Immigration and Crime in Frictional Labor Markets*

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July 29, 2020

Abstract

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

JEL Classification: E24, F22, J60, J61, J63, J64

Keywords: Immigration, Crimes, Search and matching, Unemployment

*I am grateful to the editor, Vincenzo Quadrini, and two anonymous referees for their helpful suggestions that improved the paper significantly. I also thank Miroslav Gabrovski, Jang-Ting Guo, Matthew Lang, Bree Lang, David Malueg, Victor Ortego-Marti, Nicolas Petrosky-Nadeau, Guillaume Rocheteau, Peter Rupert, and participants at the UC Irvine Macro Workshops, the 2017 fall Midwest Macroeconomics Meeting, the 93rd Western Economic Association International Annual Conference, and APPAM 2018 California Regional Student Conference for their helpful comments and suggestions.

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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, respectively. However, 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 waves of asylum seekers in the United Kingdom led to a rise in property crime rates but migration flows from the A8 countries had opposite effects.[1] Neither wave had any effect on the rate of violent crimes. Bianchi et al. (2012) and Spenkuch (2014) find that immigration positively correlates only with property crimes. However, this literature is not able to explain how immigrants affect crime rates.

This is a theoretical study on the effects of immigration on crime rates. 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 the immigrant population directly affects the host country's composition of labor force. The propensity to commit crimes varies for immigrants and native workers: compared with native workers, unemployed immigrants have more difficulties when they search the labor market, while employed immigrants have a higher value of employment in the labor market. As a result, unemployed immigrants tend to commit more crimes while employed immigrants are less likely to commit crimes among the work force. When the share of immigrants increases, 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 it operates through labor market friction. Firms' expected profits increase when more immigrants seek employment in the labor market. Such

[1] The A8 countries are a group of eight countries that joined the European Union (EU) in 2004: Poland, Hungary, Czechia, Slovakia, Slovenia, Latvia, Lithuania, and Estonia.

a compositional change in the labor force compels firms to create more jobs that benefit both native and immigrant workers in terms of employment and wages. Thus, unemployed workers' incentive to commit a crime—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 decreases in labor markets. Thus, analytically, the overall effect of immigration on the crime rate is ambiguous.

The existing literature concludes that workers' criminal behavior regarding property crimes relates strongly 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 higher 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 is unemployment utility. Immigrants earn less than native workers. According to the Current Population Survey (CPS), is a monthly survey of households conducted by the U.S. Bureau of Census for the Bureau of Labor Statistics, during the 1990s, the wage gap between immigrants and native workers was about 20% in the U.S. It is reasonable to consider that this wage gap is attributable to the low unemployment value of immigrants for two reasons. First, immigrants have limited access to the federal 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 cultural conflicts in the host country. Given these constraints, immigrants are compelled to search more intensively for employment than do natives. As a result, immigrants enjoy less leisure when they are unemployed. According to the Annual Social and Economic supplement (ASEC) of the CPS from 1994 to 2009, the mean unemployment income of foreign-born workers was lower than that of native workers. The data show that from 1994 onward, the mean unemployment income of immigrants with college degrees and above is \$1281.29, lower than native workers with the same educational attainment. The mean unemployment income of Immigrants without any college degree is $264.28, lower than that for no-college-degree native workers. 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 will tend to commit more crimes. Employed immigrants receive a higher surplus from employment than do natives. Therefore, employed immigrants are selective than employed natives when they encounter criminal opportunities. Among all the workers, employed immigrants are the least likely to commit crimes, while unemployed immigrants are the most likely to commit crimes. Any increase in immigrants directly affects the composition of the workforce. Moreover, increase in employed immigrants decreases the crime rate, but the increase in unemployed immigrants drives up the crime rate directly.

The criminal behavior of workers also affects the crime rate. In this paper, criminal behavior follows the model of Engelhardt et al. (2008). As immigration changes workers' distribution directly, these changes also affect labor markets and workers' criminal behavior via labor markets. Workers encounter criminal opportunities at random, but they commit crimes only when the payoff is sufficiently high. An increase in immigrant flows does not change the criminal behavior of workers explicitly, instead, creates more jobs in the labor market. Both employed and unemployed workers respond differently to job creation resulting from immigration. With more jobs in the markets, unemployed workers prefer remaining unemployed instead of getting involved in criminal activities because they can find jobs faster, as it increases the value of unemployment. Employed workers, however, commit more crimes because their jobs become less valuable. The opposite effect of an increase in immigration on the criminal behavior of both employed and unemployed workers may explain the ambiguity of the impact of immigration on crimes 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 decreased by 0.3859 percentage points, skilled native workers' wage increased by 0.21%, and unskilled native workers' wage increased by 0.15%. The overall crime rate decreased by 0.2334 per 1,000 population, which means that the total number of criminal offenses decreased by approximately 68,805 cases nationwide. Specifically, with the wave of skilled immigrants seen only in the 2000s, the overall crime rate decreased by 0.3054 per 1,000 and the overall unemployment rate reduced by 0.1481 percentage points. With the wave of unskilled immigrants, the overall unemployment rate will decrease by 0.2495 percentage points, but the overall crime rate increases by 0.0603 per 1,000. For the numerical exercise, I also extend the model with imperfect substitution between both skilled and unskilled labor. The crime rate decreases by 0.1666 offenses per 1,000 with the increase in immigrants. In particular, with an increase in skilled immigrants, the crime rate decreases by 0.2342 offenses per 1,000 but increases by 0.0660 offenses per 1,000 with the increase in unskilled immigrants.

Finally, this paper studies several relevant public policies. First, I consider the impact 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 by 1.1566 percentage points. It lowers the skilled native wage by 0.72% and unskilled native wage by 0.44%, while increasing the overall crime rate by 0.3725 offenses per 1,000 population. Second, an extended duration of incarceration and deportation policies reduce the crime rate by increasing the opportunity cost of committing a crime. A longer period of incarceration affects the criminal behavior of both natives and immigrants. The crime rate declines by 20.31 offenses per 1,000 when the average jail sentence is extended from 16 months to 48 months. The difference following a change in the deportation policy is that deportation only affects immigrant criminals. With this policy, the crime rate drops by 1.38 offenses to 4.26 offenses per 1,000, depending on country of origin. Both incarceration and deportation policies have little effect on labor market outcomes.

This is the first paper to study the impact of immigration on both labor market outcomes and crime in a search and matching framework. I extend the Engelhardt et al. (2008)

criminal behavior model with skill bias and the immigrant population. A closely related paper on immigration is Chassamboulli and Palivos (2014), which 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 impact of immigration on crime rates. In this paper, criminal behavior of workers follows Engelhardt et al. (2008). As immigration changes workers' distribution directly, these changes also affect labor markets and the criminal behavior of workers via labor markets. As the paper shows, this novel mechanism is important for understanding the consequences of migration policies 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 (2013) 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 (2015) 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. In Section 3, the steady-state equilibrium of the model is solved. In a steady-state equilibrium, an increase in the number of immigrants affects the composition of the labor force. The impact of immigration on labor market outcomes and crimes is 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 number of immigrants and comparison to the data are reported in Section 6. Section 7 discusses the outcomes of the policy. Section 8 extends the model with skill bias and imperfect substitution between skilled and unskilled labor. Section 9 concludes the paper.

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 levels of skill for workers in this economy: high and low. Workers with college degrees or above are considered high-skilled workers with productivity y_H. Workers without college degrees are defined as low-skilled workers with productivity y_L, where $y_L < y_H$.[2] Workers are either native workers (N) born in the host country, or immigrant workers (I) born outside the host country, regardless of their skills.[3] The measure of total native workers is normalized to 1, the measure of skilled

[2] In the baseline model, I assume that both high-skilled and low-skilled workers are perfectly substituted. A model with imperfect substitution between skilled and unskilled labor is shown in Section 8.

[3] The superscript/subscript variable i represents workersï¿œ skill level, high-skilled (H) and low-skilled (L); s represents the labor market status, employed (E), unemployed (U), or in jail (P); j represents the

natives is denoted as λ. 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-skilled and low-skilled.[4] Only unemployed workers search the labor market conditionally based 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 is due to the different unemployment utility flows between immigrants and native workers. As immigrants lack social security, social networks, and can have communication difficulties and other hardships, they receive lower unemployment benefits and are forced to search for employment more vigorously to compete with native workers. Therefore, unemployed immigrants receive a lower flow of utility than do natives, even if some of the 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,

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immigration status, native (N) or immigrant (I).

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

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

[6]This assumption is consistent with empirical evidence. Using CPS and a standard Mincerias regression—see, for example, Ortego-Marti (2016) and Ortego-Marti (2017)—immigrants earn lower wages than native workers, which is even conditional on observables. I run the following regression model

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

where $I_{immigration}$ is a dummy variable that captures the immigration status of the sample and equals one if the worker is a native-born worker. The variable X contains a standard set of observable variables and includes year dummies, education, age, and occupation. The coefficient of $I_{immigration}$ is 0.075 (standard error: 0.0008) when vector X includes occupation, which means that native workers earn 7.5% more than immigrants after controlling for observables. The coefficient of $I_{immigration}$ is 0.108 (standard error: 0.0008) when the vector X does not include occupation, which means that native workers earn 10.8% more than immigrants without controlling occupations—a detriment of being an immigrant is that one may have to take jobs in worse occupations. Both coefficients are statistically significant. The results are also consistent with the empirical literature—for example, Peri et al. (2015); Borjas (1987). The full regression results are available upon request.

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

which depends on her immigration status and skill, $j \in \{N, I\}$, $i \in \{H, L\}$ and $B_i^N > B_i^I = B_i^N - h_{iI}$, where h_i^I represents the search cost that immigrants have to pay in a foreign country. Skilled native workers have higher unemployment utilities than unskilled native workers because their productivity is higher. However, unemployment utilities of skilled immigrants are not necessarily higher than unskilled immigrants because of the search cost. The variable M_i represents the number of matches that are made in the 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 θ_i is defined as 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 a productivity of y_i. Exogenous job separation shocks arrive at a Poisson rate δ_i.

Every worker in the economy is both a potential victim and criminal. All the workers encounter criminal opportunities at an exogenous Poisson rate μ. The rate μ also equals the fraction of workers who may commit crimes. The probability of meeting a type-ij unemployed criminal is μu_i^j, while the probability of meeting a type-ij employed criminal is μe_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 as transfer of wealth from victims to criminals. Therefore, a worker's expected loss from crime is

$$\tau = \mu[\sum_i \sum_j u_i^j \mathbb{E}_U(g) + \sum_i \sum_j e_i^j \mathbb{E}_E(g)]. \tag{1}$$

When the worker encounters a criminal opportunity, she can observe the value of this criminal opportunity, g, that is, how much she can get from the 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 police can arrest the criminal with an exogenous probability π. When the criminal is in jail, she receives a constant flow of utility x. Assume that workers value their freedom, so that $V^j_{U,i} > V^j_{P,i}$.[8] Incarcerated workers are released from jail and return to the labor market at an exogenous rate ρ, 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 that requires the worker to pay a one-time hiring fee ϕ^j_i when hired, and the firm pays a flow wage w^j_i to the worker during the match. This employment contract $\{\phi^j_i, w^j_i\}$ is determined by some bargaining solutions. Once production begins, the firm receives productivity y_i from the employee. The firm loses its employee either when a separation shock arrives or when the employee commits a crime and is arrested.

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. A firm expects capital gain from the match, $\mathbb{E}(\Pi_{F,i} + \phi) - \Pi_{V,i}$, as 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 wage w^j_i, which is determined by the employment contract. The firm suffers capital loss $\Pi^j_{F,i} - \Pi_{V,i}$ 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

[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.

asset equations of firms are

$$r\Pi_{V,i} = -k_i + q(\theta_i)[\mathbb{E}(\Pi_{F,i} + \phi) - \Pi_{V,i}] \tag{2}$$

$$r\Pi^j_{F,i} = y_i - w^j_i - [\delta_i + \mu\pi(1 - F(\bar{g}^j_{E,i}))](\Pi^j_{F,i} - \Pi_{V,i}), \tag{3}$$

where $\mathbb{E}(\Pi_{F,i} + \phi) = \sum_j (u^j_i/u_i)(\Pi^j_{F,i} + \phi^j_i)$, for all $i \in \{H, L\}$ and $j \in \{I, N\}$.

Denote the value of individual of type s-ij as $V^j_{s,i}$. An individual can belong to one of the three states s: employed (E), unemployed (U), or in jail (P). Everyone has a burden τ that occurs due to criminal activity. Employed workers earn wages w^j_i from firms and suffer a capital loss $V^j_{E,i} - V^j_{U,i}$ when separation occurs. Unemployed workers receive a flow of utility B^j_i. They find a job at the rate $f(\theta_i) = \theta_i q(\theta_i)$, which yields a capital gain $V^j_{E,i} - V^j_{U,i}$. Upon finding a job, workers must pay the hiring fee ϕ^j_i determined by the employment contract. Both employed and unemployed workers encounter a criminal opportunity at the rate μ 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. Imprisoned workers receive a flow utility x. They are released from jail and return to the labor market as unemployed workers at the rate ρ, and obtain the capital gain $V^j_{U,i} - V^j_{P,i}$.[9] The value functions of workers satisfy the following Bellman equations

$$rV^j_{E,i} = w^j_i - \tau - \delta_i(V^j_{E,i} - V^j_{U,i}) + \mu \int_0^{g^m} \max\{K^j_{E,i}(g) - V^j_{E,i}, 0\} dF(g). \tag{4}$$

$$rV^j_{U,i} = B^j_i - \tau + \theta_i q(\theta_i)(V^j_{E,i} - V^j_{U,i} - \phi^j_i) + \mu \int_0^{g^m} \max\{K^j_{U,i}(g) - V^j_{U,i}, 0\} dF(g) \tag{5}$$

$$rV^j_{P,i} = x - \tau + \rho(V^j_{U,i} - V^j_{P,i}). \tag{6}$$

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, that is,

[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.

the payoff from the crime should be greater than 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 $V_{s,i}^j$ if she does not get arrested. If the criminal gets arrested, which happens with a probability of π, she becomes a prisoner and suffers an expected capital loss $\pi(V_{P,i}^j - V_{s,i}^j)$. The payoff of a crime is given as

$$K_{s,i}^j(g) = g + V_{s,i}^j + \pi(V_{P,i}^j - V_{s,i}^j), \tag{7}$$

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 the value of the current state, the reservation crime value determines her criminal behavior, that is, whether to commit a crime. The endogenous reservation value is given as

$$\bar{g}_{s,i}^j = \pi(V_{s,i}^j - V_{P,i}^j) \tag{8}$$

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, which is strictly greater than the reservation crime value $\bar{g}_{s,i}^j$, she commits a crime.

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

$$S_i^j = V_{E,i}^j - V_{U,i}^j + \Pi_{F,i}^j,$$

for type-ij workers. From Equations (3) to (5), the total surplus can be rewritten as

$$rS_i^j = y_i - \tau - rV_{U,i}^j - \delta S_i^j + \mu \int_{\bar{g}_{E,i}^j}^{g^m} [g - \pi S_i^j + \pi(V_{P,i}^j - V_{U,i}^j)] dF(g).$$

Suppose that workers and firms determine 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 an 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 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 $\beta \in [0, 1]$, that is,

$$(w^j_i, \phi^j_i) = \underset{w^j_i, \phi^j_i}{\operatorname{argmax}} (V^j_{E,i} - V^j_{U,i} - \phi^j_i)^{\beta} (\Pi^j_{F,i} + \phi^j_i)^{1-\beta}. \tag{9}$$

Lemma 1. *The optimal employment contract that solves equation (9) satisfies*

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

The proofs for all lemmas and propositions are in given Appendix A. The intuition is as follows. According to the optimal contract, workersï¿œ wages equal their productivity, which depends only on their skill. Since the firm pays productivity as a wage to its employee and does not profit from the match, the hiring fee is the single source of revenue for 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 β, so that the optimal hiring fee equals the firm's share of match surplus. Since the hiring fee covers the firm's share of 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.

2.3 Discussion: optimal contract and Nash bargaining

According to Nash (1953), Nash efficiency requires convexity of the bargaining set. Shimer (2006) shows that on-the-job search violates the convexity of the bargaining set. Like on-the-job search, 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. As with on-the-job search, employeesï¿œ criminal behavior generates inefficient job separations. The standard Nash bargaining share rule is not able to provide a Pareto-efficient outcome, as it does not consider the asymmetric information of criminal behavior between workers and firms. This situation may reduce 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. Following Stevens (2004) and Engelhardt et al. (2008) closely, I assume that firms offer their employees an employment contract with a hiring fee and constant wages. According to Stevens (2004), this employment contract is the first best contract for on-the-job search. Assuming that workers and employers can cooperate, they will deviate from Nash bargaining to this employment contract and achieve Pareto optimum.

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

3 Equilibrium

From equation (2) and $\Pi_{V,i} = 0$, the job creation condition (JC) is

$$\frac{k_i}{q(\theta_i)} = \mathbb{E}(\Pi_{F,i} + \phi_i). \tag{10}$$

In equilibrium, the average cost of posting a vacancy equals the expected revenue of firms. The left hand side of equation (10) represents the average cost of a match. The job filling rate $q(\theta_i)$ is defined as the ratio of matches to vacancies, that is, $q(\theta_i) \equiv M_i/v_i$. Hence,

$$k_i/q(\theta_i) = k_i v_i/M_i. \tag{11}$$

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 (11) represents the average cost of matches. The right hand side of equation (10) represents the expected revenue of a match. Given the zero profit condition of vacant and filled jobs ($\Pi_{V,i} = 0, \Pi^j_{F,i} = 0$), hiring fee is the only source of revenue for firms. 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, namely $\phi^e_i = \sum_j (u^j_i/u_i)\phi^j_i$. Using (4) and (5), the hiring fee of type-ij is

$$\begin{aligned} \phi^j_i &= (1-\beta)(V^j_{E,i} - V^j_{U,i}) \\ &= \frac{1-\beta}{r+\delta_i+\beta\theta_i q(\theta_i)} \left[y_i - B^j_i - \mu \int_{\bar{g}^j_{U,i}}^{\bar{g}^j_{E,i}} (1-F(g))dg \right]. \end{aligned} \tag{12}$$

Given equation (10) and lemma 1, the job creation condition can be rewritten as

$$\begin{aligned} \frac{k_i}{q(\theta_i)} &= \phi^e_i \\ &= \frac{1-\beta}{r+\delta_i+\beta\theta_i q(\theta_i)} \mathbb{E} \left[y_i - B_i - \mu \int_{\bar{g}_{U,i}}^{\bar{g}_{E,i}} (1-F(g))dg \right]. \end{aligned} \tag{13}$$

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

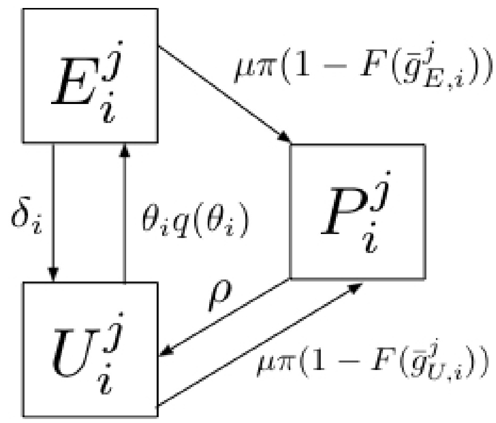

Figure 1: Workers' flows

Figure 1 shows workers' flows. There are three states of workers: employed, unemployed, and in jail. At a steady state, the inflows of each pool are equal to its outflows. Equation (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, $\eta^j_{U,i} u_i^j$. 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. Similarly, the flows into unemployment correspond to employed individuals who lose their jobs $\delta_i e_i^j$ and individuals who are released from jail ρP_i^j. Equation (15) represents the flows into and out of employment. Similarly, the flows into employment include individuals that get hired $\theta_i q(\theta_i) u_i^j$. The flows out of employment represent employees that suffer a job separation shock $\delta_i e_i^j$, and employed workers who commit crimes and get arrested $\eta^j_{E,i} e_i^j$. The population of type-ij workers is the sum of employed workers, unemployed workers, and prisoners.

$$\delta_i e_i^j + \rho P_i^j = [\theta_i q(\theta_i) + \eta_{U,i}^j] u_i^j, \tag{14}$$

$$(\delta_i + \eta_{E,i}^j) e_i^j = \theta_i q(\theta_i) u_i^j, \tag{15}$$

$$\lambda = e_H^N + u_H^N + P_H^N, \tag{16}$$

$$1 - \lambda = e_L^N + u_L^N + P_L^N, \tag{17}$$

$$I_H = e_H^I + u_H^I + P_H^I, \tag{18}$$

$$I_L = e_L^I + u_L^I + P_L^I, \tag{19}$$

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

$$u_H^N = \frac{\rho(\delta_H + \eta_{E,H}^N)\lambda}{\theta_H q(\theta_H)(\eta_{E,H}^N + \rho) + (\eta_{E,H}^N + \delta_H)(\eta_{U,H}^N + \rho)}, \tag{20}$$

$$u_H^I = \frac{\rho(\delta_H + \eta_{E,H}^I) I_H}{\theta_H q(\theta_H)(\eta_{E,H}^I + \rho) + (\eta_{E,H}^I + \delta_H)(\eta_{U,H}^I + \rho)}, \tag{21}$$

$$u_L^N = \frac{\rho(\delta_L + \eta_{E,L}^N)(1-\lambda)}{\theta_L q(\theta_L)(\eta_{E,L}^N + \rho) + (\eta_{E,L}^N + \delta_L)(\eta_{U,L}^N + \rho)}, \tag{22}$$

$$u_L^I = \frac{\rho(\delta_L + \eta_{E,L}^I) I_L}{\theta_L q(\theta_L)(\eta_{E,L}^I + \rho) + (\eta_{E,L}^I + \delta_L)(\eta_{U,L}^I + \rho)}. \tag{23}$$

Before solving the equilibrium, the formal definition of steady-state equilibrium is as follows.

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: θ_i satisfies equation (13); $\{u_i^j, e_i^j, P_i^j\}$ satisfy equations (14) – (19); $\{\bar{g}_{E,i}^j, \bar{g}_{U,i}^j\}$ satisfy equation (8); and τ satisfies equation (1).

The equilibrium is recursively solvable. Equations (14) to (19) determine the distribution of workers, given any θ_i. The pair of reservation crime values of employed and unemployed workers $\{\bar{g}^j_{E,i}, \bar{g}^j_{U,i}\}$ are solved jointly by equations (4) to (6) and (8). The expected revenue of a match is determined by equations (4) and (5). Finally, θ_i satisfies (13).

Figure 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, that is, equilibrium is the intersection of the AC and HF curves. With a higher market tightness, the firm needs to wait longer to hire a worker, so the average recruitment cost increases. Hence, the AC curve is upward sloping. The slope of curve HF depends on workers' distribution and the match surplus. Unemployed workers get hired sooner when market tightness increases. Thus, 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 workers' distribution is ambiguous. Given (20) and (21), 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^j_i/u_i hardly changes. Therefore, the impact of market tightness on the match surplus dominates. The hiring fee is constantly in proportion to the match surplus, so it also decreases with the market tightness. The slope of the curve HF is downward sloping.

[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.

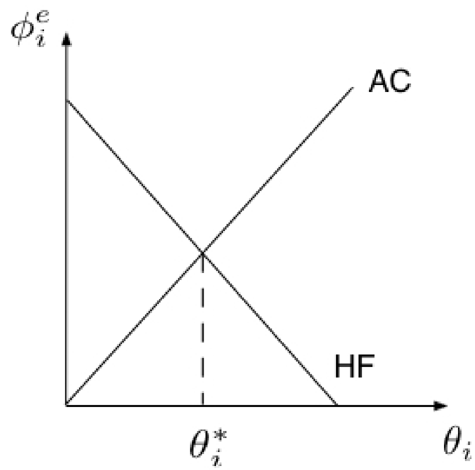

Figure 2: Equilibrium

Lemma 2. *The expected hiring fee ϕ_i^e decreases with θ_i.*

When θ_i moves 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 reaches 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 $\theta_i = 0$, curves AC and HF have a unique intersection on (θ_i, ϕ_i^e) space and $\theta_i > 0$ at the equilibrium.

Proposition 1. *An equilibrium exists with $\theta_i > 0$ 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 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. Consequently, employed workers have a higher reservation crime value and more selective than unemployed workers when encountering criminal opportunities.

4 Effects of Immigration

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

4.1 Composition (direct) effects

When the immigrant population increases, the share of immigrants in the total labor force distribution increases directly. To see how this increase in immigrant population affects the overall crime rate, I compare the reservation value of immigrants committing crimes with native workers. Employed immigrants, conditional on their skills, are less likely to commit crimes than employed native workers. Meanwhile, unemployed immigrants have a greater incentive to commit crimes compared with unemployed native workers because of their lower unemployment utility. Moreover, employed workers commit fewer crimes than unemployed workers, regardless of their skill and immigration types. Employed workers earn labor productivity with an optimal contract so that their reservation crime value is higher than that of unemployed workers.

Lemma 3. *For all* $i \in \{H, L\}$,
i) $\bar{g}^{I}_{E,i} > \bar{g}^{N}_{E,i}$ *if* $\delta_i < \rho$,
ii) $\bar{g}^{I}_{U,i} < \bar{g}^{N}_{U,i}$, *and*
iii) $\bar{g}^{j}_{E,i} > \bar{g}^{j}_{U,i}$ *for all* $j \in \{N, I\}$.

The reservation value of crime also relates to the skill level. Skilled workers provide higher productivity than unskilled workers. Skilled native workers have a higher reservation crime value than unskilled native workers, regardless of their employment status. Employed skilled immigrants also have a higher reservation crime value than employed unskilled immigrants because of their higher productivity. However, the relationship between the reservation crime value of unemployed skilled and unskilled immigrants is ambiguous analytically. The relationship of these two reservation crime values depends on unemployment utilities and the expected capital gain of a match in both labor markets. The expected capital gain of a match of skilled immigrants is strictly greater than that of unskilled immigrants, while the unemployment utilities of skilled immigrants are not necessarily higher than those of unskilled immigrants. Thus, analytically the reservation crime value of unemployed skilled immigrants may be lower than unemployed unskilled immigrants. Quantitatively, the difference of expected capital gain between skilled and unskilled immigrants is greater than the difference of unemployment utilities. Therefore, the reservation crime value of unemployed skilled immigrants is greater than unemployed unskilled immigrants.

Lemma 4. *For all $s \in \{E, U\}$,*

i) $\bar{g}^N_{s,H} > \bar{g}^N_{s,L}$,

ii) $\bar{g}^I_{E,H} > \bar{g}^I_{E,L}$, and

iii) the relationship between $\bar{g}^I_{U,H}$ and $\bar{g}^I_{U,L}$ is ambiguous if $B^I_H < B^I_L$.

The overall crime rate is defined as

$$c = \frac{\mu \sum_i \sum_j [(1 - F(\bar{g}^j_{E,i}))e^j_i + (1 - F(\bar{g}^j_{U,i}))u^j_i]}{\sum_i \sum_j (e^j_i + u^j_i)}, \tag{24}$$

which is the weighted average of crime rates of each worker type.

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

Both employed and unemployed skilled immigrants increase with the upsurge in the population of skilled immigrants. It changes the composition of the total labor force and criminals. Compared with the reservation value of crime, employed skilled immigrants are the highest among all types of workers, while unemployed skilled immigrants are less likely to commit crimes than all unskilled workers but are more likely to commit crimes than other skilled workers. Also, the increase in employed skilled immigrants is greater than the increase in unemployed skilled immigrants with the rise in the population of skilled immigrants. As a result, the negative effect (decreasing crime rates) of skilled immigrants through employed skilled immigrants dominates the effect through unemployed skilled immigrants.

Proposition 3. *Given a certain market tightness, the overall crime rate is ambiguous with an increase in the population of skilled immigrants,* I_L.

The reservation crime value of unskilled immigrants is low. Specifically, employed unskilled immigrants are less likely to commit crimes than other unskilled workers. Quantitatively, they even commit fewer crimes than unemployed skilled immigrants. Unemployed unskilled immigrants have the lowest reservation crime values among all types of workers. The impact of unskilled immigrants through employed unskilled immigrants can be positive (increasing crime rates) or negative (decreasing crime rates), while the effect through unemployed unskilled immigrants is positive.

4.2 Labor market (indirect) effects

In either the skilled or unskilled labor markets, 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 immigrant flows, 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 a greater surplus than native workers, the expected hiring fee increases when the weight of unemployed immigrants increases. Figure 3 shows that a rise in the number of immigrants shifts the curve HF to the right and increases market tightness.

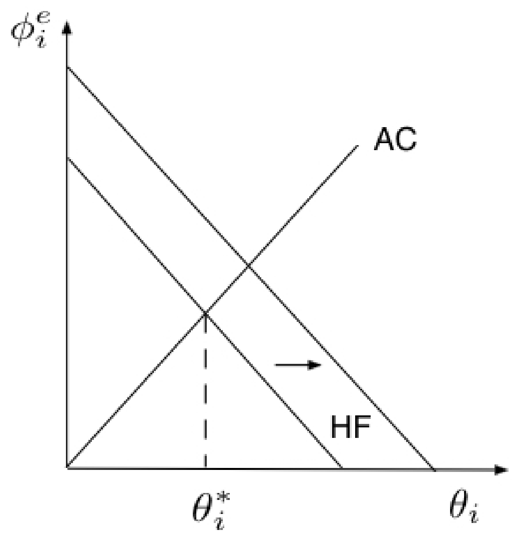

Figure 3: Effects of immigration on labor market

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

Intuitively, immigrants have lower unemployment value than do natives, so they pay higher hiring fees compared to natives. Since the hiring fee is the single source of revenue for firms, a higher number of immigrants raises the expected revenue of firms, thereby encouraging more firms to enter the labor market and post vacancies. The average cost of a match increases with the increase in expected revenue to balance the equality of equation (13) and move to the new equilibrium. Intuitively, firms can wait longer to hire a worker with higher expected revenue; therefore, market tightness increases. Proposition 2 shows the impact of an rise in immigrants on labor market tightness. According to lemma 6, labor market tightness intensifies with the number of immigrants.

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

As shown in (4) to (6) and (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 declines with market tightness.

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

Proposition 5. *If the market tightness θ_i increases,*

i) $\bar{g}^j_{E,i}$ decreases if $\rho > \delta_i$, and

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

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

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. (2000), I define skilled workers as those who have at least a college degree, and unskilled workers as those without college degrees. 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 γ 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 from the March CPS of the 1990s. Based on the estimation in Petrongolo and Pissarides (2001), I assume the matching function is $m(v_i, u_i) = Au_i^{\alpha}v_i^{1-\alpha}$ and α to be 0.5. The bargaining power of workers β is 0.5, satisfying the Hosios (1990) 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 θ_i, and the constant recruitment cost k_i can be determined using (13) with a given job finding rate. The job finding rates are estimated by the employment rate in skilled and unskilled labor market. Chassamboulli and Palivos (2014) estimate the employment rate in skilled and unskilled labor market by using the March CPS in the 1990s, which are 0.976 and 0.939, respectively. The overall market tightness is 0.72, which is drawn from Pissarides (2009). The job finding rate is 9.2910 in the skilled labor market and 6.2863 in the unskilled labor market. Thus, the calibration of the matching efficiency A equals to 7.9592, while the constant recruitment cost k_H is 0.8655 and k_L is 0.7633.[11]

Since the optimal employment contract requires that wages must equal workers' productivity, the implied wage can be recovered using

$$\tilde{w}_i^j = y_i - (r + \delta_i + \pi\mu(1 - F(\bar{g}_{E,i}^j)))\phi_i^j. \tag{25}$$

Implied wage is the difference between workers' productivity and flow hiring fee, which is the second term of (25). A 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 duration of employment. Given (25), the implied wage of skilled native workers is 0.9829 and 0.5958 for unskilled natives. Shimer (2005) estimates that the replacement ratio of unemployment and employment income is 0.4. Given the replacement ratio of

[11] The calibration strategy follows Pissarides (2009) and Chassamboulli and Palivos (2014). I iterate the guess of matching efficiency to target the overall market tightness. By the iteration, the model produced moments perfectly match the empirical moments. The detailed calibration strategy is explained in Appendix B.

unemployment and employment income, and the productivity difference between skilled and unskilled workers, 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 -5.1455 and -1.2610 respectively.

I normalize all dollar figures in the data by the annualized earnings of workers aged over 25 years 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 μ targets the crime rate and equals to 0.0707. Since loss of crime is a form of wealth transfer from victims to criminals, I set the expected loss τ equal to the mean of the crime value. The probability of getting caught is the ratio of the number of people sent to jail to the total number of offenses, which is 0.019 following Engelhardt et al. (2008). In 2002, the mean length of incarceration of property crimes was 16 months, which is also from Engelhardt et al. (2008). Hence, the rate of being released is $\rho = 0.75$. Due to lack of information on the utility flow in jail, I normalize this utility flow to $x = 0$.[13] The calibration is summarized in table 1.

[12] According to the UCR, the distribution of property crime value in 2004 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.

6 Effects of Immigration: A Numerical Exercise

This section studies the quantitative impact of immigration waves from 2000 to 2009. Using the findings in Chassamboulli and Palivos (2014), both skilled and unskilled immigrants increased by 0.026 and 0.051, respectively, in the 2000s. The simulation results are presented in table 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% 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 0.15%, with the wave of immigrants. Compared with the de-trended wage, the impact of immigration on wages includes about 1/3 of the increase of de-trended wages from the 1990s to the 2000s.[14] Since immigrants create jobs for both natives and immigrants, the overall unemployment rate decreases by 0.3859 percentage points.

Without effects through the labor market, the increase in immigrants in the 2000s decreases the overall crime rate by 0.3937 per 1,000 population. Table 3 reports the respective crime rates for 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

[14]The reason for de-trending the wage is that wage growth is mainly driven by productivity growth, which is not represented in my model. I run a regression of hourly real wages on labor productivity from 1990 to 2000,

$$w_t = \beta p_t + \epsilon.$$

where t represents the year, w_t represents the average wage in year t, and p_t represents labor productivity in year t. The de-trended wages are the residuals of this regression. According to the 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.

types of workers. When there is a wave of only skilled immigrants, the overall crime rate drops by 0.4191 per 1,000, and increases by 0.0084 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 declines. 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 impact of criminal behavior, the overall crime rate decreases by 0.2334 per 1,000 population, which is equivalent to 68,805 criminal offenses nationwide.[15]

Column 3 of table 2 reports the results with an increase in skilled immigrants only. Column 4 of table 2 reports the results with an increase in unskilled immigrants only. When the economy gains only skilled immigrants, the skilled market tightness increases by 0.4245, which lowers the unemployment rate by 0.1481 percentage points and increases skilled native workers' wages by 0.21%. When there are more unskilled immigrants, the unskilled labor market tightness increases by 0.0963. The overall unemployment rate decreases by 0.3859 percentage points.

In the crime sector, the model predicts that the overall crime rate decreases by 0.3054 (-0.0603) 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

[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.

a lower reservation crime value than skilled immigrants. Overall, the crime rate decreases by 0.2334 per 1000 population with both skilled and unskilled immigrants.

7 Discussion: Policies

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

7.1 Unemployment benefits

Machin and Marie (2006) and Fougère et al. (2009) document that unemployment benefits affect workers' criminal behavior. Since 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 6. *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) θ_i decreases,

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

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

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

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

With this unemployment insurance system, natives and immigrants are now the same in the model. The increasing flow of unemployment utility 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 rises, immigrants are more patient and wait to find a job. More unemployed workers and fewer vacancies diminish the equilibrium in labor market tightness.

Quantitatively, market tightness decreases by 0.7153 for the skilled market and 0.1987 for the unskilled market. The overall unemployment rate increases by 1.1566 percentage points with this generous unemployment insurance system. Due to the drop in market tightness, skilled natives' implied wage decreases by 0.7240% and unskilled natives' implied wage decreases by 0.4357%. The overall crime rate increases by 0.3725 per 1,000, which is attributable 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 0.6134 and 0.1919, 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 0.3496 and 0.2712, respectively.

Unemployed immigrants enjoy higher unemployment utility, even though it is hard for them to get hired with low market tightness. They prefer to stay unemployed rather than committing crimes. Thus, the number of crimes committed by unemployed immigrants decreases. As a result, the crime rate of unemployed skilled (unskilled) immigrants decreases by 8.0334 (5.9982). Employed immigrants, by contrast, commit more crimes. A more generous social security system narrows the difference between employed and unemployed immigrants' value, even though market tightness decreases, employed immigrants have a lower employment premium, so the opportunity cost of committing a crime declines. Therefore, the crime rate of skilled (unskilled) employed immigrants increases by 10.7643 (3.8353). The results are summarized in Table 4.

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 ρ of 0.375 and 0.25, respectively. Table 5 reports the policy effects on labor market outcomes and crime rates.

Proposition 7. *With a decrease in ρ,*

i) θ_i increases, and

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

A longer jail term 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 incarceration period, 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 legal sector value goes up, and this increases the match surplus. There are fewer unemployed workers in the market when sentence lengths increase. As criminals must stay longer in jail, fewer criminals return 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, their distribution barely changes. Therefore, it shifts curve HF to the right and increases market tightness in equilibrium.

Quantitatively, there is no significant impact of more severe sentences on labor market outcomes, but this policy reduces crime rates significantly. With the sentence extended to 32 months and 48 months, the overall crime rate decreases by 12.3498 and 20.3146 per 1,000 population, respectively.

7.3 Deportation

Under a deportation policy, immigrants who commit a crime and get arrested are sent back to their country of origin. The assumption in this model is that some immigrants come from countries with worse labor markets than 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 jail, that is, for all $i \in \{H, L\}$,

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

where the variable $a \in [0, 1)$ is the proportion the 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

$$\begin{aligned} \bar{g}^I_{s,i} &= \pi(V^I_{s,i} - V^I_{D,i}) = \pi(V^I_{s,i} - aV^I_{P,i}). \\ &> \pi(V^I_{s,i} - V^j_{P,i}) \end{aligned} \tag{26}$$

, which is higher than the one without deportation.

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

$$\begin{aligned} (\theta_i q(\theta_i) + \eta^I_{U,i})u^I_i &= I_{N,i} + \delta_i e^I_i \\ (\delta_i + \eta^I_{E,i})e^I_i &= \theta_i q(\theta_i)u^I_i \\ u^I_i + e^I_i &= I_i \end{aligned}$$

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

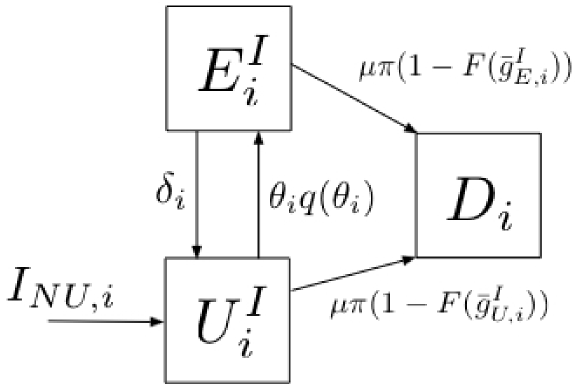

Figure 4: Immigrant flows

measure of newcomers is

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

and the measure of unemployed immigrants is

$$u_i^I = \frac{I_i(\delta_i + \eta^I_{E,i})}{\theta_i q(\theta_i) + \eta^I_{E,i} + \delta_i}.$$

Proposition 8. *With the deportation policy,*

i) θ_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 $\rho > \delta_i$.

A 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 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 when there is no deportation. Thus, 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 ρ of total prisoners are released from jail and they return to the labor market as unemployed workers. With deportation, there are 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 arrived immigrants equal the number of immigrants being deported. The reservation crime value of immigrants increases, therefore, the number of newcomers is less than the number of immigrants released from jail. Hence, the number of unemployed immigrants decreases with deportation, and the share of unemployed immigrants diminishes. Consequently, 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 comes from a country that has labor market conditions similar 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 (i.e., 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 6 shows the effects of deportation on labor market outcomes and crime rates. The impact of deportation on workers' distribution is limited. When the reservation crime value of immigrants increases 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 native workers' criminal behavior 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. There is a greater decline in the crime rate when the coefficient a is smaller. When immigrants belong to less-developed countries, they pay a higher opportunity cost if they commit a crime. Very few of these immigrants commit crimes under the deportation policy. Thus, for immigrants who belong to a country with labor market conditions similar to those of the host country, the crime rate decreases by 1.3844 per 1,000. In the case of immigrants from a country where the labor market conditions are worse than the host country, the deportation policy decreases the overall crime rate by 3.7037 ($a = 0.5$) and 4.2569 ($a = 0.1$).

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]

8.1 Production

There are two sectors in this extension: final and intermediate goods. Firms in the final goods sector produce the final products by purchasing intermediate goods from the 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 goods sector hire workers from the skilled/unskilled labor market.

The output of the final goods follows the constant elasticity of substitution (CES) production function with constant returns to scale,

[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. The latter two extensions do not significantly change the baseline results, so they are not presented 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.

$$Y = [\alpha Y_H^\sigma + (1-\alpha) Y_L^\sigma]^{1/\sigma}, \tag{27}$$

where variable Y is the production of final goods, Y_H is the production of the skilled intermediate goods, and Y_L is the production of the unskilled intermediate goods. The parameter α represents the importance of skilled intermediate goods. The parameter σ represents the elasticity of substitution, which is $1/(1-\sigma)$. One employed skilled/unskilled worker, regardless of his/her immigration status, produces one unit of the skilled/unskilled intermediate goods, that is,

$$Y_H = e_H^N + e_H^I \tag{28}$$

$$Y_L = e_L^N + e_L^I. \tag{29}$$

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

$$p_H = \alpha[\alpha + (1-\alpha)(\frac{Y_L}{Y_H})^\sigma]^{\frac{1-\sigma}{\sigma}}, \tag{30}$$

$$p_L = (1-\alpha)[\alpha(\frac{Y_L}{Y_H})^{-\sigma} + (1-\alpha)]^{\frac{1-\sigma}{\sigma}}. \tag{31}$$

8.2 Impact of immigration

Firms in the intermediate goods 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

$$
\begin{aligned}
\frac{k_i}{q(\theta_i)} &= \phi_i^e \\
&= \frac{1-\beta}{r+\delta_i+\beta\theta_i q(\theta_i)}\mathbb{E}\left[p_i - B_i - \mu\int_{\bar{g}_{U,i}}^{\bar{g}_{E,i}}(1-F(g))dg\right]. \qquad (32)
\end{aligned}
$$

The imperfect substitution between skilled and unskilled labor provides an additional channel for the effects of immigration, and 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 skilled/unskilled intermediate goods increases and the price of skilled/unskilled labor decreases, while the price of unskilled/skilled labor increases.

Lemma 7. *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 7, the immigrant population affects the reservation value of crime through the price channel.

Lemma 8. *Given a certain θ_i, when I_i increases,*
(i) $\bar{g}^j_{s,i}$ decreases,
(ii) $\bar{g}^j_{s,i'}$ 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 (33) can be rewritten as

$$\frac{k_i}{q(\theta_i)} + \frac{1-\beta}{r+\delta_i+\beta\theta_i q(\theta_i)}\mathbb{E}\left[B_i - \mu\int_{\bar{g}_{U,i}}^{\bar{g}_{E,i}}(1-F(g))dg\right] = \frac{1-\beta}{r+\delta_i+\beta\theta_i q(\theta_i)}p_i. \tag{33}$$

The left hand side of equation (33) can be considered as 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 goods 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 goods decreases as well. The market tightness of labor market i increases with skilled-i immigrants only if impact on the cost is greater than that on the price.

Proposition 9. *When I_i increases,*
(i) θ_i increases if the cost effect dominates the price effect, and
(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 7 shows the simulation results of the extended model. Compared with table 2, the overall crime rate decreases less than the baseline model with both skilled and unskilled immigrants. Due to the price effects, the impact of skilled immigrants on the overall crime rate is smaller while the effect of unskilled immigrants is larger than the baseline model. The implied wage of skilled native workers shows the opposite direction from the baseline model because the price of skilled labor decreases. The crime rate of unemployed skilled native workers increases marginally in this model while the one in the baseline model decreases. The price effects through skilled immigrants dominates the one through unskilled immigrants. Since the price of skilled labor decreases with skilled immigrants, the capital gain of employment decreases. Even an increase in skilled immigrants increases labor market tightness in the skilled labor market, the reservation crime value of unemployed skilled native workers continues to decrease, and the crime rate of employed skilled native workers increases. On the other hand, the price of skilled labor increases with unskilled immigrant flows. The reservation crime value of employed skilled native workers increases as they have higher capital gains of a matching. When only the skilled immigrants increase, the crime rate of employed skilled native workers increases by 0.3273, which is higher than the decline from the increase in unskilled immigrants. In the baseline model, the increase in unskilled immigrants does not affect the crime rate of employed or unemployed skilled immigrants, and the capital gain of matches does not decrease through labor productivity. With the combined effects from skilled and unskilled immigrants, the overall effect on the crime rate of unemployed skilled immigrants increases marginally. Similarly, the crime rate of employed unskilled native workers also shows an opposite sign than the baseline model. When there is an increase in skilled immigrants, the price of unskilled labor increases. The price effect dominates the labor market effect through labor market tightness. As a result, the crime rate of employed unskilled native workers decreases by 0.2034 with skilled immigrants. The crime rate of employed unskilled native workers increases more with unskilled immigrants than the baseline model. Both price and labor market effects raise the crime rate by 0.1946. Overall, the crime rate of employed unskilled native workers decreases 0.0033 as the effects from skilled immigrants dominate.

The effects on immigrants' crime rates have the same signs as the baseline model, but with a smaller magnitude. The mechanism is similar for native workers' crime rates. However, the price effects on immigrants' crime rates are dominated by the composition and labor market effects. Overall, crime rates of immigrants change in the same direction as the baseline model, although margins are smaller.

9 Conclusion

This paper studies the joint impact of immigration on labor market outcomes and crime. A wave of immigrant flows 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 increasing labor market tightness. Compared to skilled immigrants, unskilled immigrants are more likely to commit crimes because of poor outside options. Therefore, the overall crime rate decreases with an increase in skilled immigrants but surges with an increase in unskilled immigrants. Immigration also affects the criminal behavior of workers by increasing 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 outcome of immigration on the overall crime rate is ambiguous.

Quantitatively, with the increase in both skilled and unskilled immigrants observed in the 2000s, the unemployment rate decreased by 0.3859 percentage points, while the crime rate decreased by 0.2334 per 1,000 population. The model also discusses policy effects. With a more generous unemployment insurance system for immigrants, both unemployment and crime rates increase, and the wages of native workers decrease. Deportation and a longer duration of the incarceration period 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.

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A 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 (3), the value of a filled job is

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

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

$$w^j_i = y_i.$$

Solve equation (9),

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

□

Proof of Lemma 2

Proof. According to equation (13), take the first order derivatives of ϕ^e,

$$\begin{aligned}
\frac{\partial \phi^e_i}{\partial \theta_i} &= (1 - \beta)\sum_j [\frac{\partial(u^j_i/u_i)}{\partial \theta_i}(V^j_{E,i} - V^j_{U,i}) + \frac{u^j_i}{u_i}\frac{\partial(V^j_{E,i} - V^j_{U,i})}{\partial \theta_i}] \\
&= (1 - \beta)\sum_j [\frac{u_i(\partial u^j_i/\partial \theta_i) - u^j_i(\partial u_i/\partial \theta_i)}{u^2_i}(V^j_{E,i} - V^j_{U,i}) \\
&+ \frac{u^j_i}{u_i}\frac{\partial(V^j_{E,i} - V^j_{U,i})}{\partial \theta_i}].
\end{aligned}$$

According to a set of reasonable parameter value,

$$\frac{u_i(\partial u^j_i/\partial \theta_i) - u^j_i(\partial u_i/\partial \theta_i)}{u^2_i} \to 0.$$

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 $(V_{E,i}^j - V_{U,i}^j)$ is

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

as $\partial(\theta_i q(\theta_i))/\partial\theta_i > 0$. Thus, $\partial \phi_i^e/\partial\theta_i < 0$. □

Proof of Proposition 1

Proof. At $\theta_i = 0$,

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

If

$$\begin{aligned}\phi_i^e &= (1-\beta)\mathbb{E}\frac{y_i - B_i - \mu\int_{\bar{g}_{U,i}^j}^{\bar{g}_{E,i}^j}(1-F(g))dg}{r+\delta_i} \\ &> 0,\end{aligned}$$

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

Since $y_i > B_i^j$ for all $i \in \{H, L\}$ and $j \in \{N, I\}$, $V_{E,i}^j - V_{U,i}^j > 0$. According to (8),

$$\begin{aligned}\bar{g}_{E,i}^j - \bar{g}_{U,i}^j &= \pi(V_{E,i}^j - V_{U,i}^j) \\ &> 0.\end{aligned}$$

Thus, $\bar{g}_{E,i}^j > \bar{g}_{U,i}^j$ at any equilibrium. □

Proof of Lemma 3

Proof. (i)According to equation (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 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 skilled workers have higher productivity, $B_H^N > B_L^N$ and $V_{U,H}^N > V_{U,L}^N$ for natives. Thus, $\bar{g}_{U,H}^N > \bar{g}_{U,L}^N$. However, B_H^I is not necessary to be greater than B_L^I because of h_{iI}. The difference between the reservation crime value of unemployed skilled and unskilled immigrants is

$$\begin{aligned}
\bar{g}_{U,H}^I - \bar{g}_{U,L}^I &= \frac{\pi r}{r+\rho}(V_{U,H}^I - V_{U,L}^I) \\
&= \frac{\pi}{r+\rho}(B_H^I - B_L^I + \beta\theta_H q(\theta_H)(V_{E,H}^I - V_{U,H}^I) - \beta\theta_L q(\theta_L)(V_{E,L}^I - V_{U,L}^I) \\
&+ \mu\int_{\bar{g}_{U,H}^I}^{\bar{g}_{E,H}^I}(1-F(g))dg - \mu\int_{\bar{g}_{U,L}^I}^{\bar{g}_{E,L}^I}(1-F(g))dg)
\end{aligned}$$

If unemployment utilities of skilled immigrants are lower than unskilled immigrants, the reservation value of unemployed skilled immigrants is greater than unemployed unskilled immigrants only when the difference of expected capital gain between skilled and unskilled immigrants is greater than the difference of unemployment utilities between skilled and unskilled immigrants. If unemployment utilities of skilled immigrants are greater than unskilled immigrants, it is unambiguous that the reservation crime value of unemployed skilled immigrants is higher than unemployed unskilled immigrants. □

Proof of Proposition 2 and 3

Proof. Take the first order derivative of c with respect to I_H and I_L

$$\begin{aligned}
\frac{\partial c}{\partial I_H} &= \frac{\mu}{(\sum_i\sum_j(e_i^j + u_i^j))^2}\{[\sum_i\sum_j(e_i^j + u_i^j)][(1-F(\bar{g}_{E,H}^I))\frac{\partial e_H^I}{\partial I_H} + (1-F(\bar{g}_{U,H}^I))\frac{\partial u_H^I}{\partial I_H}] \\
&- (\sum_i\sum_j[(1-F(\bar{g}_{E,i}^j))e_i^j + (1-F(\bar{g}_{U,i}^j))u_i^j])(\frac{\partial e_H^I}{\partial I_H} + \frac{\partial u_H^I}{\partial I_H})\} \\
&\propto \frac{\partial e_H^I}{\partial I_H}\{\sum_i\sum_j[e_i^j(F(\bar{g}_{E,i}^j) - F(\bar{g}_{E,H}^I))) + u_i^j(F(\bar{g}_{U,i}^j) - F(\bar{g}_{U,H}^I))]\} \\
&- \frac{\partial u_H^I}{\partial I_H}\{\sum_i\sum_j[e_i^j(F(\bar{g}_{E,i}^j) - F(\bar{g}_{U,H}^I)) + u_i^j(F(\bar{g}_{U,i}^j) - F(\bar{g}_{U,H}^I))]\}
\end{aligned}$$

and

$$\begin{aligned}
\frac{\partial c}{\partial I_L} &= \frac{\mu}{(\sum_i \sum_j (e_i^j + u_i^j))^2}\{[\sum_i \sum_j (e_i^j + u_i^j)][(1 - F(\bar{g}_{E,L}^I))\frac{\partial e_L^I}{\partial I_L} + (1 - F(\bar{g}_{U,L}^I))\frac{\partial u_L^I}{\partial I_L}] \\
&- (\sum_i \sum_j [(1 - F(\bar{g}_{E,i}^j))e_i^j + (1 - F(\bar{g}_{U,i}^j))u_i^j])(\frac{\partial e_L^I}{\partial I_L} + \frac{\partial u_L^I}{\partial I_L})\} \\
&\propto \frac{\partial e_L^I}{\partial I_L}\{\sum_i \sum_j [e_i^j(F(\bar{g}_{E,i}^j) - F(\bar{g}_{E,L}^I))) + u_i^j(F(\bar{g}_{U,i}^j) - F(\bar{g}_{U,L}^I))]\} \\
&- \frac{\partial u_L^I}{\partial I_L}\{\sum_i \sum_j [e_i^j(F(\bar{g}_{E,i}^j) - F(\bar{g}_{U,L}^I)) + u_i^j(F(\bar{g}_{U,i}^j) - F(\bar{g}_{U,L}^I))]\}
\end{aligned}$$

According to lemma 3 and 4, we can find

$$\bar{g}_{E,H}^I > \bar{g}_{E,H}^N > \bar{g}_{U,H}^N > \bar{g}_{U,H}^I \tag{34}$$

and

$$\bar{g}_{E,L}^I > \bar{g}_{E,L}^N > \bar{g}_{U,L}^N > \bar{g}_{U,L}^I. \tag{35}$$

Also, compared $\bar{g}_{U,H}^I$ and $\bar{g}_{E,L}^I$, we have

$$\begin{aligned}
\bar{g}_{U,H}^I - \bar{g}_{E,L}^I &= \pi(V_{U,H}^I - V_{P,H}^I - V_{E,L}^I + V_{P,L}^I) \\
&= \frac{\pi}{r + \rho}(rV_{U,H}^I - rV_{E,L}^I - \rho(V_{E,L}^I - V_{U,L}^I)) \\
&= B_H^I - y_L + \beta\theta_H q(\theta_H)(V_{E,H}^I - V_{U,H}^I) + (\delta_L - \rho)(V_{E,L}^I - V_{U,L}^I) + \mu\int_{\bar{g}_{U,H}^I}^{\bar{g}_{E,L}^I}(1 - F(g))dg
\end{aligned}$$

Quantitatively, B_H^I is too small so that $\bar{g}_{E,L}^I$ is greater than $\bar{g}_{U,H}^I$.

According to the rank of reservation crime value, the coefficient of $\partial e_H^I/\partial I_H$ is negative. The coefficent of $\partial u_H^I/\partial I_H$ can be positive or negative because it is in the middle of the rank. No matter the coefficient of $\partial u_H^I/\partial I_H$ is positive or negative, the magnitude will not be greater than the coefficient of $\partial e_H^I/\partial I_H$. The first order derivatives of e_H^I and u_H^I with repect to I_H are

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

Quantitatively, $\theta_H q(\theta_H) > \delta_H + \eta_{E,H}^I$. Clearly, the effect through e_H^I dominates and $\partial c/\partial I_H$ is negative.

However, the effect of I_L is tricky as $\bar{g}_{E,L}^I$ is greater than $\bar{g}_{U,H}^I$. The coefficient of $\partial u_L^I/\partial I_L$ is positive while the coefficent of $\partial e_L^I/\partial I_L$ can be positive or negative at small margin. The first order derivatives of e_L^I and u_L^I with repect to I_L are

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

The effect through unskilled employed immigrants is greater than unskilled unemployed immigrants. If the effect through unskilled employed workers is negative, it dominates the effect throught unskilled unemployed workers. The effect of unskilled immigrants on the overall crime rate is negative, which means the overall crime rate decreases with I_L. If the effect through unskilled employed workers is positive, the overall crime increases with I_L.

□

Proof of Lemma 5

Proof. Equation (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 (21) and (23) with respect to I_H and I_L respectively, then

$$\begin{aligned}\frac{\partial u_H^I}{\partial I_H} &= \frac{\rho(\delta_H + \eta_{E,H}^I)}{\theta_H q(\theta_H)(\rho + \eta_{E,H}^I) + (\delta_H + \eta_{E,H}^I)(\rho + \eta_{U,H}^I)} \\ &> 0,\end{aligned}$$

and

$$\begin{aligned}\frac{\partial u_L^I}{\partial I_L} &= \frac{\rho(\delta_L + \eta_{E,L}^I)}{\theta_L q(\theta_L)(\rho + \eta_{E,L}^I) + (\delta_L + \eta_{E,L}^I)(\rho + \eta_{U,L}^I)} \\ &> 0.\end{aligned}$$

Since $u_i = \sum_j u_i^j$,

$$\begin{aligned}\frac{\partial(u_H^I/u_H)}{\partial u_H^I} &= \frac{u_H - u_H^I}{u_H^2} \\ &> 0\end{aligned}$$

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 rises.

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 Proposition 5

Proof. According to equations (4), (5) and (8), the reservation crime value of employed and unemployed workers can be written as

$$\bar{g}_{E,i}^j = \frac{\pi}{r+\rho}(y_i + (\rho - \delta_i)(V_{E,i}^j - V_{U,i}^j) + \mu \int_{\bar{g}_{E,i}^j}^{g^m} 1 - F(g)dg - x). \tag{36}$$

and

$$\bar{g}_{U,i}^j = \frac{\pi}{r+\rho}(B_i^j + \theta_i q(\theta_i)(V_{E,i}^j - V_{U,i}^j) + \mu \int_{\bar{g}_{U,i}^j}^{g^m} 1 - F(g)dg - x). \tag{37}$$

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

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

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 (4) and (5) the employment premium is

$$V^j_{E,i}-V^j_{U,i}=\frac{y_i-B^j_i-\mu\int_{\bar{g}^j_{U,i}}^{\bar{g}^j_{E,i}}(1-F(g))dg}{r+\delta_i+\beta\theta_i q(\theta_i)}. \tag{38}$$

Then

$$\begin{aligned}\frac{\partial(V^j_{E,i}-V^j_{U,i})}{\partial\theta_i}&=-\beta\frac{y_i-B^j_i-\mu\int_{\bar{g}^j_{U,i}}^{\bar{g}^j_{E,i}}(1-F(g))dg}{(r+\delta_i+\beta\theta_i q(\theta_i))^2}\frac{\partial\theta_i q(\theta_i)}{\partial\theta_i}\\&<0.\end{aligned}$$

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

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

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

Therefore, $\partial\bar{g}^j_{U,i}/\partial\theta_i>0$. □

Proof of Proposition 6

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 (13), market tightness decreases to balance the equilibrium.

According to equation (5), $\partial V^j_{U,i}/\partial B^j_i > 0$. 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 (38), 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 (36).

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 θ_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 7

Proof. According to (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 lemma 4, $\bar{g}_{E,i}^j > \bar{g}_{U,i}^j$ 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 8

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 (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

$$\begin{aligned}\Delta u^I_i &= \frac{(\delta_i + \tilde{\eta}^I_{E,i})I_i}{\theta_i q(\theta_i) + \tilde{\eta}^I_{E,i} + \delta_i} - \frac{\rho(\delta_i + \eta^I_{E,i})I_i}{\theta_i q(\theta_i)(\rho + \eta^I_{E,i}) + (\delta_i + \eta^I_{E,i})(\rho + \eta^I_{U,i})} \\ &< 0,\end{aligned}$$

where $\tilde{\eta}^I_{E,i}$ 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 $\bar{g}^N_{E,i}$

and $\bar{g}^N_{U,i}$ follows Lemma 5. □

Proof of Lemma 7

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 8

Proof. Given a certain θ_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,

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

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 9

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 (7), p_i decreases. The tightness in market i only increases when the match revenue increases. Therefore, when the cost effect dominates the price effect, θ_i increases.

(ii) According to lemma (7), $p_{i'}$ increases with an increase in I_i. It is simple to prove that $\theta_{i'}$ increases with an increase in I_i. □

B Calibration strategy

B.1 Market tightness in the skilled and unskilled labor market

This section describes the calibration strategy in section 5. The overall labor market tightness is normalize to 1, which means

$$\theta = \frac{v_H + v_L}{u_H + u_L}.$$

Therefore, the total vacancy is

$$\begin{aligned} v &= v_H + v_L \\ &= (u_H + u_L)\theta \end{aligned}$$

The market tightness in each market is

$$\begin{aligned} \theta_H &= \frac{v_H}{u_H} \\ \theta_L &= \frac{v_L}{u_L}. \end{aligned}$$

To calculate the market tightness in each labor market, I estimate the vacancy and unemployment rates in each market as follows. Firstly, I adpot the employment rate e_i from Chassamboulli and Palivos (2014), which is 0.976 in the skilled labor market and 0.939 in the unskilled labor market. The unemployment rate in each market is equal to $u_i = 1 - e_i$.

Next, I start guessing the value of A, the matching efficiency. The guess of A is denoted $\tilde{A}$. According to equation (12), (20) to (23), and (36) to (37), and the unemployment of workers with skill i are functions of θ_i. With the guess of A and the unemployment rate in skilled and unskilled labor markets, I am able to calculate the market tightness in each of the labor market, $\tilde{\theta}_i$.[17]

With the market tightness $\tilde{\theta}_i$, I solve the job finding rate $f(\tilde{\theta}_i) = \tilde{A}\tilde{\theta}_i^{1-\alpha}$. The ratio of market tightness by job finding rates,

$$\begin{aligned}\frac{\tilde{\theta}_H}{\tilde{\theta}_L} &= \left(\frac{f(\tilde{\theta}_H)}{f(\tilde{\theta}_L)}\right)^{\frac{1}{1-\alpha}} \\ &= \frac{v_H}{u_H}\frac{u_L}{v_L}\end{aligned}$$

Thus, the ratio of vacancies in skilled and unskilled labor market is

$$\frac{\tilde{v}_H}{\tilde{v}_L} = \frac{u_H}{u_L}\left(\frac{f(\tilde{\theta}_H)}{f(\tilde{\theta}_L)}\right)^{\frac{1}{1-\alpha}}$$

and

$$\tilde{v}_H = \tilde{v}_L\frac{u_H}{u_L}\left(\frac{f(\tilde{\theta}_H)}{f(\tilde{\theta}_L)}\right)^{\frac{1}{1-\alpha}} \tag{39}$$

The vacancies in the unskilled labor market can be calculated by $\tilde{v}_L = \tilde{\theta}_L u_L$. Substitute

[17] All variables x that are calculated by the guess of A are denoted as $\tilde{x}$.

equation (39) into total vacancy, I get

$$\tilde{v}_H + \tilde{v}_L = \tilde{v}_L \left[\frac{u_H}{u_L} \left(\frac{f(\tilde{\theta}_H)}{f(\tilde{\theta}_L)} \right)^{\frac{1}{1-\alpha}} + 1 \right]$$
$$= (u_H + u_L)\theta.$$

Then the overall market tightness is

$$\tilde{\theta} = \frac{\tilde{v}_L}{u_H + u_L} \left[\frac{u_H}{u_L} \left(\frac{f(\tilde{\theta}_H)}{f(\tilde{\theta}_L)} \right)^{\frac{1}{1-\alpha}} + 1 \right]$$

I iterate the guess of A until $\tilde{\theta}$ converges towards $\theta = 0.72$. As a result, the calibration perfectly matches

B.2 Unemployment benefit of native workers

The unemployment benefits of native workers are estimated by the replacement ratio from Shimer (2005), which is 40% of the implied wages. Substitute the unemployment benefits of natives workers $B_i^N = 0.4\tilde{w}_i^N$ into equation (12) and (25), B_H^N and B_L^N are solved.

C The Model without a hiring fee

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

$$rV_{U,i}^j = B_i^j - \tau + \theta_i q(\theta_i)(V_{E,i}^j - V_{U,i}^j) + \mu \int_0^{g^m} \max\{K_{U,i}^j - V_{U,i}^j, 0\} dF(g) \tag{40}$$

$$r\Pi_{V,i} = -k_i + q(\theta_i)(\Pi_{F,i}^e - \Pi_{V,i}). \tag{41}$$

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. $\Pi_{V,i} = 0$. Following Pissarides

(2000) closely, the wage are determined by the Nash bargaining share rule as

$$(1-\beta)(V_{E,i}^j - V_{U,i}^j) = \beta \Pi_{F,i}^j. \tag{42}$$

From (3), the value of filled job can be written as

$$\Pi_{F,i}^j = \frac{y_i - w_i^j}{r + \delta_i + \mu\pi(1 - F(\bar{g}_{E,i}^j))}. \tag{43}$$

Given (4) and (40), the premium of employment is

$$V_{E,i}^j - V_{U,i}^j = \frac{w_i^j - B_i^j - \mu \int_{\bar{g}_{U,i}^j}^{\bar{g}_{E,i}^j} 1 - F(g) dg}{r + \delta_i + \theta_i q(\theta_i)}. \tag{44}$$

Substitute (43) and (44) into (42), and rewrite it as

$$(1-\beta)\frac{w_i^j - B_i^j - \mu \int_{\bar{g}_{U,i}^j}^{\bar{g}_{E,i}^j} 1 - F(g) dg}{r + \delta_i + \theta_i q(\theta_i)} = \beta \frac{y_i - w_i^j}{r + \delta_i + \mu\pi(1 - F(\bar{g}_{E,i}^j))}. \tag{45}$$

Therefore, the wage is

$$w_i^j = \frac{\beta(r + \delta_i + \theta_i q(\theta_i)) y_i + (1-\beta)(r + \delta_i + \mu\pi(1 - F(\bar{g}_{E,i}^j)))(B_i^j + \mu \int_{\bar{g}_{U,i}^j}^{\bar{g}_{E,i}^j} 1 - F(g) dg)}{r + \delta_i + \beta\theta_i q(\theta_i) + (1-\beta)\mu\pi(1 - F(\bar{g}_{E,i}^j))}. \tag{46}$$

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

$$\frac{k_i}{q(\theta_i)} = \Pi_{F,i}^e, \tag{47}$$

where $\Pi_{F,i}^e = \sum_j (u_i^j / u_i) \Pi_{F,i}^j$. Equation (47) gives the condition of equilibrium.

Table 8 presents the simulation results with this model. In this case, the reservation crime value of employed workers does not only depend on the match surplus, but also on the wage, which is

$$\bar{g}^j_{E,i} = \frac{\pi}{r+\rho}[w^j_i + (\rho - \delta_i)(V^j_{E,i} - V^j_{U,i}) + \mu \int_{\bar{g}^j_{E,i}}^{\bar{g}_m} (1 - F(g))dg - x].$$

When the market tightness increases, wages increase and the surplus of a match decreases. As a result, effects of immigration on employed worker's crime rate are ambiguous. Quantitatively, the effect through the match surplus dominates in skilled market while the effect through wages dominates in unskilled market. Therefore, the crime rate of employed skilled workers increases and the crime rate of employed unskilled workers decreases, regardless of their immigration status.

Also, the reservation crime value of employed unskilled immigrants is lower than employed unskilled native workers. The wage of unskilled native workers is higher than unskilled immigrants but the match surplus of unskilled immigrants is larger. In unskilled market, the wage gap between native workers and immigrants is greater than the difference of surplus. Hence, the reservation crime value of unskilled immigrants is lower and the overall crime rate increases more than the baseline model when only unskilled immigrants increase.

D 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 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.

E 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 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 1: Calibration results

		description	sources/target
y_H	1.0	Normalized skilled productivity	The college-plus
y_L	0.62	Relative unskilled productivity	wage premium: 61.1%[1]
β	0.5	Bargaining power	Hosios (1990)
α	0.5	Elasticity of matching function	Petrongolo and Pissarides (2001)
			Estimated from data:
r	0.048	real interest rate	Fed. of Saint Louis
δ_H	0.228	Annual job separation rate in the skilled labor market	Chassamboulli and Palivos (2014)
δ_L	0.408	Annual job separation rate in the unskilled labor market	Chassamboulli and Palivos (2014)
ρ	0.75	Rate of exit from jail	Engelhardt et al. (2008)
π	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	
τ	0.0391	Expected loss of victims	equal to g^e
γ	0.274	Fraction of skilled native workers to total natives workers	Chassamboulli and Palivos (2014)
			Jointly calibrated to match:
A	7.9592	Match efficiency	Employment rate in the skilled
k_h	0.8655	Fixed recruitment cost in the skilled labor market	and unskilled market: 0.976 and 0.939.[2]
k_l	0.7633	Fixed recruitment cost in the unskilled labor market	The skilled native-immigrant wage gap: -19%
$B_{H,N}$	0.3932	Unemploy. flow value, skilled natives	The unskilled native-immigrant
$B_{L,N}$	0.2383	Unemploy. flow value, unskilled natives	wage gap: -18.8%
$B_{H,I}$	-5.1355	Unemploy. flow value, skilled immigrant	$\theta = 0.72$.[3]
$B_{L,I}$	-1.2610	Unemploy. flow value, unskilled immigrant	The overall crime rate: 0.0451.[4]
μ	0.0707	Arrival rate of criminal opportunity	Ratio of unemployed and employed income: 40%

[1] March CPS in the 1990s, Chassamboulli and Palivos (2014)
[1] Chassamboulli and Palivos (2014)
[2] Pissarides (2009)
[3] Uniform crime report in the 1990s

Table 2: Effect of immigration

	increase in I_H and I_L	increase in I_H	Increase in I_L
θ_H	0.4257	0.4257	no effects
θ_L	0.0963	no effects	0.0963
u	-0.3857	-0.1479	-0.2494
c	-0.2334	-0.3054	0.0603
	skilled natives		
u_H^N	-0.2989	-0.2989	
w_H^N	0.2096	0.2096	no effects
$c_{E,H}^N$	0.1795	0.1795	
$c_{U,H}^N$	-0.1007	-0.1007	
	unskilled natives		
u_L^N	-0.3988		-0.3988
w_L^N	0.1479	no effects	0.1479
$c_{E,L}^N$	0.0653		0.0653
$c_{U,L}^N$	-0.0918		-0.0918
	skilled immigrants		
$c_{E,H}^I$	1.2999	1.2999	no effects
$c_{U,H}^I$	-1.2176	-1.2176	
	unskilled immigrants		
$c_{E,L}^I$	0.2960	no effects	0.2960
$c_{U,L}^I$	-0.5058		-0.5058

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 θ_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 and crime rates are changes in percentage points. The changes in the wages are percentage changes.

Table 3: Crime rate of workers

Type of worker	crime rate	Type of worker	crime rate
Skilled employed natives	37.8604	Skilled employed immigrants	26.4831
Skilled unemployed natives	40.1978	Skilled unemployed immigrants	48.5792
Unskilled employed natives	48.5287	Unskilled employed immigrants	44.5014
Unskilled unemployed natives	51.0944	Unskilled unemployed immigrants	57.3636

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 4: Effects of increasing unemployment benefits

	$B_H^I = B_H^N$ $B_L^I = B_L^N$	$B_H^I = B_H^N$	$B_L^I = B_L^N$
θ_H	-0.7174	-0.7174	no effects
θ_L	-0.1987	no effects	-0.1987
u	1.1564	0.2898	0.8666
c	0.3726	0.1960	0.1766
	skilled natives		
u_H^N	1.0511	1.0511	
w_H^N	-0.7237	-0.7237	no effects
$c_{E,H}^N$	-0.6132	-0.6132	
$c_{U,H}^N$	0.3495	0.3495	
	unskilled natives		
u_L^N	1.1962		1.1962
w_L^N	-0.4357	no effects	-0.4357
$c_{E,L}^N$	-0.1919		-0.1919
$c_{U,L}^N$	0.2712		0.2712
	skilled immigrants		
$c_{E,H}^I$	10.7640	10.7640	no effects
$c_{U,H}^I$	-8.0319	-8.0319	
	unskilled immigrants		
$c_{E,L}^I$	3.8354	no effects	3.8354
$c_{U,L}^I$	-5.9981		-5.9981

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

Table 5: Effects of increasing duration of incarceration

	32 months	48 months
θ_H	0.0004	0.0005
θ_L	0.0001	0.0001
u	-0.0036	-0.0058
c	-12.3507	-20.3158
skilled natives		
u_H^N	-0.0032	-0.0049
w_H^N	0.0019	0.0029
$c_{E,H}^N$	-14.9082	-23.1747
$c_{U,H}^N$	-15.8287	-24.6055
unskilled natives		
u_L^N	-0.0035	-0.0057
w_L^N	0.0019	0.0032
$c_{E,L}^N$	-12.1428	-20.3828
$c_{U,L}^N$	-12.7847	-21.4603
skilled immigrants		
$c_{E,H}^I$	-7.4991	-12.3778
$c_{U,H}^I$	-13.7581	-22.7069
unskilled immigrants		
$c_{E,L}^I$	-7.5374	-13.1738
$c_{U,L}^I$	-9.7158	-16.9810

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

Table 6: Effects of deportation

	a		
	0.1	0.5	0.9
θ_H	-0.0008	-0.0008	-0.0001
θ_L	-0.0001	0.0000	0.0001
u	-0.0006	-0.0006	-0.0007
c	-4.2569	-3.7038	-1.3845
skilled natives			
u_H^N	0.0007	0.0007	0.0001
w_H^N	-0.0005	-0.0005	-0.0001
$c_{E,H}^N$	-0.0004	-0.0004	-0.0001
$c_{U,H}^N$	0.0002	0.0002	0.0000
unskilled natives			
u_L^N	0.0003	0.0001	-0.0006
w_L^N	-0.0001	0.0000	0.0002
$c_{E,L}^N$	0.0000	0.0000	0.0001
$c_{U,L}^N$	0.0001	0.0000	-0.0001
skilled immigrants			
$c_{E,H}^I$	-26.3477	-25.0707	-11.7539
$c_{U,H}^I$	-48.3307	-45.9876	-21.5591
unskilled immigrant			
$c_{E,L}^I$	-42.1332	-35.7878	-12.4096
$c_{U,L}^I$	-54.3108	-46.1309	-15.9965

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

Table 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
θ_H	0.4181	0.3966	0.0224
θ_L	0.0990	0.0125	0.0869
p_H	-0.5628	-2.4769	1.9966
p_L	0.3623	1.6465	-1.2330
u	-0.3922	-0.1833	-0.2284
c	-0.1666	-0.2342	0.0660
	skilled natives		
u_H^N	-0.2957	-0.2830	-0.0192
w_H^N	-0.3511	-2.2587	1.9880
$c_{E,H}^N$	0.2217	0.5541	-0.3432
$c_{U,H}^N$	0.0211	0.3273	-0.3162
	unskilled natives		
u_L^N	-0.4092	-0.0566	-0.3634
w_L^N	0.5095	1.6430	-1.0823
$c_{E,L}^N$	-0.0033	-0.2034	0.1946
$c_{U,L}^N$	-0.0972	-0.1810	0.0784
	skilled immigrants		
$c_{E,H}^I$	1.0793	1.3106	-0.2154
$c_{U,H}^I$	-0.6684	-0.2973	-0.4023
	unskilled immigrants		
$c_{E,L}^I$	0.1552	-0.1706	0.3251
$c_{U,L}^I$	-0.3528	-0.2293	-0.1364

Note: See the footnotes 2 and 3 in table 2 for the definitions of variables and the explanation of rates. The variable p_H and p_L represents the price of skilled and unskilled labor. The entries of p_H and p_L are reported as percentage changes.

Table 8: Effects of immigration (Nash bargaining)

	increase in I_H and I_L	increase in I_H	Increase in I_L
θ_H	0.4236	0.4236	no effects
θ_L	0.0962	no effects	0.0962
u	-0.3860	-0.1481	-0.2496
c	-0.0569	-0.2070	0.1445
skilled natives			
u_H^N	-0.2995	-0.2995	
w_H^N	0.2101	0.2101	no effects
$c_{E,H}^N$	0.0418	0.0418	
$c_{U,H}^N$	-0.0970	-0.0970	
unskilled natives			
u_L^N	-0.3991		-0.3991
w_L^N	0.2481	no effects	0.2481
$c_{E,L}^N$	-0.0108		-0.0108
$c_{U,L}^N$	-0.0883		-0.0883
skilled immigrants			
$c_{E,H}^I$	0.3905	0.3905	no effects
$c_{U,H}^I$	-1.1711	-1.1711	
unskilled immigrants			
$c_{E,L}^I$	-0.0541	no effects	-0.0541
$c_{U,L}^I$	-0.4865		-0.4865

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

Table 9: Effects of immigration: one-skilled market

	increase in I
θ	0.1101
u	-0.4504
c	-0.1610
Natives	
u^N	-0.4503
w^N	0.2769
c_E^N	0.1033
c_U^N	-0.1513
Immigrants	
c_E^I	0.3991
c_U^I	-0.8013

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

Table 10: Effects of Immigration: random search

	increase in I_H and I_L	increase in I_H	Increase in I_L
θ	0.1142	0.0594	0.0585
u	-0.4667	-0.2549	-0.2511
c	-0.1501	-0.1951	0.0362
Skilled natives			
$u_{H,N}$	-0.4665	-0.2548	-0.2511
$\tilde{w}_{H,N}$	0.2870	0.1563	0.1540
$c^N_{E,H}$	0.0863	0.0470	0.0463
$c^N_{U,H}$	-0.1264	-0.0689	-0.0679
Unskilled Natives			
$u_{L,N}$	Same as skilled natives		
$\tilde{w}_{L,N}$	Same as skilled natives		
$c^N_{E,L}$	0.0685	0.0373	0.0367
$c^N_{U,L}$	-0.0968	-0.0528	-0.0520
Skilled Immigrants			
$c^I_{E,H}$	0.3312	0.1800	0.1773
$c^I_{U,H}$	-0.6623	-0.3621	-0.3568
Unskilled immigrants			
$c^I_{E,L}$	0.2779	0.1512	0.1489
$c^I_{U,L}$	-0.4776	-0.2607	-0.2569

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