibrium is that the population of skilled workers is too large such that skilled workers are indifferent to search in the skilled or unskilled labor market. Overeducation exists in this equilibrium. This equilibrium is solved recursively and the equilibrium underemployment can be measured.

When the population of skilled immigrants increases, it affects labor market outcomes in two channels. The first channel is the price channel. According to the production function, the price of skilled intermediate good decreases with an increase in the skilled labor. Skilled immigrants are only allowed to search in the skilled labor market so that they directly increase the labor in the skilled labor market. Therefore, the price of skilled intermediate good drops. The overeducation enlarges because of the worse labor market outcomes in the skilled labor market. On the other hand, the expected surplus of skilled filled jobs increases with this increase in the population of skilled immigrants. Compared with skilled native workers, skilled immigrants have worse outside options so that they accept lower wages than natives. Since the labor cost decreases with an increase in skilled immigrants, the expected surplus goes up and makes labor market outcomes better off. Overeducation declines as skilled workers prefer to stay in the skilled labor market.

To see the overall effect of skilled immigration on overeducation, this paper adopts the mismatch index from Şahin et al. (2014). This index measures the loss of matches by mismatch. With this measure, I can compare the mismatch before and after the population of skilled immigrants increases. I am going to use the vacancies data from the Help Wanted OnLine (HWOL) dataset provided by The Conference Board (TCB) and the unemployment data from the Current Population Survey (CPS) to measure the mismatch index quantitatively.

Related Literature as following. Chassamboulli and Palivos (2014) study immigration impact on labor market with skill heterogeneity. They apply the Acemoglu production function to introduce the imperfect substitution between labor and capital. Their work shows that immigration can benefit unskilled native workers on both unemployment and wages. Skilled native workers can only be benefited on unemployment under perfect substitution, but benefited on both of unemployment and wages under imperfect substitution.

Ortega (2000) studies two-country immigration, i.e. workers can choose to immigrate or not. Compared social welfare of an economy with and without immigration, he proves that immigration is Pareto improving. The closest study is Liu et al. (2014). The differences between my paper and their work are that 1) they do not consider the imperfect substitution between native workers and immigrants; 2) they introduce different search cost between native workers and immigrants but I differ native workers and immigrants by using different unemployment benefit.

## 4.2 Social planner's problem

Time is discrete and indexed by $t$. The economy has two sectors, the final good sector and the intermediate good sectors. There are two types of intermediate goods, skilled and unskilled intermediate goods. Firms in the intermediate good sectors enter the skilled or unskilled labor markets and hire workers from them. Firms in the final good sector produce final good by using the skilled and unskilled intermediate good, following the production function

$$Y = A[\alpha Y_H^\rho + (1-\alpha)Y_L^\rho]^{1/\rho}, \tag{4.1}$$

where $A$ is the production efficiency, $\alpha$ is the share of skilled intermediate good, $\rho$ is given by the substitution between skilled and unskilled goods. The variable $Y_H$ represents the skilled intermediate good and $Y_L$ represents the unskilled intermediate good. Assume that every employed worker can produce one unit of skilled/unskilled intermediate good, which depends on the labor market that they are employed. The price of skilled and unskilled intermediate good are

$$p_H = A[\alpha + (1-\alpha)(\frac{Y_L}{Y_H})^{\rho}]^{\frac{(1-\rho)}{\rho}} \tag{4.2}$$

$$p_L = A[\alpha(\frac{Y_H}{Y_H})^{\rho} + (1-\alpha)]^{\frac{(1-\rho)}{\rho}} \tag{4.3}$$

The labor markets are frictional. The total labor force is normalized and it equals to the sum of employed and unemployed workers in both labor markets, i.e. $\sum(e_{it} + u_{it}) = 1$. Each unemployed workers searches in one labor market only. Workers match with vacancies following a matching function $m(v_i, u_i)$. The variable $v_i$ represents the number of vacancies in market $i$ and $u_i$ represents the number of unemployed workers search in market $i$. The matching function $m(v_i, u_i)$ is strictly increasing and concave in both arguments and homogeneous of degree one in $(v_i, u_i)$.

In each period, activities are as follows. At the beginning of every period, the employment $e_{it}$ in the labor markets are given from the last period. The vacancies in each labor market is drawn from a distribution $F(v_t)$. The social planner allocates unemployed skilled workers into skilled and unskilled labor market without labor mobility cost. After these skilled workers are allocated, they search in the market that they are allocated. Unskilled workers are only able to search in the unskilled labor market. Workers matches with vacancies at rate $f(\theta_i)$, which is defined as $f(\theta_i) = m(v_i, u_i)/u_i$. The variable $v_i$ is the number of vacancies in market $i$ and $u_i$ is the number of unemployed workers that search in the labor market $i$. The variable $\theta_i$ is defined as the market tightness of market $i$, which is the ratio of vacancies to unemployment. When workers matches with a vacancies, they start producing the intermediate good $Y_i$. At the end of the period, there is a job separation shock at rate $\delta_i$. The social planner's problem is written as follow,

$$V(E_{HH}, E_{HL}, E_{LL}; V_H, V_L) = \max_{U_{HL}, U_{HH}} F(Y_H, Y_L) + \beta V(E'_{HH}, E'_{HL}, E'_{LL}; V'_H, V'_L) \tag{4.4}$$

$$s.t. N_L = E_{LL} + U_{LL}$$

$$N_H = E_{HH} + U_{HH} + E_{HL} + U_{HL}$$

$$Y_H = E_{HH} + m(v_H, U_{HH})$$

$$Y_L = E_{LL} + E_{HL} + m(v_L, U_{HL} + U_{LL})$$

$$E'_{HH} = (1 - \delta_H)(E_{HH} + m(v_H, U_{HH}))$$

$$E'_{HL} = (1 - \delta_L)(E_{HL} + U_{HL} m(v_L, U_{HL} + U_{LL})/(U_{HL} + U_{LL}))$$

$$E'_{LL} = (1 - \delta_L)(E_{LL} + U_{LL} m(v_L, U_{HL} + U_{LL})/(U_{HL} + U_{LL})).$$

To solve this maximization problem, I obtain the optimal allocation condition of the centralized economy. According to the first order condition,

$$m_2(v_H, U_{HH}) = f(\theta_L) + U_L \frac{\partial f(\theta_L)}{\partial U_{HL}}, \tag{4.5}$$

where $f(\theta_L) = m(v_L, U_{HL} + U_{LL})/(U_{HL} + U_{LL})$. Assume that the matching function is Cobb-Douglas, which is $m(v_i, U_i) = \phi_i v_i^{\varphi} U_i^{1-\varphi}$. The first order condition can be rewritten as

$$\phi_H \theta_H^{\varphi} = \phi_L \theta_L^{\varphi}, \tag{4.6}$$

where $\phi_i$ is the efficiency of labor market $i$ and $\theta_i \equiv v_i/U_i$ is the market tightness of labor market $i$.

## 4.3 Decentralized markets

In decentralized markets, unemployed skilled workers choose to search in either skilled or unskilled labor market. If a skilled unemployed worker chooses to search in unskilled labor market and matches a unskilled job, she is the one that underemployed.

All immigrants in this economy are skilled immigrants. They are not allowed to search in the unskilled labor market, according to the working visa restriction. The difference between immigrants and native workers is that the unemployment benefits of immigrants are lower than the ones of native workers.

### 4.3.1 Workers

In period $t$, if a worker is employed, she earns wage $w_{ij}^{\kappa}$, which depends on her immigration status $\kappa$, her skilled $i$ and the labor market $j$ that she works, where $i \in \{H, L\}$, $j \in \{H, L\}$ and $\kappa \in \{N, I\}$. The variable $H$ represents skilled worker/skilled labor market, $L$ represents unskilled worker/unskilled labor market, $N$ represents natives, and $I$ represents immigrants. For example, if a skilled immigrant worker works in a unskilled job, her wage is $w_{HL}^{I}$. She may lose her job at the end of the period at rate $\delta_j$. Therefore, the value function of an employed worker is

$$\mathcal{W}_{ij}^{\kappa} = w_{ij}^{\kappa} + \beta[(1 - \delta_j)\mathcal{W}_{ij}^{\kappa} + \delta_j \mathcal{U}_{ij}^{\kappa}]. \tag{4.7}$$

For an unemployed worker, if she is unskilled, she searches in the unskilled labor market only. For a skilled unemployed native worker, she can choose to search in the skilled or unskilled labor market by comparing the value of searching, which is

$$\mathcal{U}_H^N = \max\{\mathcal{U}_{HH}^N, \mathcal{U}_{HL}^N\}. \tag{4.8}$$

Any unemployed workers receive a flow of unemployment benefits $b_{ij}^{\kappa}$ in period $t$. During period $t$, they may match a vacant job and become an employed worker at rate $f(\theta_j)$. Thus the value function of skilled and unskilled workers as follow respectively,

$$\mathcal{U}_{HH}^{\kappa} = b_{HH}^{\kappa} + \beta[f(\theta_H)\mathcal{W}_{HH}^{\kappa} + (1 - f(\theta_H))\mathcal{U}_{HH}^{\kappa}] \tag{4.9}$$

$$\mathcal{U}_{HL}^N = b_{HL}^N + \beta[f(\theta_L)\mathcal{W}_{HL}^N + (1 - f(\theta_L))\mathcal{U}_{HL}^N] \tag{4.10}$$

$$\mathcal{U}_{LL}^N = b_{LL}^N + \beta[f(\theta_L)\mathcal{W}_{LL}^N + (1 - f(\theta_L))\mathcal{U}_{LL}^N]. \tag{4.11}$$

### 4.3.2 Firms

Firms enter both of markets freely. Assume that they are all small firms and each firm has one job, either vacant or filled. If a firm holds a vacant job in a labor market $j$, it pays a flow of recruitment cost $k_j$. It may match an unemployed worker at rate $q(\theta_j)$. This firm starts producing intermediate good in next period. If it do not match with a worker, the vacancy passes to next period. Firms in the skilled labor market match skilled workers only. Since skilled workers are able to search in both of skilled and unskilled labor market, firms in the unskilled labor market may hire a skilled or unskilled worker, which is different from firms in the skilled labor market. The value functions of vacant jobs in the skilled and unskilled labor markets are

$$\mathcal{V}_H = -k_H + \beta[q(\theta_H)\mathcal{J}^e_{HH} + (1 - q(\theta_H))\mathcal{V}_H] \tag{4.12}$$

$$\mathcal{V}_L = -k_L + \beta[q(\theta_L)\mathcal{J}^e_L + (1 - q(\theta_L))\mathcal{V}_L], \tag{4.13}$$

where $\mathcal{J}^e_{HH} = (U^N_{HH}/U_{HH})\mathcal{J}^N_{HH} + (U^I_{HH}/U_{HH})\mathcal{J}^I_{HH}$, $\mathcal{J}^e_L = (U_{HL}/U_L)\mathcal{J}_{HL} + (U_{LL}/U_L)\mathcal{J}_{LL}$, $U_L = U_{HL} + U_{LL}$, and $U_{HH} = U^I_{HH} + U^N_{HH}$. If a firm hires a worker and has a filled job, it produces intermediate good $j$ and sells it to a final producer in the competitive intermediate good market. Meanwhile, the firm pays $w_{ij}$ to the worker that it hires. At the end of the period, this job may be destroyed at rate $\delta_j$. The value functions of filled jobs in the skilled labor market is

$$\mathcal{J}^\kappa_{ij} = p_j - w^\kappa_{ij} + \beta[(1 - \delta_j)\mathcal{J}^\kappa_{ij} + \delta_j\mathcal{V}_j]. \tag{4.14}$$

### 4.3.3 Wage determination

The wage is determined by Nash bargaining when firms and workers match. Closely following the traditional Pissarides labor search and matching model, the wage maximizes the surplus of a match, i.e.,

$$w^\kappa_{ij} = \arg\max(\mathcal{W}^\kappa_{ij} - \mathcal{U}^\kappa_{ij})^\xi(\mathcal{J}^\kappa_{ij} - \mathcal{V}_j)^{1-\xi} \tag{4.15}$$

where $\xi$ is the bargaining power of workers. The wage of a worker with immigration status $\kappa$ and skill $i$ works in labor market $j$ is

$$w_{ij}^{\kappa} = \frac{\xi(1-\beta(1-\delta_j - f(\theta_j)))p_j + (1-\xi)(1-\beta(1-\delta_j))b_{ij}^{\kappa}}{1-\beta(1-\delta_j)+\xi\beta f(\theta_j)}. \tag{4.16}$$

### 4.3.4 Workers flows

Workers flows in this economy depends on the type of workers. For unskilled native workers, they find jobs in the unskilled labor market at rate $f(\theta_L)$ if they are unemployed or lose their jobs at rate $\delta_L$ if they are employed. For skilled native workers, they find jobs in the skilled labor market at rate $f(\theta_H)$ if they decide to search in the skilled labor market. Otherwise, they find jobs in the unskilled labor market at rate $f(\theta_L)$. If a skilled native worker is unemployed in skilled/unskilled labor market, she loses her job at rate $\delta_H$ or $\delta_L$. For skilled immigrants, their flows are similar as unskilled native workers since they are not allowed to search in the unskilled labor market. The flows are represents as following graphs.

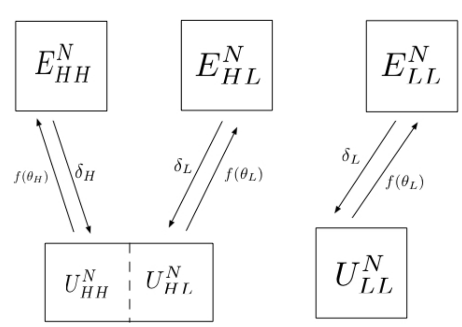


Figure 4.1: Flows of native workers

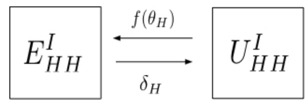


Figure 4.2: Flows of immigrants

At the steady state, inflows and outflows are equal. The distribution of workers are given by the equality of inflows and outflows. The measure of skilled native workers $N_H$, unskilled native workers $N_L$ and skilled immigrants $I_H$ are exogenous. The total population of native workers is normalized, which is $N_H + N_L = 1$. The steady state workers distribution is solved by following equation system,

$$N_H + N_L = 1 \tag{4.17}$$

$$U_{HH}^{N} + U_{HL}^{N} + E_{HL}^{N} + E_{HH}^{N} = N_H \tag{4.18}$$

$$U_{LL}^{N} + E_{LL}^{N} = N_L \tag{4.19}$$

$$U_{HH}^{I} + E_{HH}^{I} = I_H \tag{4.20}$$

$$f(\theta_H)U_{HH}^{N} = \delta_H E_{HH}^{N} \tag{4.21}$$

$$f(\theta_H)U_{HH}^{I} = \delta_H E_{HH}^{I} \tag{4.22}$$

$$f(\theta_L)U_{HL}^{N} = \delta_L E_{HL}^{I} \tag{4.23}$$

$$f(\theta_L)U_{LL}^{N} = \delta_L E_{LL}^{N}. \tag{4.24}$$

Therefore, the unemployment of each type of workers are

$$U_{HH}^{I} = \frac{I_H \delta_H}{f(\theta_H) + \delta_H} \tag{4.25}$$

$$U_{LL}^{N} = \frac{N_L \delta_L}{f(\theta_L) + \delta_L} \tag{4.26}$$

$$[1 + \frac{f(\theta_H)}{\delta_H}]U_{HH}^{N} + [1 + \frac{f(\theta_L)}{\delta_L}]U_{HL}^{N} = N_H. \tag{4.27}$$

### 4.3.5 Equilibrium

The equilibrium can be solved recursively. The wage is determined by Nash bargaining in section 3.3. The workers distribution is given by the workers flows in section 3.4. According to the free entry condition, the job creation conditions in skilled and unskilled labor market are

$$\frac{k_H}{\beta q(\theta_H)} = \mathcal{J}_{HH}^{e} \tag{4.28}$$

$$\frac{k_L}{\beta q(\theta_L)} = \mathcal{J}_{L}^{e} \tag{4.29}$$

and

$$\mathcal{J}_{HH}^{e} = \frac{p_H - w_{HH}^{e}}{\beta(1 - \delta_H)} \tag{4.30}$$

$$\mathcal{J}_{L}^{e} = \frac{p_L - w_{L}^{e}}{\beta(1 - \delta_L)}. \tag{4.31}$$

The expected wage in the skilled labor market is

$$w_{HH}^{e} = (U_{HH}^{N}/U_{HH})w_{HH}^{N} + (U_{HH}^{I}/U_{HH})w_{HH}^{I} \tag{4.32}$$

and the expected wage in the unskilled labor market is

$$w_L^e = (U_{LL}^N / U_L) w_{LL}^N + (U_{HL}^N / U_L) w_{HL}^I. \tag{4.33}$$

**Definition 3** *The equilibrium is defined as a sequence of variables* $\{\theta_j, U_{ij}^{\kappa}, w_{ij}^{\kappa}, p_j\}$ *for all* $i, j \in \{H, L\}$ *and* $\kappa \in \{N, I\}$ *such that:* $\theta_j$ *is determined by (4.28) and (4.29);* $U_{ij}^{\kappa}$ *is determined by (4.25) to (4.27);* $w_{ij}^{\kappa}$ *is determined by (4.16); and* $p_j$ *is determined by (4.2) and (4.3).*

At the equilibrium, for skilled unemployed workers, the value of searching in the skilled labor market is greater or equal the value of searching in the unskilled labor market. If the value of searching in the skilled labor market is higher than the value of searching in the unskilled labor market, all skilled workers stay in the skilled labor market. There is no underemployment in this case. If the value of searching in unskilled labor market is greater than the value of searching in the skilled labor market, all skilled workers move to the unskilled labor market and no one is in the skilled labor market. Therefore, the price of skilled intermediate good goes to infinite and makes the value of searching in the skilled labor market higher than the value of searching in the unskilled labor market. When they search in the skilled labor market, they are able to get high value of employment as a skilled worker but they need to wait longer time for this skilled job. When these skilled unemployed workers search in the unskilled labor market, they can get a job fast but accept that their value of employment as an unskilled worker cannot be higher than as a skilled worker.

**Proposition 14** *There is no overeducation exists if* $\mathcal{U}_{HH}^N > \mathcal{U}_{HL}^N$.

**Proposition 15** *There exists overeducation if and only if* $\mathcal{U}^N_{HL} = \mathcal{U}^N_{HH}$.

## 4.4 Effects of skilled immigrants

This section discusses the effects of skilled immigrants. When the population of skilled immigrants increases, there are more skilled intermediate good. It directly lowers the price of skilled intermediate good $p_H$. This is the price effect. When $p_H$ decreases, the surplus of a skilled filled job decreases so that the skilled labor market is worse off.

**Proposition 16** *The price of intermediate good* $p_H$ *decreases with an increase in* $I_H$.

On the other hand, skilled immigrants have low value of unemployment. The expected surplus of a skilled filled job increases with an increase in the share of skilled immigrants. This effect is called the composition effect.

**Proposition 17** *The expected value of a match* $\mathcal{J}^e_{HH}$ *increases with an increases in* $I_H$.

## 4.5 Mismatch index: quantitative examination

To measure the overeducation, I apply the definition of mismatch index from Şahin et al. (2014).

$$\mathcal{M} = 1 - \frac{\sum m(v_i, u_i)}{\sum m(v_i, u_i^*)} \tag{4.34}$$

It provides a method to look at the overall effect of skilled immigration on overeducation. This mismatch index compares loss of the total match when overeducation exists. The numerator of the second term is the total number of matches in the decentralized market and the denominator is the total number of matches in the social planner's problem.

I am going to use the vacancies data from the Help Wanted OnLine (HWOL) dataset provided by The Conference Board (TCB) and the unemployment data from the Current Population Survey (CPS) to measure the mismatch index quantitatively. HWOL provides the information of vacancy posting, including the education requirement of each vacancy since 2005. The model will be calibrated by using HWOL and CPS in 2005 for the measure of vacancies and unemployment. Also, other parameter values will be calibrated by using CPS in 2005.

To see the overall effect of skilled immigration on this mismatch index, I will increase the measure of skilled immigrants, which is the same as the CPS from 2005 to 2015. This numerical exercise is going to show how skilled immigrants congest job opportunities from domestic workers or create jobs for all workers in the skilled labor market.

## 4.6 Conclusion

This paper studies the effects of skilled immigrants on the measure of underemployment in the United States. The model is based on skilled-bias labor market with search frictions. Compared with the optimal allocation of unemployed workers by solving the social planner's problem, the model provides two equilibria. If there are no enough skilled workers in the skilled labor market, the overeducation does not exist. The overeducation exists only when the number of skilled workers are too big and skilled workers are indifferent to search in the skilled or unskilled labor market. This theoretical framework provides two channels that skilled immigrants affect the mismatch in the labor market. The price channel implies that the price of skilled intermediate good decreases with an increase in skilled immigrants. While the composition effect shows that the expected match surplus goes up because skilled immigrants have worse outside options than domestic workers. Thus, the job creation goes up and there is less mismatch.

The next step of this paper is to calibrate the model by using HWOL and CPS in 2005. To look at the overall effect of skilled immigrants, I will increase the measure of skilled immigrants from CPS in 2005 to 2015. With the numerical exercise, I am able to find the overall effect of skilled immigrants on the mismatch.

# Chapter 5

# Conclusions

These three essays study the immigration impacts on labor market outcomes using the frictional labor market framework. Chapter 2 shows the impact of immigration on labor market outcomes and crime is determined by a direct and an indirect channel. The direct channel shows that skilled immigrants decrease the property crime rate while unskilled immigrants drive up the property crime rate directly. The indirect channel through the frictional labor market shows that an increase in immigrants improves labor market outcomes. Thus, unemployed workers are less likely to commit crimes.

Quantitatively, the effects on the indirect channel dominates and the crime rate decreases with an increase in the number of immigrants. The model also runs policies experiments. With a more generous unemployment insurance system for immigrants, the unemployment rate and the crime rate increases, and the wages of native workers decrease. A longer prison duration and deportation lower the crime rate by increasing the opportunity cost of committing a crime. The former affects the criminal behavior of both native and immigrant workers, but the latter affects only the criminal behavior of immigrants. Thus, the magnitude of the effect of incarceration is larger than the deportation policy.

Chapter 3 examines the migration behavior of workers. The labor-oriented immigrants take labor market conditions of both the home country and destination country. I apply a search and matching framework to model the migration behavior with two skill-bias labor markets and two countries. In this model, all unemployed workers encounter with a migration opportunity with heterogenous migration cost and there is a double-direction labor mobility between a developed and a developing country exists in the skilled labor market. However, workers in the unskilled labor market only move from the developing country to the developed country. The model is able to predict effects of immigration policies. The model is calibrated to the labor market data in the US and Mexico and captures the labor mobility between the US and Mexico. A subsidy to firms who hire native workers in the US attracts more Mexicans to move to the US, since the US labor markets improve. Taxing firms who hire Mexican workers decrease the labor mobility between the US and Mexico, because the labor market tightness in the US goes down. A tax on Mexicans who move to the US discourage Mexicans to move to US as the migration cost goes up. Subsiding to US-born workers to search in Mexico attracts US-born workers to move to Mexico.

Chapter 4 studies the effects of skilled immigrants on the measure of underemployment in the United States. The model is based on skilled-bias labor market with search frictions. Skilled workers are able to search in the skilled or unskilled labor market. Overeducation exists only when the number of skilled workers are too large and skilled workers are indifferent to search in the skilled or unskilled labor market. This theoretical framework provides two channels that cause mismatch in the labor market for skilled immigrants. The price channel implies that the price of intermediate goods produced by skilled workers decreases with an increase in skilled immigrants. The cost channel shows that skilled immigrants lower the expected labor cost. Therefore, firms are encouraged to post more vacancies in the skilled labor market, the job creation increases and there is less mismatch.

# Bibliography


Acemoglu, D. (2001). Good jobs versus bad jobs. *Journal of Labor Economics*, 19(1):1–21.

Alba-Ramirez, A. (1993). Mismatch in the spanish labor market: overeducation? *Journal of Human Resources*, pages 259–278.

Albrecht, J. and Vroman, S. (2002). A matching model with endogenous skill requirements. *International Economic Review*, 43(1):283–305.

Aleksynska, M. and Tritah, A. (2013). Occupation–education mismatch of immigrant workers in europe: Context and policies. *Economics of Education Review*, 36:229–244.

Alonso-Borrego, C., Garoupa, N., and Vzquez, P. (2012). Does immigration cause crime? evidence from spain. *American Law and Economics Review*, 14(1):165–191.

Aydemir, A. and Borjas, G. J. (2007). Cross-country variation in the impact of international migration: Canada, mexico, and the united states. *Journal of the European Economic Association*, 5(4):663–708.

Baker, M. and Benjamin, D. (1994). The performance of immigrants in the canadian labor market. *Journal of labor economics*, pages 369–405.

Basso, G. and Peri, G. (2015). The association between immigration and labor market outcomes in the united states. *IZA Discussion Paper*.

Battisti, M., Felbermayr, G., Peri, G., and Poutvaara, P. (2014). Immigration, search frictions and redistribution: A quantitative welfare analysis. In *International conference on International labor mobility and inequality across nations*, volume 23.

Becker, G. (1968). Crime and punishment: an optimal approach. *Journal of Political Economy*, 76:169–217.

Beckhusen, J., Florax, R. J., Poot, J., and Waldorf, B. S. (2013). Attracting global talent and then what? overeducated immigrants in the united states. *Journal of Regional Science*, 53(5):834–854.

Bell, B., Fasani, F., and Machin, S. (2013). Crime and immigration: Evidence from large immigrant waves. *The Review of Economics and Statistics*, 95(4):1278–1290.

Bell, B. D. (1997). The performance of immigrants in the united kingdom: evidence from the ghs. *The Economic Journal*, 107(441):333–344.

Bianchi, M., Buonanno, P., and Pinotti, P. (2012). Do immigrants cause crime? *Journal of the European Economic Association*, 10(6):1318–1347.

Borjas, G. J. (1987). Self-selection and the earnings of immigrants. *The American Economic Review*, pages 531–553.

Borjas, G. J. (2003a). The labor demand curve is downward sloping: Reexamining the impact of immigration on the labor market*. *The Quarterly Journal of Economics*, 118(4):1335–1374.

Borjas, G. J. (2003b). The labor demand curve is downward sloping: Reexamining the impact of immigration on the labor market. Technical report, National Bureau of Economic Research.

Borjas, G. J. (2005). The labor-market impact of high-skill immigration. *American Economic Review*, 95(2):56–60.

Borjas, G. J. (2017). The labor supply of undocumented immigrants. *Labour Economics*, 46:1–13.

Borjas, G. J. and Friedberg, R. M. (2009). Recent trends in the earnings of new immigrants to the united states. Technical report, National Bureau of Economic Research.

Borjas, G. J., Grogger, J., and Hanson, G. H. (2008). Imperfect substitution between immigrants and natives: a reappraisal. Technical report, National Bureau of Economic Research.

Borjas, G. J., Grogger, J., and Hanson, G. H. (2011). Substitution between immigrants, natives, and skill groups. Working Paper 17461, National Bureau of Economic Research.

Boyd, M. and Thomas, D. (2001). Match or mismatch? the employment of immigrant engineers in canada's labor force. *Population Research and Policy Review*, 20(1-2):107–133.

Burdett, K., Lagos, R., and Wright, R. (2003). Crime, inequality, and unemployment. *American Economic Review*, 93(5):1764–1777.

Burdett, K., Lagos, R., and Wright, R. (2004). An on-the-job search model of crime, inequality, and unemployment. *International Economic Review*, 45(3):681–706.

Butcher, K. F. and Piehl, A. M. (1998). Cross-city evidence on the relationship between immigration and crime. *Journal of Policy Analysis and Management*, 17(3):457–493.

Butcher, K. F. and Piehl, A. M. (2007). Why are immigrants' incarceration rates so low? evidence on selective immigration, deterrence, and deportation. Working Paper 13229, National Bureau of Economic Research.

Card, D. (2009a). Immigration and inequality. *American Economic Review*, 99(2):1–21.

Card, D. (2009b). Immigration and inequality. Technical report, National Bureau of Economic Research.

Chassamboulli, A. and Palivos, T. (2013a). The impact of immigration on the employment and wages of native workers. *Journal of Macroeconomics*, 38:19 – 34. Dynamics, Economic Growth and International Trade.

Chassamboulli, A. and Palivos, T. (2013b). The impact of immigration on the employment and wages of native workers. *Journal of Macroeconomics*, 38:19 – 34. Dynamics, Economic Growth and International Trade.

Chassamboulli, A. and Palivos, T. (2014). A search-equilibrium approach to the effects of immigration on labor market outcomes. *International Economic Review*, 55(1):111–129.

Chassamboulli, A. and Peri, G. (2015a). The labor market effects of reducing the number of illegal immigrants. *Review of Economic Dynamics*, 18(4):792 – 821.

Chassamboulli, A. and Peri, G. (2015b). The labor market effects of reducing the number of illegal immigrants. *Review of Economic Dynamics*, 18(4):792–821.

Chiswick, B. R. (1978). The effect of americanization on the earnings of foreign-born men. *Journal of Political Economy*, 86(5):897–921.

Chiswick, B. R. and Miller, P. W. (2009). The international transferability of immigrants? human capital. *Economics of Education Review*, 28(2):162–169.

Chiswick, B. R. and Miller, P. W. (2010). The effects of educational-occupational mismatch on immigrant earnings in australia, with international comparisons1. *International Migration Review*, 44(4):869–898.

Cuesta, M. B. (2005). Youth labour market integration in spain: Search time, job duration and skill mismatch. *Spanish Economic Review*, 7(3):191–208.

Dai, T., Liu, X., and Xie, B. (2013). The impact of immigrants on host country crime. *Economics Letters*, 119(2):157–161.

Docquier, F., Ozden, Ç., and Peri, G. (2014). The labour market effects of immigration and emigration in oecd countries. *The Economic Journal*, 124(579):1106–1145.

Dolado, J. J., Jansen, M., and Jimeno, J. F. (2009). On-the-job search in a matching model with heterogeneous jobs and workers. *The Economic Journal*, 119(534):200–228.

Dustmann, C., Frattini, T., and Preston, I. P. (2013). The effect of immigration along the distribution of wages. *The Review of Economic Studies*, 80(1):145–173.

Engelhardt, B. (2010). The effect of employment frictions on crime. *Journal of Labor Economics*, 28(3):677–718.

Engelhardt, B., Rocheteau, G., and Rupert, P. (2008). Crime and the labor market: A search model with optimal contracts. *Journal of Public Economics*, 92(10):1876 – 1891.

Fougère, D., Kramarz, F., and Pouget, J. (2009). Youth unemployment and crime in france. *Journal of the European Economic Association*, 7(5):909–938.

Freeman, R. (1976). *The Overeducated American.* Academic Press.

Gautier, P. A. (2002). Unemployment and search externalities in a model with heterogeneous jobs and workers. *Economica*, 69(273):21–40.

Gautier, P. A., Teulings, C. N., and Van Vuuren, A. (2010). On-the-job search, mismatch and efficiency. *The Review of Economic Studies*, 77(1):245–272.

Green, C., Kler, P., and Leeves, G. (2007). Immigrant overeducation: Evidence from recent arrivals to australia. *Economics of Education Review*, 26(4):420–432.

Greenwood, M. J. (1969). An analysis of the determinants of geographic labor mobility in the united states. *The review of Economics and Statistics*, pages 189–194.

Hall, R. E. (2005). Employment fluctuations with equilibrium wage stickiness. *American economic review*, 95(1):50–65.

Hall, R. E. and Milgrom, P. R. (2008). The limited influence of unemployment on the wage bargain. *The American Economic Review*, 98(4):1653–1674.

Handel, M. J. (2003). Skills mismatch in the labor market. *Annual Review of Sociology*, pages 135–165.

Hornstein, A., Krusell, P., and Violante, G. L. (2011). Frictional wage dispersion in search models: A quantitative assessment. *The American Economic Review*, 101(7):2873–2898.

Hosios, A. J. (1990a). On the efficiency of matching and related models of search and unemployment. *The Review of Economic Studies*, 57(2):279–298.

Hosios, A. J. (1990b). On the efficiency of matching and related models of search and unemployment. *The Review of Economic Studies*, 57(2):279–298.

Jaeger, D. A. (1996). Skill differences and the effect of immigrants on the wages of natives. *US Bureau of Labor Statistics Working Paper.*

Jovanovic, B. (1979). Job matching and the theory of turnover. *The Journal of Political Economy*, pages 972–990.

Khalifa, S. (2013). Labor mismatch, skill obsolescence and unemployment persistence. *Journal of Quantitative Economics*, 11(1&2).

Kler, P. (2006). Graduate overeducation and its effects among recently arrived immigrants to australia: A longitudinal survey. *International Migration*, 44(5):93–128.

Krusell, P., Ohanian, L. E., Ríos-Rull, J.-V., and Violante, G. L. (2000a). Capital-skill complementarity and inequality: A macroeconomic analysis. *Econometrica*, 68(5):1029–1053.

Krusell, P., Ohanian, L. E., Ros-Rull, J.-V., and Violante, G. L. (2000b). Capital-skill complementarity and inequality: A macroeconomic analysis. *Econometrica*, 68(5):1029–1053.

Laing, D., Palivos, T., and Wang, P. (1995). Learning, matching and growth. *The Review of Economic Studies*, 62(1):115–129.

Laing, D., Palivos, T., and Wang, P. (2003). The economics of new blood? *Journal of Economic Theory*, 112(1):106–156.

Larsen, B. (2001). Minimum wages, technological progress and loss of skill. *European Economic Review*, 45(8):1521–1544.

Leuven, E., Oosterbeek, H., et al. (2011). Overeducation and mismatch in the labor market. *Handbook of the Economics of Education*, 4:283–326.

Liu, K., Salvanes, K. G., and Sørensen, E. Ø. (2016). Good skills in bad times: Cyclical skill mismatch and the long-term effects of graduating in a recession. *European Economic Review*, 84:3–17.

Liu, X. (2010). On the macroeconomic and welfare effects of illegal immigration. *Journal of Economic Dynamics and Control*, 34(12):2547 – 2567.

Liu, X., Palivos, T., and Zhang, X. (2014). Immigration, skill heterogeneity and qualification mismatch. Mpra paper, University Library of Munich, Germany.

Liu, X., Palivos, T., and Zhang, X. (2017). Immigration, skill heterogeneity, and qualification mismatch. *Economic Inquiry*, 55(3):1231–1264.

Machin, S. and Marie, O. (2006). Crime and benefit sanctions. *Portuguese Economic Journal*, 5(2):149–165.

Marimon, R. and Zilibotti, F. (1999). Unemployment vs. mismatch of talents: reconsidering unemployment benefits. *The Economic Journal*, 109(455):266–291.

Mears, D. P. (2001). The immigration-crime nexus: Toward an analytic framework for assessing and guiding theory, research, and policy. *Sociological Perspectives*, 44(1):1–19.

Mears, D. P. (2002). Immigration and crime: What's the connection? *Federal Sentencing Reporter*, 14(5):284–288.

Miles, T. J. and Cox, A. B. (2014). Does immigration enforcement reduce crime? evidence from secure communities. *Journal of Law and Economics*, 57(4):937–973.

Moscarini, G. (2001). Excess worker reallocation. *The Review of Economic Studies*, 68(3):593–612.

Nash, J. (1953). Two-person cooperative games. *Econometrica*, 21(1):128–140.

Nielsen, C. P. (2011). Immigrant over-education: evidence from denmark. *Journal of Population Economics*, 24(2):499–520.

Nieto, S., Matano, A., and Ramos, R. (2013). Skill mismatches in the eu: Immigrants vs. natives. *IZA Discussion Paper*.

Ortega, J. (2000). Pareto-improving immigration in an economy with equilibrium unemployment. *The Economic Journal*, 110(460):92–112.

Ortego-Marti, V. (2016). Unemployment history and frictional wage dispersion. *Journal of Monetary Economics*, 78:5–22.

Ortego-Marti, V. (2017). Loss of skill during unemployment and tfp differences across countries. *European Economic Review*, 100:215–235.

Ottaviano, G. I., Peri, G., and Wright, G. C. (2010). Immigration, offshoring and american jobs. Technical report, National Bureau of Economic Research.

Ottaviano, G. I. P. and Peri, G. (2012). Rethinking the effect of immigration on wages. *Journal of the European Economic Association*, 10(1):152–197.

Palivos, T. (2009). Welfare effects of illegal immigration. *Journal of Population Economics*, 22(1):131–144.

Peri, G. (2014). Do immigrant workers depress the wages of native workers? *IZA world of Labor*.

Peri, G., Shih, K., and Sparber, C. (2015). Stem workers, h-1b visas, and productivity in us cities. *Journal of Labor Economics*, 33(S1):S225–S255.

Petrongolo, B. and Pissarides, C. A. (2001). Looking into the black box: A survey of the matching function. *Journal of Economic Literature*, 39(2):390–431.

Pissarides, C. A. (1992). Loss of skill during unemployment and the persistence of employment shocks. *The Quarterly Journal of Economics*, pages 1371–1391.

Pissarides, C. A. (2000). *Equilibrium Unemployment Theory*. MIT press.

Pissarides, C. A. (2009). The unemployment volatility puzzle: Is wage stickiness the answer? *Econometrica*, 77(5):1339–1369.

Pries, M. J. (2008). Worker heterogeneity and labor market volatility in matching models. *Review of Economic Dynamics*, 11(3):664–678.

Reid, L. W., Weiss, H. E., Adelman, R. M., and Jaret, C. (2005). The immigration–crime relationship: Evidence across us metropolitan areas. *Social Science Research*, 34(4):757–780.

Şahin, A., Song, J., Topa, G., and Violante, G. L. (2014). Mismatch unemployment. *The American Economic Review*, 104(11):3529–3564.

Shimer, R. (2005). The cyclical behavior of equilibrium unemployment and vacancies. *American Economic Review*, 95(1):25–49.

Shimer, R. (2006). On-the-job search and strategic bargaining. *European Economic Review*, 50:811–830.

Shimer, R. (2007). Mismatch. *The American Economic Review*, 97(4):1074–1101.

Spenkuch, J. L. (2014). Understanding the impact of immigration on crime. *American Law and Economics Review*, 16(1):177–219.

Stevens, M. (2004). Wage-tenure contracts in a frictional labour market: Firms' strategies for recruitment and retention. *The Review of Economic Studies*, 71(2):535–551.

Tani, M. (2012). Does immigration policy affect the education-occupation mismatch? evidence from australia. *Australian Bulletin of Labour*, 38(2):111.

Thisse, J.-F. and Zenou, Y. (2000). Skill mismatch and unemployment. *Economics Letters*, 69(3):415–420.

Topel, R. H. and Ward, M. P. (1992). Job mobility and the careers of young men. *The Quarterly Journal of Economics*, pages 439–479.

Wadsworth, T. (2010). Is immigration responsible for the crime drop? an assessment of the influence of immigration on changes in violent crime between 1990 and 2000. *Social Science Quarterly*, 91(2):531–553.

# Appendix A

# Appendix for Chapter 2

## A.1 Proofs of Lemmas and Propositions

### Proof of Lemma 1

**Proof.** According to the Nash bargaining, the surplus must be maximized by the optimal employment contract. Compared with the expected capital loss of a match, $\pi(\Pi^j_{F,i} + V^j_{E,i} - V^j_{P,i})$, and the employees' opportunity cost of committing a crime, $\pi(V^j_{E,i} - V^j_{P,i})$, the surplus is maximized iff when $\Pi^j_{F,i} = 0$. According to equation (2.3), the value of a filled job is

$$\Pi^j_{F,i} = \frac{y_i - w^j_i}{r + \delta + \pi\mu(1 - F(\bar{g}^j_{E,i}))}.$$

Therefore, $\Pi^j_{F,i} = 0$ requires

$$w^j_i = y_i.$$

Solve equation (2.9),

$$\phi_i^j = (1-\beta)(V_{E,i}^j - V_{U,i}^j).$$

■

**Proof of Lemma 2**

**Proof.** According to equation (2.13), take the first order derivatives of $\phi^e$,

$$\begin{aligned}\frac{\partial \phi_i^e}{\partial \theta_i} &= (1-\beta)\sum_j [\frac{\partial (U_i^j/U_i)}{\partial \theta_i}(V_{E,i}^j - V_{U,i}^j) + \frac{U_i^j}{U_i}\frac{\partial (V_{E,i}^j - V_{U,i}^j)}{\partial \theta_i}] \\ &= (1-\beta)\sum_j [\frac{U_i(\partial U_i^j/\partial \theta_i) - U_i^j(\partial U_i/\partial \theta_i)}{U_i^2}(V_{E,i}^j - V_{U,i}^j) \\ &+ \frac{U_i^j}{U_i}\frac{\partial (V_{E,i}^j - V_{U,i}^j)}{\partial \theta_i}].\end{aligned}$$

According to a set of reasonable parameter value,

$$\frac{U_i(\partial U_i^j/\partial \theta_i) - U_i^j(\partial U_i/\partial \theta_i)}{U_i^2} \to 0.$$

Therefore,

$$\frac{\partial \phi_i^e}{\partial \theta_i} \to (1-\beta)\sum_j \frac{U_i^j}{U_i}\frac{\partial (V_{E,i}^j - V_{U,i}^j)}{\partial \theta_i}.$$

The first order partial derivatives of $(V^j_{E,i} - V^j_{U,i})$ is

$$\frac{\partial(V^j_{E,i} - V^j_{U,i})}{\partial\theta_i} = -(V^j_{E,i} - V^j_{U,i})\frac{\beta[\partial(\theta_i q(\theta_i))/\partial\theta_i]}{r + \delta_i + \beta\theta_i q(\theta_i)}$$

$$< 0$$

as $\partial(\theta_i q(\theta_i))/\partial\theta_i > 0$. Thus, $\partial\phi^e_i/\partial\theta_i < 0$. ■

## Proof of Proposition 1

**Proof.** At $\theta_i = 0$,

$$\frac{k_i}{q(\theta_i)} = 0.$$

If

$$\phi^e_i = (1-\beta)\mathbb{E}\frac{y_i - B_i - \mu\int_{\bar{g}^j_{U,i}}^{\bar{g}^j_{E,i}}(1 - F(g))dg}{r + \delta_i}$$

$$> 0,$$

at $\theta_i = 0$, $k_i/q(\theta_i) < \phi^e_i$. According to lemma 2 and $\partial[k_i/q(\theta_i)]/\partial\theta_i > 0$, there exists an unique $\theta_i$ that $k_i/q(\theta_i) = \phi^e_i$ and $\theta_i > 0$.

Since $y_i > B^j_i$ for all $i \in \{H, L\}$ and $j \in \{N, I\}$, $V^j_{E,i} - V^j_{U,i} > 0$. According to (2.8),

$$\bar{g}^j_{E,i} - \bar{g}^j_{U,i} = \pi(V^j_{E,i} - V^j_{U,i})$$

$$> 0.$$

Thus, $\bar{g}^j_{E,i} > \bar{g}^j_{U,i}$ at any equilibrium. ■

## Proof of Lemma 3

**Proof.** (i)According to equation (2.8),

$$\begin{aligned}\bar{g}^I_{E,i} - \bar{g}^N_{E,i} &= \pi(V^I_{E,i} - V^N_{P,i} - V^N_{E,i} + V^N_{P,i}) \\ &\approx \pi(\frac{\delta_i}{r+\delta_i} - \frac{\rho}{r+\rho})(V^I_{U,i} - V^N_{U,i}).\end{aligned}$$

Since $B^I_i < B^N_i$, $V^I_{U,i} < V^N_{U,i}$. Therefore, $\bar{g}^I_{E,i} > \bar{g}^N_{E,i}$ if $\delta_i < \rho$.

(ii) Similarly as (i),

$$\begin{aligned}\bar{g}^I_{U,i} - \bar{g}^N_{U,i} &= \pi(V^I_{U,i} - V^N_{P,i} - V^N_{U,i} + V^N_{P,i}) \\ &= \pi\frac{r}{r+\rho}(V^I_{U,i} - V^N_{U,i}) \qquad < 0\end{aligned}$$

as $V^I_{U,i} < V^N_{U,i}$. Therefore, $\bar{g}^I_{U,i} < \bar{g}^N_{U,i}$.

■

## Proof of Lemma 4

**Proof.** According to equation 2.8,

$$\begin{aligned}\bar{g}^j_{E,H} - \bar{g}^j_{E,L} &= \pi(V^j_{E,H} - V^j_{P,H} - V^j_{E,L} + V^j_{P,L}) \\ &= \frac{\pi}{r+\rho}[rV^j_{E,H} - rV^j_{E,L} + \rho(V^j_{E,H} - V^j_{U,H} - V^j_{E,L} + V^j_{U,L})].\end{aligned}$$

Skilled workers provide high productivity. Thus, $V^j_{E,H} > V^j_{E,L}$ and $V^j_{E,H} - V^j_{U,H} > V^j_{E,L} - V^j_{U,L}$. As a result, $\bar{g}^j_{E,H} > \bar{g}^j_{E,L}$. Similarly,

$$\begin{aligned}\bar{g}^j_{U,H} - \bar{g}^j_{U,L} &= \pi(V^j_{U,H} - V^j_{P,H} - V^j_{U,L} + V^j_{P,L}) \\ &= \pi\frac{r}{r+\rho}(V^j_{U,H} - V^j_{U,L}).\end{aligned}$$

Because $B^j_H > B^j_L$, $V^j_{U,H} > V^j_{U,L}$. Thus, $\bar{g}^j_{U,H} > \bar{g}^j_{U,L}$. In conclusion, $\bar{g}^j_{s,H} > \bar{g}^j_{s,L}$ for all $s \in E, U$ and $j \in I, N$. ■

## Proof of Proposition 2 and 3

**Proof.** According to equation (2.8), the reservation value of employed and unemployed workers are

$$\begin{aligned}\bar{g}^j_{E,i} &= \pi(V^j_{E,i} - V^j_{P,i}) \\ \bar{g}^j_{U,i} &= \pi(V^j_{U,i} - V^j_{P,i}).\end{aligned}$$

Since $y_H > y_L$ and $B^N > B^I$, it is obvious that employed skilled immigrants have highest reservation crime value and unemployed unskilled immigrants are the most likely commit crimes. It is straightforward to show that the overall crime rate decreases with skilled immigrants and increases with unskilled immigrants. ■

## Proof of Lemma 5

**Proof.** Equation (2.12) gives the hiring fee of type-$ij$ workers. It is obvious that

$$\phi_i^I - \phi_i^N = \frac{1-\beta}{r+\delta+\beta\theta q(\theta)}(B_i^N - B_i^I + \mu\int_{\bar{g}_{U,i}^N}^{\bar{g}_{E,i}^N}(1-F(g))dg + \mu\int_{\bar{g}_{E,i}^I}^{\bar{g}_{U,i}^I}(1-F(g))dg)$$

$$> 0$$

as $B_i^N > B_i^I$ and $\mu(\int_{\bar{g}_{U,i}^N}^{\bar{g}_{E,i}^N}(1-F(g))dg+\int_{\bar{g}_{E,i}^I}^{\bar{g}_{U,i}^I}(1-F(g))dg)$ is quantitatively small. Therefore, $\phi_i^I > \phi_i^N$. ■

## Proof of Lemma 6

**Proof.** The partial derivatives of the fraction of unemployed immigrants with respect to $I_H$ and $I_L$ are

$$\frac{\partial(U_H^I/U_H)}{\partial I_H} = \frac{\partial(U_H^I/U_H)}{\partial U_H^I}\frac{\partial U_H^I}{\partial I_H}$$

and

$$\frac{\partial(U_L^I/U_L)}{\partial I_L} = \frac{\partial(U_L^I/U_L)}{\partial U_L^I}\frac{\partial U_L^I}{\partial I_L}.$$

Take the first order derivatives of (2.21) and (2.23) with respect to $I_H$ and $I_L$ respectively, then

$$\frac{\partial U_H^I}{\partial I_H} = \frac{\rho(\delta_H + \eta_{E,H}^I)}{\theta_H q(\theta_H)(\rho+\eta_{E,H}^I) + (\delta_H+\eta_{E,H}^I)(\rho+\eta_{U,H}^I)}$$

$$> 0,$$

and

$$\frac{\partial U_L^I}{\partial I_L} = \frac{\rho(\delta_L + \eta_{E,L}^I)}{\theta_L q(\theta_L)(\rho + \eta_{E,L}^I) + (\delta_L + \eta_{E,L}^I)(\rho + \eta_{U,L}^I)}$$

$$> 0.$$

Since $U_i = \sum_j U_i^j$,

$$\frac{\partial (U_H^I / U_H)}{\partial U_H^I} = \frac{U_H - U_H^I}{U_H^2}$$

$$> 0$$

and

$$\frac{\partial (U_L^I / U_L)}{\partial U_L^I} = \frac{U_L - U_L^I}{U_L^2}$$

$$> 0.$$

Therefore, $\partial(U_H^I/U_H)/\partial I_H > 0$ and $\partial(U_L^I/U_L)/\partial I_L > 0$. When $I_H$ or $I_L$ increases, the fraction of unemployed skilled or unskilled immigrants increases.

According to lemma 5, the hiring fee of immigrants is higher than native workers, conditional on their skills. When the fraction of unemployed immigrants increases, the expected hiring fee increases. ■

## Proof of Proposition 4

**Proof.** According to the proof of lemma 5 and 6, Proposition 4 is proved. ■

### Proof of Lemma 7

**Proof.** According to equations (2.4), (2.5) and (2.8), the reservation crime value of employed and unemployed workers can be written as

$$\bar{g}^j_{E,i} = \frac{\pi}{r+\rho}(y_i + (\rho - \delta_i)(V^j_{E,i} - V^j_{U,i}) + \mu \int_{\bar{g}^j_{E,i}}^{g^m} 1 - F(g)dg - x). \tag{A.1}$$

and

$$\bar{g}^j_{U,i} = \frac{\pi}{r+\rho}(B^j_i + \theta_i q(\theta_i)(V^j_{E,i} - V^j_{U,i}) + \mu \int_{\bar{g}^j_{U,i}}^{g^m} 1 - F(g)dg - x). \tag{A.2}$$

Take the first order derivatives of $\bar{g}^j_{E,i}$ and $\bar{g}^j_{U,i}$ with respect to $\theta_i$,

$$(1 + \frac{\pi\mu}{r+\rho}(1 - F(\bar{g}^j_{E,i})))\frac{\partial \bar{g}^j_{E,i}}{\partial \theta_i} = \frac{\pi(\rho - \delta_i)}{r+\rho}\frac{\partial (V^j_{E,i} - V^j_{U,i})}{\partial \theta_i}$$

and

$$(1 + \frac{\pi\mu}{r+\rho}(1 - F(\bar{g}^j_{U,i})))\frac{\partial \bar{g}^j_{U,i}}{\partial \theta_i} = \frac{\pi}{r+\rho}\frac{\partial (\theta_i q(\theta_i)(V^j_{E,i} - V^j_{U,i}))}{\partial \theta_i}.$$

The sign of $\partial \bar{g}^j_{E,i}/\partial \theta_i$ is same as $\partial (V^j_{E,i} - V^j_{U,i})/\partial \theta_i$ if $\rho > \delta_i$. According to equation (2.4) and (2.5) the employment premium is

$$V^j_{E,i} - V^j_{U,i} = \frac{y_i - B^j - \mu \int_{\bar{g}^j_{U,i}}^{\bar{g}^j_{E,i}} (1 - F(g))dg}{r + \delta_i + \beta\theta_i q(\theta_i)}. \tag{A.3}$$

Then

$$\frac{\partial(V_{E,i}^j - V_{U,i}^j)}{\partial\theta_i} = -\beta\frac{y_i - B^j - \mu\int_{\bar{g}_{U,i}^j}^{\bar{g}_{E,i}^j}(1-F(g))dg}{(r+\delta_i+\beta\theta_i q(\theta_i))^2}\frac{\partial\theta_i q(\theta_i)}{\partial\theta_i}$$
$$< 0.$$

Thus, $\partial\bar{g}_{E,i}^j/\partial\theta_i < 0$ if $\rho < \delta_i$.

When it turns to $\partial\bar{g}_{U,i}^j/\partial\theta_i$, its sign depends on $\partial(\theta_i q(\theta_i)(V_{E,i}^j - V_{U,i}^j))/\partial\theta_i$. Then

$$\begin{aligned}\frac{\partial(\theta_i q(\theta_i)(V_{E,i}^j - V_{U,i}^j))}{\partial\theta_i} &= (V_{E,i}^j - V_{U,i}^j)\frac{\partial\theta_i q(\theta_i)}{\partial\theta_i} + \theta_i q(\theta_i)\frac{\partial(V_{E,i}^j - V_{U,i}^j)}{\partial\theta_i}\\ &= \frac{\partial\theta_i q(\theta_i)}{\partial\theta_i}[V_{E,i}^j - V_{U,i}^j - \frac{\beta\theta_i q(\theta_i)}{r+\delta_i+\beta\theta_i q(\theta_i)}(V_{E,i}^j - V_{U,i}^j)]\\ &= \frac{r+\delta_i}{r+\delta_i+\beta\theta_i q(\theta_i)}\frac{\partial\theta_i q(\theta_i)}{\partial\theta_i}(V_{E,i}^j - V_{U,i}^j)\\ &> 0\end{aligned}$$

Therefore, $\partial\bar{g}_{U,i}^j/\partial\theta_i > 0$. ■

### Proof of Proposition 5

**Proof.** When the unemployment utility flow of immigrants increases to that of native workers, their match surplus decreases to that of natives. Therefore, the expected hiring fee, which is proportion $(1-\beta)$ to the match surplus, decreases. According to (2.13), market tightness decreases to balance the equilibrium.

According to equation (2.5), $\partial V_{U,i}^j/\partial B_i^j > 0$. When the unemployment utility flow of skilled-$i$ immigrants $B_i^I$ increases, the reservation crime value of unemployed immigrant with skill $i$ is following

$$\begin{aligned}\bar{g}^{i}_{U,i} &= \pi(V^{I}_{U,i} - V^{I}_{P,i}) \\ &= \frac{\pi}{r+\rho}(rV^{j}_{U,i} - x + \tau)\end{aligned}$$

increases as $V^{I}_{U,i}$ increases with $B^{I}_{i}$. Therefore, $\partial \bar{g}^{I}_{U,i}/\partial B^{I}_{i} > 0$. For employed immigrant with skill $i$, according to (A.3), the match surplus of skilled-$i$ immigrant decreases with $B^{I}_{i}$. Therefore, $\bar{g}^{I}_{E,i}$ decreases with $B^{I}_{i}$ if $\rho > \delta_i$ given (A.1).

The reservation crime value of native workers is only affected by the market tightness. Based on lemma 5,

$$\frac{\partial \bar{g}^{N}_{E,i}}{\partial B^{I}_{i}} = \frac{\partial \bar{g}^{N}_{E,i}}{\partial \theta_i}\frac{\partial \theta_i}{\partial B^{I}_{i}} > 0$$

if $\rho > \delta_i$ and

$$\frac{\partial \bar{g}^{N}_{U,i}}{\partial B^{I}_{i}} = \frac{\partial \bar{g}^{N}_{U,i}}{\partial \theta_i}\frac{\partial \theta_i}{\partial B^{I}_{i}} < 0.$$

Similarly, the reservation crime value of immigrants with skill $i'$, where $i' \neq i$, is also affected by $\theta_i$. Therefore,

$$\frac{\partial \bar{g}^{I}_{E,i'}}{\partial B^{I}_{i}} = \frac{\partial \bar{g}^{N}_{E,i'}}{\partial \theta_i}\frac{\partial \theta_i}{\partial B^{I}_{i}} > 0$$

if $\rho > \delta_i$ and

$$\frac{\partial \bar{g}^{I}_{U,i'}}{\partial B^{I}_{i}} = \frac{\partial \bar{g}^{I}_{U,i'}}{\partial \theta_i}\frac{\partial \theta_i}{\partial B^{I}_{i}} < 0.$$

■

### Proof of Proposition 6

**Proof.** According to (2.13),

$$\frac{1}{d\rho}(d\frac{k_i}{q(\theta_i)}) = \frac{1}{d\rho}d[(1-\beta)\sum_j \frac{U_i^j}{U_i}(V_{E,i}^j - V_{U,i}^j)]$$

which can be written as

$$\frac{\partial(\frac{k_i}{q(\theta_i)})}{\partial\theta_i}\frac{\partial\theta_i}{\partial\rho} = (1-\beta)\sum_j[(V_{E,i}^j - V_{U,i}^j)\frac{\partial(U_i^j/U_i)}{\partial\rho} + \frac{U_i^j}{U_i}\frac{\partial(V_{E,i}^j - V_{U,i}^j)}{\partial\rho}].$$

For composition effect,

$$\partial(U_i^j/U_i)/\partial\rho = \frac{1}{U_i^2}[U_i\frac{\partial U_i^j}{\partial\rho} - U_i^j\frac{\partial U_i}{\partial\rho}].$$

The composition effect is ambiguous analytically. According to the set of parameter value that is applied in this paper, this effect is close to zero.

For match surplus,

$$\begin{aligned}\frac{\partial(V_{E,i}^j - V_{U,i}^j)}{\partial\rho} &= \frac{\partial(V_{E,i}^j - V_{U,i}^j)}{\partial\bar{g}_{E,i}^j}\frac{\partial\bar{g}_{E,i}^j}{\partial\rho} + \frac{\partial(V_{E,i}^j - V_{U,i}^j)}{\partial\bar{g}_{U,i}^j}\frac{\partial\bar{g}_{U,i}^j}{\partial\rho} \\ &= -\mu[(1-F(\bar{g}_{E,i}^j))\frac{\partial\bar{g}_{E,i}^j}{\partial\rho} - (1-F(\bar{g}_{U,i}^j))\frac{\partial\bar{g}_{U,i}^j}{\partial\rho}]\end{aligned}$$

According to equations (A.1) and (A.2), $\bar{g}_{E,i}^j > \bar{g}_{U,i}^j$ and $| \partial\bar{g}_{E,i}^j/\partial\rho | < | \partial\bar{g}_{U,i}^j/\partial\rho |$. Therefore, $\partial(V_{E,i}^j - V_{U,i}^j)/\partial\rho > 0$. As a consequence, the effect of incarceration on the market tightness is positive. ■

### Proof of Proposition 7

**Proof.** Take first order derivatives of the match surplus of immigrants with respect to $a$,

$$\frac{\partial(V^I_{E,i} - V^I_{U,i})}{\partial a} = \frac{-\mu}{r + \delta + \beta\theta q(\theta)}((1 - F(\bar{g}^I_{E,i}))\frac{\partial \bar{g}^I_{E,i}}{\partial a} - (1 - F(\bar{g}^I_{U,i}))\frac{\partial \bar{g}^I_{U,i}}{\partial a})$$

According to (2.26),

$$\begin{aligned}\frac{\partial \bar{g}^I_{E,i}}{\partial a} &= \frac{\partial \bar{g}^I_{U,i}}{\partial a} \\ &= -V^I_{P,i} \\ &= -\frac{x + \rho V^I_{U,i}}{r + \rho} \\ &< 0.\end{aligned}$$

Thus,

$$\begin{aligned}\frac{\partial(V^I_{E,i} - V^I_{U,i})}{\partial a} &= \frac{-\mu}{r + \delta_i + \beta\theta_i q(\theta_i)}(F(\bar{g}^I_{U,i}) - F(\bar{g}^I_{E,i}))\frac{\partial \bar{g}^I_{E,i}}{\partial a} \\ &< 0.\end{aligned}$$

Comparing the unemployment of immigrants before and after the deportation policy, the reservation crime value increases, the unemployment of immigrants with deportation decreases, which is

$$\Delta U_i^I = \frac{(\delta_i + \tilde{\eta}_{E,i}^I)I_i}{\theta_i q(\theta_i) + \tilde{\eta}_{E,i}^I + \delta_i} - \frac{\rho(\delta_i + \eta_{E,i}^I)I_i}{\theta_i q(\theta_i)(\rho + \eta_{E,i}^I) + (\delta_i + \eta_{E,i}^I)(\rho + \eta_{U,i}^I)}$$
$$< 0,$$

where $\tilde{\eta}_{E,i}^I$ represents the rate of getting arrested with deportation. Therefore the share of unemployed immigrants decreases and the market tightness is ambiguous. Quantitatively, the effect on the market tightness decreases by a small margin with $a$. The effects on $\bar{g}_{E,i}^N$ and $\bar{g}_{U,i}^N$ follows Lemma 5. ■

## Proof of Lemma 8

**Proof.** When $I_i$ increases, employment in the skilled-$i$ labor market increases, i.e.,

$$\frac{dE_i}{dI_i} > 0.$$

The intermediate good in skill $i$ increases as there is more employment in market $i$. According to equation (29) and (30), and $E_i = Y_i$ ,

$$\frac{dp_i}{dE_i} < 0,$$
$$\frac{dp_{i'}}{dE_i} > 0.$$

■

## Proof of Lemma 9

**Proof.** Given a certain $\theta_i$, when $I_i$ increases, the price of good $i$ decreases and the price of good $i'$ increases. According to the value functions of workers,

$$\begin{aligned}\frac{\partial V_{E,i}^j}{\partial p_i} &= 1, \\ \frac{\partial V_{U,i}^j}{\partial p_i} &= \theta_i q(\theta_i) \partial V_{E,i}^j / \partial p_i \\ &> 0.\end{aligned}$$

When $p_i$ decreases, the reservation crime value of workers with skill $i$ decreases. Similarly, the reservation crime value of workers with skill $i'$ increases. ■

## Proof of Proposition 8

**Proof.** (i) When $I_i$ increases, the cost of a match decreases because of the low outside options value from immigrants. At the same time, according to lemma (8), $p_i$ decreases. The tightness in market $i$ only increases when the match revenue increases. Therefore, when the cost effect dominates the price effect, $\theta_i$ increases.

(ii) According to lemma (8), $p_{i'}$ increases with an increase in $I_i$. It is simple to prove that $\theta_{i'}$ increases with an increase in $I_i$. ■

## A.2 The Model without a hiring fee

This section shows the model without a hiring fee. The value functions of unemployed workers and vacancies are

$$rV_{U,i}^{j} = B_i^j - \tau + \theta q(\theta)(V_{E,i}^{j} - V_{U,i}^{j}) + \mu \int_0^{g^m} \max\{K_{U,i}^{j} - V_{U,i}^{j}, 0\} dF(g) \tag{A.4}$$

$$r\Pi_V = -k + q(\theta)(\Pi_F^e - \Pi_V). \tag{A.5}$$

The value functions of employed workers and filled jobs are the same as the model with hiring fee. The free entry condition is still satisfied, i.e. $\Pi_V = 0$. Following Pissarides (2000) closely, the wage are determined by the Nash bargaining share rule as

$$(1-\beta)(V_{E,i}^{j} - V_{U,i}^{j}) = \beta \Pi_{F,i}^{j}. \tag{A.6}$$

From (2.3), the value of filled job can be written as

$$\Pi_{F,i}^{j} = \frac{y_i - w_i^j}{r + \delta + \mu\pi(1 - F(\bar{g}_{E,i}^{j}))}. \tag{A.7}$$

Given (2.4) and (A.4), the premium of employment is

$$V_{E,i}^{j} - V_{U,i}^{j} = \frac{w_i^j - B_i^j - \mu \int_{\bar{g}_{U,i}^{j}}^{\bar{g}_{E,i}^{j}} 1 - F(g) dg}{r + \delta + \theta q(\theta)}. \tag{A.8}$$

Substitute (A.7) and (A.8) into (A.6), and rewrite it as

$$(1-\beta)\frac{w_i^j - B_i^j - \mu\int_{\bar{g}_{U,i}^j}^{\bar{g}_{E,i}^j} 1 - F(g)dg}{r+\delta+\theta q(\theta)} = \beta\frac{y_i - w_i^j}{r+\delta+\mu\pi(1-F(\bar{g}_{E,i}^j))}. \tag{A.9}$$

Therefore, the wage is

$$w_i^j = \frac{\beta(r+\delta+\theta q(\theta))y_i + (1-\beta)(r+\delta+\mu\pi(1-F(\bar{g}_{E,i}^j)))(B_i^j + \mu\int_{\bar{g}_{U,i}^j}^{\bar{g}_{E,i}^j} 1 - F(g)dg)}{r+\delta+\beta\theta q(\theta) + (1-\beta)\mu\pi(1-F(\bar{g}_{E,i}^j))}. \tag{A.10}$$

Similar to the model with the hiring fee, the free entry condition gives

$$\frac{k}{q(\theta)} = \Pi_F^e, \tag{A.11}$$

where $\Pi_J^e = \sum_i \sum_j (U_i^j/U)\Pi_{J,i}^j$. Equation (A.11) gives the condition of equilibrium.

Table A.8 presents the simulation results with this model. The main difference between these two situations is the reservation crime value of employees, $\bar{g}_{E,i}^j$. In the case of a hiring fee, employees earn all the productivity and the match surplus is higher than the case with standard Nash bargaining. Therefore, the $\bar{g}_{E,i}^j$ is higher than with standard Nash bargaining. With standard Nash bargaining, the reservation crime value of skilled employed immigrants, $\bar{g}_{E,H}^I$, is still high among all types of workers, but is lower than that of skilled native employed workers, $\bar{g}_{E,H}^N$. Hence, when the population of skilled immigrants increases, the overall crime rate decreases but the decrease is quantitatively smaller than with an employment contract. The reservation crime value of unskilled employed immigrants, $\bar{g}_{E,L}^I$, is lower than the unskilled native workers, $\bar{g}_{E,L}^N$, with standard Nash bargaining. Hence, when the population of unskilled immigrants increases, the overall crime rate decreases more than with the employment contract. Overall, when both groups of immigrants increase, the overall crime rate decreases at a smaller margin than the one with the employment contract.

## A.3 A simpler model with one skill

A simpler model with one skill only is presented in this section. To see the composition and labor market effects of immigration on labor market outcomes and crimes, this model only has immigrant and native workers with the same skill level. Table A.9 shows the simulation results with this model. In this model, an increase in the population of immigrants decreases the overall unemployment rate by 0.4497 percentage points and decreases the overall crime rate by 0.17 per 1,000 in the population.

## A.4 A model with random search

The main model assumes there are two segmented labor markets, skilled and unskilled. In this section, I relax this assumption because skilled workers can work in the unskilled labor market as well. Workers search in the same labor market. Firms post identical vacancies in the labor market. Other model setups are the same as the main model. Table A.10 represents the simulation results for this model. In this case, the market tightness increases by 0.1586. The overall unemployment rate decreases by 0.4665 percentage points. The overall crime rate decreases by 0.164 per 1,000 in the population.

# Tables

Table A.1: Calibration results

| | | description | sources/target |
|---|---|---|---|
| $y_H$ | 1.0 | Normalized skilled productivity | |
| $y_L$ | 0.62 | Relative unskilled productivity | The college-plus wage premium: 61.1% |
| $\beta$ | 0.5 | Bargaining power | Hosios (1990a) |
| $\alpha$ | 0.5 | Elasticity of matching function | Petrongolo and Pissarides (2001) |
| | | | Estimated from data: |
| $r$ | 0.048 | real interest rate | Fed. of Saint Louis |
| $\delta_H$ | 0.228 | Annual job separation rate in the skilled labor market | Chassamboulli and Palivos (2014) |
| $\delta_L$ | 0.408 | Annual job separation rate in the unskilled labor market | Chassamboulli and Palivos (2014) |
| $\rho$ | 0.75 | Rate of exit from jail | Engelhardt et al. (2008) |
| $\pi$ | 0.019 | Apprehension probability | Engelhardt et al. (2008) |
| $I_H$ | 0.036 | Mass of skilled immigrants | Chassamboulli and Palivos (2014) |
| $I_L$ | 0.089 | Mass of unskilled immigrants | |
| $\tau$ | 0.0391 | Expected loss of victims | equal to $g^e$ |
| $\gamma$ | 0.274 | Fraction of skilled native workers to total natives workers | Chassamboulli and Palivos (2014) |
| | | | Jointly calibrated to match: |
| $A$ | 6.7455 | Match technology | Employment rate |
| $k_h$ | 0.4260 | Fixed recruitment cost | in the skilled market: 0.976 |
| | | in the skilled labor market | Employment rate |
| $k_l$ | 0.5283 | Fixed recruitment cost | in the unskilled market: 0.939 |
| | | in the unskilled labor market | The skilled native-immigrant |
| $B_{H,N}$ | 0.3932 | Unemployed. flow value, skilled natives | wage gap: -19% |
| $B_{L,N}$ | 0.2383 | Unemploy. flow value, unskilled natives | The unskilled native-immigrant |
| $B_{H,I}$ | -1.7263 | Unemploy. flow value, skilled immigrant | wage gap: -18.8% |
| $B_{L,I}$ | -1.0703 | Unemploy. flow value, unskilled immigrant | $\theta$ normalized to 1 |
| $\mu$ | 0.0704 | Arrival rate of criminal opportunity | The overall crime rate: 0.0451 |
| | | | Ratio of unemployed |
| | | | and employed income: 40% |
| | | | The college-plus wage premium: 61.1% |

Table A.2: Effect of immigration

| | increase in $I_H$ and $I_L$ | increase in $I_H$ | Increase in $I_L$ |
|---|---|---|---|
| $\theta_H$ | 0.3291 | 0.3291 | No effect |
| $\theta_L$ | 0.1214 | No effect | 0.1214 |
| $u$ | -0.3288 | -0.1137 | -0.2248 |
| $c$ | -0.156 | -0.226 | 0.061 |
| | skilled natives | | |
| $u_H^N$ | -0.1818 | -0.1818 | |
| $\tilde{w}_H^N$ | 0.13 | 0.13 | No effect |
| $c_{E,H}^N$ | 0.109 | 0.109 | |
| $c_{U,H}^N$ | -0.061 | -0.061 | |
| | unskilled natives | | |
| $u_L^N$ | -0.3655 | | -0.3655 |
| $\tilde{w}_L^N$ | 0.23 | No effect | 0.23 |
| $c_{E,L}^N$ | 0.059 | | 0.059 |
| $c_{U,L}^N$ | -0.084 | | -0.084 |
| | skilled immigrants | | |
| $c_{E,H}^I$ | 0.429 | 0.429 | No effect |
| $c_{U,H}^I$ | -0.295 | -0.295 | |
| | unskilled immigrants | | |
| $c_{E,L}^I$ | 0.245 | No effect | 0.245 |
| $c_{U,L}^I$ | -0.409 | | -0.409 |

Note: 1. Skilled immigrants increase by 0.026. Unskilled immigrants increase by 0.051 for the simulation, which are normalized to the size of native population.
2. The variable $\theta_i$ is the market tightness, $c$ is the overall crime rate, $u$ is the overall unemployment rate, $\tilde{w}_i^j$ is the implied wage of type-$ij$ workers, $u_i^j$ is unemployment rate of type-$ij$ workers, and $c_{s,i}^j$ is the crime rate of type-$ij$ workers under $s$ labor market status. The subscript $U$ represents unemployed, $E$ is employed, $L$ is unskilled, and $H$ is skilled. The superscript $N$ represents native and $I$ represents immigrant. The unemployment rates are defined as the number of unemployed workers over the population of type-$ij$ of workers, presented as percentage. The crime rates represents the number of criminal offenses per 1000 population of type-$ij$ of workers.
3. The table presents the changes with the increase in the immigrants. The changes in the market tightness are changes in level. The changes in the unemployment rates are changes in percentage points. The changes in the wages are percentage changes. The changes in crime rates are changes in level.

Table A.3: Crime rate of workers

| Type of worker | crime rate | Type of worker | crime rate |
|---|---|---|---|
| Skilled employed natives | 37.665 | Skilled employed immigrants | 32.843 |
| Skilled unemployed natives | 39.995 | Skilled unemployed immigrants | 43.007 |
| Unskilled employed natives | 48.281 | Unskilled employed immigrants | 44.762 |
| Unskilled unemployed natives | 50.836 | Unskilled unemployed immigrants | 56.244 |

Note: This table shows the crime rate of each type of workers, which is the number that criminal offenses per 1000 population of the type-$ij$ of workers.

Table A.4: Effects of increasing unemployment benefits

| | $B_H^I = B_H^N$ <br> $B_L^I = B_L^N$ | $B_H^I = B_H^N$ | $B_L^I = B_L^N$ |
|---|---|---|---|
| $\theta_H$ | -0.558 | -0.558 | no effects |
| $\theta_L$ | -0.2507 | no effects | -0.2507 |
| $u$ | 0.8886 | 0.1237 | 0.7651 |
| $c$ | 0.235 | 0.082 | 0.154 |
| skilled natives | | | |
| $u_H^N$ | 0.4484 | 0.4484 | |
| $w_H^N$ | -0.3103 | -0.3103 | no effects |
| $c_{E,H}^N$ | -0.264 | -0.264 | |
| $c_{U,H}^N$ | 0.149 | 0.149 | |
| unskilled natives | | | |
| $u_L^N$ | 1.056 | | 1.056 |
| $w_L^N$ | -0.6462 | no effects | -0.6462 |
| $c_{E,L}^N$ | -0.169 | | -0.169 |
| $c_{U,L}^N$ | 0.238 | | 0.238 |
| skilled immigrants | | | |
| $c_{E,H}^I$ | 4.558 | 4.558 | no effects |
| $c_{U,H}^I$ | -2.863 | -2.863 | |
| unskilled immigrants | | | |
| $c_{E,L}^I$ | 3.35 | no effects | 3.35 |
| $c_{U,L}^I$ | -5.17 | | -5.17 |

Table A.5: Effects of increasing duration of incarceration

| | 32 months | 48 months |
|---|---|---|
| $\theta_H$ | 0.0002 | 0.0003 |
| $\theta_L$ | 0.0001 | 0.0001 |
| $u$ | 0.0035 | -0.0058 |
| $c$ | -12.461 | -20.475 |
| skilled natives | | |
| $u_H^N$ | -0.0030 | -0.0047 |
| $w_H^N$ | 0.0020 | -0.0057 |
| $c_{E,H}^N$ | -14.83 | -23.054 |
| $c_{U,H}^N$ | -15.748 | -24.48 |
| unskilled natives | | |
| $u_L^N$ | -0.0035 | -0.0057 |
| $w_L^N$ | 0.0001 | 0.0034 |
| $c_{E,L}^N$ | -12.08 | -20.278 |
| $c_{U,L}^N$ | -12.719 | -21.351 |
| skilled immigrants | | |
| $c_{E,H}^I$ | -11.611 | -18.456 |
| $c_{U,H}^I$ | -15.205 | -24.168 |
| unskilled immigrants | | |
| $c_{E,L}^I$ | -8.059 | -14.012 |
| $c_{U,L}^I$ | -10.126 | -17.606 |

Note: See the footnotes 2 and 3 in table A.2 for the definitions of variables and the explanation of rates.

Table A.6: Effects of deportation

| | a | | |
|---|---|---|---|
| | 0.1 | 0.5 | 0.9 |
| $\theta_H$ | -0.0012 | -0.0012 | -0.0007 |
| $\theta_L$ | -0.0002 | -0.0002 | -0.00005 |
| $u$ | -0.0003 | -0.0003 | -0.0001 |
| $c$ | -4.481 | -3.973 | -1.606 |
| skilled natives | | | |
| $u_H^N$ | 0.0007 | 0.0007 | 0.0004 |
| $w_H^N$ | -0.001 | -0.001 | 0.001 |
| $c_{E,H}^N$ | -0.0005 | -0.0004 | -0.0002 |
| $c_{U,H}^N$ | 0.0003 | 0.0003 | 0.0001 |
| unskilled natives | | | |
| $u_L^N$ | 0.0009 | 0.0002 | 0.0002 |
| $w_L^N$ | -0.0005 | -0.0004 | -0.0001 |
| $c_{E,L}^N$ | -0.0001 | -0.0001 | -0.00003 |
| $c_{U,L}^N$ | 0.0002 | 0.0002 | 0.00004 |
| skilled immigrants | | | |
| $c_{E,H}^I$ | -32.8114 | -32.1395 | -17.618 |
| $c_{U,H}^I$ | -42.9633 | -42.0834 | -23.067 |
| unskilled immigrants | | | |
| $c_{E,L}^I$ | -42.4885 | -36.4443 | -12.882 |
| $c_{U,L}^I$ | -53.906 | -46.237 | -16.343 |

Note: See the footnotes 2 and 3 in table A.2 for the definitions of variables and the explanation of rates.

Table A.7: Extension 1: imperfect substitution between skilled and unskilled labor

| | increase in $I_H$ and $I_L$ | increase in $I_H$ | Increase in $I_L$ |
|---|---|---|---|
| $\theta_H$ | 0.3552 | 0.3218 | 0.0009 |
| $\theta_L$ | 0.1570 | 0.0334 | 0.1562 |
| $u$ | -0.397 | -0.1261 | -0.2840 |
| $c$ | -0.139 | -0.193 | 0.053 |
| | skilled natives | | |
| $u_H^N$ | -0.2629 | -0.2414 | -0.0285 |
| $w_H^N$ | 2.089 | 0.035 | 2.056 |
| $c_{E,H}^N$ | -0.231 | 0.13 | -0.36 |
| $c_{U,H}^N$ | -0.37 | -0.035 | -0.335 |
| | unskilled natives | | |
| $u_L^N$ | -0.4308 | -0.0027 | -0.4288 |
| $w_L^N$ | -0.834 | 0.085 | -0.916 |
| $c_{E,L}^N$ | 0.183 | -0.01 | 0.192 |
| $c_{U,L}^N$ | 0.057 | -0.009 | 0.065 |
| | skilled immigrants | | |
| $c_{E,H}^I$ | 0.261 | 0.54 | -0.263 |
| $c_{U,H}^I$ | -0.713 | -0.329 | -0.395 |
| | unskilled immigrants | | |
| $c_{E,L}^I$ | 0.381 | -0.008 | 0.389 |
| $c_{U,L}^I$ | -0.275 | -0.012 | -0.264 |

Note: See the footnotes 2 and 3 in table A.2 for the definitions of variables and the explanation of rates.

Table A.8: Effects of immigration (Nash bargaining)

| | increase in $I_H$ and $I_L$ | increase in $I_H$ | Increase in $I_L$ |
|---|---|---|---|
| $\theta_H$ | 0.326 | 0.326 | No effect |
| $\theta_L$ | 0.1171 | No effect | 0.1171 |
| $u$ | -0.3489 | -0.118 | -0.240 |
| $c$ | -0.102 | -0.223 | 0.113 |
| | skilled natives | | |
| $u_H^N$ | -0.1876 | -0.1876 | |
| $w_H^N$ | 0.13 | 0.13 | No effect |
| $c_{E,H}^N$ | 0.077 | 0.077 | |
| $c_{U,H}^N$ | -0.091 | -0.091 | |
| | unskilled natives | | |
| $u_L^N$ | -0.3901 | | -0.3901 |
| $w_L^N$ | 0.24 | No effect | 0.24 |
| $c_{E,L}^N$ | 0.013 | | 0.013 |
| $c_{U,L}^N$ | -0.124 | | -0.124 |
| | skilled immigrants | | |
| $c_{E,H}^I$ | 0.314 | 0.314 | No effect |
| $c_{U,H}^I$ | -0.456 | -0.456 | |
| | unskilled immigrants | | |
| $c_{E,L}^I$ | 0.057 | no effect | 0.057 |
| $c_{U,L}^I$ | -0.633 | | -0.633 |

Note: See the footnotes 2 and 3 in table A.2 for the definitions of variables and the explanation of rates.

Table A.9: Effects of immigration: one-skilled market

| | increase in $I$ |
|---|---|
| $\theta$ | 0.1522 |
| $u$ | -0.4497 |
| $c$ | -0.17 |
| Natives | |
| $u^N$ | -0.4496 |
| $w^N$ | 0.28% |
| $c_E^N$ | 0.109 |
| $c_U^N$ | -0.16 |
| Immigrants | |
| $c_E^I$ | 0.421 |
| $c_U^I$ | -0.841 |

Note: See the footnotes 2 and 3 in table A.2 for the definitions of variables and the explanation of rates.

Table A.10: Effects of Immigration: random search

| | increase in $I_H$ and $I_L$ | increase in $I_H$ | Increase in $I_L$ |
|---|---|---|---|
| $\theta$ | 0.1586 | 0.0825 | 0.0825 |
| $u$ | -0.4665 | -0.2548 | -0.2510 |
| $c$ | -0.1640 | -0.2130 | 0.0400 |
| | Skilled natives | | |
| $u_{H,N}$ | -0.4700 | -0.2500 | -0.2500 |
| $\tilde{w}_{H,N}$ | 0.29 | 0.16 | 0.15 |
| $c^N_{E,H}$ | 0.0940 | 0.0510 | 0.0500 |
| $c^N_{U,H}$ | -0.1370 | -0.0740 | -0.0730 |
| | Unskilled Natives | | |
| $u_{L,N}$ | Same as skilled natives | | |
| $\tilde{w}_{L,N}$ | 1.51 | 0.82 | 0.81 |
| $c^N_{E,L}$ | 0.0750 | 0.0410 | 0.0400 |
| $c^N_{U,L}$ | -0.1050 | -0.0570 | -0.0560 |
| | Skilled Immigrants | | |
| $c^I_{E,H}$ | 0.3610 | 0.1970 | 0.1940 |
| $c^I_{U,H}$ | -0.7190 | -0.3930 | -0.3870 |
| | Unskilled immigrants | | |
| $c^I_{E,L}$ | 0.3030 | 0.1640 | 0.1620 |
| $c^I_{U,L}$ | -0.5180 | -0.2830 | -0.2790 |

Note: See the footnotes 2 and 3 in table A.2 for the definitions of variables and the explanation of rates.

# Appendix B

# Appendix for Chapter 3

## B.1 Solution of the steady state equilibrium

According to (3.1) to (3.9), the workers surplus are following,

$$\mathcal{W}_{ii}^{H} - \mathcal{U}_{ii}^{H} = \frac{w_{ii}^{H} - b_{ii}^{H} - f(\theta_i^{L})(\mathcal{W}_{ii}^{HL} - \mathcal{U}_{ii}^{H}) - \int_0^{\bar{c}_i^{H}} F(c)dc}{r + s^{H} + f(\theta_i^{H})} \tag{B.1}$$

$$\mathcal{W}_{ii}^{HL} - \mathcal{U}_{ii}^{H} = \frac{w_{ii}^{HL} - b_{ii}^{H} - f(\theta_i^{H})(\mathcal{W}_{ii}^{H} - \mathcal{U}_{ii}^{H}) - \int_0^{\bar{c}_i^{H}} F(c)dc}{r + s^{L} + f(\theta_i^{L})} \tag{B.2}$$

$$\mathcal{W}_{ii}^{L} - \mathcal{U}_{ii}^{L} = \frac{w_{ii}^{L} - b_{ii}^{L} - \int_0^{\bar{c}_i^{L}} F(c)dc}{r + s^{L} + f(\theta_i^{L})} \tag{B.3}$$

$$\mathcal{W}_{ji}^{H} - \mathcal{U}_{ji}^{H} = \frac{w_{ji}^{H} - b_{ji}^{H}}{r + s^{H} + d + f(\theta_i^{H})} \tag{B.4}$$

$$\mathcal{W}_{ji}^{L} - \mathcal{U}_{ji}^{L} = \frac{w_{ji}^{L} - b_{ji}^{L}}{r + s^{L} + d + f(\theta_i^{L})}. \tag{B.5}$$

According to (3.10) to (3.16) and the free entry condition, the firms surplus are following,

$$\mathcal{J}_{ii}^{H} - \mathcal{V}_{i}^{H} = \frac{y_{ii}^{H} - w_{ii}^{H}}{r + s^{H}} \tag{B.6}$$

$$\mathcal{J}_{ii}^{HL} - \mathcal{V}_{i}^{L} = \frac{y_{ii}^{HL} - w_{ii}^{HL}}{r + s^{L}} \tag{B.7}$$

$$\mathcal{J}_{ii}^{L} - \mathcal{V}_{i}^{L} = \frac{y_{ii}^{L} - w_{ii}^{L}}{r + s^{L}} \tag{B.8}$$

$$\mathcal{J}_{ji}^{H} - \mathcal{V}_{i}^{H} = \frac{y_{ji}^{H} - w_{ji}^{H}}{r + s^{H}} \tag{B.9}$$

$$\mathcal{J}_{ji}^{L} - \mathcal{V}_{i}^{L} = \frac{y_{ji}^{L} - w_{ji}^{L}}{r + s^{L}}. \tag{B.10}$$

Following the share rule of Nash Bargaining, the wages are solved, which are

$$w_{ii}^{H} = \beta y_{ii}^{H} + (1-\beta)\frac{b_{ii}^{H} + \mu_i \int_0^{\bar{c}_i^{H}} F(c)dc + \beta f(\theta_i^{H}) y_{ii}^{H}/(r+s^{H}) + \beta f(\theta_i^{L}) y_{ii}^{HL}/(r+s^{L})}{1 + \beta f(\theta_i^{H})/(r+s^{H}) + \beta f(\theta_i^{L})/(r+s^{L})} \tag{B.11}$$

$$w_{ii}^{HL} = \beta y_{ii}^{HL} + (1-\beta)\frac{b_{ii}^{H} + \mu_i \int_0^{\bar{c}_i^{H}} F(c)dc + \beta f(\theta_i^{H}) y_{ii}^{H}/(r+s^{H}) + \beta f(\theta_i^{L}) y_{ii}^{HL}/(r+s^{L})}{1 + \beta f(\theta_i^{H})/(r+s^{H}) + \beta f(\theta_i^{L})/(r+s^{L})} \tag{B.12}$$

$$w_{ii}^{L} = \frac{\beta(r + s^{L} + f(\theta_i^{L}))y_{ii}^{L} + (1-\beta)(r+s^{L})(b_{ii}^{L} + \mu_i \int_0^{\bar{c}_i^{L}} F(c)dc)}{M_i^{L}} \tag{B.13}$$

$$w_{ji}^{H} = \frac{\beta(r + s^{H} + f(\theta_i^{H}))y_{ji}^{H} + (1-\beta)(r+s^{H})b_{ji}^{H}}{M_i^{H} + d} \tag{B.14}$$

$$w_{ji}^{L} = \frac{\beta(r + s^{L} + f(\theta_i^{L}))y_{ji}^{L} + (1-\beta)(r+s^{L})b_{ji}^{L}}{M_i^{L} + d}, \tag{B.15}$$

where $M_i^{\kappa} = r + s^{\kappa} + \beta f(\theta_i^{\kappa})$ for all $\kappa \in \{H, L\}$ and $i \in \{1, 2\}$. The first digit of the subscript represents the country that the worker was born and the second digit represents the location of her job. Per the value of unemployment in the foreign country and in the country of origin, the reservation migration cost of a worker who was born in country $i$ with skill $\kappa$ is solved as

$$(r+d)\bar{c}_i^H = \max\{\frac{\beta f(\theta_j^H)y_{ij}^H + (r+s^H+d)b_{ij}^H}{r+s^H+d+\beta f(\theta_j^H)} \tag{B.16}$$

$$-\frac{b_{ii}^H + \beta f(\theta_i^H)y_{ii}^H/(r+s^H) + \beta f(\theta_i^L)y_{ii}^{HL}/(r+s^L) + \mu_i \int_0^{\bar{c}_i^H} F(c)dc}{1+\beta f(\theta_i^H)/(r+s^H) + \beta f(\theta_i^L)/(r+s^L)}, 0\} \tag{B.17}$$

$$(r+d)\bar{c}_i^L = \max\{\frac{\beta f(\theta_j^L)y_{ij}^L + (r+s^L+d)b_{ij}^L}{r+s^L+d+\beta f(\theta_j^L)} \tag{B.18}$$

$$-\frac{\beta f(\theta_i^L)y_{ii}^L + (r+s^L)(b_{ii}^L + \mu_i \int_0^{\bar{c}_i^L} F(c)dc)}{r+s^L+\beta f(\theta_i^L)}, 0\}. \tag{B.19}$$

The unemployment of each type of workers are solved with (3.23) to (3.28), which are

$$U_{ii}^H = \frac{s^L H_i}{f(\theta_i^L) + s^L + s^L f(\theta_i^H)/s^H + s^L \mu_i F(\bar{c}_i^H)/d} \tag{B.20}$$

$$U_{ji}^H = \frac{s^H \mu_j F(\bar{c}_j^H) U_{jj}^H}{d[f(\theta_i^H) + s^H + d]} \tag{B.21}$$

$$U_{ii}^L = \frac{s^L(N_i - H_i)}{s^L + f(\theta_i^L) + \mu_i F(\bar{c}_i^L)/d} \tag{B.22}$$

$$U_{ji}^L = \frac{(d+s^L)\mu_j F(\bar{c}_j^L) U_{jj}^L}{d[s^L + d + f(\theta_i^L)]}. \tag{B.23}$$

## B.2 Proofs of Lemmas and Propositions

### Proof of Propersition 1

**Proof.** According to (B.2) and (B.12), the surplus of mismatched skilled workers in country $i$ is rewritten as

$$\mathcal{W}_{ii}^{HL} - \mathcal{U}_{ii}^{H} = \frac{\beta[y_{ii}^{HL} + (\beta f(\theta_i^H)/(r+s^H))(y_{ii}^{HL} - y_{ii}^{H}) - b_{ii}^{H} - \mu_i \int_0^{\bar{c}_i^H} F(c)dc]}{1 + \beta f(\theta_i^H)/(r+s^H) + \beta f(\theta_i^L)/(r+s^L)}. \quad \text{(B.24)}$$

If this surplus is negative, no skilled worker searches in the unskilled labor market. They prefer to stay unemployed and search in the skilled labor market only. Therefore, the productivity of skilled workers who work in the unskilled labor market should be high enough to ensure that the surplus of skilled workers in unskilled labor market is non-negative. Per equation (B.24), the productivity of skilled workers in the unskilled labor market satisfied

$$\frac{r + s^H + \beta f(\theta_i^H)}{r + s^H} y_{ii}^{HL} \geq \frac{\beta f(\theta_i^H)}{r + s^H} y_{ii}^{H} + b_{ii}^{H} + \mu_i \int_0^{\bar{c}_i^H} F(c)dc.$$

■

## Proof of Propersition 2

**Proof.** According to (B.17) and (B.19), it is obvious that $\bar{c}_2^H$ and $\bar{c}_2^L$ are positive, and $\bar{c}_1^L = 0$. The reservation cost of skilled workers in country 1 is positive if and only if

$$\frac{\beta f(\theta_j^H) y_{ij}^H + (r + s^H + d) b_{ij}^H}{r + s^H + d + \beta f(\theta_j^H)} > \frac{b_{ii}^H + \beta f(\theta_i^H) y_{ii}^H / (r + s^H) + \beta f(\theta_i^L) y_{ii}^{HL} / (r + s^L) + \mu_i \int_0^{\bar{c}_i^H} F(c) dc}{1 + \beta f(\theta_i^H)/(r + s^H) + \beta f(\theta_i^L)/(r + s^L)}$$

■

## B.3 Tables and graphs

Table B.1: Calibration results

| | | description | sources/target |
|---|---|---|---|
| $y_{11}^H$ | 1 | Normalized skilled productivity in the US | |
| $y_{11}^L$ | 0.4699 | Relative unskilled productivity in the US | The college-plus wage premium: 1.1281 |
| $y_{11}^{HL}$ | 0.7143 | Mismatch productivity in the US | Wage gap between college workers work in professional and in unprofessional jobs:1.4 |
| $y_{22}^H$ | 0.6944 | skilled productivity in Mexico | TFP gap between US and Mexico: 1.44 |
| $y_{22}^L$ | 0.1968 | relative unskilled productivity in Mexico | college-plus wage permium in Mexico: 2.53 |
| $y_{22}^{HL}$ | 0.1736 | Mismatch productivity in Mexico | Wage gap between college workers work in professional and in unprofessional jobs: 5.6 |
| $y_{12}^H$ | 0.9561 | skilled productivity of US-born in Mexico | Wage gap between skilled US-born and Mexicans: 0.3767 |
| $\beta$ | 0.5 | Bargaining power | Hosios (1990) |
| $\alpha$ | 0.5 | Elasticity of matching function | Pretongolo and Pissarides (2001) |
| | | | Estimated from data: |
| $r$ | 0.0040 | real interest rate | Fed. of Saint Louis |
| $s^H$ | 0.0240 | job separation rate in skilled labor market | Chassamboulli and Peri (2015b) |
| $s^L$ | 0.0320 | job separation rate in unskilled labor market | |
| $d$ | 0.0023 | return rate of immigrants | |
| $N_2$ | 1/3 | measure of population in Mexico | |
| $H_1$ | 0.3144 | measure of skilled workers in US | |
| $H_2$ | 0.0265 | measure of skilled workers in Mexico | |
| | | | Jointly calibrated to match: |
| $A$ | 0.3501 | Match technology | Employment rate of skilled labor market in US: 0.9520 |
| $k^H$ | 0.4349 | Fixed recruitment cost in skilled labor market | Employment rate of unskilled labor market in US: 0.8743 |
| $k^L$ | 0.0371 | Fixed recruitment cost in unskilled labor market | Employment rate of skilled labor market in Mexico: 0.9671 |
| $b_{11}^H$ | 0.6760 | Unemployed. flow value, skilled natives | Employment rate of unskilled labor market in Mexico: 0.9553 |
| $b_{11}^L$ | 0.3207 | Unemploy. flow value, unskilled natives | Measure of skilled US-born workers in Mexico: 0.0030 |
| $b_{21}^H$ | 0.6979 | | Measure of skilled Mexicans in US: 0.0096 |
| $b_{21}^L$ | 0.2264 | | Measure of unskilled Mexicans in US: 0.0638 |
| $b_{22}^H$ | 0.2511 | Unemploy. flow value, skilled immigrant | ratio of employed income to unemployed income in US: 0.71 |
| $b_{22}^L$ | 0.0779 | Unemploy. flow value, unskilled immigrant | ratio of employed income to unemployed income in Mexico: 0.4 |
| $b_{12}^H$ | 0.3732 | | Labor market tightness: 0.62 |
| $b_{12}^L$ | 0.1672 | | |
| $\mu_1/c^{max}$ | $1.4 \times e^{-4}$ | Arrival rate of migration opportunity in US | |
| $\mu_2/c^{max}$ | $2.86 \times e^{-4}$ | Arrival rate of migration opportunity in Mexico | |

Note: Subscripts represent countries. The first digit of the subscript represents the country that the worker was born. The second digit of subscripts represents the location of the job. The superscript represents the skill of the market/workers.

Table B.2: Policy: subsidy of firms in the US

| sub | 0.1 | 0.2 | 0.3 | 0.4 |
|---|---|---|---|---|
| $\theta_1^H$ | 22.91% | 51.91% | 88.46% | 133% |
| $\theta_1^L$ | 60.50% | 166.91% | 359.31% | 708% |
| $\theta_2^H$ | -3.22% | -6.42% | -9.33% | -12% |
| $\theta_2^L$ | -5.11% | -9.98% | -14.44% | -18% |
| $w_{11}^H$ | -0.28% | -0.65% | -1.10% | -2% |
| $w_{11}^L$ | 0.60% | 1.15% | 1.64% | 2% |
| $w_{22}^H$ | 0.08% | 0.16% | 0.24% | 0% |
| $w_{22}^L$ | 0.06% | 0.13% | 0.19% | 0% |
| $u_{11}^H$ | -12.97% | -25.17% | -36.49% | -47% |
| $u_{11}^L$ | -19.26% | -36.16% | -50.54% | -62% |
| $u_{22}^H$ | -0.51% | -0.95% | -1.27% | -1% |
| $u_{22}^L$ | -3.43% | -6.36% | -8.78% | -11% |
| $h_{12}$ | 9.02% | 18.63% | 27.46% | 34% |
| $h_{21}$ | 0.75% | 1.48% | 2.13% | 3% |
| $l_{12}$ | 0.00% | 0.00% | 0.00% | 0% |
| $l_{21}$ | 0.98% | 1.84% | 2.57% | 3% |

Table B.3: Policy: Tax to firms in the US

| Tax | 0.1 | 0.2 | 0.3 | 0.4 |
|---|---|---|---|---|
| $\theta_1^H$ | -0.1649% | -0.3294% | -0.4933% | -0.6569% |
| $\theta_1^L$ | -0.5051% | -1.0072% | -1.5063% | -2.0024% |
| $\theta_2^H$ | 0.0509% | 0.1019% | 0.1529% | 0.2039% |
| $\theta_2^L$ | 0.0575% | 0.1150% | 0.1725% | 0.2300% |
| $w_{11}^H$ | 0.0038% | 0.0076% | 0.0114% | 0.0151% |
| $w_{11}^L$ | -0.0069% | -0.0139% | -0.0208% | -0.0277% |
| $w_{22}^H$ | -0.0001% | -0.0003% | -0.0004% | -0.0005% |
| $w_{22}^L$ | -0.0007% | -0.0014% | -0.0021% | -0.0028% |
| $u_{11}^H$ | 0.1276% | 0.2552% | 0.3828% | 0.5104% |
| $u_{11}^L$ | 0.2266% | 0.4533% | 0.6804% | 0.9076% |
| $u_{22}^H$ | 0.0109% | 0.0218% | 0.0328% | 0.0437% |
| $u_{22}^L$ | 0.0410% | 0.0821% | 0.1232% | 0.1644% |
| $h_{12}$ | -0.2041% | -0.4082% | -0.6124% | -0.8167% |
| $h_{21}$ | -0.0129% | -0.0259% | -0.0389% | -0.0518% |
| $l_{12}$ | 0.0000% | 0.0000% | 0.0000% | 0.0000% |
| $l_{21}$ | -0.0115% | -0.0230% | -0.0345% | -0.0461% |

Table B.4: Tax on Mexicans

| tax on mexican | 0.08 | 0.16 | 0.24 | 0.32 | 0.4 |
|---|---|---|---|---|---|
| $\theta_1^H$ | -0.0463% | -0.0463% | -0.0463% | -0.0463% | 0.1264% |
| $\theta_1^L$ | -0.7860% | -0.7860% | -0.7860% | -0.7860% | -0.3694% |
| $\theta_2^H$ | 28.9478% | 28.9478% | 28.9478% | 28.9478% | 28.9355% |
| $\theta_2^L$ | 55.1542% | 55.1542% | 55.1542% | 55.1542% | 55.4663% |
| $w_{11}^H$ | 0.0103% | 0.0103% | 0.0103% | 0.0103% | 0.0078% |
| $w_{11}^L$ | -0.0108% | -0.0108% | -0.0108% | -0.0108% | -0.0051% |
| $w_{22}^H$ | -0.8799% | -0.8799% | -0.8799% | -0.8799% | -0.8906% |
| $w_{22}^L$ | -0.6091% | -0.6091% | -0.6091% | -0.6091% | -0.6063% |
| $u_{11}^H$ | 0.0503% | 0.0503% | 0.0503% | 0.0503% | -0.0672% |
| $u_{11}^L$ | 0.3532% | 0.3532% | 0.3532% | 0.3532% | 0.1655% |
| $u_{22}^H$ | 231.97% | 231.97% | 231.97% | 231.97% | 231.99% |
| $u_{22}^L$ | 462.10% | 462.10% | 462.10% | 462.10% | 461.56% |
| $h_{12}$ | 21.55% | 21.55% | 21.55% | 21.55% | 21.59% |
| $h_{21}$ | -100% | -100% | -100% | -100% | -100% |
| $l_{12}$ | 0% | 0% | 0% | 0% | 0% |
| $l_{21}$ | -100% | -100% | -100% | -100% | -100% |

Table B.5: Subsidy to US workers

| subsidy to US workers | 0.2 | 0.3 | 0.4 |
|---|---|---|---|
| $\theta_1^H$ | -41.3511% | -40.1470% | -42.3996% |
| $\theta_1^L$ | -84.3294% | -82.7549% | -86.4749% |
| $\theta_2^H$ | -71.1264% | -70.9811% | -64.9997% |
| $\theta_2^L$ | 25.4813% | -3.2807% | -10.9265% |
| $w_{11}^H$ | 1.2482% | 1.2034% | 1.2950% |
| $w_{11}^L$ | -3.0482% | -2.8672% | -3.3230% |
| $w_{22}^H$ | -7.5549% | -6.2860% | -4.9260% |
| $w_{22}^L$ | -0.1843% | -0.0927% | -0.6989% |
| $u_{11}^H$ | 43.9958% | 41.6115% | 48.0424% |
| $u_{11}^L$ | -26.3794% | -26.3178% | -27.8059% |
| $u_{22}^H$ | -52.46% | -45.49% | -38.17% |
| $u_{22}^L$ | 18.69% | 2.14% | 27.25% |
| $h_{12}$ | 959.52% | 981.85% | 708.43% |
| $h_{21}$ | 27% | 25% | 23% |
| $l_{12}$ | 5% | 5% | 5% |
| $l_{21}$ | -5% | 0% | -3% |