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RIVERSIDE

Essays on Immigration and the Macroeconomy

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

Doctor of Philosophy

in

Economics

by

Xiangbo Liu

June 2011

Dissertation Committee:

Dr. Jang-Ting Guo, Co-Chairperson  
Dr. Richard M.H. Suen, Co-Chairperson  
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# ABSTRACT OF THE DISSERTATION

Essays on Immigration and the Macroeconomy

by

Xiangbo Liu

Doctor of Philosophy, Graduate Program in Economics

University of California, Riverside, June 2011

Dr. Jang-Ting Guo, Co-Chairperson

Dr. Richard M.H. Suen, Co-Chairperson

This dissertation is comprised of three chapters that study the impact of different types of immigration on the macroeconomy in the presence of labor market frictions.

Chapter 2 employs a dynamic general equilibrium model with labor market frictions to explore the economic consequences of illegal immigration. The novel feature of the model is that I allow domestic workers and illegal foreign workers to search for jobs in the same market. An increase in the number of illegal immigrants thus intensifies job competition in the domestic labor market. To the best of my knowledge, it is the first study that explicitly takes into account the job displacement effect induced by illegal immigrants. This study identifies four different channels via which illegal immigration can affect domestic consumption. Previous studies, however, only capture a subset of these forces. Using some realistic parameter values, this study assesses the macroeconomic and welfare effects of illegal immigration quantitatively. The calibrated model generates a U-shaped relationship between the population share of illegal immigrants and consumption per domestic resident in the long run. In the numerical analysis, I also find that increasing the population share of illegal immigrants would induce a welfare gain for the native population.

Chapter 3 extends the baseline model developed in Chapter 2 by including heterogeneous workers in the domestic population. In the extended model, all illegal immigrants are unskilled and thus only compete with the domestic unskilled workers for jobs. Skilled domestic workers are insulated from job competition with the illegal immigrants. The main idea of this extended model is to examine the asymmetric effects of illegal immigration on different skill groups in the native population. It is shown that the long-run effects of illegal immigration on skilled and unskilled domestic consumers are very different. An increase in illegal immigration raises the consumption of skilled consumers and improves their labor market outcomes. On the contrary, unskilled domestic workers' consumption and labor market outcomes are negatively affected by the inflow of illegal immigrants.

Chapter 4 focuses on the effects of legal immigration on the native population. To achieve this, I adopt a dynamic general equilibrium model with skill heterogeneity and labor market frictions. Unlike the previous chapters that focus exclusively on unskilled illegal workers, this chapter explicitly takes into account the skill composition of immigrants. Specifically, this study considers the inflows of both skilled and unskilled immigrant workers. The model in this chapter captures two opposing effects of immigration. First, native and immigrant workers of the same skill group search in the same labor market. This creates a job displacement effect of immigration. Second, workers with different skills are complementary in the production process. Thus, immigrants might benefit the natives in a different skill group. A calibrated version of the model is used to quantify these effects. In the numerical analysis, I also examine how unemployment benefits can be used to mitigate the welfare loss due to immigration.

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# Chapter 1

## Introduction

Immigration has become a common phenomenon facing most developed countries. In the last few decades, the world has witnessed a historically high rate of immigration. The rapid inflow of immigrants has spurred heated debate over its economic consequences. On the one hand, those in favor of immigration argue that the inflow of foreign workers helps increase the supply of labor, reduces the cost of production and is thus beneficial for the host country. On the other hand, opponents of immigration argue that the inflow of foreign workers intensifies job competition and consequently deteriorates the labor market position of domestic workers. The issue of immigration has also attracted attention from macroeconomists. Recently, there is a growing literature that investigates the economic consequences of immigration using the standard neoclassical growth model. These studies all fall short in capturing the impact of immigration on the employment opportunities of domestic workers. As suggested by empirical evidence, the job displacement effects of immigration is substantial and therefore should not be overlooked. To overcome this limitation, this dissertation, consisting of three chapters, revisits the question of the impact of immigration using a different approach.

Chapter 2 employs a dynamic general equilibrium model with labor market frictions to explore the economic consequences of illegal immigration. The novel feature of the model is that I allow domestic workers and illegal foreign workers to search for jobs in the same market. An increase in the number of illegal immigrants thus intensifies job competition in the domestic labor market. To the best of my knowledge, it is the first study that explicitly takes into account the job displacement effect induced by illegal immigrants. This study identifies four different channels via which illegal immigration can affect domestic consumption. Previous studies, however, only capture a subset of these forces. Using some realistic parameter values, this study assesses the macroeconomic and welfare effects of illegal immigration quantitatively. The calibrated model generates a U-shaped relationship between the population share of illegal immigrants and consumption per domestic resident in the long run. In the numerical analysis, I also find that increasing the population share of illegal immigrants would induce a welfare gain for the native population.

Chapter 3 extends the baseline model developed in Chapter 2 by including heterogeneous workers in the domestic population. In the extended model, all illegal immigrants are unskilled and thus only compete with the domestic unskilled workers for jobs. Skilled domestic workers are insulated from job competition with the illegal immigrants. The main idea of this extended model is to examine the differential effects of illegal immigration on different skill groups in the native population. It is shown that the long-run effects of illegal immigration on skilled and unskilled domestic consumers are very different. An increase in illegal immigration raises the consumption of skilled consumers and improves their labor market outcomes. On the contrary, unskilled domestic workers' consumption and labor market outcomes are negatively affected by the inflow of illegal immigrants.

Chapter 4 focuses on the effects of legal immigration on the native population. To achieve this, I adopt a dynamic general equilibrium model with skill heterogeneity and labor market frictions. Unlike the previous chapters that focus exclusively on unskilled illegal workers, this chapter explicitly takes into account the skill composition of immigrants. Specifically, this study considers the inflows of both skilled and unskilled immigrant workers. The model in this chapter captures two opposing effects of immigration. First, native and immigrant workers of the same skill group search in the same labor market. This creates a job displacement effect of immigration. Second, workers with different skills are complementary in the production process. Thus, immigrants might benefit the natives in a different skill group. A calibrated version of the model is used to quantify these effects. In the numerical analysis, I also examine how unemployment benefits can be used to mitigate the welfare loss due to immigration.

## Chapter 2

# On the Macroeconomic and Welfare Effects of Illegal Immigration

### 2.1 Introduction

Illegal immigration is a contentious issue facing most developed countries. In the United States, the number of illegal immigrants has grown rapidly since the 1970s and the 1980s.<sup>1</sup> Passel (2006) estimates that the total population of unauthorized migrants in the United States has increased from three million to about twelve million over the period 1980-2006. In 2005, illegal immigrants accounted for about 4.9 percent of the U.S. civilian labor force. The rapid inflow of illegal immigrants has spurred heated debate over its economic consequences. Those in favor of legalizing the status of illegal immigrants argue that the inflow of foreign workers helps increase the supply of

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<sup>1</sup>For a detailed historical account on the size and composition of illegal immigrants in the United States, see Chiswick (1988) and Hanson (2006).

labor, reduces the cost of production and is thus beneficial for the host country. On the other hand, opponents of illegal immigration argue that the inflow of foreign workers intensifies job competition and consequently deteriorates the labor market position of domestic workers.<sup>2</sup>

There is now a large number of empirical studies that examines the impact of immigration (both legal and illegal) in the United States. However, these studies typically rely on partial-equilibrium analysis and focus exclusively on labor market outcomes. On the other hand, there is only a small number of theoretical studies on this topic. Earlier studies, such as Ethier (1986) and Bond and Chen (1987), employ a static framework to analyze issues related to border enforcement. Djajić (1997) also uses a static framework to analyze the effects of illegal immigration on resources allocation, commodity prices and wages. More recently, there is a growing literature that investigates the economic consequences of illegal immigration using the standard neoclassical growth model. Examples of this include Hazari and Sgro (2003), Moy and Yip (2006), Palivos and Yip (2007), and Palivos (2009). One common assumption made by these studies is that, regardless of the number of illegal immigrants in the domestic economy, there is always full employment in the domestic labor market. This assumption in effect rules out any potential impact of illegal immigration on the employment opportunities of domestic workers. As mentioned above, one of the main concerns about illegal immigration is that it might deteriorate the labor market position of native workers. Using U.S. Census data over the period 1960-2000, Borjas et al. (2007) show that the employment rates of native workers are strongly and negatively affected by the inflow of foreign workers. According to this study, a 10-percent immigrant-induced increase in

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<sup>2</sup>For a more detailed review on these discussions, see Greenwood and McDowell (1986), Chiswick (1988), Djajić (1997) and the references therein.

labor supply lowers the employment rate of white male workers by 1.6 percentage points. The same increase lowers the employment rate of black male workers by 3.5 percentage points. These results suggest that the job displacement effects of illegal immigration might be substantial and should not be overlooked.

The primary objective of this paper is to develop a dynamic general equilibrium model that explicitly takes into account the job displacement effects of illegal immigration. To achieve this, the current study generalizes the labor-market search model à la Shi and Wen (1997) by incorporating an exogenous inflow of illegal foreign workers into the domestic economy.<sup>3</sup> Labor market frictions (in the form of time-consuming job search and matching) are now commonly used to generate unemployment in dynamic general equilibrium models. However, very few studies have used this type of framework to examine issues related to legal or illegal immigration. One novel feature of my model is that I allow domestic workers and illegal foreign workers to search for jobs in the same market. An increase in the number of illegal immigrants thus intensifies job competition in the domestic labor market. This affects the labor market outcomes of domestic workers in two ways. First, unemployed domestic workers are now less likely to find a job. Second, those who find a job would face a lower wage offer from the firm. These in turn affect domestic workers' consumption-saving decisions, and hence the capital accumulation process in the host country. Using this framework, the current study aims to answer the following questions: (1) What is the long-run impact of illegal immigration on the consumption, employment and wage rate of domestic consumers? (2) What are the welfare consequences of illegal immigration on domestic consumers?

The answers to these questions depend crucially on one factor, namely the

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<sup>3</sup>The current study takes as given the inflow of illegal immigrants and does not consider the migration decisions made by foreign workers. The current study also abstracts from *legal* immigration.

degree of substitutability between domestic workers and illegal immigrants in the production process. Empirical evidence shows that illegal immigrants in the United States are mostly low skill by the U.S. standard (see, among others, Massey, 1987; Borjas and Katz, 2005; Hanson, 2009). This means the two types of workers are likely to be imperfect substitutes in the production process. In the baseline model, the degree of substitutability between the two types of workers is captured by a CES aggregator.<sup>4</sup> There is, however, only one labor market in which all the domestic workers compete with the illegal foreigners for jobs. Under this framework, illegal immigration would affect the labor market position of all domestic workers in the same way.

Under the baseline model, the current study identifies four different channels via which illegal immigration can affect domestic consumption. First, as job competition intensifies due to the inflow of illegal immigrants, some domestic workers are displaced. This in turn lowers the labor income of domestic households and hence their consumption. This effect of illegal immigration on domestic consumption is referred to as the *displacement effect*. Second, since there are now more job-searchers in the labor market, both domestic and illegal workers are willing to work for a lower wage rate. This again lowers the labor income of domestic households and hence their consumption. This effect is referred to as the *wage-depressing effect*. Third, the reduction in wage rates raises the firms' profits and hence the dividend income received by the domestic households. This effect, referred to as the *exploitation effect*, raises domestic consumption when the number of illegal immigrants increases. Fourth, increasing the number of illegal immigrants would also affect the level of capital per domestic resident. Since illegal immigrants does not contribute to the capital accumulation process in the host country, their presence would use up some of the output that could have been used for

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<sup>4</sup>The same approach is used in Bentolila et al. (2008).

domestic consumption and investment. This fourth effect is referred to as the *capital consumption effect*. Previous studies by Hazari and Sgro (2003), Moy and Yip (2006), Palivos and Yip (2007), and Palivos (2009) only capture a subset of these forces.

The overall effect of illegal immigration on domestic consumption is determined by the relative magnitude of these four effects which work in opposite directions. In order to determine the quantitative importance of these effects, I consider a calibrated version of the baseline model. Under the benchmark parameterization, the model generates a U-shaped relationship between the population share of illegal immigrants and consumption per domestic resident in the long run. More specifically, when the population share of illegal immigrants is small, an increase in this share leads to a mild reduction in domestic consumption. However, once the population share of illegal immigrants passes a certain threshold, an increase in this share will generate significant increase in domestic consumption. To gauge the welfare consequences of illegal immigration, I compare the following two scenarios. In the first scenario (the status quo), the economy remains in a steady state in which illegal immigrants account for 4% of the total population. This number is consistent with the estimated size of illegal population in the United States in 2006. In the second scenario, the domestic economy starts at the status quo but then experiences an one-time unanticipated change in the population share of illegal immigrants. The economy then gradually converges to a new steady state. To quantify the differences in consumer welfare in these two scenarios, I construct a consumption-equivalent measure along the line of Lucas (1987), taking into account the transitional dynamics. Under the benchmark parameter values, I found that increasing the population share of illegal immigrants from 4% to 5% would induce a welfare gain for the native population that is equivalent to a 0.45% increase in the status-quo consumption in every period. Further increase in the population share would create an even larger

gain in welfare.

The current study complements the previous studies by Hazari and Sgro (2003), Moy and Yip (2006), Palivos and Yip (2007), and Palivos (2009) in two different ways.<sup>5</sup> First, the current study explicitly takes into account the job displacement effect induced by illegal immigrants. Second, while the previous studies examine *qualitatively* the effects of illegal immigration on the native population, the current study assesses these effects *quantitatively* using some realistic parameter values.

The reminder of this paper is structured as follows. Section 2.2 presents the baseline model and characterizes the search equilibrium. Section 2.3 describes the calibration procedure and presents the quantitative results for the baseline model. Finally, Section 2.4 offers some concluding remarks.

## 2.2 The Baseline Model

### 2.2.1 Demographics

Consider an economy inhabited by two types of households, namely domestic ( $D$ ) and illegal immigrant ( $M$ ) households. The number of each type of household is normalized to one. Each household consists of many infinitely lived agents. Denote by  $L(t)$  and  $M(t)$  the size of domestic and illegal immigrant household at time  $t \geq 0$ , respectively. The total population is given by  $N(t) = L(t) + M(t)$ . Both  $L(t)$  and  $M(t)$  are assumed to grow at the same constant rate  $g > 0$ .<sup>6</sup> It follows that the share of illegal immigrants in the total population is constant over time and is denoted by  $m \in [0, 1]$ .

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<sup>5</sup>A more detailed comparison between these studies and the current one is given in Section 2.3.2.

<sup>6</sup>This assumption is imposed so that all the per-capita variables in the model economy are stationary in the long run.

In each period, each individual is endowed with one indivisible unit of time that has three mutually exclusive uses: searching for a job, working for wages, or enjoying leisure. An agent who is searching for job is called unemployed. Throughout this paper, an index  $i \in \{D, M\}$  is used to indicate household type. Let  $s_1^i(t)$  be the fraction of members in a type- $i$  household that are searching for jobs at time  $t$ , and  $s_2^i(t)$  be the fraction of members that are employed. The variable  $s_1^i(t)$  is also referred to as search effort. At the household level, the total amount of time that a domestic household spent on search and work are given by

$$L_1(t) = s_1^D(t) L(t) \quad \text{and} \quad L_2(t) = s_2^D(t) L(t),$$

respectively. Similarly, the total amount of time that an illegal immigrant household spent on search and work are

$$M_1(t) = s_1^M(t) M(t) \quad \text{and} \quad M_2(t) = s_2^M(t) M(t).$$

### 2.2.2 Domestic Household's Problem

In each period, each domestic household derives utility from consumption and disutility from hours worked and search effort. The preferences of a domestic household can be represented by

$$\int_0^\infty e^{-(\rho-g)t} u[c(t), s_1^D(t) + s_2^D(t)] dt, \quad (2.1)$$

where  $c(t)$  is the consumption of each individual member at time  $t$ , and  $\rho > 0$  is the rate of time preference. I assume  $\rho > g$  so that the effective discount rate is strictly positive. The momentary utility function is given by

$$u[c(t), s_1^D(t) + s_2^D(t)] = \log[c(t)] - \xi \frac{[s_1^D(t) + s_2^D(t)]^{1+\phi}}{1+\phi}, \quad (2.2)$$

where  $\phi > 0$  is the inverse of labor supply elasticity and  $\xi > 0$  is a preference parameter.

In each period, each household member faces uncertainty in his employment status and hence his labor income. If an agent is currently unemployed, then he faces a certain probability of finding a job. The rate at which unemployed workers find jobs is denoted by  $\gamma(t)$ . This rate is taken as exogenously given by the agents, but is endogenously determined in equilibrium. If an agent is currently employed, then he faces a certain probability of becoming unemployed. The rate of job separation is assumed to be an exogenous constant  $\theta > 0$ . At the household level, the number of working hours evolves according to

$$\dot{L}_2(t) = \gamma(t)L_1(t) - \theta L_2(t).$$

Upon dividing this by  $L(t)$ , we have

$$\dot{s}_2^D(t) = \gamma(t)s_1^D(t) - (\theta + g)s_2^D(t). \quad (2.3)$$

Although each individual faces substantial risk in his labor income, I assume that members within a household can provide each other with complete insurance against this risk. The same assumption is adopted in Merz (1995) and Shi and Wen (1997,1999) among others. More specifically, I assume that each domestic household consists of a very large number of individuals who pool their income together and care only about the welfare of the household that they belong to. Under this assumption, household consumption and asset holdings are independent of the idiosyncratic income shocks. The household budget constraint in each period  $t \geq 0$  is then given by

$$\dot{K}(t) + C(t) = w(t)L_2(t) + r(t)K(t) + \Pi(t),$$

where  $w(t)$  is the market wage rate for domestic workers,  $r(t)$  is the effective rate of return from investment,  $C(t)$  is the household's consumption,  $K(t)$  is the household's capital stock, and  $\Pi(t)$  is the dividend income distributed by the firms. Dividing the

household's budget constraint by the size of population  $N(t)$  gives

$$\dot{k}(t) + k(t)g + c(t)(1 - m) = w(t)s_2^D(t)(1 - m) + r(t)k(t) + \pi(t), \quad (2.4)$$

where  $\pi(t) = \Pi(t)/N(t)$  is dividend per capita and  $k(t) = K(t)/N(t)$  is capital per capita.

A domestic household's problem is to choose a set of time paths  $\{c(t), s_1^D(t), s_2^D(t), k(t) | t \geq 0\}$  so as to maximize the utility function in (2.1) subject to the law of motion in (2.3), the budget constraint in (2.4), and two initial conditions:  $k(0) > 0$ ,  $1 > s_2^D(0) > 0$ . Let  $\psi(t)$  and  $\lambda(t)$  be the current-value shadow price of capital and employment to the household, respectively. The first-order conditions with respect to  $\{c(t), s_1^D(t), s_2^D(t), k(t)\}$  are given by

$$u'_c(t) = \psi(t)(1 - m), \quad (2.5)$$

$$-u'_{s_1^D}(t) = \lambda(t)\gamma(t), \quad (2.6)$$

$$\dot{\lambda}(t) = (\rho + \theta)\lambda(t) - [\psi(t)w(t)(1 - m) + u'_{s_2^D}(t)], \quad (2.7)$$

$$\frac{\dot{\psi}(t)}{\psi(t)} = \rho - r(t), \quad (2.8)$$

where  $u'_c(t)$  is the marginal utility of individual consumption,  $u'_{s_1^D}(t)$  is the marginal disutility from search effort, and  $u'_{s_2^D}(t)$  is the marginal disutility from labor. The transversality conditions for this problem are

$$\lim_{t \rightarrow \infty} e^{-(\rho - g)t} \psi(t)k(t) = 0,$$

$$\lim_{t \rightarrow \infty} e^{-(\rho - g)t} \lambda(t)s_2^D(t) = 0.$$

Equation (2.6) states the rule for the household to decide how much effort it should put into search. It requires the marginal cost of search to be equal to its marginal benefit.

Combining equations (2.5) and (2.8) gives the standard Euler equation for consumption,

$$\frac{\dot{c}(t)}{c(t)} = r(t) - \rho. \quad (2.9)$$

This condition describes the evolution of individual consumption. In other words, it states that if  $r(t)$  exceeds  $\rho$ , then individual consumption will increase over time. Combining equations (2.5)-(2.7) gives

$$\dot{\lambda}(t) = (\rho + \theta)\lambda(t) + [w(t)\frac{u'_c(t)}{u'_{s_2^D}(t)} + 1]\gamma(t)\lambda(t). \quad (2.10)$$

This equation describes how the shadow price of employment  $\lambda(t)$  would evolve over time. An important implication of (2.10) is that in order to compensate for the search cost, the wage rate  $w(t)$  has to be set above the marginal rate of substitution between leisure and consumption, which is given by  $-u'_{s_2^D}(t)/u'_c(t)$ .<sup>7</sup>

### 2.2.3 Immigrant Household's Problem

Similar to a domestic household, an illegal immigrant household derives utility from consumption and disutility from hours worked and search effort. The utility function of a migrant household is characterized by

$$\int_0^\infty e^{-(\rho-g)t} v[c_M(t), s_1^M(t) + s_2^M(t)] dt, \quad (2.11)$$

where  $c_M(t)$  is the consumption of each household member at time  $t$ . The momentary utility function is identical to the one in (2.2), i.e.,

$$v[c_M(t), s_1^M(t) + s_2^M(t)] = \log[c_M(t)] - \xi_M \frac{[s_1^M(t) + s_2^M(t)]^{1+\phi}}{1+\phi},$$

with  $\xi_M > 0$  and  $\phi > 0$ .

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<sup>7</sup>It can be shown that if  $w = -u'_{s_2^D}(t)/u'_c(t)$  as in a frictionless, neoclassical environment, then the shadow price of employment  $\lambda(t)$  can grow without bound.

Upon arrival in the host country, all illegal immigrants will search for jobs in the domestic labor market. In particular, illegal immigrants face the same job-finding rate  $\gamma(t)$  and the same separation rate  $\theta$  as the native workers. The number of employed illegal immigrants thus evolves according to

$$\dot{M}_2(t) = \gamma(t)M_1(t) - \theta M_2(t),$$

which can be expressed as

$$\dot{s}_2^M(t) = \gamma(t)s_1^M(t) - (\theta + g)s_2^M(t), \quad (2.12)$$

after dividing both sides by  $M(t)$ .

Following the convention in the existing literature, it is assumed that illegal immigrants cannot save or borrow in the host country.<sup>8</sup> This assumption can be justified by the fact that illegal immigrants in most developed countries cannot legally establish credit or own assets. An immediate implication is that illegal immigrant households would consume the entire amount of labor income in every period. Hence, household consumption is given by

$$C_M(t) \equiv c_M(t)M(t) = w_M(t)M_2(t), \quad (2.13)$$

where  $w_M(t)$  is the market wage rate for illegal workers. In the current setting, the wage rate for illegal immigrants  $w_M(t)$  is different from the one for domestic workers,  $w(t)$ .

The mechanisms to determine these wage rates will be explained later on.

An illegal immigrant household's problem is to choose a set of time paths  $\{c_M(t), s_1^M(t), s_2^M(t) | t \geq 0\}$  so as to maximize the utility function in (2.11), subject to

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<sup>8</sup>This assumption is used in Hazari and Sgro (2003), Moy and Yip (2006), and Palivos (2009). In Hazari and Sgro (2003) and Moy and Yip (2006), it is assumed that illegal immigrants do not save and hence their consumption is equal to their income in every period. Palivos (2009) assumes that immigrants do save but they channel all their savings abroad. In both cases, the capital accumulation process in the host country is not affected by the illegal immigrants' consumption-saving decisions.

the law of motion in (2.12), the budget constraint in (2.13), and the initial condition:  $1 > s_2^M(0) > 0$ . Let  $\tilde{\lambda}(t)$  be the current-value shadow price of employment for an illegal immigrant household. The first-order conditions and the transversality condition for this problem are

$$-u'_{s_1^M}(t) = \tilde{\lambda}(t)\gamma(t), \quad (2.14)$$

$$\dot{\tilde{\lambda}}(t) = (\rho + \theta)\tilde{\lambda}(t) - [u'_{c_M}(t)w_M(t) + u'_{s_2^M}(t)], \quad (2.15)$$

$$\lim_{t \rightarrow \infty} e^{-(\rho-g)t} \tilde{\lambda}(t) s_2^M(t) = 0.$$

The household's optimal decision on search effort is governed by equation (2.14).

#### 2.2.4 Production

There is a large number of identical firms in this economy. In each period, each firm rents capital and hires both domestic and illegal foreign workers in order to produce output. Aggregate output  $Y(t)$  is produced according to a Cobb-Douglas production technology

$$Y(t) = F[K(t), X(t)] = [K(t)]^\epsilon [X(t)]^{1-\epsilon},$$

where  $K(t)$  denotes capital input,  $X(t)$  denotes labor input, and  $\epsilon \in (0, 1)$  is the share of capital income in total output. The labor input  $X(t)$  is in turn determined by two components, namely domestic labor  $L_2(t)$  and illegal immigrants  $M_2(t)$ . The two types of workers are aggregated through a CES function

$$X(t) = \{[L_2(t)]^\varrho + [M_2(t)]^\varrho\}^{\frac{1}{\varrho}},$$

where  $(1 - \varrho)^{-1}$  is the elasticity of substitution between the two types of labor. Since the production function has constant returns to scale, the aggregate input of capital and labor can be determined by solving a representative firm's problem.

In order to hire workers, the representative firm has to post some job vacancies in every period. Each vacancy costs  $d > 0$  units of current output. The rate at which a posted vacancy is matched to an unemployed worker at time  $t$  is given by  $\mu(t)$ . Similar to the job-finding rate  $\gamma(t)$ , the vacancy-matching rate  $\mu(t)$  is taken as exogenously given by individual firms, but is endogenously determined in equilibrium. Let  $V(t)$  be the number of job vacancies posted at time  $t$ . The firm's employment then evolves according to

$$\dot{L}_2(t) + \dot{M}_2(t) = \mu(t)V(t) - \theta[L_2(t) + M_2(t)], \quad (2.16)$$

where  $\theta[L_2(t) + M_2(t)]$  is the number of job separations. Any firm hiring illegal immigrants is subject to a fine if detected. The expected value of the fine for each illegal worker is  $q > 0$ .<sup>9</sup>

Taking the factor prices as given, the representative firm chooses a set of time paths  $\{K(t), L_2(t), M_2(t), V(t) | t \geq 0\}$  so as to maximize the present value of its future profit stream. Formally, this is given by

$$\max_{\{K(t), L_2(t), M_2(t), V(t) | t \geq 0\}} \left\{ \int_0^\infty e^{-\int_0^t r(\tau) d\tau} \Pi(t) dt \right\},$$

subject to the law of motion in (2.16), and

$$\Pi(t) = Y(t) - [r(t) + \delta]K(t) - w(t)L_2(t) - w_M(t)M_2(t) - qM_2(t) - dV(t). \quad (2.17)$$

The parameter  $\delta > 0$  is the depreciation rate of capital. Let  $\chi(t)$  and  $\Omega(t)$  be the current-value shadow price of  $L_2(t)$  and  $M_2(t)$ , respectively. Interior solutions of the firm's problem are characterized by the first-order conditions

$$F_K(t) = r(t) + \delta, \quad (2.18)$$

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<sup>9</sup>The expected value of the fine is defined as the probability that the firm gets caught by hiring an illegal immigrant times the fine per illegal immigrant worker. In the current framework, both the probability and fine are assumed to be exogenous and time-invariant. The same assumptions have been used in Palivos and Yip (2007).

$$\chi(t) = \frac{d}{\mu(t)}, \quad (2.19)$$

$$\Omega(t) = \chi(t), \quad (2.20)$$

$$\dot{\chi}(t) = [r(t) + \theta]\chi(t) + w(t) - F_{L_2}(t), \quad (2.21)$$

$$\dot{\Omega}(t) = [r(t) + \theta]\Omega(t) + w_M(t) + q - F_{M_2}(t), \quad (2.22)$$

where  $F_Z(t)$  is the marginal product of input  $Z$  at time  $t$ , for  $Z \in \{K, L_2, M_2\}$ . Equation (2.18) is the usual condition which states that the rate of return from investment is given by the marginal product of capital net of depreciation rate. Equation (2.19) governs the firm's optimal vacancy decisions. In any optimal solution, the marginal cost of vacancy  $d$  must be equated to its marginal benefit  $\chi(t)\mu(t)$ . If it is costless to post a job vacancy, i.e.,  $d = 0$ , then it follows from (2.19) that  $\chi(t) = 0$  for all  $t$ . In this case, equation (2.21) can be simplified to become

$$w(t) = F_{L_2}(t),$$

which is the first-order condition with respect to labor in a frictionless environment. Intuitively, if there is no cost in posting a vacancy, then a firm would simply post an infinite number of them so that there won't be any search frictions in the labor market. When the cost of vacancy is strictly positive, the wage rate for domestic workers  $w(t)$  is always lower than their marginal product of labor  $F_{L_2}(t)$ .

From equations (2.20)-(2.22), one can obtain the following relationship between  $w(t)$  and  $w_M(t)$ ,

$$w_M(t) = w(t) - q - [F_{L_2}(t) - F_{M_2}(t)]. \quad (2.23)$$

This condition implies that the penalty of hiring illegal immigrants is completely borne by the illegal immigrants themselves. Firms therefore do not suffer directly from employing illegal immigrant workers.

### 2.2.5 Matching and Wage Determination

In every period, vacant jobs and unemployed workers are randomly matched in a pair-wise fashion. The matching process is governed by a matching function which combines the total number of job vacancies  $V(t)$  and the total number of unemployed workers  $L_2(t) + M_2(t)$  to determine the number of successful job matches.<sup>10</sup> For analytical convenience, I assume that the matching function takes the Cobb-Douglas form<sup>11</sup>

$$\Phi[V(t), L_1(t) + M_1(t)] = \gamma_0[V(t)]^\eta[L_1(t) + M_1(t)]^{1-\eta}.$$

The parameter  $\eta \in (0, 1)$  is the elasticity of vacancy in job matches, and  $\gamma_0$  is a positive constant.

Define the tightness of the labor market  $x(t)$  as the ratio between vacancies and unemployed workers, i.e.,  $x(t) \equiv V(t)/[L_1(t) + M_1(t)]$ . Given the Cobb-Douglas matching function, the vacancy-matching rate  $\mu(t)$ , defined as the number of successful matches per vacancy, can be expressed as

$$\mu(t) = \frac{\Phi(t)}{V(t)} = \gamma_0[x(t)]^{\eta-1}. \quad (2.24)$$

Since  $\eta \in (0, 1)$ , the vacancy-matching rate is strictly decreasing in  $x(t)$ . Intuitively, this means it is more difficult for a firm to hire workers when the value of  $x(t)$  is large. Similarly, the job-finding rate  $\gamma(t)$ , defined as the number of successful matches per unemployed worker, can be expressed as

$$\gamma(t) = \frac{\Phi(t)}{L_1(t) + M_1(t)} = \gamma_0[x(t)]^\eta. \quad (2.25)$$

The job-finding rate is strictly increasing in  $x(t)$ , which means it becomes easier for an unemployed worker to find a job when the value of  $x(t)$  is large.

<sup>10</sup>For a textbook treatment of the matching process and the matching function, see Pissarides (2000).

<sup>11</sup>The Cobb-Douglas matching function is also empirically verified. See, for instance, Blanchard and Diamond (1989).

A successful job match generates a surplus for both the firm and the worker. How is this surplus shared between them? This depends on whether the worker is a native or an illegal immigrant.<sup>12</sup> For domestic workers, their wage rate  $w(t)$  is determined through a Nash bargaining process. From the firm's perspective, hiring an additional domestic worker at wage rate  $w(t)$  would generate a surplus of  $F_{L_2}(t) - w(t)$ . From the worker's perspective, accepting an offer of wage rate  $w(t)$  would generate a gain of  $w(t) - [-u'_{s_2}(t)/u'_c(t)]$ . The expression  $-u'_{s_2}(t)/u'_c(t)$  is the worker's marginal rate of substitution between consumption and leisure. It can also be interpreted as the worker's reservation wage. The outcome of the bargaining process is a wage rate  $w(t)$  that solves the following maximization problem

$$\max_{w(t)} \{ (1 - \beta) \log[F_{L_2}(t) - w(t)] + \beta \log[w(t) - (-\frac{u'_{s_2}(t)}{u'_c(t)})] \},$$

where  $\beta \in (0, 1)$  can be interpreted as the bargaining power of domestic workers. The optimal wage rate is given by

$$w(t) = \beta F_{L_2}(t) + (1 - \beta) \left[ -\frac{u'_{s_2}(t)}{u'_c(t)} \right]. \quad (2.26)$$

This wage rate is a weighted average of the worker's marginal product of labor and his reservation wage. If the domestic workers have relative stronger bargaining strength, i.e.,  $\beta$  is closer to one, then the optimal wage is closer to the marginal product of labor.

As for the illegal immigrants, I assume that they do not bargain over the wage with the firm. This assumption can be justified on the ground that any contract between an illegal worker and a firm is unlikely to be enforceable due to the worker's illegal status. Thus there is little point in bargaining. The wage rate  $w_M(t)$  is determined by equation (2.23), which is obtained from the firm's profit-maximization problem.

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<sup>12</sup>Implicitly this assumes that the firm can identify the identity of the worker (native or foreign) immediately after the match is formed.

### 2.2.6 Search Equilibrium

A search equilibrium for this economy consists of a set of allocations for the domestic household  $\{c(t), k(t), s_1^D(t), s_2^D(t) | t \geq 0\}$ , a set of allocations for the illegal immigrant household  $\{c_M(t), s_1^M(t), s_2^M(t) | t \geq 0\}$ , a set of prices  $\{r(t), w(t), w_M(t) | t \geq 0\}$ , aggregate inputs  $\{K(t), L_2(t), M_2(t) | t \geq 0\}$ , profits and vacancies  $\{\Pi(t), V(t) | t \geq 0\}$ , and matching rates  $\{\gamma(t), \mu(t) | t \geq 0\}$  such that

1. Given the prices  $\{r(t), w(t) | t \geq 0\}$ , the profits  $\{\Pi(t) | t \geq 0\}$ , and the job-finding rates  $\{\gamma(t) | t \geq 0\}$ , the allocation  $\{c(t), k(t), s_1^D(t), s_2^D(t) | t \geq 0\}$  solves the domestic household's problem.
2. Given  $\{w_M(t), \gamma(t) | t \geq 0\}$ , the allocation  $\{c_M(t), s_1^M(t), s_2^M(t) | t \geq 0\}$  solves the immigrant household's problem.
3. Given the prices  $\{r(t), w(t), w_M(t) | t \geq 0\}$  and the vacancy-matching rates  $\{\mu(t) | t \geq 0\}$ , the aggregate inputs  $\{K(t), L_2(t), M_2(t) | t \geq 0\}$  and the vacancies  $\{V(t) | t \geq 0\}$  solve the representative firm's problem. For every  $t \geq 0$ , the profits  $\Pi(t)$  is determined by (2.17).
4. For every  $t \geq 0$ , the wage rates  $w_M(t)$  and  $w(t)$ , are determined by (2.23) and (4.18), respectively.
5. For every  $t \geq 0$ , the matching rates  $\mu(t)$  and  $\gamma(t)$  are determined by (4.11) and (4.12), respectively.
6. All markets clear in every period  $t \geq 0$ .

An equilibrium defined above can be completely characterized by a system of seven differential equations which governs the dynamic properties of seven variables

$\Psi \equiv \{c, k, x, s_1^D, s_2^D, s_1^M, s_2^M\}$ . This system is given by

$$\frac{\dot{c}(t)}{c(t)} = f_k(t) - \delta - \rho, \quad (2.27)$$

$$\dot{k}(t) = f(t) - k(t)g - k(t)\delta - c(t)(1 - m) - [w_M(t) + q]s_2^M(t)m - dv(t), \quad (2.28)$$

$$\dot{x}(t) = \frac{x(t)}{1 - \eta} [r(t) + \theta] - \frac{\gamma(t)(1 - \beta)}{d(1 - \eta)} [f_{s_2^D}(t) + \frac{u'_{s_2^D}(t)}{u'_c(t)}], \quad (2.29)$$

$$\dot{s}_1^D(t) = [\rho + \theta + \gamma(t) + \frac{\dot{\gamma}(t)}{\gamma(t)} \frac{u'_{s_1^D}(t)}{u''_{s_1^D}(t)} + \frac{u'_c(t)w(t)\gamma(t)}{u''_{s_1^D}(t)} - \dot{s}_2^D(t)], \quad (2.30)$$

$$\dot{s}_2^D(t) = \gamma(t)s_1^D(t) - (\theta + g)s_2^D(t), \quad (2.31)$$

$$\dot{s}_1^M(t) = [\rho + \theta + \gamma(t) + \frac{\dot{\gamma}(t)}{\gamma(t)} \frac{v'_{s_1^M}(t)}{v''_{s_1^M}(t)} + \frac{v'_{cM}(t)w_M(t)\gamma(t)}{v''_{s_1^M}(t)} - \dot{s}_2^M(t)], \quad (2.32)$$

$$\dot{s}_2^M(t) = \gamma(t)s_1^M(t) - (\theta + g)s_2^M(t), \quad (2.33)$$

where  $f(t)$  is output per capita at time  $t$ , i.e.,

$$f(t) = [k(t)]^\epsilon \{[(1 - m)s_2^D(t)]^e + [ms_2^M(t)]^e\}^{\frac{1-\epsilon}{e}}.$$

The notation  $u''_{s_1^D}(t)$  represents the second-order derivative of the momentary utility function  $u$  with respect to  $s_1^D$ . The notation  $v''_{s_1^M}$  is similarly defined. Among the seven variables,  $(k, s_2^D, s_2^M)$  are predetermined. The initial conditions of the dynamical system are  $k(0) > 0$ ,  $s_2^D(0) \in (0, 1)$ , and  $s_2^M(0) \in (0, 1)$ . Once the time path of  $\Psi$  is known, it can be used to construct other variables of interest. For instance, the labor force participation rate and the unemployment rate of domestic workers are given by

$$s_1^D(t) + s_2^D(t) \quad \text{and} \quad \frac{s_1^D(t)}{s_1^D(t) + s_2^D(t)},$$

respectively. The labor force participation rate and the unemployment rate of illegal workers can be defined in a similar fashion. Finally, a steady state of this economy is a search equilibrium in which all variables in  $\Psi$  are stationary over time.

## 2.3 Quantitative Analysis

The main objective of this section is to explore the quantitative implications of the baseline model. To achieve this, I first assign specific values to the model parameters and then solve the model numerically. The details of the calibration procedure are explained below. The model's quantitative predictions are then discussed in order. Specifically, I focus on the impact of illegal immigration on domestic workers' consumption, employment opportunities, and overall welfare.

### 2.3.1 Parameterization

There are fourteen model parameters that need to be determined. These include the preference parameters  $\{\rho, \phi, \xi, \xi_M\}$ , the production parameters  $\{\epsilon, \varrho\}$ , parameters in the matching function  $\{\gamma_0, \eta\}$ , the job separation rate  $\theta$ , the population growth rate  $g$ , the depreciation rate of capital  $\delta$ , the bargaining power of domestic worker  $\beta$ , the unit cost of vacancy  $d$ , and the population share of illegal immigrants  $m$ .<sup>13</sup> One period in the model economy represents one quarter, so all the parameters are interpreted quarterly. Some of the parameter values are chosen based on empirical findings. Others are chosen so that the model can match as closely as possible some key statistics for the U.S. economy. These statistics include the labor force participation rate, the unemployment rate, the capital-output ratio, and the real interest rate.

In the baseline calibration, I set  $\phi = 2.5$  so that the elasticity of labor supply  $\varpi \equiv 1/\phi$  is 0.4. This value is consistent with the estimates reported in MaCurdy (1981)

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<sup>13</sup>The expected value of fine per illegal worker,  $q$ , is not specified in the calibration procedure due to the following reason. Using equation (2.23), one can replace the term  $w_M(t) + q$  with  $w(t) - [F_{L_2}(t) - F_{M_2}(t)]$  in equation (4.32). The dynamical system in Section 2.6 is then independent of  $q$ . In other words, the time paths of  $\{c, k, x, s_1^D, s_2^D, s_1^M, s_2^M\}$  and their steady-state values are all independent of  $q$ . The only use of this parameter is to determine the wage rate of illegal workers,  $w_M(t)$ , through equation (2.23). Since my main concern is the effects of illegal immigration on the consumption and labor market outcomes of domestic consumers, I do not consider the model's predictions on  $w_M(t)$ .

and Killingsworth (1983).<sup>14</sup> As a robustness check, I also consider three other values of  $\varpi$ , namely 0.2, 0.7 and 1.0. The share of capital income in total output  $\epsilon$  is set to 0.25, which is consistent with the estimates reported by Gollin (2002).<sup>15</sup> The parameter  $\varrho$  is taken to be 0.95. This implies that the elasticity of substitution between the two types of labor is 20 as indicated in Ottaviano and Peri (2008). The parameter  $\gamma_0$  is commonly normalized to one. The elasticity of vacancy in job matches  $\eta$  is 0.6, which is consistent with the estimates reported in Blanchard and Diamond (1989). The exogenous job separation rate is  $\theta = 0.05$ , which resembles the average quarterly rate of job destruction reported in Davis and Haltiwanger (1990).<sup>16</sup> The quarterly population growth rate is  $g = 0.27\%$ . This implies an annual population growth rate of 1.1%, which is the average growth rate of U.S. civilian population over the period 1954-2006. The value of bargaining power of domestic worker  $\beta$  is set to 0.5, a value commonly used in the literature. As for the population share of illegal immigrants, Passel (2006) estimates that there are about twelve million illegal immigrants in the United States in 2006. This accounts for about 4% of the U.S. population in 2006, so  $m = 0.04$ .

The preference parameters  $\xi$  and  $\xi_M$  are set to 4.028 and 4.998, respectively, so that the labor force participation rate in the steady state is 63%. This matches the U.S. labor force participation rate over the period 1954-2006.<sup>17</sup> The depreciation rate of capital  $\delta$  is 0.0108 so that the quarterly capital-output ratio in the steady state is 12. The unit cost of vacancy  $d$  is set at 1.907 so that the steady-state unemployment rate is 5.8%, which matches the U.S. quarterly average unemployment rate over the

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<sup>14</sup>For a more detailed review on the empirical estimates for this parameter, see Browning et al. (1999) p.614-620.

<sup>15</sup>Using data from 31 countries over the period 1977-1992, Gollin (2002) estimates that the share of national income accruing to labor is in the range of 0.65 to 0.80.

<sup>16</sup>The same value of  $\theta$  is also used in Mortensen and Pissarides (1993) and Shi and Wen (1999).

<sup>17</sup>Specifically, this is the participation rate for people aged 16 years old or above. Source: U.S Bureau of Labor Statistics.

period 1954-2006.<sup>18</sup> The rate of time preference  $\rho$  is taken to be 0.01 so that the annual interest rate in the steady state is about 4% . According to Siegel (2002), the average real return to stock and long-term bonds over the period 1946-2001 is 4.2%. The baseline parameterization is summarized in Table 2.1.

### 2.3.2 Macroeconomic Effects

In this subsection, I examine the effects of changing the population share of illegal immigrants on the steady-state level of per-capita variables. To achieve this, I compute a series of steady states using different values of  $m$ , ranging from zero to 0.5. The same exercise is repeated under four different values of labor supply elasticity,  $\varpi \in \{0.2, 0.4, 0.7, 1.0\}$ . In all the cases reported below, a unique steady state always exists. In addition, when the Jacobian matrix of the linearized system is evaluated at the unique steady state, it always possesses three stable eigenvalues. Since the dynamical system has three predetermined variables, this means the unique steady state is saddle-path stable.

The long-run effects of illegal immigration under  $\varpi = 0.4$  are depicted in Figure 2.1. The relationship between the long-run level of consumption per domestic consumer ( $c^*$ ) and the population share of illegal immigrants is non-monotonic. When the share of illegal immigrants  $m$  is small (less than 9% when  $\varpi = 0.4$ ), domestic consumption decreases mildly as  $m$  increases.<sup>19</sup> However, when the share of illegal immigrants is sufficiently large, domestic consumption becomes monotonically increasing with  $m$ . These results are due to the presence of four opposing forces of illegal immigration on domestic consumption. The intuitions of these forces are as follows. As more illegal immigrants

<sup>18</sup>Source: U.S. Bureau of Labor Statistics.

<sup>19</sup>The reduction in  $c^*$  is very mild and is thus hardly noticeable in the diagram. The levels of  $c^*$  when  $m = 2\%, 4\%, 6\%$  and  $8\%$  are 1.1143, 1.1136, 1.1131 and 1.1129, respectively.

enter into the host country, the competition for jobs becomes more intense. This is evident from Figure 2.1, which shows that labor-market tightness  $x^*$  decreases as the share of illegal immigrants  $m$  increases. A lower value of  $x^*$  implies a lower job-finding rate for *all* unemployed workers. This has two immediate effects on the labor income of domestic consumers. First, some domestic workers are now displaced by the illegal workers. As a result, the employment rate of domestic consumers decreases as  $m$  goes up. This can also be seen from Figure 2.1, which shows that the unemployment rate of domestic workers increases when  $m$  increases, while their labor force participation rate decreases. This in turn lowers the labor income of domestic households and hence their consumption. This effect of illegal immigration on domestic consumption is called the *displacement effect*. Second, since there are now more job-searchers in the labor market, both domestic and illegal workers are willing to work for a lower wage rate. This again lowers the labor income of domestic households and hence their consumption. This second effect is called the *wage-depressing effect*. The third effect is about the impact of illegal immigration on the firms' profits. The reduction in wage rates for domestic and illegal workers raises the firms' profits and hence the dividend income received by the domestic households. This effect, referred to as the *exploitation effect*, raises domestic consumption when the share of illegal immigrants increases. This is called the "exploitation" effect because at least part of the increase in profits can be attributed to the firms' ability to exploit the illegal workers by offering them a lower wage. This also implies that the magnitude of the exploitation effect is increasing with  $m$ . Finally, an increase in  $m$  would also affect the per-capita level of capital  $k^*$ . Since illegal immigrants do not contribute to the capital accumulation process in the host country, their presence would use up some of the output that could have been used for domestic consumption and investment. This fourth effect is referred to as the *capital consumption effect*. In general, this effect could

either raise or lower the long-run level of domestic consumption. The reason for this will be explained later on.

The four effects of illegal immigration on domestic consumption can be formally described as follows. To begin with, the steady-state value of consumption per domestic consumer is given by<sup>20</sup>

$$c^* = w^* s_2^{D*} + (\rho - g) \frac{k^*}{1 - m} + \frac{\pi^*}{1 - m}. \quad (2.34)$$

Differentiating this expression with respect to  $m$  gives

$$\begin{aligned} \frac{dc^*}{dm} = & \underbrace{\left[ w^* \frac{ds_2^{D*}}{dm} \right]}_{\substack{\text{negative} \\ \text{the displacement effect}}} + \underbrace{\left[ s_2^{D*} \frac{dw^*}{dm} \right]}_{\substack{\text{negative} \\ \text{the wage-depressing effect}}} + \underbrace{\left[ \frac{1}{1 - m} \frac{d\pi^*}{dm} + \frac{\pi^*}{(1 - m)^2} \right]}_{\substack{\text{positive} \quad \text{positive} \\ \text{the exploitation effect}}} \\ & + \underbrace{\left[ \frac{1}{1 - m} (\rho - g) \frac{dk^*}{dm} + (\rho - g) \frac{k^*}{(1 - m)^2} \right]}_{\substack{\text{negative} \quad \text{positive} \\ \text{the capital consumption effect}}} \end{aligned} \quad (2.35)$$

In the above expression, the first square bracket captures the effect of  $m$  on labor income per domestic consumer. This consists of two components. The first term inside the bracket captures the effect of  $m$  on the number of employed workers in the domestic population  $s_2^D$ , which is the displacement effect. The second term captures the effect of  $m$  on the wage rate of domestic worker, which is the wage-depressing effect. The second square bracket captures the effect of  $m$  on the amount of dividend income received by each domestic consumer. This reflects the exploitation effect described above which is positive. The last square bracket shows how the amount of capital income received by each domestic consumer is affected by the share of illegal immigrants, that is the capital consumption effect. Since illegal immigrants do not save in the host country, their presence would use up some of the output and capital that could have been used

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<sup>20</sup>This expression can be obtained by setting  $\dot{k}(t) = 0$  in equation (2.4).

for investment. This leads to a reduction in the long-run level of capital  $k^*$  which is captured by the first term in the last bracket. However, an increase in  $m$  also means that there is a smaller share of domestic consumers in the population. Holding other things constant, each domestic consumer now owns a larger stock of capital. This in turn raises the capital income and hence domestic consumption. This effect is captured by the second term in the last bracket. Thus the overall outcome of the capital use-up effect is undetermined.

In sum, an increase in  $m$  will induce a number of positive and negative forces on domestic consumption. The results in Figure 2.1 show that the negative forces dominate when  $m$  is small so that domestic consumption decreases as  $m$  increases. However, when  $m$  continues to increase, the positive forces will eventually override the negative ones so that domestic consumption is monotonically increasing with  $m$ .

As mentioned above, an increase in  $m$  lowers the labor-market tightness  $x^*$  and creates more intense competition in the labor market. This in turn lowers the wage rate and the employment rate of domestic workers. The baseline model thus predicts that an increase in illegal immigration would deteriorate the labor market opportunities of native workers. This prediction is largely consistent with the existing empirical findings in Borjas et al. (2007).

Figures 2.2 to 2.4 show the results obtained under  $\varpi = 0.2, 0.7$  and  $1.0$ , respectively. When comparing between Figures 2.1, 2.3 and 2.4, one can see that increasing the labor supply elasticity does not change the model's qualitative predictions. In particular, a U-shaped relationship between domestic consumption and the share of illegal immigrants is also observed in Figures 2.3 and 2.4. As the labor supply elasticity increases, the reduction in  $c^*$  (when  $m$  is small) becomes more pronounced. Intuitively, a more elastic labor supply would strengthen the displacement effect of illegal immigration

because the domestic workers are now more responsive to a reduction in the wage rate. This leads to a larger reduction in domestic consumption when  $m$  increases. On the contrary, when the labor supply elasticity is low, say  $\varpi = 0.2$ , the negative displacement effect becomes weaker so that domestic consumption is monotonically increasing with  $m$  for all values of  $m$  considered. These results show that the labor supply elasticity  $\varpi$  plays a key role in determining the long-run effects of illegal immigration on domestic consumption. Specifically, the relationship between  $m$  and  $c^*$  is non-monotonic only when the labor supply elasticity is high.

### ***Comparisons***

I now highlight some of the major differences between the results reported above and those obtained in earlier studies. Hazari and Sgro (2003) and Moy and Yip (2006) examine *qualitatively* the effect of illegal immigration in a neoclassical environment with full employment. Similar to the current study, Moy and Yip (2006) point out the presence of an exploitation effect, which tends to raise domestic consumption when the share of illegal immigrants increases, and a capital consumption effect which tends to lower domestic consumption when  $m$  increases. However, due to the full-employment assumption, these studies do not capture the displacement effect of illegal immigration. In addition, these studies do not capture the effects of illegal immigration on market wages because they only consider the social planner's problem. Since the exploitation effect and the capital using-up effect work in opposite directions, these studies conclude that the overall effect of illegal immigration on domestic consumption is ambiguous in general. The same conclusion holds regardless of the degree of substitutability between domestic and illegal workers.

Using a similar framework as in Hazari and Sgro (2003) and Moy and Yip

(2006), Palivos (2009) examines *qualitatively* the effects of illegal immigration in a decentralized environment. Under the full-employment assumption, this author finds that an increase in illegal immigration raises unambiguously the level of domestic consumption. This result is obtained because an increase in the population share of illegal immigrants raises both the dividend income and the capital income of domestic households. However, Palivos shows that this result no longer holds when the full-employment assumption is removed. More specifically, this author shows that domestic consumption is strictly decreasing in the share of illegal immigrants when unemployment emerges due to a minimum wage requirement. This result is obtained because the reduction in income due to the displacement effect outweighs the gain in dividend income.

### 2.3.3 Welfare Effects

To quantify the welfare implications of illegal immigration, I consider the following counterfactual experiments. Suppose the economy is in an initial steady state with  $m = 0.04$ , i.e., illegal immigrants account for 4% of the total population. Suppose at time  $t = 0$ , there is an one-time change in the population share of illegal immigrants from 0.04 to another level, say  $m' \geq 0$ . The economy then gradually converges to the new steady state. The main objective in here is to quantify the welfare gain or loss involved in this scenario. To achieve this, I construct a consumption-equivalent measure along the line of Lucas (1987).

In the counterfactual experiments, the status quo is a steady state with  $m = 0.04$ . Let  $\{c^*, s_1^{D*}, s_2^{D*}\}$  be the values of consumption, working hours and search effort per domestic consumer in the status quo. The associated lifetime utility of a domestic

household is

$$\begin{aligned} U^* &= \int_0^\infty e^{-(\rho-g)t} \left[ \log c^* - \xi \frac{(s_1^{D*} + s_2^{D*})^{1+\phi}}{1+\phi} \right] dt \\ &= \frac{1}{\rho - g} \left[ \log c^* - \xi \frac{(s_1^{D*} + s_2^{D*})^{1+\phi}}{1+\phi} \right]. \end{aligned}$$

After the one-time increase in the population share, the equilibrium time paths of consumption, search effort and work hours are given by  $\{c(t; m'), s_1^D(t; m'), s_2^D(t; m') | t \geq 0\}$ .

The lifetime utility of the representative domestic household is now

$$U(m') = \int_0^\infty e^{-(\rho-g)t} \left\{ \log [c(t; m')] - \xi \frac{[s_1^D(t; m') + s_2^D(t; m')]^{1+\phi}}{1+\phi} \right\} dt.$$

Define a consumption-equivalent measure  $\kappa(m')$  according to

$$\frac{1}{\rho - g} \left\{ \log[1 + \kappa(m')]c^* - \xi \frac{(s_1^{D*} + s_2^{D*})^{1+\phi}}{1+\phi} \right\} = U(m'). \quad (2.36)$$

This equation can be simplified to become

$$\log[1 + \kappa(m')] = (\rho - g) [U(m') - U^*].$$

The intuitions of the consumption-equivalent measure  $\kappa(m')$  are as follows.

If  $U(m') > U^*$ , then domestic households are better off after the one-time increase in illegal immigrants and the welfare measure  $\kappa(m')$  is strictly positive. The gain in welfare is equivalent to increasing the status-quo consumption  $c^*$  by a factor of  $1 + \kappa(m')$ . Contrarily if  $U^* > U(m')$ , then domestic households are worse off after the one-time change in the population share and the welfare measure  $\kappa(m')$  is strictly negative. In this case, domestic consumers are willing to surrender a fraction  $\kappa(m')$  of  $c^*$  so as to prevent the change in the population share of illegal immigrants.

Table 2.2 shows the welfare measures for  $m' \in \{0.05, 0.07, 0.09\}$  under four different values of labor supply elasticity. Three observations can be made from these

results. First, illegal immigration induces a welfare gain in all the cases considered. For instance, increasing the share of illegal immigration from 4% to 5% would create a welfare gain that is equivalent to a 0.45% increase in  $c^*$  when  $\varpi = 0.4$ . In the current framework, individuals' welfare depends on both consumption and hours worked. So even though increasing the population share of illegal immigrants lowers the long-run level of domestic consumption in some cases, this is more than compensated for by the welfare gain from a reduction in labor hours. This also points to another difference between this paper and previous studies. In Moy and Yip (2006) and Palivos (2009), consumers derive utility from consumption alone. Thus the long-run effect of increasing  $m$  on domestic consumption is identical to that on consumer welfare.

The second observation one can make from Table 2.2 is that, for all four values of  $\varpi$  considered, the welfare gains are increasing with the population share of illegal immigrants. Finally, for each value of  $m'$ , the welfare gain decreases as the labor supply elasticity increases. This is consistent with my earlier findings that a more elastic labor supply would exacerbate the negative impacts of illegal immigration on domestic consumption.

## 2.4 Conclusion

This paper develops a dynamic general equilibrium model with labor market frictions in order to examine the effects of illegal immigration on the native population. One advantage of this model is that it explicitly captures the effect of illegal immigration on the employment opportunities of the native born. This effect has been largely overlooked by the existing studies. The calibrated version of the baseline model generates three major findings. First, in all cases considered, the inflow of illegal im-

migrants significantly deteriorates the labor market outcomes of the domestic workers. More specifically, it increases their unemployment rates and lowers their wage rates. These results are qualitatively consistent with empirical evidence. Second, under the benchmark parameter values, I find a non-monotonic relationship between the population share of illegal immigrants and the long-run level of domestic consumption. In particular, I find that increasing the share of illegal immigration can increase domestic consumption once the share is above a certain threshold. This result is robust under various choices of labor supply elasticity. Third, despite its potential negative effects on domestic consumption, illegal immigration generates substantial welfare gains to the native population after taking into account both consumption and leisure.

Table 2.1: Baseline Parameter Values

|                |                                                        |
|----------------|--------------------------------------------------------|
| Demographics   | $g = 0.0027, m = 0.04.$                                |
| Preferences    | $\rho = 0.01, \phi = 2.5, \xi = 4.028, \xi_M = 4.998.$ |
| Production     | $\epsilon = 0.25, \delta = 0.0108, \varrho = 0.95.$    |
| Job Matching   | $\gamma_0 = 1, \eta = 0.6.$                            |
| Job Separation | $\theta = 0.05.$                                       |
| Others         | $\beta = 0.5, d = 1.907.$                              |

Table 2.2: Welfare Measure of Illegal Immigration

| $m'$ | $\varpi = 0.2$ | $\varpi = 0.4$ | $\varpi = 0.7$ | $\varpi = 1.0$ |
|------|----------------|----------------|----------------|----------------|
| 0.05 | 0.47%          | 0.45%          | 0.44%          | 0.43%          |
| 0.07 | 1.18%          | 1.16%          | 1.14%          | 1.12%          |
| 0.09 | 1.99%          | 1.95%          | 1.91%          | 1.88%          |

\*Values of other parameters remain the same as in Table 2.1.

Figure 2.1: Long-run Effects of Illegal Immigration When  $\varpi = 0.4$ .

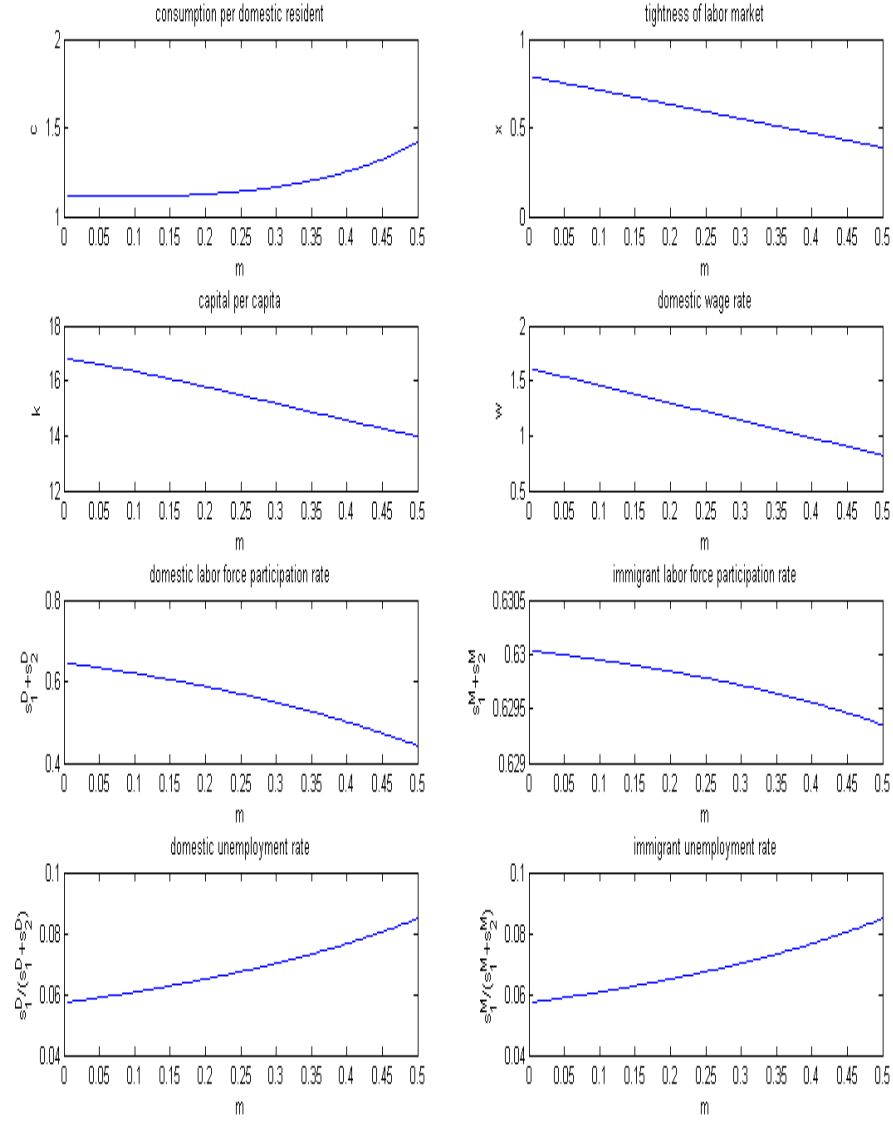


Figure 2.2: Long-run Effects of Illegal Immigration When  $\varpi = 0.2$ .

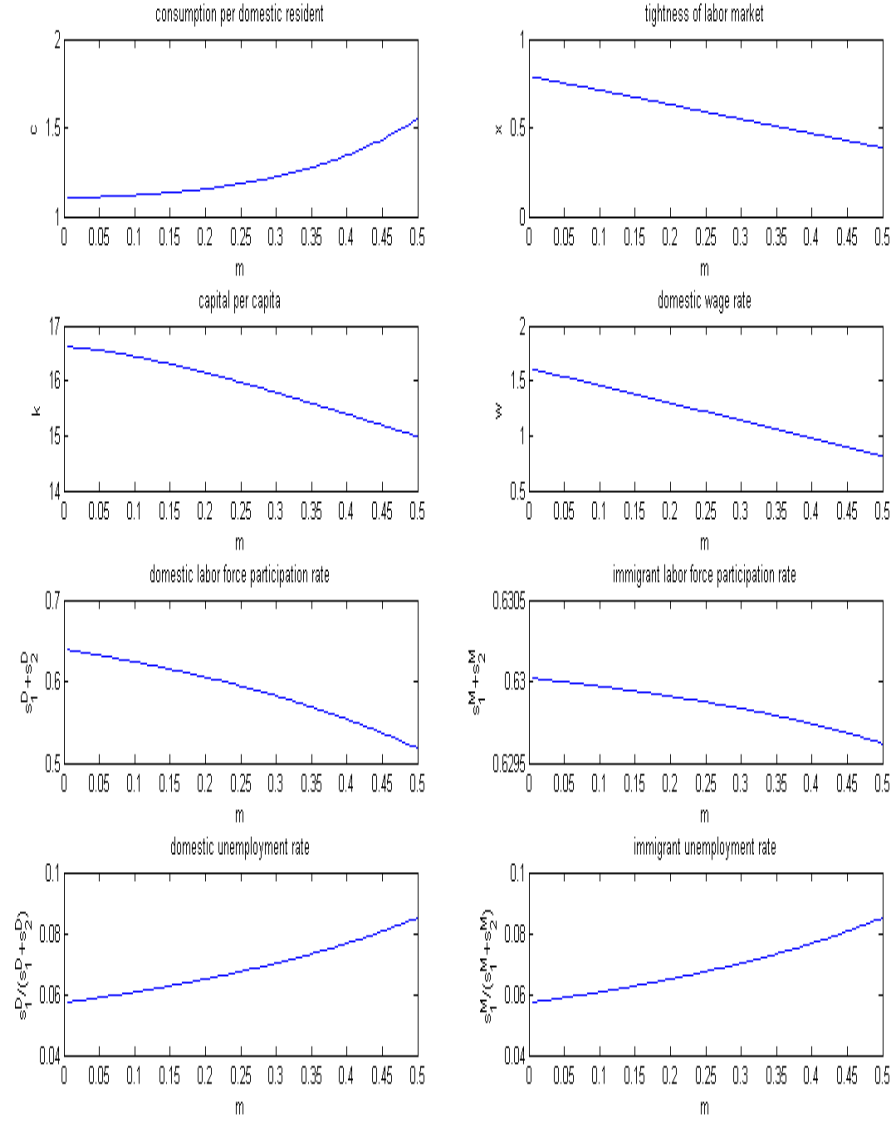


Figure 2.3: Long-run Effects of Illegal Immigration When  $\varpi = 0.7$ .

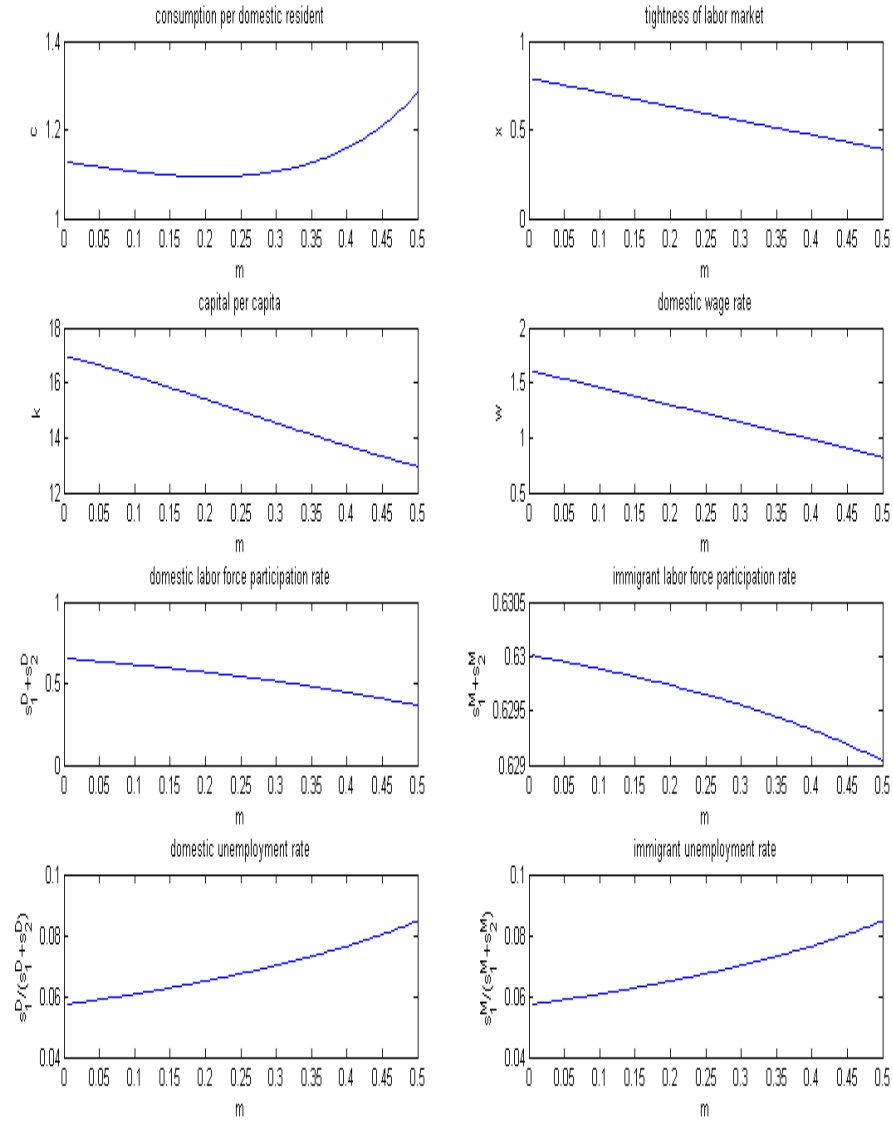
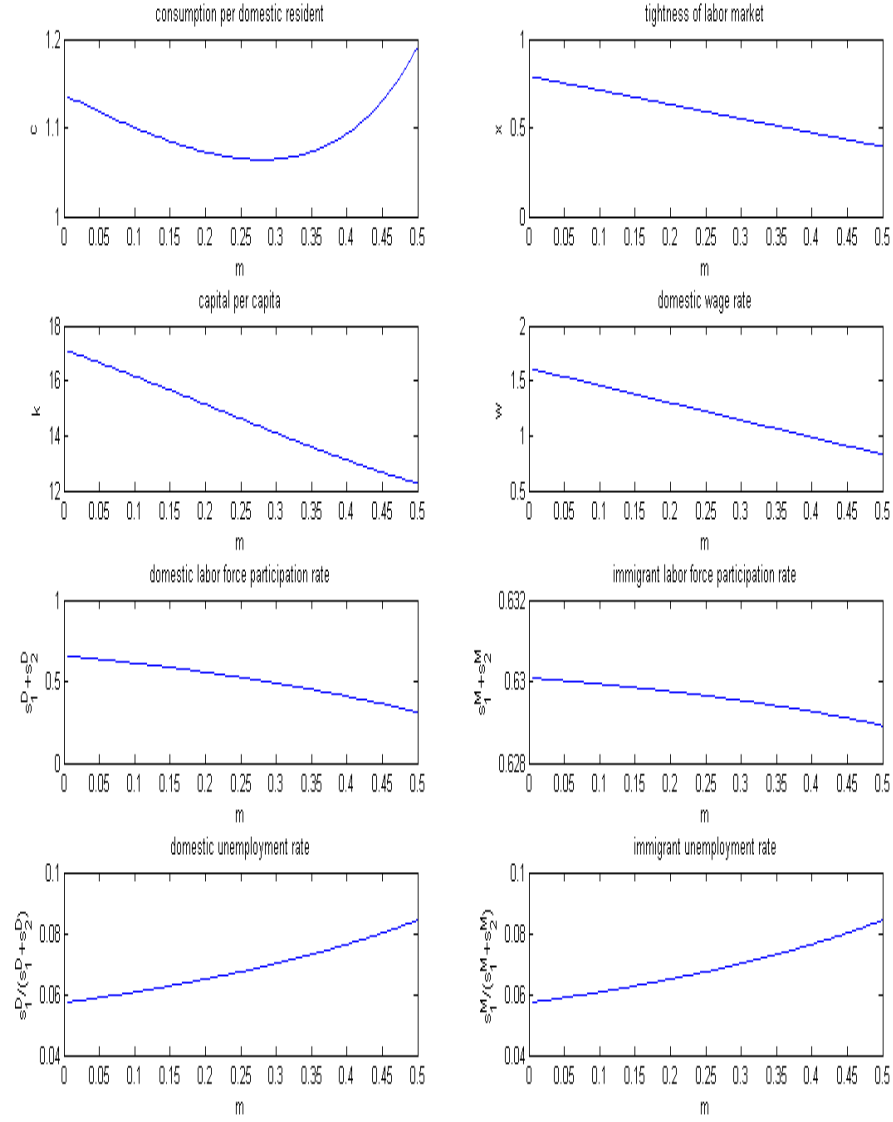


Figure 2.4: Long-run Effects of Illegal Immigration When  $\varpi = 1$ .



## Chapter 3

# The Asymmetric Effects of Illegal Immigration

### 3.1 Introduction

In chapter 2, I assume that illegal immigrants compete with all the domestic workers in a single labor market. Consequently, illegal immigrants would affect the labor market outcomes of all domestic workers in the same way. As mentioned before, empirical evidence shows that illegal immigrants in the United States are primarily unskilled workers. Thus it is likely that illegal immigrants would *only* compete with the unskilled workers in the domestic population. It follows that the wage-depressing effect and the displacement effect mentioned above would only affect the domestic unskilled workers, but not the skilled ones. Moreover, if skilled and unskilled workers are complementary in the production process, then an increase in the supply of unskilled illegal workers will benefit the skilled workers by raising their marginal product of labor. In other words, illegal immigration might induce asymmetric effects on different skill groups in the domestic population.

In order to capture these asymmetric effects, I extend the baseline model developed in chapter 2 by allowing for two types of domestic workers, skilled and unskilled, which search for jobs in two separate markets. All illegal immigrants are unskilled. Thus they only compete with the domestic unskilled workers. Skilled domestic workers are insulated from job competition with the illegal immigrants. The main idea of this extended model is to examine the differential effects of illegal immigration on different skill groups in the native population.

The model economy is now inhabited by three types of households, namely unskilled domestic ( $L$ ), skilled domestic ( $H$ ), and illegal immigrant ( $M$ ) households. The number of each type of household is again normalized to one. The size of each type of household at time  $t$  is denoted by  $L(t)$ ,  $H(t)$  and  $M(t)$ . The total population is now  $N(t) = L(t) + H(t) + M(t)$ . The variables  $L(t)$ ,  $H(t)$  and  $M(t)$  are all growing at the same constant rate  $g > 0$ . The share of unskilled domestic workers in the native population is constant over time and is represented by  $l \in (0, 1)$ . The population share of illegal immigrants is again denoted by  $m \in [0, 1)$ . In each period, each individual is endowed with one unit of time which can be used in only one of three activities: searching for a job, working for a firm, or enjoying leisure. Throughout this section, an index  $i \in \{L, H, M\}$  is used to indicate household type. The variables,  $s_1^i(t)$  and  $s_2^i(t)$ , are defined as in Section 2.2.1.

## 3.2 The Baseline Model

### 3.2.1 Households' Problems

The preferences of a type- $i$  household,  $i \in \{L, H, M\}$ , is now given by

$$\int_0^\infty e^{-(\rho-g)t} u_i[c_i(t), s_1^i(t) + s_2^i(t)] dt, \quad (3.1)$$

where the momentary utility function is

$$u_i[c_i(t), s_1^i(t) + s_2^i(t)] = \log[c_i(t)] - \xi_i \frac{[s_1^i(t) + s_2^i(t)]^{1+\phi}}{1+\phi}, \quad (3.2)$$

with  $\xi_i > 0$  and  $\phi > 0$ . In the extended model, I allow the preference parameter  $\xi_i$  to differ across skill groups. In the quantitative exercise, the parameters  $\xi_H$  and  $\xi_L$  are chosen so that the model can match the labor force participation rates of skilled and unskilled workers in the United States.

As mentioned above, illegal immigrants only compete with the unskilled domestic workers for jobs. In particular, these two groups of workers face the same job-finding rate  $\gamma_L(t)$  and the same job-separation rate  $\theta_L > 0$ . The variables  $s_2^L(t)$  and  $s_2^M(t)$  thus evolve according to

$$\dot{s}_2^i(t) = \gamma_L(t)s_1^i(t) - (\theta_L + g)s_2^i(t), \quad (3.3)$$

for  $i \in \{L, M\}$ . Meanwhile, skilled domestic workers search in another market with job-finding rate  $\gamma_H(t)$  and job-separation rate  $\theta_H > 0$ . Thus the variable  $s_2^H(t)$  evolves according to

$$\dot{s}_2^H(t) = \gamma_H(t)s_1^H(t) - (\theta_H + g)s_2^H(t).$$

Similar to the baseline model developed in chapter 2, illegal immigrant households are not allowed to save or borrow in the host country. The consumption of an illegal immigrant household is again given by

$$C_M(t) \equiv c_M(t) M(t) = w_M(t) M_2(t),$$

where  $w_M(t)$  is the wage rate for an illegal worker. In here, I also assume that unskilled domestic households do not save or borrow. This assumption is imposed for the following reason. Suppose unskilled domestic households can save or borrow and the market rate of return is  $r(t)$ . Then both skilled and unskilled domestic households will have the same

Euler equation for consumption as in (2.9). It follows that the consumption of the two types of households,  $C_L(t)$  and  $C_H(t)$ , will grow at the same rate in every period. Thus, in equilibrium, one can only determine their total consumption, i.e.,  $C_L(t) + C_H(t)$ , but not the separate values of  $C_L(t)$  and  $C_H(t)$ .<sup>1</sup> However, in order to examine the welfare effects of illegal immigration on these two types of households *separately*, I need to know the values of  $C_L(t)$  and  $C_H(t)$ . Assuming that the unskilled domestic households do not save or borrow is the simplest way to achieve this.<sup>2</sup>

In every period  $t$ , the budget constraint faced by an unskilled domestic household is given by

$$C_L(t) \equiv c_L(t) L(t) = w_L(t) L_2(t), \quad (3.4)$$

where  $w_L(t)$  is the market wage rate for an unskilled domestic worker. The budget constraint for a skilled domestic household is given by

$$\dot{K}(t) + C_H(t) = w_H(t)H_2(t) + r(t)K(t) + \Pi(t), \quad (3.5)$$

where  $w_H(t)$  is the market wage rate for a skilled worker. It is evident from (3.4) and (3.5) that the skilled households are the owners of capital and the owners of the firms in this economy. Dividing equation (3.5) by  $H(t)$  gives

$$\dot{k}(t) + k(t)g + c_H(t) = w_H(t)s_2^H(t) + r(t)k_H(t) + \pi(t), \quad (3.6)$$

The maximization problems faced by each type of household are similar to those considered in Sections 2.2.2 and 2.2.3, and are thus not repeated in here.<sup>3</sup>

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<sup>1</sup>Put it differently, the Euler equations for the two types of households are identical means that one of the equilibrium conditions is redundant. Thus there is not enough equations to determine  $C_L(t)$  and  $C_H(t)$  independently.

<sup>2</sup>Alternatively, one can assume that the ratio between  $C_L(t)$  and  $C_H(t)$  is a given constant  $\psi$  and then calibrate the value of  $\psi$  using data. However, this means the two variables are always proportional to each other and move in the same direction in all the counterfactual experiments considered below. This will strongly distort the conclusions of the welfare analysis. Because of this reason, I do not adopt this approach in here.

<sup>3</sup>Palivos (2009) considers a model that is close in spirit to the current one. First, there are both skilled

### 3.2.2 Production

Aggregate output is produced according to

$$Y(t) = [K(t)]^\epsilon [X(t)]^{1-\epsilon},$$

where  $K(t)$  denotes aggregate capital,  $X(t)$  denotes aggregate labor input and  $\epsilon \in (0, 1)$ . Unskilled domestic workers and illegal workers are in the same skill group, thus they are regarded as perfect substitutes in the production process. Meanwhile, skilled and unskilled workers are imperfect substitutes. To capture these formally, I use the following CES function to determine the aggregate labor input,

$$X(t) = \{\vartheta[H_2(t)]^\varrho + (1 - \vartheta)[L_2(t) + M_2(t)]^\varrho\}^{\frac{1}{\varrho}},$$

where the parameter  $\vartheta \in (0, 1)$  determines the intensity of skilled labor used in production, and  $(1 - \varrho)^{-1}$  governs the elasticity of substitution between skilled and unskilled labor.

In order to hire both skilled and unskilled workers, firms have to post two types of job vacancies,  $V_L(t)$  and  $V_H(t)$ . Each type- $i$  vacancy costs  $d_i > 0$  units of output, for  $i = L, H$ . The probability that a firm finds an unemployed type- $i$  worker is  $\mu_i(t)$ . The laws of motion of the firm's employment of unskilled and skilled labor are given by:

$$\dot{H}_2(t) = \mu_H(t)V_H(t) - \theta_H H_2(t), \quad (3.7)$$

$$\dot{L}_2(t) + \dot{M}_2(t) = \mu_L(t)V_L(t) - \theta_L[L_2(t) + M_2(t)]. \quad (3.8)$$

Taking the factor prices as given, a representative firm chooses a set of time paths  $\{K(t), H_2(t), L_2(t), M_2(t), V_L(t), V_H(t) | t \geq 0\}$  so as to maximize its present value

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and unskilled workers in the domestic population. Second, all illegal immigrants are unskilled. Third, unemployment exists due to a binding minimum wage requirement which only applies to unskilled workers. However, in Palivos' model, skilled and unskilled workers are pooled together in the same household (and have the same consumption). Thus it is not possible to capture the differential welfare effects of illegal immigration on the two groups of workers.

of the future profit streams. Formally, this is given by

$$\max \int_0^\infty e^{-\int_0^t r(\tau) d\tau} \Pi(t) dt,$$

subject to (3.7), (3.8) and

$$\begin{aligned} \Pi(t) = & Y(t) - [r(t) + \delta]K(t) - w_H(t)H_2(t) - w_L(t)L_2(t) \\ & - w_M(t)M_2(t) - qM_2(t) - d_L V_L(t) - d_H V_H(t). \end{aligned} \quad (3.9)$$

The parameter  $q > 0$  is again interpreted as the expected value of the fine for each illegal worker. The first-order conditions and the transversality condition for the firm's problem are similar to those derived in Section 2.2.4. The wage rate for an illegal worker is now given by

$$w_M(t) = w_L(t) - q.$$

Since illegal workers and unskilled domestic workers are perfect substitutes in the production process, they have the same marginal product. As in the baseline model, the penalty of hiring illegal workers are borne by the illegal workers themselves.

### 3.2.3 Matching and Wage Determination

In the current model, skilled and unskilled workers search for jobs in two separate markets. In here, I assume that the two markets have the same matching function

$$\begin{aligned} \Phi[V_H(t), H_1(t)] &= \gamma_0 [V_H(t)]^\eta [H_1(t)]^{1-\eta}, \\ \Phi[V_L(t), L_1(t) + M_1(t)] &= \gamma_0 [V_L(t)]^\eta [L_1(t) + M_1(t)]^{1-\eta}, \end{aligned} \quad (3.10)$$

with  $\gamma_0 > 0$  and  $\eta \in (0, 1)$ . The tightness of the skilled and unskilled labor markets are given by

$$x_H(t) = \frac{V_H(t)}{H_1(t)} \quad \text{and} \quad x_L(t) = \frac{V_L(t)}{L_1(t) + M_1(t)},$$

respectively. For domestic workers, once a type- $i$  vacancy is matched with an unemployed type- $i$  worker,  $i \in \{H, L\}$ , the wage rate  $w_i(t)$  is determined by Nash bargaining. I assume that all domestic workers have the same bargaining strength  $\beta \in (0, 1)$ . So the optimal wage rate for a type- $i$  domestic worker is

$$w_i(t) = \beta F'_i(t) + (1 - \beta) \left[ -\frac{u'_{s_2^i}(t)}{u'_{c_i}(t)} \right], \quad (3.11)$$

where  $F'_i(t)$  denotes the marginal product of labor for a type- $i$  worker.

### 3.2.4 Characterization of Equilibrium

A search equilibrium for this economy can be defined similarly as in Section 2.2.6. There are now eleven variables  $\Psi \equiv \{c_L, c_H, k, x_L, x_H, s_1^L, s_2^L, s_1^H, s_2^H, s_1^M, s_2^M\}$  that can be determined by solving a system of eleven equations

$$\begin{aligned} \frac{\dot{c}_H(t)}{c_H(t)} &= f'_k(t) - \delta - \rho, \\ c_L(t) &= w_L(t) s_2^L(t), \\ \dot{k}(t) &= f(t) - (g + \delta)k(t) - c_H(t) \\ &\quad - w_L(t) \left[ s_2^L(t) \frac{l}{1-l} + s_2^M(t) \frac{m}{(1-m)(1-l)} \right] \\ &\quad - d_L v_L(t) - d_H v_H(t), \\ \dot{x}_L(t) &= \frac{x_L(t)}{1-\eta} [r(t) + \theta_L] - \frac{\gamma_L(t)(1-\beta)}{d_L(1-\eta)} \left[ f'_{s_2^L}(t) + \frac{u'_{s_2^L}(t)}{u'_{c_L}(t)} \right], \\ \dot{x}_H(t) &= \frac{x_H(t)}{1-\eta} [r(t) + \theta_H] - \frac{\gamma_H(t)(1-\beta)}{d_H(1-\eta)} \left[ f'_{s_2^H}(t) + \frac{u'_{s_2^H}(t)}{u'_{c_H}(t)} \right], \\ \dot{s}_1^L(t) &= [\rho + \theta_L + \gamma_L(t) + \frac{\dot{\gamma}_L(t)}{\gamma_L(t)} \frac{u'_{s_1^L}(t)}{u''_{s_1^L}(t)} + \frac{u'_{c_L}(t) w_L(t) \gamma_L(t)}{u''_{s_1^L}(t)}] s_1^L(t) - \dot{s}_2^L(t), \\ \dot{s}_2^L(t) &= \gamma_L(t) s_1^L(t) - (\theta_L + g) s_2^L(t), \end{aligned}$$

$$\begin{aligned}
\dot{s}_1^H(t) &= [\rho + \theta_H + \gamma_H(t) + \frac{\dot{\gamma}_H(t)}{\gamma_H(t)} \frac{u'_{s_1^H}(t)}{u''_{s_1^H}(t)} + \frac{u'_{c_H}(t)w_H(t)\gamma_H(t)}{u''_{s_1^H}(t)} - \dot{s}_2^H(t), \\
\dot{s}_2^H(t) &= \gamma_H(t)s_1^H(t) - (\theta_H + g)s_2^H(t), \\
\dot{s}_1^M(t) &= [\rho + \theta_L + \gamma_L(t) + \frac{\dot{\gamma}_L(t)}{\gamma_L(t)} \frac{u'_{s_1^M}(t)}{u''_{s_1^M}(t)} + \frac{u'_{c_M}(t)w_M(t)\gamma_L(t)}{u''_{s_1^M}(t)} - \dot{s}_2^M(t), \\
\dot{s}_2^M(t) &= \gamma_L(t)s_1^M(t) - (\theta_L + g)s_2^M(t).
\end{aligned}$$

This system has four predetermined variables  $\{k, s_2^L, s_2^H, s_2^M\}$ . The corresponding initial values are  $k(0)$ ,  $s_2^L(0)$ ,  $s_2^H(0)$ , and  $s_2^M(0)$ .

### 3.3 Quantitative Analysis

#### 3.3.1 Parameterization

In the model with heterogeneous labor, there are eighteen parameters that need to be determined. One period in the model economy again represents one quarter, so all the parameters are interpreted quarterly. Following Borjas et al. (1997), I define skilled workers as those who have completed at least high school and unskilled workers as high school dropouts. Some of the parameter values are the same as in Table 2.1. Others are chosen so that the model can match as closely as possible the labor force participation rates of the two educational groups, the unemployment rates of the two groups, the average capital-output ratio, and the average skill premium between skilled and unskilled workers observed in the United States.

To begin with, the following parameter values are the same as in the baseline model. The growth rate of population  $g$  is 0.27%. The share of illegal immigrants in total population  $m$  is 4%. The rate of time preference  $\rho$  is 0.01. The share of capital income in total output  $\epsilon$  is 0.25. The depreciation rate of capital  $\delta$  is 0.0108. The bargaining strength of domestic workers  $\beta$  is 0.5. In the matching function, the elasticity of vacancy

$\eta$  is 0.6 and the parameter  $\gamma_0$  is normalized to one. The labor supply elasticity  $\varpi$  is 0.4, so that the parameter  $\phi = 1/\chi$  is 2.5. Similar to the baseline model, I consider three other values of  $\varpi$  in the sensitivity analysis.

The proportion of unskilled domestic household  $l$  is set at 0.13. This matches the share of high school dropouts in the U.S. labor force over the period 1970-2005 as reported by the U.S. Census Bureau. As for the elasticity of substitution between skilled and unskilled workers  $(1 - \varrho)^{-1}$ , most of the estimates in the existing literature are between one and two. The most commonly used value is 1.4 (Autor et al., 1998). Thus, I set  $\varrho = 1 - 1/1.4 = 0.286$ . The remaining parameter values are chosen to match a number of key statistics for the U.S. economy. First, I set  $\xi_L = 14.006$  and  $\xi_H = 1.303$  so that the steady-state labor force participation rates of unskilled and skilled workers are 46.9% and 73.6%, respectively. These are consistent with the U.S. labor force participation rates of the two educational groups over the period 1970-2005.<sup>4</sup> Second, the parameters  $d_L$  and  $d_H$  are set at 0.312 and 0.213 so that the steady-state unemployment rates of unskilled and skilled workers are 8.97% and 3.91%, respectively. These are the unemployment rates of the two educational groups over the period 1970-2005.<sup>5</sup> Third, the parameter  $\vartheta$  in the production function is set at 0.419 to match the skill premium of 1.839.<sup>6</sup> Fourth, following Pries (2008) the heterogeneous separation rates  $\theta_L$  and  $\theta_H$  are chosen to match the average aggregate separation rate. Specifically, I choose the exogenous job separation rates  $\theta_L = 0.08$  and  $\theta_H = 0.045$  to match the average quarterly job separation rate of 0.05.<sup>7</sup> The baseline parameter values are listed

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<sup>4</sup>Source: Current Population Survey.

<sup>5</sup>Source: Current Population Survey.

<sup>6</sup>I build the wage ratio using CPS data from 1996 to 2005. In the CPS, civilian population is divided into four educational groups: (1) less than high school diploma; (2) high school graduates, no college degree; (3) less than a bachelor's degree; and (4) college graduate. The first group is taken as the unskilled workers, and the remaining three groups are taken as skilled labor. Skill premium is defined as the ratio of weekly earnings between these two types of labor. The weekly earnings of skilled workers are those of (2), (3) and (4), weighted by their size.

<sup>7</sup>For robustness check, I also consider several different combinations of  $\theta_L$  and  $\theta_H$ . Following Pries

in Table 3.1.

### 3.3.2 Numerical Results

In this subsection, I consider the same numerical exercises as in Sections 2.3.2 and 2.3.3. First, I construct a series of steady states using different values of  $m$  in order to gauge the asymmetric effects of illegal immigration on the native population. Second, I evaluate the welfare consequences of illegal immigration on the two types of domestic consumers.

The long-run effects of illegal immigration on skilled and unskilled domestic consumers under  $\varpi = 0.4$  are shown in Figure 3.1. The effects on the two groups of workers are completely different. To begin with, an increase in the population share of illegal immigrants  $m$  raises the consumption of skilled consumers and improves their labor market outcomes. Specifically, such an increase raises the tightness of the labor market for skilled workers and hence raises their job-finding rate. It also leads to an increase in the wage rate for skilled workers and lowers their unemployment rate. As for the unskilled domestic workers, their consumption and labor market outcomes are negatively affected by an increase in  $m$ . The intuitions of these results are as follows. As more illegal immigrants enter into the host country, the job competition in the unskilled labor market becomes more intense. Unskilled domestic workers thus suffer from the displacement effect and the wage-depressing effect mentioned above. On the contrary, skilled domestic workers are insulated from the job competition with illegal immigrants. In fact, they benefit from the inflow of unskilled workers because it raises their marginal product of labor. As a result of this, the firms now have higher demand for skilled labor and post more job vacancies in the skilled labor market. This raises

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(2008), I restrict my attention only to the case in which  $\theta_L \geq \theta_H$ .

the tightness of this market and enhances the job-finding rate of the skilled workers. Since the skilled domestic households are the owners of capital and the firms, their consumption is also affected by the exploitation effect and the capital consumption effect mentioned above. The results in Figure 3.1 show that the overall effect of illegal immigration on the consumption of skilled domestic residents is positive. As a robustness check, I have repeated the same exercise using three alternative values of labor supply elasticity, namely 0.2, 0.7 and 1.0. These results show that the asymmetric effects of illegal immigration are robust under different choices of  $\varpi$ .

To gauge the asymmetric welfare consequences of illegal immigration, I perform the same counterfactual experiments as in Section 2.3.3 and construct the consumption-equivalent measures  $\kappa_H(m')$  and  $\kappa_L(m')$  for skilled and unskilled domestic households, respectively. I also construct an overall welfare measure  $\bar{\kappa}(m')$  for the entire domestic population as follows. Let  $\{c_i^*, s_1^{i*}, s_2^{i*}\}$  be the consumption, search effort and labor hours of a type- $i$  consumer in the status quo, for  $i \in \{H, L\}$ . Let  $U_i(m')$  be the lifetime utility of a type- $i$  household after an one-time change in the population share of illegal immigrants from 4% to a new value  $m'$ , taking into account the transitional dynamics. The overall welfare measure is defined according to

$$\begin{aligned} & \frac{l}{\rho - g} \left\{ \log[1 + \bar{\kappa}(m')] c_L^* - \xi_L \frac{(s_1^{L*} + s_2^{L*})^{1+\phi}}{1+\phi} \right\} \\ & + \frac{1-l}{\rho - g} \left\{ \log[1 + \bar{\kappa}(m')] c_H^* - \xi_H \frac{(s_1^{H*} + s_2^{H*})^{1+\phi}}{1+\phi} \right\} \\ & = l U_L(m') + (1-l) U_H(m'), \end{aligned}$$

where  $l = 0.13$  is the share of unskilled residents in the domestic population. Let  $U_i^*$  be the lifetime utility for a type- $i$  household in the status quo. Then the above expression

can be simplified to become

$$\frac{\log[1 + \bar{\kappa}(m')]}{\rho - g} = l [U_L(m') - U_L^*] + (1 - l) [U_H(m') - U_H^*]. \quad (3.12)$$

If the one-time change in population share  $m$  induces a welfare gain *on average*, i.e.,

$$l [U_L(m') - U_L^*] + (1 - l) [U_H(m') - U_H^*] > 0,$$

then the overall welfare measure  $\bar{\kappa}(m')$  is strictly positive. The gain in welfare is equivalent to increasing the status-quo consumption  $c_H^*$  and  $c_L^*$  by a factor of  $[1 + \bar{\kappa}(m')]$  in every period. Equation (3.12) can be further simplified to become

$$1 + \bar{\kappa}(m') = [1 + \kappa_L(m')]^l [1 + \kappa_H(m')]^{1-l}.$$

This means the overall welfare measure is a geometric weighted average of  $\kappa_H(m')$  and  $\kappa_L(m')$ . The results of this exercise are reported in Table 3.2. These results show that illegal immigration induces substantial welfare gains to the skilled households and substantial welfare losses to the unskilled ones. Similar to the baseline model developed in chapter 2, the magnitude of the welfare measure is increasing with  $m$ .

### 3.4 Conclusion

In this chapter, I relax the assumption of homogeneous labor and model explicitly the heterogeneity of labor in the native population. Specifically, there are now skilled and unskilled workers in the native population and the illegal foreign workers are all unskilled. All illegal immigrants thus only compete with the domestic unskilled workers for jobs. Skilled domestic workers are insulated from job competition with the illegal immigrants. Having heterogeneity in skills allows me to investigate the asymmetric impacts of illegal immigration in a search-matching framework. Calibration exercises

show that the long-run effects of illegal immigration on skilled and unskilled domestic consumers are very different. Under baseline parameter values, the consumption of domestic skilled workers is monotonically increasing with the population share of illegal immigrants, while the consumption of domestic unskilled workers is monotonically decreasing. An increase in illegal immigration also raises the wage rate for skilled workers and lowers their unemployment rate. The opposite is true for the unskilled workers. Under this framework, only the unskilled domestic workers would suffer from the displacement effect and the wage-depressing effect. Skilled domestic workers, on the contrary, benefit from the inflow of illegal immigrant because it raises their marginal product of labor. This increases the demand for skilled workers and thus improves their labor market outcomes. In terms of welfare consequences, the extended model suggests that an increase in illegal immigration would induce a welfare gain to the skilled consumers and a welfare loss for the unskilled ones.

To close the paper, I like to point out one line of future research. In this study, I do not model illegal immigrants' incentives to immigrate; rather, I assume that they will continue to arrive into the United States period after period. In addition, I restrict my attention only to the long run impacts of illegal immigration. As pointed out in Hanson (2006), the inflow of illegal immigrants are sensitive to business cycle conditions. To capture this feature, the model can be modified to incorporate immigration decision and technological shocks so as to quantify the short run implications of illegal immigration over the business cycle. I plan to pursue this topic in future research.

Table 3.1: Baseline Parameter Values

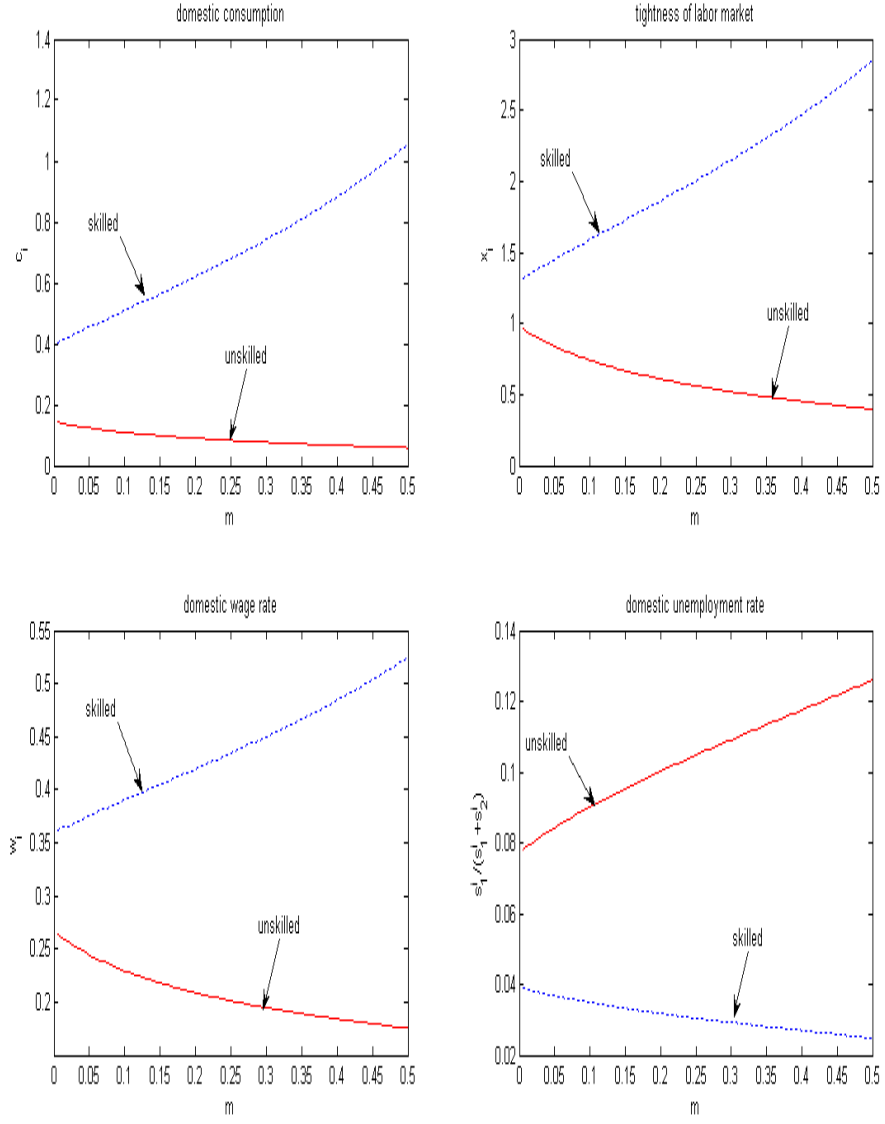
|                |                                                                         |
|----------------|-------------------------------------------------------------------------|
| Demographics   | $g = 0.0027, m = 0.04, l = 0.13.$                                       |
| Preferences    | $\rho = 0.01, \phi = 2.5, \xi_L = 14.006, \xi_H = 1.303.$               |
| Production     | $\epsilon = 0.25, \delta = 0.0108, \varrho = 0.286, \vartheta = 0.419.$ |
| Job Matching   | $\gamma_0 = 1, \eta = 0.6.$                                             |
| Job Separation | $\theta_L = 0.08, \theta_H = 0.045.$                                    |
| Others         | $\beta = 0.5, d_L = 0.312, d_H = 0.213.$                                |

Table 3.2: Welfare Measure of Illegal Immigration

|      | $\varpi = 0.2$ |               |                   | $\varpi = 0.4$ |               |                   | $\varpi = 0.7$ |               |                   | $\varpi = 1$  |               |                   |
|------|----------------|---------------|-------------------|----------------|---------------|-------------------|----------------|---------------|-------------------|---------------|---------------|-------------------|
| $m$  | $\kappa_L(m)$  | $\kappa_H(m)$ | $\bar{\kappa}(m)$ | $\kappa_L(m)$  | $\kappa_H(m)$ | $\bar{\kappa}(m)$ | $\kappa_L(m)$  | $\kappa_H(m)$ | $\bar{\kappa}(m)$ | $\kappa_L(m)$ | $\kappa_H(m)$ | $\bar{\kappa}(m)$ |
| 0.05 | -1.32%         | 2.52%         | 2.02%             | -1.1%          | 2.57%         | 2.09%             | -1.11%         | 2.59%         | 2.11%             | -1.24%        | 2.62%         | 2.10%             |
| 0.07 | -6.31%         | 7.15%         | 5.29%             | -6.09%         | 7.18%         | 5.37%             | -6.82%         | 7.16%         | 5.22%             | -6.74%        | 7.17%         | 5.24%             |
| 0.09 | -10.77%        | 11.74%        | 8.52%             | -10.46%        | 11.76%        | 8.59%             | -11.35%        | 11.73%        | 8.42%             | -11.01%       | 11.75%        | 8.48%             |

\* Values of other parameters remain the same as in Table 3.1.

Figure 3.1: Long-run Asymmetric Effects of Illegal Immigration When  $\varpi = 0.4$ .



## Chapter 4

# Labor Market Search and the Dynamic Effects of Immigration

### 4.1 Introduction

In most developed countries, the share of working-age people in the population has been declining due to various reasons, such as decreasing fertility rates and increasing life expectancy. A decline in the number of workers has negative impacts on economic growth and on the maintenance of some government funded social programs. To help mitigate a shortfall in labor supply and thus upset its negative consequences, many countries have chosen to admit more immigrants. In fact, in the last few decades, the world has witnessed a historically high rate of immigration. The United Nations estimates that in the year 2005, the total number of people residing outside of their country of birth was around 195.2 million, which comprised 3 percent of the world's population. At country level, in traditional immigrant-receiving countries, a large percentage of their population is foreign-born. For instance, immigrants made up 23.8 percent in Australia, 19.4 percent in New Zealand, 19.1 percent in Canada, and 12.9 percent in

the United States.<sup>1</sup> On the other hand, opening doors to immigration has also forced these countries to confront some potentially serious problems related to immigration. There is a vast empirical literature that investigates the impact of immigration on the labor market outcomes of native-born workers.<sup>2</sup> Studies using national-level data typically find that an inflow of immigrants causes intense competition in the domestic labor market and consequently lowers wages and employment rates of domestic workers (see, among others, Borjas, 2003; Borjas *et al.*, 2007).<sup>3</sup> However, while empirical evidence has shown that immigration deteriorates the labor market position of domestic workers, existing theoretical literature has made little attempt to model any potential impact of immigration on the employment opportunities of domestic workers.

The main objective of this paper is to examine the impacts of immigration on the domestic economy using a dynamic general equilibrium model. Specifically, I focus on two important aspects of immigration. The first one is the job displacement effects of immigrant workers. The second one is the skill composition of immigrants. The second feature is important because conventional wisdom appears to suggest that the skill composition of immigrants is an important factor in determining how native workers are affected by immigration. For instance, unskilled immigrants are expected to harm the employment opportunities of unskilled natives, while unskilled immigrants can benefit skilled natives by increasing their productivity if they are complementary in the production process. Hence, it is important to disentangle the effects of immigration across skill groups in the domestic population. To achieve these, I add two modifications to the labor market search model developed in Shi and Wen (1997). First, I introduce heterogeneous labor (skilled and unskilled) in their model. Second, I incorporate an exogenous

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<sup>1</sup>Source: OECD, 2007. International Migration Outlook.

<sup>2</sup>A detailed review of this literature can be found in Hanson (2009).

<sup>3</sup>Using regional-level data in the United Kingdom, Hatton and Tani (2005) also find the job displacement effect of immigration.

inflow of foreign workers of both skill types into the domestic economy.<sup>4</sup> Specifically, the benchmark economy consists of skilled and unskilled households, firms and the government. Households' preferences are defined over their consumption and leisure. On the production side, firms rent capital and hire skilled and unskilled workers to produce output. The government plays two roles in this economy. First, it imposes taxes on labor income, capital income and dividend income. Second, it provides unemployment benefits to unemployed workers. In each period, an exogenous inflow of foreign workers of both skill types enters into the domestic economy. Unemployment arises due to labor market frictions (in the form of time-consuming job search and matching). In addition, I make two important assumptions to facilitate the analysis. (1) The occupational labor markets assumption: I assume that skilled and unskilled workers search for jobs in two separate markets. As a result, only immigrant and domestic workers of the same skill group will compete for job opportunities.<sup>5</sup> (2) The complementarity assumption: it means that the two types of labor (skilled and unskilled) are complementary in the production process. Hence, an increase in the number of one type of workers will raise the productivity of the other type.<sup>6</sup>

Given the occupational labor markets assumption, an inflow of skilled immigrants intensifies job competition only in the skilled labor market. Unskilled domestic workers are insulated from the competition with skilled immigrants. This affects the labor market outcomes of skilled domestic workers in two ways. First, unemployed

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<sup>4</sup>In the United States, the inflow of legal immigrants is large and regulated by the rationing of visas. These facts justify that the current study takes as given the inflow of immigrants and does not consider the immigration decisions made by foreign workers.

<sup>5</sup>This assumption is made to accommodate the fact that it requires extensive investment in training and qualifications for unskilled and skilled labor to switch between their occupations. Thus, making the transition from one type of job to another difficult. The same assumption is also used in Mortensen and Pissarides (1999).

<sup>6</sup>This assumption is supported by empirical evidence. Gang and Rivera-Batiz (1994) find that in both United States and European production, education, unskilled labor and experience are complementary inputs.

skilled domestic workers are now less likely to find a job. Second, those who find a job would face a lower wage offered from the firm. These in turn affect skilled domestic workers' consumption-saving decisions, and hence the capital accumulation process in the host country. Likewise, an increase in unskilled immigration induces similar effects on unskilled domestic workers, making it more difficult for them to find a job and lowering their wage. On the other hand, given the complementarity assumption, an inflow of skilled immigrants benefits the unskilled domestic workers by raising their marginal product of labor. Firms have a higher demand for unskilled labor and thus post more job vacancies for this type of workers. Consequently, this raises unskilled workers' wage rate and lowers their unemployment rate. Similarly, a rise in the number of unskilled immigrants improves the labor market outcomes of skilled workers.

In order to confirm these intuitive arguments of the impacts of immigration, I consider a calibrated version of the baseline model. I find that the quantitative results coincide with the intuition. Under the benchmark parameterization, I demonstrate that skilled (unskilled) immigration creates a tighter skilled (unskilled) labor market and thus lowers the job-finding probability, wage rate, employment rate as well as consumption for the skilled (unskilled) workers.<sup>7</sup> On the other hand, I show how domestic population can benefit from immigration. For instance, when more unskilled immigrants enter the domestic country, I find that the labor market for the skilled domestic workers is less tight and their employment rate, wage rate and consumption all rise with unskilled immigration.

In the quantitative analysis, I also consider the welfare implications of immigration on the native born. To achieve this, I compare four counterfactual scenarios

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<sup>7</sup>There are four different channels via which skilled immigration affects the consumption of skilled households. These four channels will be discussed in Section 4.3.2.

to a benchmark scenario and compute the gains or losses in consumer welfare. In the benchmark scenario, the economy remains in a steady state in which the population shares of immigrants in both skill groups are consistent with their realistic counterparts in the United States over the period 1994-2005; unemployment benefits also match the US system; and skilled immigrants bring no capital into the domestic economy. The first counterfactual scenario (S1) involves a policy shift, the domestic economy starts at the benchmark scenario but then experiences a one-time unanticipated change only in the number of skilled immigrants. The economy then gradually converges to a new steady state. The second counterfactual scenario (S2) is also a policy shift. It is similar to S1 in every aspect but we observe a one-time unanticipated change in the number of unskilled immigrants instead. Another policy shift (S3) is an increase in the unemployment benefits provided by the government. In particular, when more immigrants of one skill group are granted entrance into the domestic economy, the government will allocate more unemployment benefits to unemployed native workers of the same skill group holding the amount of unemployment benefits received by those in a different skill group unchanged. In the last counterfactual scenario (S4), I change immigrants' initial wealth. Specifically, I allow skilled immigrants to import a certain amount of capital when they arrive in the domestic country. To quantify the welfare differences for both types of domestic households between the benchmark scenario and the other four scenarios, I construct their respective consumption-equivalent measure along the line of Lucas (1987), taking into account the transitional dynamics. The main findings of this exercise are summarized as follows. First, an increase in skilled immigration would induce a welfare gain to the unskilled consumers and a welfare loss for the skilled ones. Second, in contrast with skilled immigration, opposite results are found with an increase in unskilled immigration. Unskilled immigration creates a welfare gain to the

skilled residents and a welfare loss for the unskilled ones. Third, increasing government provided unemployment benefits can effectively mitigate the households loss in welfare due to immigration. Last, for the unskilled households, their welfare gains are increasing with the amount of capital skilled immigrants arrive with. As for the skilled residents, raising the amount of capital the skilled immigrants bring with them reduces the harm to the skilled households, or even generates a welfare gain to them.

This paper is complementary to previous studies that quantify the effects of immigration in both static (Borjas, 1995) and dynamic frameworks (Ben-Gad, 2004, 2008; Liu, 2010; Chassamboulli and Palivos, 2010).<sup>8</sup> Borjas (1995) uses a static framework with fixed capital to analyze the economic benefit of immigration into the US and Ben-Gad (2004) investigates the dynamic general equilibrium effects of immigration in the presence of endogenous capital accumulation. Unlike the current study, these authors adopt a framework in which there is only one type of domestic labor and thus do not capture the differential effects of both skilled and unskilled immigration on different skill groups in domestic population. More importantly, their studies assume full employment in the domestic labor market. As a result, they rule out any potential impact of immigration on the employment opportunities of domestic workers. Ben-Gad (2008) extends his model by introducing heterogeneous labor (skilled and unskilled). However, the problem of full employment still remains unsolved. Liu (2010) explicitly takes into account the job displacement effect induced by illegal immigrants. However, assuming that illegal immigrants are low skilled, it is thus unable to explore the effects of skilled immigration. Furthermore, this study does not consider unemployment benefits and

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<sup>8</sup>Previous research has also been carried out to study other issues related to immigration. For instance, Storesletten (2000) uses an overlapping generations model to examine whether immigration can help the U.S. government sustain its fiscal policy. There is also an extensive literature that analyzes various impacts of immigration from an immigrant-sending country's perspective. See, for instance, Wong and Yip (1999), Beine, Docquier and Rapoport (2001) and the references therein.

hence cannot examine how unemployment benefits can be used to mitigate the welfare loss due to immigration. In an interesting recent paper, Chassamboulli and Palivos consider skill composition of immigrants within a search and matching framework. There are two main differences between their study and the current one. First, Chassamboulli and Palivos assume that consumers are risk neutral and do not take into account their saving decisions. Second, their work focuses on steady-state analysis only.

The remainder of this paper is structured as follows. Section 4.2 presents the baseline model and characterizes the search equilibrium. Section 4.3 describes the calibration procedure and presents the baseline results and the counterfactual experiments. Finally, Section 4.4 offers some concluding remarks.

## 4.2 The Baseline Model

### 4.2.1 Population

Consider an economy inhabited by two types of representative households, namely unskilled ( $L$ ) and skilled ( $H$ ) households. I normalize the number of each type of representative household to one. At time  $t = 0$ , a set number of unskilled and skilled immigrants is admitted to the economy. Upon arrival in the host country, an immigrant will join a representative household according to his skill type. Denote by  $L^D(t)$ ,  $L^F(t)$  the number of unskilled native- and foreign-born members in a representative unskilled household at time  $t \geq 0$ , respectively. Similarly, a representative skilled household consists of members from domestic and foreign countries, denoted as  $H^D(t)$  and  $H^F(t)$ . I assume that immigrants and natives of the same skill group share the same preferences and face the same factor price.<sup>9</sup> With two types of members, the size of each type of

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<sup>9</sup>One important implication of this assumption is that domestic and immigrant workers of the same skill group are regarded as perfect substitutes in the production process. This implication is supported

representative household is given by  $L(t) = L^D(t) + L^F(t)$  and  $H(t) = H^D(t) + H^F(t)$ . The native population is comprised of domestic unskilled and skilled residents and is given by  $N(t) = L^D(t) + H^D(t)$ . The variables  $L^D(t)$ ,  $L^F(t)$ ,  $H^D(t)$  and  $H^F(t)$  are assumed to all grow at the same constant rate  $g > 0$ .<sup>10</sup> It follows that the share of skilled domestic residents in the native population is constant over time and is represented by  $\sigma \in (0, 1)$ . The population share of unskilled immigrants in the representative unskilled household is  $l \in (0, 1)$  and that of skilled immigrants in the representative skilled household is  $h \in (0, 1)$ .

In each period, each individual is endowed with one unit of time that has three mutually exclusive uses: searching for a job, working for wages, or enjoying leisure. An agent who is searching for a job is called unemployed. Throughout this paper, an index  $i \in \{L, H\}$  is used to indicate household type. At the household level, the total amount of time that a representative unskilled household spent on search and work are given by  $L_1(t)$  and  $L_2(t)$ , respectively. Similarly, the total amount of time that a representative skilled household spent on search and work are  $H_1(t)$  and  $H_2(t)$ . Furthermore, I assume occupational labor markets so that skilled and unskilled agents search for jobs in two separate markets.

#### 4.2.2 Representative Skilled Household's Problem

Representative skilled households have preferences over their consumption and leisure. They are represented by

$$\int_0^\infty e^{-\rho t} u^H[C_H(t), H(t) - H_1(t) - H_2(t)]dt, \quad (4.1)$$

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by empirical evidence. Borjas *et al.* (2008) find that the native and immigrant labor of the same skill group are perfect substitutes. A similar assumption has also been used in previous studies (see, for instance, Ben-Gad, 2004, 2008).

<sup>10</sup>This assumption is imposed so that all the per-capita variables in the model economy are stationary in the long run.

where  $C_H(t)$  is the skilled household's consumption at time  $t$ , and  $\rho > 0$  is the rate of time preference. The momentary utility function is given by

$$u^H[C_H(t), H(t) - H_1(t) - H_2(t)] = \alpha_H \log[C_H(t)] + (1 - \alpha_H) \log[H(t) - H_1(t) - H_2(t)], \quad (4.2)$$

where  $\alpha_H \in (0, 1)$  is a preference parameter.

In each period, each household member faces uncertainty in his employment status and hence his labor income. If an agent is currently unemployed, then he faces a certain probability of finding a job. The rate at which unemployed workers find jobs is denoted by  $\gamma_H(t)$ . This rate is taken as exogenously given by the agents, but is endogenously determined in equilibrium. If an agent is currently employed, then he faces a certain probability of becoming unemployed. The rate of job separation is assumed to be an exogenous constant  $\theta_H > 0$ . At the household level, the number of working hours evolves according to

$$\dot{H}_2(t) = \gamma_H(t)H_1(t) - \theta_H H_2(t). \quad (4.3)$$

Although each individual faces substantial risk in his labor income, I assume that members within a household can provide each other with complete insurance against this risk. This assumption is commonly used in the literature (see, for instance, Merz, 1995; Shi and Wen, 1997, 1999). More specifically, I assume that each household consists of a very large number of individuals who pool their income together and care only about the welfare of the household that they belong to. Under this assumption, household consumption and asset holdings are independent of the idiosyncratic income shocks.

In the real world, an inflow of immigrants may be accompanied by an inflow of physical capital. To capture this, I allow skilled immigrants to import some amount of capital when they enter the domestic economy. Denote by  $K^H(t)$  and  $K^F(t)$  the

stock of domestic and foreign capital at time  $t \geq 0$ , respectively. When foreign capital is present, the aggregate capital stock  $K(t)$  is given by

$$K(t) = K^H(t) + K^F(t).$$

The skilled household's budget constraint in each period  $t \geq 0$  is then given by

$$\dot{K}(t) + C_H(t) = (1 - \tau)w_H(t)H_2(t) + (1 - \tau_K)[r(t)K(t) + \Pi(t)] + B_H, \quad (4.4)$$

where  $w_H(t)$  is the market wage rate for skilled workers,  $\tau$  is the labor income tax rate,  $r(t)$  is the effective rate of return from investment,  $\tau_K$  is the capital income tax rate,  $\Pi(t)$  is the dividend income distributed by the firms and  $B_H$  is the skilled household's unemployment benefits received from the government which are assumed to be constant over time.<sup>11</sup>

A skilled household's problem is to choose a set of time paths  $\{C_H(t), H_1(t), H_2(t), K(t) | t \geq 0\}$  so as to maximize the utility function in (4.1) subject to the law of motion in (4.3), the budget constraint in (4.4), and two initial conditions:  $K(0) > 0$ ,  $H_2(0) > 0$ . Let  $\lambda(t)$  be the current-value shadow price of employment to the household. The current-value shadow price of capital to the household can be derived as  $u_1^H$ . The first-order conditions and the transversality condition for this problem are given by

$$\frac{\dot{C}_H(t)}{C_H(t)} = (1 - \tau_K)r(t) - \rho, \quad (4.5)$$

$$\lambda(t)\gamma_H(t) = \frac{1 - \alpha_H}{H(t) - H_1(t) - H_2(t)}, \quad (4.6)$$

$$\dot{\lambda}(t) = (\rho + \theta_H)\lambda(t) + \frac{1 - \alpha_H}{H(t) - H_1(t) - H_2(t)} - \frac{\alpha_H w_H(t)(1 - \tau)}{C_H(t)}, \quad (4.7)$$

$$\lim_{t \rightarrow \infty} e^{-\rho t} \lambda(t) H_2(t) = 0.$$

---

<sup>11</sup>Alternatively, I can endogenize the unemployment benefits as in Shi and Wen (1999). However, this will substantially complicate the dynamical system shown in Section 2.7 and make welfare analysis a rather difficult task.

Equation (4.5) is the standard Euler equation for consumption. Equation (4.6) states the rule for the household to decide how much effort it should put into search. It requires the marginal cost of search to be equal to its marginal benefit.

Combining equations (4.6)-(4.7) gives

$$\dot{\lambda}(t) = (\rho + \theta_H)\lambda(t) + \left\{1 - \frac{\alpha_H w_H(t)(1 - \tau)[H(t) - H_1(t) - H_2(t)]}{(1 - \alpha_H)C_H(t)}\right\}\gamma_H(t)\lambda(t). \quad (4.8)$$

This equation describes how the shadow price of employment  $\lambda(t)$  would evolve over time. An important implication of (4.8) is that in order to compensate for the search cost, the after-tax wage rate  $(1 - \tau)w_H(t)$  has to be set above the marginal rate of substitution between leisure and consumption, which is given by  $(1 - \alpha_H)C_H(t)/\{\alpha_H[H(t) - H_1(t) - H_2(t)]\}$ .

### 4.2.3 Representative Unskilled Household's Problem

Similar to skilled households, representative unskilled households have preferences over their consumption and leisure. They are represented by

$$\int_0^\infty e^{-\rho t} u^L[C_L(t), L(t) - L_1(t) - L_2(t)] dt, \quad (4.9)$$

where  $C_L(t)$  is the unskilled household's consumption at time  $t$ . The momentary utility function is similar to the one in (4.2), i.e.,

$$u^L[C_L(t), L(t) - L_1(t) - L_2(t)] = \alpha_L \log[C_L(t)] + (1 - \alpha_L) \log[L(t) - L_1(t) - L_2(t)],$$

with  $\alpha_L \in (0, 1)$ .

In each period, unskilled workers search for jobs in another labor market with job-finding rate  $\gamma_L(t)$  and job-separation rate  $\theta_L > 0$ . At the household level, the number of working hours evolves according to

$$\dot{L}_2(t) = \gamma_L(t)L_1(t) - \theta_L L_2(t). \quad (4.10)$$

I assume that unskilled households neither save nor borrow. This assumption can be justified on two grounds. First, according to Rodríguez *et al.* (2002), the households in the bottom 20% of the U.S. wealth distribution in 1998 hold negative wealth and the head of the household typically does not have a high school diploma. Hence, unskilled households are likely to account for an insignificant fraction of the total wealth. Second, as explained in Liu (2010), if I allow unskilled households to save or borrow, it will be impossible to determine the separate values of  $C_L(t)$  and  $C_H(t)$  in equilibrium. However, I need to know the values of  $C_L(t)$  and  $C_H(t)$  in order to examine the welfare effects of immigration on these two types of households *separately*. Assuming that the unskilled households do not save or borrow is the simplest way to achieve this.

In each period  $t$ , the budget constraint faced by an unskilled household is then given by

$$C_L(t) = (1 - \tau)w_L(t)L_2(t) + B_L, \quad (4.11)$$

where  $w_L(t)$  is the market wage rate for an unskilled worker, and  $B_L$  is the unskilled household's unemployment benefits received from the government which are again assumed to be constant over time.

An unskilled household's problem is to choose a set of time paths  $\{C_L(t), L_1(t), L_2(t) | t \geq 0\}$  so as to maximize the utility function in (4.9) subject to the law of motion in (4.10), the budget constraint in (4.11), and one initial condition:  $L_2(0) > 0$ . Let  $\psi(t)$  be the current-value shadow price of employment to the household. The first-order conditions and the transversality condition for this problem are

$$\psi(t)\gamma_H(t) = \frac{1 - \alpha_L}{L(t) - L_1(t) - L_2(t)}, \quad (4.12)$$

$$\dot{\psi}(t) = (\rho + \theta_L)\psi(t) + \frac{1 - \alpha_L}{L(t) - L_1(t) - L_2(t)} - \frac{\alpha_L w_L(t)(1 - \tau)}{C_L(t)}, \quad (4.13)$$

$$\lim_{t \rightarrow \infty} e^{-\rho t} \psi(t) L_2(t) = 0.$$

The household's optimal decision on search effort is governed by equation (4.12).

#### 4.2.4 Production

There is a large number of identical firms in this economy. In each period, each firm rents capital and hires both skilled and unskilled workers to produce output. Empirical evidence (for instance, Autor *et al.* 1998) typically suggests that unskilled and skilled workers are imperfect substitutes in the production process. To allow for imperfect substitutability between these two types of workers, I employ a CES aggregator. Aggregate output  $Y(t)$  is then produced according to

$$Y(t) = F[K(t), L_2(t), H_2(t)] = [K(t)]^\varepsilon \{ \vartheta [L_2(t)]^\varrho + (1 - \vartheta) [H_2(t)]^\varrho \}^{\frac{1-\varepsilon}{\varrho}},$$

where  $K(t) = K^H(t) + K^F(t)$  denotes aggregate capital input,  $\varepsilon \in (0, 1)$  is the share of capital income in total output, the parameter  $\vartheta \in (0, 1)$  determines the intensity of unskilled labor used in production, and  $(1 - \varrho)^{-1}$  is the elasticity of substitution between skilled and unskilled labor.

In order to hire both skilled and unskilled workers, firms have to post two types of job vacancies,  $V_L(t)$  and  $V_H(t)$ . Each type- $i$  vacancy costs  $d_i > 0$  units of output, for  $i = L, H$ . The probability that a firm finds an unemployed type- $i$  worker at time  $t$  is given by  $\mu_i(t)$ . Similar to the job-finding rate  $\gamma_i(t)$ , the vacancy-matching rate  $\mu_i(t)$  is taken as exogenously given by individual firms, but is endogenously determined in equilibrium. The laws of motion of the firm's employment of unskilled and skilled labor are given by:

$$\dot{L}_2(t) = \mu_L(t)V_L(t) - \theta_L L_2(t), \quad (4.14)$$

$$\dot{H}_2(t) = \mu_H(t)V_H(t) - \theta_H H_2(t), \quad (4.15)$$

where  $\theta_H H_2(t)$  and  $\theta_L L_2(t)$  are the number of each type of job separations.

Taking the factor prices as given, the representative firm chooses a set of time paths  $\{K(t), L_2(t), H_2(t), V_L(t), V_H(t) | t \geq 0\}$  so as to maximize the present value of its future profit stream. Formally, this is given by

$$\max_{\{K(t), L_2(t), H_2(t), V_L(t), V_H(t) | t \geq 0\}} \left\{ \int_0^\infty e^{-\int_0^t r(\tau) d\tau} \Pi(t) dt \right\},$$

subject to the laws of motion in (4.14), (4.15) and

$$\Pi(t) = Y(t) - [r(t) + \delta]K(t) - w_L(t)L_2(t) - w_H(t)H_2(t) - d_L V_L(t) - d_H V_H(t), \quad (4.16)$$

where the parameter  $\delta > 0$  is the depreciation rate of capital. Let  $\chi(t)$  and  $\Omega(t)$  be the current-value shadow price of  $L_2(t)$  and  $H_2(t)$ , respectively. Interior solutions of the firm's problem are characterized by the first-order conditions

$$F_K(t) = r(t) + \delta, \quad (4.17)$$

$$\chi(t) = \frac{d_L}{\mu_L(t)}, \quad (4.18)$$

$$\Omega(t) = \frac{d_H}{\mu_H(t)}, \quad (4.19)$$

$$\dot{\chi}(t) = [r(t) + \theta]\chi(t) + w_L(t) - F_{L_2}(t), \quad (4.20)$$

$$\dot{\Omega}(t) = [r(t) + \theta]\Omega(t) + w_H(t) - F_{H_2}(t). \quad (4.21)$$

where  $F_K(t)$ ,  $F_{L_2}(t)$  and  $F_{H_2}(t)$  denote the marginal product of inputs,  $K(t)$ ,  $L_2(t)$ , and  $H_2(t)$ , at time  $t$ . Equation (4.17) is a standard condition which states that the rate of return from investment is given by the marginal product of capital net of depreciation rate. Equations (4.18) and (4.19) govern the firm's optimal vacancy decisions.

#### 4.2.5 Matching and Wage Determination

In every period, a matching function which combines the total number of job vacancies and the total number of unemployed workers is used to determine the number

of successful job matches.<sup>12</sup> In this framework, skilled and unskilled workers search for jobs in two separate markets. In here, I assume that the two markets have the same Cobb-Douglas matching function

$$\Phi_H[V_H(t), H_1(t)] = \gamma_0[V_H(t)]^\eta[H_1(t)]^{1-\eta},$$

$$\Phi_L[V_L(t), L_1(t)] = \gamma_0[V_L(t)]^\eta[L_1(t)]^{1-\eta},$$

where the parameter  $\eta \in (0, 1)$  is the elasticity of vacancy in job matches, and  $\gamma_0$  is a positive constant.<sup>13</sup>

Define the tightness of the labor market  $x_i(t)$  as the ratio between type- $i$  vacancies and type- $i$  unemployed workers. Formally, the tightness of the skilled and unskilled labor markets are given by

$$x_H(t) = \frac{V_H(t)}{H_1(t)} \quad \text{and} \quad x_L(t) = \frac{V_L(t)}{L_1(t)},$$

respectively. Given the Cobb-Douglas matching function, the type- $i$  vacancy-matching rate  $\mu_i(t)$ , defined as the number of successful type- $i$  matches per type- $i$  vacancy, can be expressed as

$$\mu_i(t) = \frac{\Phi_i(t)}{V_i(t)} = \gamma_0[x_i(t)]^{\eta-1}. \quad (4.22)$$

Since  $\eta \in (0, 1)$ , the type- $i$  vacancy-matching rate is strictly decreasing in  $x_i(t)$ . Intuitively, this means that it is more difficult for a firm to hire workers when the value of  $x_i(t)$  is large. Similarly, the type- $i$  job-finding rate  $\gamma_i(t)$ , defined as the number of successful type- $i$  matches per type- $i$  unemployed worker, can be expressed as

$$\gamma_L(t) = \frac{\Phi_L(t)}{L_1(t)} = \gamma_0[x_L(t)]^\eta, \quad (4.23)$$

$$\gamma_H(t) = \frac{\Phi_H(t)}{H_1(t)} = \gamma_0[x_H(t)]^\eta. \quad (4.24)$$

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<sup>12</sup>For a textbook treatment of the matching process and the matching function, see Pissarides (2000).

<sup>13</sup>The Cobb-Douglas matching function is also empirically verified. See, for instance, Blanchard and Diamond (1989).

The type- $i$  job-finding rate is strictly increasing in  $x_i(t)$ , which means that it becomes easier for an unemployed worker to find a job when the value of  $x_i(t)$  is large.

Once a type- $i$  vacancy is matched with an unemployed type- $i$  worker,  $i \in \{H, L\}$ , the wage rate  $w_i(t)$  is determined by Nash bargaining. Hiring an additional type- $i$  worker at wage rate  $w_i(t)$  would add firm's surplus by  $F_{i_2}(t) - w_i(t)$ . Accepting an offer of wage rate  $w_i(t)$  would generate a gain of  $w_i(t) - u_2^i / [(1 - \tau)u_1^i]$  to a type- $i$  worker. The expression  $u_2^i / [(1 - \tau)u_1^i]$  can be interpreted as a type- $i$  worker's reservation wage. I assume that all workers have the same bargaining strength  $\beta \in (0, 1)$ . The outcome of the bargaining process is a wage rate  $w_i(t)$  that solves the following maximization problem

$$\max_{w_i(t)} \left\{ (1 - \beta) \log[F_{i_2}(t) - w_i(t)] + \beta \log[w_i(t) - \frac{u_2^i}{(1 - \tau)u_1^i}] \right\}.$$

The optimal wage rate for a type- $i$  worker is given by

$$w_i(t) = \beta F_{i_2}(t) + (1 - \beta) \frac{u_2^i}{(1 - \tau)u_1^i}. \quad (4.25)$$

#### 4.2.6 Government

The government is subject to the following constraint that balances its budget each period:

$$G(t) + B_L + B_H = \tau w_L(t)L_2(t) + \tau w_H(t)H_2(t) + \tau_K[r(t)K(t) + \Pi(t)], \quad (4.26)$$

where  $G(t)$  is government spending. In here, government spending is introduced only to balance the budget. It therefore plays no role in the analysis. With the government, the aggregate resource constraint for the economy is given by

$$C_L(t) + C_H(t) + \dot{K}(t) = Y(t) - \delta K(t) - d_L V_L(t) - d_H V_H(t) - G(t). \quad (4.27)$$

#### 4.2.7 Search Equilibrium

Given the tax rates  $(\tau, \tau_K)$  and the unemployment benefits  $(B_L, B_H)$ , a search equilibrium for this economy consists of a set of allocations for the representative skilled household  $\{C_H(t), K(t), H_1(t), H_2(t) | t \geq 0\}$ , a set of allocations for the representative unskilled household  $\{C_L(t), L_1(t), L_2(t) | t \geq 0\}$ , a set of prices  $\{r(t), w_H(t), w_L(t) | t \geq 0\}$ , aggregate inputs  $\{K(t), H_2(t), L_2(t) | t \geq 0\}$ , profits and vacancies  $\{\Pi(t), V_H(t), V_L(t) | t \geq 0\}$ , matching rates  $\{\gamma_H(t), \gamma_L(t), \mu_H(t), \mu_L(t) | t \geq 0\}$  and government spending  $\{G(t) | t \geq 0\}$  such that

1. Given the prices  $\{r(t), w_H(t) | t \geq 0\}$ , the profits  $\{\Pi(t) | t \geq 0\}$ , the job-finding rates  $\{\gamma_H(t) | t \geq 0\}$  and the unemployment benefit  $B_H$ , the allocation  $\{C_H(t), K(t), H_1(t), H_2(t) | t \geq 0\}$  solves the representative skilled household's problem.
2. Given  $\{w_L(t), \gamma_L(t) | t \geq 0\}$  and  $B_L$ , the allocation  $\{C_L(t), L_1(t), L_2(t) | t \geq 0\}$  solves the representative unskilled household's problem.
3. Given the prices  $\{r(t), w_H(t), w_L(t) | t \geq 0\}$  and the vacancy-matching rates  $\{\mu_H(t), \mu_L(t) | t \geq 0\}$ , the aggregate inputs  $\{K(t), H_2(t), L_2(t) | t \geq 0\}$  and the vacancies  $\{V_H(t), V_L(t) | t \geq 0\}$  solve the representative firm's problem. For every  $t \geq 0$ , the profits  $\Pi(t)$  is determined by (4.16).
4. For every  $t \geq 0$ , the matching rates  $\mu_H(t), \mu_L(t), \gamma_H(t)$  and  $\gamma_L(t)$  are determined by (4.22)-(4.24).
5. For every  $t \geq 0$ , the wage rates  $w_H(t)$  and  $w_L(t)$  are determined by (4.25).
6. The government's budget is balanced in each period.
7. All markets clear in every period  $t \geq 0$ .

To characterize the equilibrium analytically, I rewrite all the equilibrium conditions into a system of equations. I begin by defining a number of new variables. First, let  $s_1^i(t)$  be the fraction of members in a type- $i$  representative household that are searching for jobs at time  $t$ , and  $s_2^i(t)$  be the fraction of members that are employed. The variable  $s_1^i(t)$  is also referred to as search effort. For an unskilled household,  $s_1^L(t)$  and  $s_2^L(t)$  are given by

$$s_1^L(t) = L_1(t) / L(t) \quad \text{and} \quad s_2^L(t) = L_2(t) / L(t).$$

Similarly, for a skilled household  $s_1^H(t)$  and  $s_2^H(t)$  are

$$s_1^H(t) = H_1(t) / H(t) \quad \text{and} \quad s_2^H(t) = H_2(t) / H(t).$$

Second, define holdings of capital of each skilled domestic and foreign household member as  $k_H(t) = K^H(t) / H^D(t)$  and  $k_F(t) = K^F(t) / H^F(t)$ , respectively. Moreover, I assume that each skilled immigrant arrive with a fixed fraction of the capital owned by his domestic counterpart, i.e.,  $k_F(t) = \epsilon k_H(t)$  with  $\epsilon \in [0, 1]$ . Last, the consumption of each representative skilled and unskilled household member at time  $t$  is denoted by  $c_H(t) = C_H(t) / H(t)$  and  $c_L(t) = C_L(t) / L(t)$ . Now, the equilibrium defined above can be completely characterized by a system of nine equations which governs the dynamic properties of nine variables  $\Psi \equiv \{c_H, c_L, k_H, x_H, x_L, s_1^H, s_2^H, s_1^L, s_2^L\}$ . This system is given by

$$\frac{\dot{c}_H(t)}{c_H(t)} = (1 - \tau_K)r(t) - \rho - g, \quad (4.28)$$

$$c_L(t) = (1 - \tau)w_L(t)s_2^L(t) + b_L, \quad (4.29)$$

$$\dot{k}_H(t) = \frac{1}{1 - (1 - \epsilon)h} \{ (1 - \tau)w_H(t)s_2^H(t) + (1 - \tau_K)[(1 - (1 - \epsilon)h)r(t)k_H(t) + \pi(t)] \} \quad (4.30)$$

$$+ b_H - c_H(t) - (1 - (1 - \epsilon)h)k_H(t)g\},$$

$$\dot{x}_H(t) = \frac{x_H(t)}{1-\eta}[r(t) + \theta_H] - \frac{\gamma_H(t)(1-\beta)}{d_H(1-\eta)}\{F_{H_2}(t) - \frac{c_H(t)(1-\alpha_H)}{\alpha_H[1-s_1^H(t)-s_2^H(t)](1-\tau)}\}, \quad (4.31)$$

$$\dot{x}_L(t) = \frac{x_L(t)}{1-\eta}[r(t) + \theta_L] - \frac{\gamma_L(t)(1-\beta)}{d_L(1-\eta)}\{F_{L_2}(t) - \frac{c_L(t)(1-\alpha_L)}{\alpha_L[1-s_1^L(t)-s_2^L(t)](1-\tau)}\}, \quad (4.32)$$

$$\begin{aligned} \dot{s}_1^H(t) &= [\rho + \theta_H + \gamma_H(t) + \frac{\dot{\gamma}_H(t)}{\gamma_H(t)}][1 - s_1^H(t) - s_2^H(t)] - \dot{s}_2^H(t) \\ &\quad - \frac{\alpha_H \gamma_H(t)(1-\tau)w_H(t)[1 - s_1^H(t) - s_2^H(t)]^2}{c_H(t)(1-\alpha_H)}, \end{aligned} \quad (4.33)$$

$$\dot{s}_2^H(t) = \gamma_H(t)s_1^H(t) - (\theta_H + g)s_2^H(t), \quad (4.34)$$

$$\begin{aligned} \dot{s}_1^L(t) &= [\rho + \theta_L + \gamma_L(t) + \frac{\dot{\gamma}_L(t)}{\gamma_L(t)}][1 - s_1^L(t) - s_2^L(t)] - \dot{s}_2^L(t) \\ &\quad - \frac{\alpha_L \gamma_L(t)(1-\tau)w_L(t)[1 - s_1^L(t) - s_2^L(t)]^2}{c_L(t)(1-\alpha_L)}, \end{aligned} \quad (4.35)$$

$$\dot{s}_2^L(t) = \gamma_L(t)s_1^L(t) - (\theta_L + g)s_2^L(t), \quad (4.36)$$

where  $b_i$ ,  $i \in \{L, H\}$  denotes unemployment benefits per type- $i$  household member, and  $\pi(t)$  is dividend income received by each skilled consumer. Equation (4.31) is derived from (4.19), (4.21) and (4.25); (4.32) is derived from (4.18), (4.20) and (4.25); (4.33) is derived from (4.6) and (4.7); and (4.35) is derived from (4.12) and (4.13). Among the nine variables,  $(k_H, s_2^H, s_2^L)$  are predetermined. The initial conditions of the dynamical system are  $k_H(0) > 0$ ,  $s_2^H(0) \in (0, 1)$ , and  $s_2^L(0) \in (0, 1)$ . Once the time path of  $\Psi$  is known, I use it to construct unemployment rate of type- $i$  workers as  $s_1^i(t) / [s_1^i(t) + s_2^i(t)]$ . Finally, a steady state of this economy is a search equilibrium in which all variables in  $\Psi$  are stationary over time.

### 4.3 Numerical Results

The purpose of this section is two-fold: First, to quantify the long-run macroeconomic impacts of two types of immigration on skilled and unskilled domestic workers'

wages, employment opportunities and consumption. Second, to quantify the welfare consequences of immigration of both skill types. To achieve these, I have to first parameterize the baseline model. Some of the parameter values are chosen based on empirical findings. Others are chosen so that the model can match as closely as possible some key statistics for the U.S. economy. These include the labor force participation rates of the two educational groups, the unemployment rates of the two groups, the real interest rate, the average capital-output ratio, the average replacement ratio, and the average skill premium between skilled and unskilled workers observed in the United States.<sup>14</sup> In the following subsection, I show the procedure in details.

#### 4.3.1 Parameterization

I need to assign specific values to twenty-three model parameters. These include the preference parameters  $\{\rho, \alpha_L, \alpha_H\}$ , the production parameters  $\{\varepsilon, \varrho, \vartheta\}$ , parameters in the matching function  $\{\gamma_0, \eta\}$ , the job separation rates  $\{\theta_L, \theta_H\}$ , the population growth rate  $g$ , the depreciation rate of capital  $\delta$ , the workers' bargaining power  $\beta$ , the unit cost of each type of vacancy  $\{d_L, d_H\}$ , unemployment benefits  $\{b_L, b_H\}$ , income tax rates  $\{\tau, \tau_k\}$ , the demographic parameters  $\{l, h, \sigma\}$ , and the parameter  $\epsilon$  that governs the level of capital stock that each skilled immigrant imports. One period in the model economy represents one quarter, so all the parameters are interpreted quarterly. Following Borjas *et al.* (1997), I define skilled workers as those who have completed at least high school and unskilled workers as high school dropouts.

In the baseline calibration, I set quarterly population growth rate  $g = 0.27\%$ . This implies an annual population growth rate of 1.1%, which is the average growth rate of U.S. civilian population over the period 1954-2006. The share of capital income

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<sup>14</sup>The replacement ratio describes the level of benefit of an unemployed worker as a proportion of wage when in work.

in total output  $\varepsilon$  is set to 0.36, which is consistent with the average share of capital in US over the period 1991-2000 reported by Ben-Gad (2008). Setting the parameter  $\epsilon = 0$  implies that all skilled immigrants are not endowed with capital and arrive with only labor to supply.<sup>15</sup> The value of bargaining power of all workers  $\beta$  is set to 0.5, a value commonly used in the literature. In the matching function, the parameter  $\gamma_0$  is commonly normalized to one and the elasticity of vacancy in job matches  $\eta$  is 0.6, which is consistent with the estimates reported in Blanchard and Diamond (1989). Following Judd (1987), I set factor income tax rates  $\tau = \tau_K = 0.3$ , which are consistent with the estimates in King and Fullerton (1984).

The proportion of skilled domestic residents in the native population  $\sigma$  is set at 0.87. This matches the share of those who have completed at least high school in the U.S. labor force over the period 1970-2005 as reported by the U.S. Census Bureau. The parameters  $l$  and  $h$  are set at 0.27 and 0.11 to match the share of immigrants in the aggregate population of the two educational groups over the period 1994-2005.<sup>16</sup> As for the elasticity of substitution between skilled and unskilled workers  $(1 - \varrho)^{-1}$ , most of the estimates in the existing literature are between one and two. The most commonly used value is 1.4 (Autor *et al.* 1998). Thus, I set  $\varrho = 1 - 1/1.4 = 0.286$ . The remaining parameter values are chosen to match a number of key statistics for the U.S. economy. First, I set  $\alpha_L = 0.488$  and  $\alpha_H = 0.765$  so that the steady-state labor force participation rates of unskilled and skilled workers are 46.9% and 73.6%, respectively. These are consistent with the U.S. labor force participation rates of the two educational groups over the period 1970-2005.<sup>17</sup> Second, the parameters  $d_L$  and  $d_H$

<sup>15</sup>This assumption is also used in Ben-Gad (2008). He assumes that immigrants exhaust any savings on travel expenses. Thus, they can only supply labor.

<sup>16</sup>Source: Current Population Survey.

<sup>17</sup>Specifically, this is the participation rate for people aged 16 years old or above. Source: Current Population Survey.

are set at 1.24 and 1.371 so that the steady-state unemployment rates of unskilled and skilled workers are 8.97% and 3.91%, respectively. These are the unemployment rates of the two educational groups over the period 1970-2005.<sup>18</sup> Third, the parameter  $\vartheta$  in the production function is set at 0.106 to match the skill premium of 1.839.<sup>19</sup> Fourth, I set the unemployment benefits  $b_L = 0.0217$  and  $b_H = 0.0276$  to match the average replacement ratio of 0.5 in the US as reported in Young (2004). Fifth, following Pries (2008) the heterogeneous separation rates  $\theta_L$  and  $\theta_H$  are chosen to match the average aggregate separation rate. Specifically, I choose the exogenous job separation rates  $\theta_L = 0.08$  and  $\theta_H = 0.045$  to match the average quarterly job separation rate of 0.05 as reported in Davis and Haltiwanger (1990).<sup>20</sup> Sixth, given the capital income tax rate  $\tau_K$  and the population growth rate  $g$ , the rate of time preference  $\rho$  is taken to be 0.005 so that the annual interest rate in the steady state is about 4%. According to Siegel (2002), the average real return to stock and long-term bonds over the period 1946-2001 is 4.2%. Last, the depreciation rate of capital  $\delta$  is 0.0213 so that the quarterly capital-output ratio in the steady state is 11.5. The baseline parameter values are listed in Table 4.1.

### 4.3.2 Long-run Macroeconomic Effects of Immigration

In this subsection, I examine the long-run macroeconomic effects of changing both types of immigration policy on skilled and unskilled consumers. To achieve this, I compute a series of steady states using different values of  $l$  and  $h$ , ranging from zero to

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<sup>18</sup>Source: Current Population Survey.

<sup>19</sup>I build the wage ratio using CPS data from 1996 to 2005. In the CPS, civilian population is divided into four educational groups: (1) less than high school diploma; (2) high school graduates, no college degree; (3) less than a bachelor's degree; and (4) college graduate. The first group is taken as the unskilled workers, and the remaining three groups are taken as skilled labor. Skill premium is defined as the ratio of weekly earnings between these two types of labor. The weekly earnings of skilled workers are those of (2), (3) and (4), weighted by their size.

<sup>20</sup>The same value of average quarterly job separation rate is also used in Mortensen and Pissarides (1993) and Shi and Wen (1999). For robustness check, I also consider several different combinations of  $\theta_L$  and  $\theta_H$ . Following Pries (2008), I restrict my attention only to the case in which  $\theta_L \geq \theta_H$ .

0.5. In all the cases reported below, a unique steady state always exists. In addition, when the Jacobian matrix of the linearized system is evaluated at the unique steady state, it always possesses three stable eigenvalues. Since the dynamical system has three predetermined variables, this means the unique steady state is saddle-path stable.

The long-run effects of skilled immigration are depicted in Figure 4.1. The effects on the two groups of workers are completely different. To begin with, an increase in skilled immigration  $h$  lowers the consumption of skilled workers and deteriorates their labor market outcomes. Specifically, such an increase lowers the tightness of the labor market for skilled workers and hence lowers their job-finding rate. It also leads to a decrease in the wage rate for skilled workers and increases their unemployment rate. As for unskilled workers, on the contrary, their consumption and labor market outcomes are positively affected by an increase in  $h$  (see Figure 4.2). Similar to Liu (2010), skilled immigration affects skilled consumer's consumption via four channels. First, as more skilled immigrants enter into the host country, the job competition in the skilled labor market becomes more intense. This is evident from Figure 4.1, which shows that skilled labor-market tightness  $x_H^*$  decreases as the skilled immigration  $h$  increases. A lower value of  $x_H^*$  implies a lower job-finding rate for skilled unemployed workers. Some skilled domestic workers are now displaced by the skilled immigrant workers. As a result, the unemployment rate of skilled consumers increases as  $h$  goes up as shown in Figure 4.1. This in turn lowers the labor income of skilled households and hence their consumption. This effect of skilled immigration on skilled household's consumption is called the *displacement effect*. Second, since there are now more job-searchers in the skilled labor market, skilled workers are willing to work for a lower wage rate. This again lowers the labor income of skilled households and hence their consumption. This second effect is called the *wage-depressing effect*. Third, the reduction in wage rates for skilled

workers raises the firms' profits and hence the dividend income received by the skilled households. This effect is referred to as the *exploitation effect*. However, an increase in  $h$  also means that there is a larger share of skilled consumers in the population. Holding other things constant, each skilled consumer now receives less dividend income. Thus, the overall outcome of the exploitation effect is undetermined. It could raise or lower the consumption of skilled residents when skilled immigration increases. Finally, an increase in  $h$  would also affect the level of capital that each skilled domestic resident owns  $k_H^*$ . Raising skilled immigration increases the rate of return to capital temporarily. This higher rate of return induces skilled residents to accumulate more capital. This in turn raises the capital income and hence the consumption of skilled residents. On the other hand, other things equal, increasing the number of skilled immigrants would lower the level of capital that each skilled resident owns. This leads to a decrease in skilled consumers' capital income and consumption. This fourth effect is referred to as the *capital-consumption effect*. Similar to the *exploitation effect*, this effect could either raise or lower the long-run level of skilled household's consumption.<sup>21</sup>

In sum, an increase in  $h$  will induce a number of positive and negative forces on the consumption of skilled residents. The results in Figure 4.1 show that the negative forces dominate so that  $c_H^*$  is monotonically decreasing with  $h$ . As mentioned above, an increase in  $h$  lowers the labor-market tightness  $x_H^*$  and creates more intense competition in the skilled labor market. This in turn lowers the wage rate and the employment rate of skilled workers. The baseline model thus predicts that an increase in skilled immigration would deteriorate the labor market opportunities of skilled workers.

On the contrary, unskilled workers are insulated from the job competition with

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<sup>21</sup>The opposing forces of skilled immigration on the skilled household's consumption can be formally described by differentiating  $c_H^*$  with respect to  $h$ . For a detailed technical explanation, see Liu (2010).

skilled immigrants. In fact, they benefit from the inflow of skilled immigrants because it raises their marginal product of labor. As a result of this, the firms now have higher demand for unskilled labor and post more job vacancies in the unskilled labor market. This raises the tightness of this market and improves the labor market positions of the unskilled workers. These can be seen from Figure 4.2, which shows that the wage rate and employment rate of unskilled workers increase when  $h$  rises. As a result, an increase in  $h$  raises the consumption of unskilled consumers.

The channels via which unskilled immigration affects unskilled and skilled residents are largely the same as described above so they are not repeated in here. The long-run effects of unskilled immigration are shown in Figures 4.3 and 4.4. An increase in unskilled immigration  $l$  raises the consumption of skilled consumers and improves their labor market outcomes, whereas it leads to a decrease in the consumption of unskilled workers and lowers their wage rate and employment rate.

### 4.3.3 Welfare Effects of Immigration

In order to assess the welfare consequences of both skilled and unskilled immigration on the already resident quantitatively, I perform the following counterfactual policy experiments. The benchmark scenario has the same parameter values as in the baseline calibration. In particular, it is a steady state in which the population shares of skilled and unskilled immigrants in their respective representative households are  $h = 0.11$  and  $l = 0.27$ ; the unemployment benefits for skilled and unskilled households are  $b_H = 0.0276$  and  $b_L = 0.0217$ ; skilled immigrants import no capital  $\epsilon = 0$ .

#### 4.3.3.1 Changes in Skilled or Unskilled Immigration

In the first counterfactual scenario (S1), at time  $t = 0$ , there is a one-time change in immigration policy for skilled immigrants from 0.11 to another level, say  $h' \geq 0$ . The economy then gradually converges to the new steady state. The second counterfactual scenario (S2) is similar to S1 in every aspect with one exception that the domestic economy experiences a one-time unanticipated change in unskilled immigration instead. To evaluate the welfare gain or loss involved in S1 and S2 for both skilled and unskilled households, I construct their individual consumption-equivalent measures along the line of Lucas (1987), taking into account the transitional dynamics.

Let  $\{c_H^*, s_1^{H*}, s_2^{H*}\}$  be the values of consumption, search effort and working hours per skilled consumer in the benchmark scenario. The associated lifetime utility of a representative skilled household is

$$\begin{aligned} U_H^* &= \int_0^\infty e^{-\rho t} [\alpha_H \log c_H^* + (1 - \alpha_H) \log(1 - s_1^{H*} - s_2^{H*}) + \log H(t)] dt \\ &= \frac{1}{\rho} [\alpha_H \log c_H^* + (1 - \alpha_H) \log(1 - s_1^{H*} - s_2^{H*})] + \int_0^\infty e^{-\rho t} \log H(t) dt. \end{aligned}$$

After the one-time change in the share of skilled immigrants, the equilibrium time paths of consumption, search effort and working hours are given by  $\{c_H(t; h'), s_1^H(t; h'), s_2^H(t; h') \mid t \geq 0\}$ . The lifetime utility of the representative skilled household under this new immigration policy is now

$$\begin{aligned} U_H(h') &= \int_0^\infty e^{-\rho t} \{ \alpha_H \log c_H(t; h') + (1 - \alpha_H) \log[1 - s_1^H(t; h') - s_2^H(t; h')] \} dt \\ &\quad + \int_0^\infty e^{-\rho t} \log H(t) dt. \end{aligned}$$

Define a consumption-equivalent measure  $\kappa_H(h')$  for skilled households as the percentage permanent change in their benchmark level of consumption that exactly compensates the skilled household when the government shifts its immigration policy away from the

previous one. Formally, it is given by

$$\frac{1}{\rho} \left\{ \alpha_H \log[1 + \kappa_H(h')] c_H^* + (1 - \alpha_H) \log(1 - s_1^{H*} - s_2^{H*}) \right\} + \int_0^\infty e^{-\rho t} \log H(t) dt = U_H(h').$$

Simplifying this equation yields

$$\log[1 + \kappa_H(h')] = \frac{\rho}{\alpha_H} [U_H(h') - U_H^*]. \quad (4.37)$$

Similarly, I construct the consumption-equivalent measure  $\kappa_L(h')$  for unskilled households as

$$\log[1 + \kappa_L(h')] = \frac{\rho}{\alpha_L} [U_L(h') - U_L^*], \quad (4.38)$$

where  $U_L(h')$  is the lifetime utility of the representative unskilled household under the new immigration policy, whereas  $U_L^*$  is its lifetime utility in the benchmark scenario. In order to gauge the welfare consequences of this immigration policy change on the entire population, I construct an overall welfare measure  $\bar{\kappa}(h')$ , which is defined according to

$$\begin{aligned} & \frac{\chi}{\rho} \left\{ \alpha_H \log[1 + \bar{\kappa}(h')] c_H^* + (1 - \alpha_H) \log(1 - s_1^{H*} - s_2^{H*}) \right\} + \chi \int_0^\infty e^{-\rho t} \log H(t) dt \\ & + \frac{1 - \chi}{\rho} \left\{ \alpha_L \log[1 + \bar{\kappa}(h')] c_L^* + (1 - \alpha_L) \log(1 - s_1^{L*} - s_2^{L*}) \right\} + (1 - \chi) \int_0^\infty e^{-\rho t} \log L(t) dt \\ & = \chi U_H(h') + (1 - \chi) U_L(h'), \end{aligned}$$

where  $\chi = H(t)/[L(t) + H(t)]$  is the share of skilled residents in the entire population. I use its value in the benchmark scenario  $\chi = 0.85$  for the following welfare calculations.

Solving this equation yields

$$\log[1 + \bar{\kappa}(h')] = \frac{\chi \alpha_H}{\chi \alpha_H + (1 - \chi) \alpha_L} \frac{\rho}{\alpha_H} [U_H(h') - U_H^*] + \frac{(1 - \chi) \alpha_L}{\chi \alpha_H + (1 - \chi) \alpha_L} \frac{\rho}{\alpha_L} [U_L(h') - U_L^*]. \quad (4.39)$$

Combining equations (4.37), (4.38) and (4.39) gives

$$1 + \bar{\kappa}(h') = [1 + \kappa_H(h')]^{\frac{\chi \alpha_H}{\chi \alpha_H + (1 - \chi) \alpha_L}} [1 + \kappa_L(h')]^{\frac{(1 - \chi) \alpha_L}{\chi \alpha_H + (1 - \chi) \alpha_L}}.$$

This means the overall welfare measure is a geometric weighted average of  $\kappa_H(h')$  and  $\kappa_L(h')$ .

The results of these experiments for different  $h' \in \{0.12, 0.13, 0.15\}$  are reported in Table 4.2. These results show that in all the cases considered, skilled immigration induces a welfare loss to the skilled households. For instance, an increase in the population share of skilled immigrants from 0.11 to 0.12 would generate a welfare loss that is equivalent to a decline of 0.026% in  $c_H^*$ . However, the same increase in  $h$  induces a gain in the unskilled households' welfare. For both skilled and unskilled households, I find that the magnitude of the welfare measure is increasing with  $h$ . The arrival of more skilled immigrants also leads to a welfare gain for the households on average when  $h$  is small. However, when  $h$  continues to increase, the welfare loss to the skilled households overrides the welfare gain to the unskilled households so that skilled immigration induces a welfare loss for the entire population. This result is obtained because skilled consumers constitute the majority of the entire population, the negative value of the overall welfare measure is mainly due to the welfare loss of the skilled consumers.

To explore the welfare effects of unskilled immigration, I perform similar counterfactual policy experiments and construct the consumption-equivalent measures  $\kappa_H(l')$ ,  $\kappa_L(l')$  and  $\bar{\kappa}(l')$  for skilled, unskilled households and the entire population, respectively. Table 4.3 shows the welfare measures for  $l' \in \{0.28, 0.29, 0.31\}$ . In contrast with skilled immigration, I find that the skilled households derive a benefit at the expense of unskilled households through unskilled immigration. Although the magnitude of overall welfare measure is decreasing with the number of the unskilled immigrants, its value is positive implying that unskilled immigration is welfare enhancing for the entire population.

#### 4.3.3.2 Changes in Unemployment Benefits

The results above demonstrate that a rise in a particular type of immigration always harms the households of the same skill type. One way to possibly mitigate this negative welfare impact is to provide more unemployment benefits to the unemployed workers. Holding other things constant, an increase in unemployment benefits raises a household's total income. This in turn increases its consumption and hence welfare. Here in this counterfactual scenario (S3), I consider two cases: (1) if the government grants more skilled immigrants' entrance, it will also give more unemployment benefits to skilled households with those to unskilled ones unchanged; (2) similarly, if more unskilled immigrants join the economy, only the unskilled households are allowed to collect more unemployment benefits. The main idea of these experiments is to examine if increasing unemployment benefits is effective in raising the welfare of the households that would otherwise suffer from the inflow of immigrants. The way I use to increase the unemployment benefits is to raise the average replacement ratio. In particular, I increase the replacement ratio from its benchmark level 0.5 to another level so that domestic households are just as well off as they were prior to any immigration policy change. Table 4.4 shows the values of replacement ratio I set so that the welfare measure is zero. The observation one can make from Table 4.4 is that to exactly mitigate the welfare loss due to immigration, the government should raise the replacement ratio to a greater level and this new level is increasing with the population share of immigrants. This result is obtained because my earlier findings show that further increase in the population share of immigrants creates a larger welfare loss to domestic households of the same skill group. To overcome a larger loss in welfare, these domestic households need to be compensated more.

#### 4.3.3.3 Changes in Immigrants' Initial Wealth

In the benchmark scenario, I have assumed that all the immigrants enter the domestic country without importing any capital. However, in the real world, we often observe that immigrants do arrive with some amount of asset. To capture this phenomenon, in the following counterfactual scenario (S4), I assume that each skilled immigrant brings a fraction  $\epsilon \in \{25\%, 50\%, 100\%\}$  of the capital owned by a skilled domestic resident into the economy and focus only on the welfare impacts of a rise in skilled immigration.

In Table 4.5, on the one hand, raising the amount of capital that skilled immigrants bring with them creates a larger gain in the unskilled households' welfare. Intuitively, as mentioned above, an increase in skilled immigration raises the productivity of unskilled workers. With more capital imported into the domestic economy, this complementary effect of skilled immigration would be strengthened because an increase in the supply of capital will also raise the marginal product of the unskilled labor. As a result, the labor income of unskilled households increases. This in turn raises their consumption and hence welfare. On the other hand, increasing the amount of capital that skilled immigrants import reduces the harm to the skilled households, or even induces a welfare gain to them. The reasoning behind this is that raising the amount of capital that skilled immigrants arrive with increases the marginal product of skilled labor, which upsets their wage-depressing effect. Moreover, it also mitigates the capital-consumption effect arising from an increase in skilled immigration. These contribute a decline in the welfare loss experienced by the skilled residents.

## 4.4 Conclusion

This paper analyzes the effects of two types of immigration, skilled and unskilled, on the native population within a dynamic general equilibrium model with skill heterogeneity and labor market frictions. One important contribution of this current study is that it explicitly captures the effect of immigration on the employment opportunities of the native born. This effect has been largely overlooked in the existing theoretical literature. Calibrating the baseline model to US data, I find that an increase in skilled immigration raises the wages, employment and consumption of unskilled workers and lowers skilled workers' wages, employment as well as their consumption. In contrast, an inflow of unskilled immigrants induces opposite effects on wages, employment and consumption for two types of labor. These results are qualitatively consistent with empirical evidence. Quantitative exercises also show that under the benchmark parameter values, a rise in one particular type of immigration always harms the households of the same skill type and benefits those with different skills. To mitigate the negative welfare consequences of immigration, I allow the government to give more unemployment benefits to those who would otherwise lose from the inflow of immigrants. My results demonstrate that increasing government provided unemployment benefits can effectively reduce the households' loss in welfare due to immigration. When skilled immigrants are allowed to bring substantial amount of capital into the domestic economy, I find that skilled households can no longer suffer from skilled immigration.

Table 4.1: Baseline Parameter Values

|                |                                                                                   |
|----------------|-----------------------------------------------------------------------------------|
| Demographics   | $g = 0.0027, l = 0.27, h = 0.11, \sigma = 0.87.$                                  |
| Preferences    | $\rho = 0.005, \alpha_L = 0.488, \alpha_H = 0.765.$                               |
| Production     | $\varepsilon = 0.36, \delta = 0.0213, \vartheta = 0.106, \varrho = 0.286.$        |
| Job Matching   | $\gamma_0 = 1, \eta = 0.6.$                                                       |
| Job Separation | $\theta_L = 0.08, \theta_H = 0.045$                                               |
| Tax Rates      | $\tau = 0.3, \tau_K = 0.3.$                                                       |
| Others         | $\epsilon = 0, \beta = 0.5, d_L = 1.24, d_H = 1.371, b_L = 0.0217, b_H = 0.0276.$ |

Table 4.2: Welfare Measure of Skilled Immigration

| $h'$ | $\kappa_H(h')$ | $\kappa_L(h')$ | $\bar{\kappa}(h')$ |
|------|----------------|----------------|--------------------|
| 0.12 | -0.026%        | 1.196%         | 0.097%             |
| 0.13 | -0.391%        | 2.091%         | -0.143%            |
| 0.15 | -0.716%        | 2.995%         | -0.347%            |

Table 4.3: Welfare Measure of Unskilled Immigration

| $l'$ | $\kappa_H(l')$ | $\kappa_L(l')$ | $\bar{\kappa}(l')$ |
|------|----------------|----------------|--------------------|
| 0.28 | 0.301%         | -0.021%        | 0.268%             |
| 0.29 | 0.327%         | -0.266%        | 0.266%             |
| 0.31 | 0.34%          | -1.283%        | 0.175%             |

Table 4.4: Zero Welfare Measure with Different Replacement Ratios

| $h'$ | <i>replacement ratio</i> | $l'$ | <i>replacement ratio</i> |
|------|--------------------------|------|--------------------------|
| 0.12 | 0.56                     | 0.28 | 0.52                     |
| 0.13 | 0.58                     | 0.29 | 0.54                     |
| 0.15 | 0.63                     | 0.31 | 0.57                     |

Table 4.5: Welfare Measure of Skilled Immigration with Different Amount of Capital

| $h'$ | $\epsilon = 25\%$ |                |                    | $\epsilon = 50\%$ |                |                    | $\epsilon = 100\%$ |                |                    |
|------|-------------------|----------------|--------------------|-------------------|----------------|--------------------|--------------------|----------------|--------------------|
|      | $\kappa_H(h')$    | $\kappa_L(h')$ | $\bar{\kappa}(h')$ | $\kappa_H(h')$    | $\kappa_L(h')$ | $\bar{\kappa}(h')$ | $\kappa_H(h')$     | $\kappa_L(h')$ | $\bar{\kappa}(h')$ |
| 0.12 | 0.039%            | 1.278%         | 0.164%             | 0.078%            | 1.341%         | 0.205%             | 0.157%             | 1.799%         | 0.322%             |
| 0.13 | -0.261%           | 2.217%         | -0.013%            | -0.157%           | 2.385%         | 0.097%             | 0.144%             | 2.679%         | 0.398%             |
| 0.15 | -0.522%           | 3.143%         | -0.157%            | -0.339%           | 3.291%         | 0.024%             | 0.052%             | 3.864%         | 0.431%             |

Figure 4.1: Long-run Effects of Skilled Immigration on Skilled Households

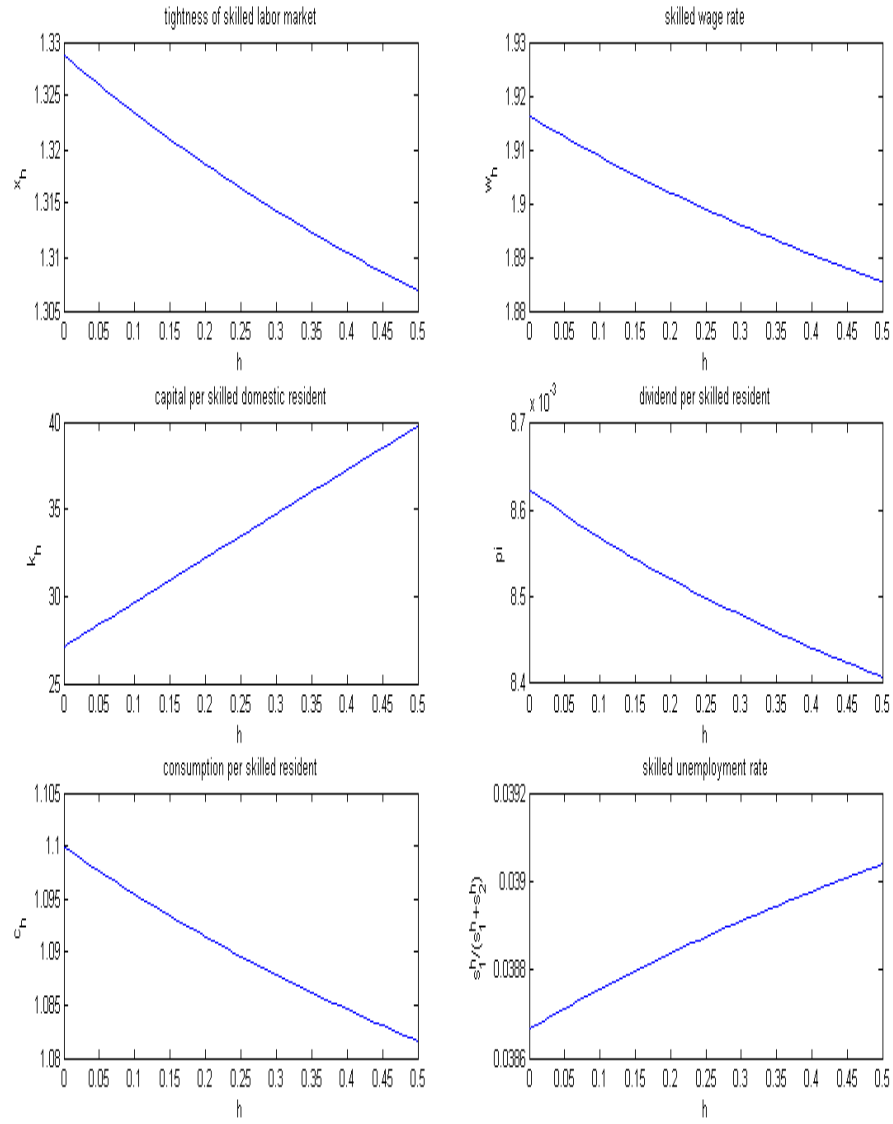


Figure 4.2: Long-run Effects of Skilled Immigration on Unskilled Households

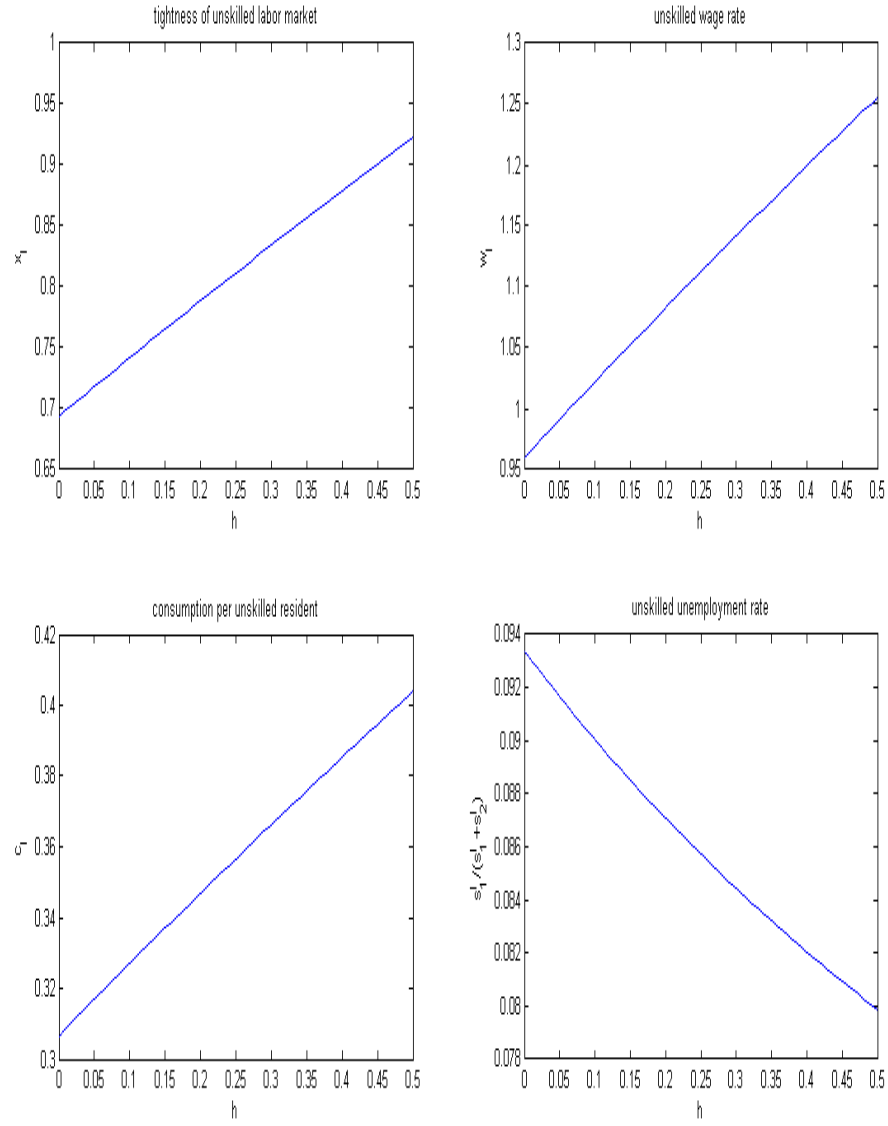


Figure 4.3: Long-run Effects of Unskilled Immigration on Skilled Households

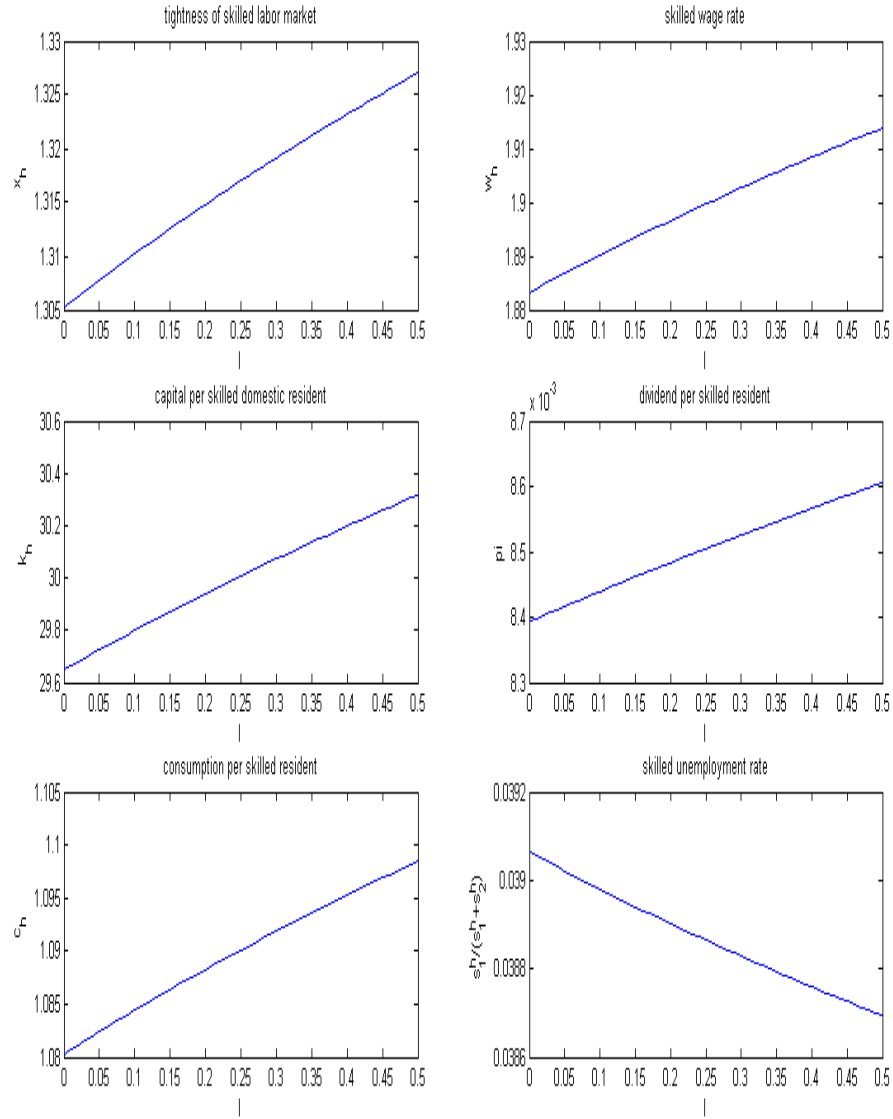
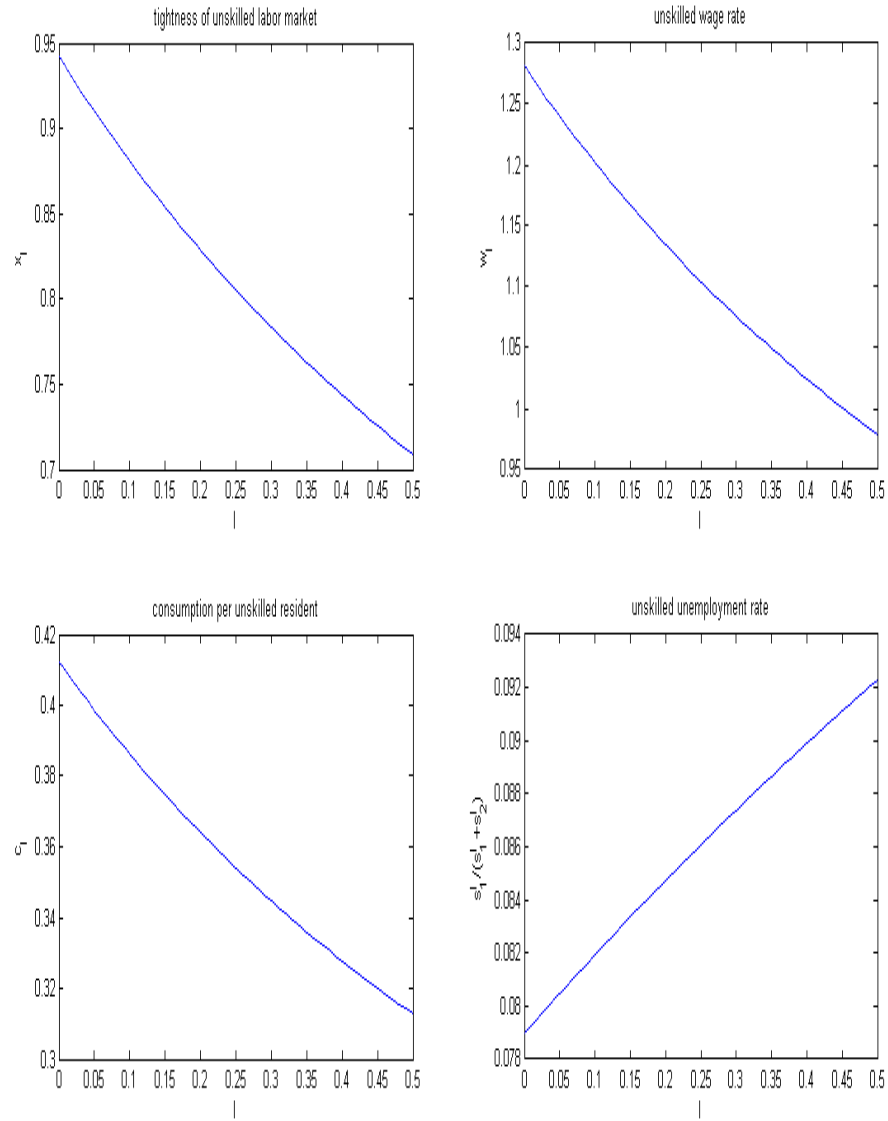


Figure 4.4: Long-run Effects of Unskilled Immigration on Unskilled Households



## Chapter 5

# Conclusions

Although empirical evidence suggests that immigration deteriorates the labor market position of native workers, existing studies assume full employment in the domestic labor market and thus rule out the impact of immigration on the employment opportunities of domestic workers. The objective of this dissertation is to find a way to explicitly capture the job displacement effect of immigration. In order to achieve this, it is necessary to introduce unemployment into the analytical model. In this dissertation, I use the labor-market search model à la Shi and Wen (1997) to capture unemployment. Unemployment arises due to labor market frictions (in the form of time-consuming job search and matching).

The first chapter focuses on the impact of illegal immigration. In this paper, I assume that illegal immigrants compete with all the domestic workers in a single labor market. Consequently, illegal immigrants would affect the labor market outcomes of all domestic workers in the same way. Under this assumption, the calibrated version of the baseline model generates three major findings. First, the inflow of illegal immigrants increases domestic workers' unemployment rates and lowers their wage rates. Second,

under the benchmark parameter values, I find a non-monotonic relationship between the population share of illegal immigrants and the long-run level of domestic consumption. This result is robust under various choices of labor supply elasticity. Third, despite its potential negative effects on domestic consumption, illegal immigration generates substantial welfare gains to the native population after taking into account both consumption and leisure.

In the second chapter, I relax the assumption of homogeneous labor and model explicitly the heterogeneity of labor in the native population. Specifically, there are now skilled and unskilled workers in the native population and the illegal foreign workers are all unskilled. All illegal immigrants thus only compete with the domestic unskilled workers for jobs. Skilled domestic workers are insulated from job competition with the illegal immigrants. Having heterogeneity in skills allows me to investigate the asymmetric impacts of illegal immigration in a search-matching framework. Calibration exercises show that an increase in illegal immigration induces a welfare gain and leads to a higher wage, and lower unemployment for skilled domestic labor. In contrast, illegal immigration is welfare reducing for unskilled domestic labor. Moreover, it deteriorates the labor market position of unskilled workers by lowering their wage as well as their employment.

The third chapter adopts a dynamic general equilibrium model with skill heterogeneity and labor market frictions to look into the effects of legal immigration on the native population. It explicitly takes into account the skill composition of immigrant workers by considering the inflows of both skilled and unskilled foreign workers. This study also incorporates two types of government policies. First, the government can choose the number and type of immigrants. Second, the government can use unemployment benefits as a policy instrument to overcome the welfare loss due to immigration. Calibrating the baseline model to US data, I find that an increase in skilled immigration

raises the wages, employment and consumption of unskilled workers and lowers skilled workers' wages, employment as well as their consumption. In contrast, an inflow of unskilled immigrants induces opposite effects on wages, employment and consumption for two types of labor. In the numerical analysis, I also show that increasing government provided unemployment benefits can effectively reduce the households' loss in welfare induced by immigrants.

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