A Search-Equilibrium Approach to the Effects of Immigration on Labor Market Outcomes

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Abstract

We analyze the impact of the skill-biased immigration influx that took place during the years 2000-2009 in the United States, within a search and matching model that allows for skill heterogeneity, differential search cost between immigrants and natives, capital-skill complementarity and possibly endogenous skill acquisition. Within such a framework, we find that although the skill-biased immigration raised the overall net income to natives, it may have had distributional effects. Specifically, unskilled native workers gained in terms of both employment and wages. Skilled native workers, on the other hand, gained in terms of employment but may have lost in terms of wages. Nevertheless, in one extension of the model, where skilled workers and immigrants are imperfect substitutes, we find that even the skilled wage may have risen.

Keywords: Immigration; Search; Unemployment; Skill-heterogeneity

JEL Classification: F22; J61; J64

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1 Introduction

The impact of immigration on the labor market outcomes in the host country has long been a subject of debate among economists. The results provided by a large number of careful empirical studies on this subject are often contradictory. For example, Borjas (2003) and Borjas, Grogger and Hanson (2008) find a large negative wage effect on natives, whereas Card (2009) and Ottaviano and Peri (2012) find this effect to be relatively small and often positive. Among the key issues behind this disagreement is the elasticity of substitution between native and immigrants in the same skill group. In particular, as it is now well understood, imperfect substitution between native and immigrant labor can generate a positive effect on native wages.

This paper aspires to contribute to the debate regarding the impact of immigration by following a different approach. We conduct our analysis within a model that belongs to the general family of search and matching models of the labor market (e.g., Diamond, 1982 and Mortensen and Pissarides, 1994). In this class of models, unemployment exists due to search frictions and job entry responds endogenously to the incentives provided by the market. Thus, contrary to the competitive paradigm, our approach allows for the analysis of the unemployment and wage effects that come from the impact of changes in the availability of jobs on the bargaining position of workers.

In addition, our baseline model has the following key features. First, it allows for the presence differential search costs between natives and immigrants, which, besides adding further realism to the model, is a key factor in explaining the equilibrium wage gap between otherwise identical native and immigrant workers. This feature generates also the possibility that immigration improves the employment and wage prospects of competing natives, since immigrants, who have a lower outside option, are willing to accept lower wages. Hence, an immigration influx lowers the average wage that firms expect to pay, leading to more job entry and consequently a better bargaining position for native workers. Second, we incorporate in the search set-up heterogeneity in terms of skills among native workers as well as between natives and immigrants. This allows us to analyze the distributional effects of immigration on different skill groups. Third, the presence of capital as an independent factor of production serves as an additional channel of adjustment to immigration-induced changes in labor supply. Fourth, our model adopts a generalized production technology that allows for the analysis of the impact of immigration under different assumptions regarding the degrees of capital-skill, within-skill and across-skill complementarity.

We calibrate the model to the US economy and find that the impact of the *skill-biased* increase in immigration that took place in the period 2000-2009 is positive on the overall net income to natives. As expected, it lowers the unemployment and raises the wage rate of unskilled native workers. This occurs for two reasons. First, skill-biased immigration influx raises the marginal product of unskilled labor and second, the entrance of unskilled immigrants lowers the expected employment cost, owing to the lower wages paid to immigrants, and encourages unskilled job entry. However, we also find that it encourages skilled job entry, leading to a smaller unemployment rate for skilled workers as well. The increase in skilled job entry is also due to firms anticipating that, with a higher number of skilled immigrants searching for jobs, they will have to pay lower wages on average. As regards the wage of skilled native workers, on the one hand, the higher availability of skilled jobs strengthens their bargaining position and pushes their wage up, but, on the other, the fall in their marginal product, due to the relatively higher quantity of skilled labor, causes their wage to fall. In our baseline calibration we let immigrants and natives of the same skill type be perfect substitutes in production and find the overall impact on the wage of skilled natives to be negative. However, once we allow for a lower degree of substitutability between natives and immigrants, we find the impact on skilled natives to be positive not only in terms of unemployment but also in terms of wages.

We also extend the model to examine the case when the immigration influx is skill-balanced, i.e., the skill distribution does not change, as well as when immigrants and natives of the same type search in different markets or, put in a different way, firms can direct their search effort towards workers of the same skill type but of different origin. Finally, we compare the results under the assumption that the proportion of skilled native workers is fixed to those obtained when the proportion of skilled natives responds endogenously to immigration-induced changes in the relative supply of skills. We view this comparison as being crucial in distinguishing between the short-run and the long-run effects of immigration.

Although there is a vast empirical literature on this topic, the number of theoretical studies that analyze immigration within a dynamic general equilibrium framework is relatively small. Furthermore, most of them employ the standard neoclassical growth model; examples include, but are not limited to, Hazari and Sgro (2003), Ben-Gad (2004, 2008), Moy and Yip (2006), and Palivos (2009). To the best of our knowledge, the only other papers that analyze immigration within a framework that allows for labor market search frictions are those of Ortega (2000) and Liu (2010). The former considers a two-country model where workers decide whether to search in their own country or immigrate. He shows that Pareto-ranked multiple steady-state equilibria may arise with or without immigration. Ortega's analysis also takes into account the positive impact of immigration on job entry due to firms anticipating that they will pay lower wages to immigrants that have higher search costs. However, the model in Ortega (2000) assumes that worker productivity is constant and therefore independent of immigration influx. Moreover, in his framework there is only one labor type. Thus, his analysis overlooks both the negative competition effects on the marginal product of native workers and the across-skill externalities that arise when otherwise identical natives and immigrants compete for the same types of jobs.

Liu (2010) concentrates on the welfare effects of *illegal* immigration within a dynamic general equilibrium model with search frictions. The presence of search frictions allows him to identify a new channel through which immigration can alter domestic consumption: intensified job competition from illegal immigrants lowers the job finding rate of native workers and forces them to accept lower wages. Our model is closer to an extended version of his baseline model, where there are two types of domestic labor in constant numbers, namely, skilled and unskilled, and illegal immigrants belong to the unskilled group. Thus, unlike Liu (2010), who considers only illegal and hence unskilled immigration, we look at the effects of total immigration during the period 2000-2009, which according to the data is skill-biased. In addition, the existence of different outside options (search costs) between natives and immigrants in our framework allows us to capture the effect of immigration on job entry through its impact on expected employment costs.

As regards the production technology, the main difference between our model and Liu's extended model is that we employ a nested CES aggregator that allows for skilled labor to be more complimentary to capital than unskilled labor, whereas Liu assumes a Cobb-Douglas production function, which implies that the two types of labor are equally complementary to capital. Furthermore, Liu's extended model assumes that immigrants and natives are perfect substitutes in production, while we also explore the case of imperfect substitutability between the two labor types. Our assumptions regarding the production technology are closer to those of Ben-Gad (2008), who analyzes a neoclassical growth model with overlapping dynasties and two types of labor, but does not allow for search frictions.

The rest of the paper is organized as follows. Section 2 presents the baseline model. Section 3 defines the steady-state equilibrium and analyzes its existence and uniqueness. In Section 4, we analyze two special cases of the model. In the first, we assume that there are no differences in search costs between otherwise identical native and immigrant workers. In the second, we assume differential search costs, but let the two labor inputs (skilled and unskilled) be perfect substitutes to each other. Considering these two cases separately allows us to identify two different channels through which immigration can affect labor market outcomes: one that comes from the impact on firms' expected cost of establishing an employment relation and one that comes from the impact on the prices of labor inputs. In Section 5 we calibrate the model and present simulation results in the general case when both of these channels are present. In Section 6 we extend the basic model in four different ways by allowing for skill-balanced immigration, imperfect substitutability within skill groups, endogenous skill acquisition and separate labor markets for natives and immigrants. Section 7 offers some concluding remarks. There are also three Appendices, named A, B and C (all available upon request), which provide detailed proofs of the propositions, perform an extensive sensitivity analysis of our results and present the dynamic adjustment of the equilibrium.

2 The Basic Model

We construct a search and matching model with two intermediate inputs and one final consumption good. Time is continuous and begins at $t = 0$. The economy is populated by a continuum of workers and a continuum of jobs. Workers are either natives (N) or immigrants (I). The mass of natives is normalized to unity, while that of immigrants is denoted by I and is determined exogenously. The mass of jobs, on the other hand, is determined endogenously as part of the equilibrium. All agents are risk neutral and discount the future at a common rate $r > 0$, which is equal to the interest rate. The rest of this section offers a detailed description of the model; see also Figure 1 for a graphic presentation of its basic structure.

2.1 Workers and Firms

Workers are either skilled (H) or unskilled (L).[1] Let λ be the fraction of native workers that are unskilled and $1-\lambda$ the fraction of those that are skilled (in the benchmark version of the model λ is taken as given). Similarly, immigrants are either skilled or unskilled and their numbers, denoted by I_H and I_L respectively, are determined exogenously. All workers are born and die at the rate n.

Our production side borrows some elements from Acemoglu (2001). Firms operate either in one of the two intermediate sectors or in the final sector. The two intermediate sectors produce inputs Y_H and Y_L using skilled and unskilled labor, respectively. More specifically, each of these two sectors operates a linear technology, which, through normalization of units, yields output equal to the number of the respective workers employed. These intermediate inputs are non-storable. Once produced, they are sold in competitive markets and are immediately used for the production of the final good (Y).

Next we turn to the final good sector. Motivated by a series of empirical papers (see, among others, Griliches 1969 and Krusell, Ohanian, Rios-Rull, and Violante 2000), which support the idea that skilled labor is relatively more complementary to capital than unskilled labor, we post the following production technology for the final good

$$Y = [\alpha Y_L^{\rho} + (1-\alpha)Q^{\rho}]^{1/\rho}, \qquad \rho \leq 1, \tag{1}$$

with

$$Q = [xK^{\gamma} + (1-x)Y_H^{\gamma}]^{1/\gamma}, \qquad \gamma \leq 1, \tag{2}$$

where K denotes capital, α and x are positive parameters that govern income shares and ρ and γ drive the elasticities of substitution between capital and the unskilled input and capital and the skilled input, respectively. Thus, the production function is a two-level CES function in which capital (K) and the skilled input (Y_H) are nested together in the sub-aggregate input Q given by equation (2) and then Q and the unskilled input (Y_L) enter the main production function (equation 1). Capital-skill complementarity is defined as $\rho > \gamma$, which implies that an increase in the capital stock raises the skill premium (see, among others, Krusell et al. 2000 and Polgreen and Silos 2008). If either ρ or γ equals zero, then the corresponding nesting is Cobb-Douglas.

Since the two intermediate inputs are sold in competitive markets, their prices, p_L and p_H, will be equal to their marginal products, that is,

[1] We use the terms skilled (unskilled) and high- (low-) skill interchangeably.

$$p_L = \alpha Y_L^{\rho-1} Y^{1-\rho}, \tag{3}$$

and

$$p_H = (1-\alpha)(1-x) Y_H^{\gamma-1} Q^{\rho-\gamma} Y^{1-\rho}. \tag{4}$$

We assume that there exists a competitive capital market in which firms can buy and sell capital without delay. Since the market is competitive, the marginal product of capital is equal to its rental price (p_K), which is in turn equal to the interest rate (r) plus its depreciation rate (δ). Thus,

$$p_K = (1-\alpha) x K^{\gamma-1} Q^{\rho-\gamma} Y^{1-\rho} = r + \delta. \tag{5}$$

2.2 Search and Matching

We dispense with the Walrasian auctioneer and assume that in each of the two labor markets unemployed workers and unfilled vacancies are brought together via a stochastic matching technology $M(U_i, V_i)$, where U_i and V_i denote respectively the number of unemployed workers and vacancies of skill type i, $i = H, L$. This function $M(\cdot)$ exhibits standard properties: it is at least twice continuously differentiable, increasing in its arguments, exhibits constant returns to scale and satisfies the familiar Inada conditions. Using the property of constant returns to scale, we can write the flow rate of a match for a worker as $M(U_i, V_i)/U_i = m(\theta_i)$ and the flow rate of a match for a vacancy as $M(U_i, V_i)/V_i = q(\theta_i)$, where $\theta_i = V_i/U_i = m(\theta_i)/q(\theta_i)$ is an indicator of the tightness prevailing in labor market i. Also, the above-mentioned assumptions on $M(\cdot)$ imply the following properties for $m(\cdot)$ and $q(\cdot)$:

$$\begin{aligned} m'(\theta_i) &> 0, \quad \lim_{\theta_i \to 0} m(\theta_i) = 0, \quad \lim_{\theta_i \to \infty} m(\theta_i) = \infty, \\ q'(\theta_i) &< 0, \quad \lim_{\theta_i \to 0} q(\theta_i) = \infty, \quad \text{and} \quad \lim_{\theta_i \to \infty} q(\theta_i) = 0. \end{aligned}$$

Firms post either high-skill vacancies, which are suited for skilled workers, or low-skill vacancies, which are suited for unskilled workers. Each firm posts at most one vacancy and the number of firms of each type is determined endogenously by free entry. Firms can choose to open either skilled or unskilled vacancies, but cannot ex-ante open vacancies suited only for natives or only for immigrants (we relax this assumption in one of the extensions of the basic model in Section 6). A vacant firm bears a recruitment cost c_i, $i = H, L$, specific to its type. This is measured in units of final output, which melts away in keeping the vacancy. On the other hand, an unemployed worker of type i receives a flow of income b_i, which can be considered as the opportunity cost of employment. There is no cross-skill matching. High skill workers direct their search towards the high-skill sector and low-skill workers towards the low-skill sector. Also, for simplicity, we assume that creating a vacancy is costless, although this can be easily amended following, for example, Laing, Palivos and Wang (1995) or Acemoglu (2001).

The instant a vacancy and a worker make contact, they bargain over the division of any surplus. The skill level of the worker as well as the output that will result from a match is known to both parties. We assume that wages are determined by an asymmetric Nash bargaining, where the worker has bargaining power β. After an agreement has been reached, production commences immediately. Moreover, we assume that matches dissolve at the rate s_i, specific to their type. Following a separation, the worker and the vacancy enter the corresponding market and search for new trading partners should it prove profitable for them to do so.

In addition, unemployed workers are subject to a per unit of time "search" cost, h_{ij}, which is specific to the worker's skill type $i = H, L$, and origin $j = N, I$, where N denotes "native" and I denotes "immigrant." There are several reasons why an immigrant may face a higher search cost or equivalently a lower income while being unemployed and searching for a job. In addition to the problems that one may encounter if being in a foreign country (e.g., lack of a social network, lower language proficiency, etc.), lower income may result if immigrants do not qualify for the same unemployment insurance benefits as natives.[2] More generally, however, h_{ij} may denote a difference in the outside option b_i. Henceforth, we assume that $h_{iN} = 0 < h_{iI}$, $i = H, L$, implying that an immigrant worker has a lower outside option than a native who is of the same skill type.

2.3 Asset Value Functions

At any point in time a worker is either employed (E) or unemployed (U). Likewise a vacancy is either filled (F) or else is looking for a worker (V). We denote the present discounted value associated with each state by J_{ij}^{κ}, where the subscript $i = H, L$ denotes the skill type (high- or low-skill), the subscript $j = N, I$ denotes the origin (native or im-

[2] Illegal immigrants are often not eligible for any unemployment insurance benefits. Also, in the United States, for example, legal immigrants qualify for unemployment insurance benefits that are covered by the state governments and last for 26 weeks. Nevertheless, not all of them qualify for benefits, covered by the federal government, that extend beyond the 26-week period and are paid during times of recession (see, for example, NELP 2002).

migrant), and the superscript $\kappa = V, U, F, E$, indicates the state (vacant firm, unemployed worker, filled job, employed worker). Then in steady state:

$$
\begin{aligned}
rJ_i^V &= -c_i + q(\theta_i)\left[\phi_i J_{iN}^F + (1-\phi_i)J_{iI}^F - J_i^V\right], &(6)\\
rJ_{ij}^F &= p_i - w_{ij} - (s_i + n)\left[J_{ij}^F - J_i^V\right], &(7)\\
(r+n)J_{ij}^U &= b_i - h_{ij} + m(\theta_i)\left[J_{ij}^E - J_{ij}^U\right], &(8)\\
(r+n)J_{ij}^E &= w_{ij} - s_i\left[J_{ij}^E - J_{ij}^U\right], &(9)
\end{aligned}
$$

where ϕ_i is the fraction of unemployed workers of skill type i that are natives and $h_{ij} = 0$ if $j = N$. Also, w_{ij} denotes the wage rate for a worker of skill type $i = H, L$ and origin $j = N, I$. Expressions such as these have, by now, a familiar interpretation. For instance, consider equation (6). The term rJ_i^V is the flow value accrued to an unmatched vacancy of type i: it equals the loss from maintaining a vacant position plus the flow probability of becoming matched with a worker of the same type multiplied by the expected capital gain from such an event. The other asset value equations possess similar interpretation.

As there is free entry and exit on the firm side in each intermediate input market, an additional vacancy of skill type i should make expected net profit equal to zero, that is,

$$J_i^V = 0. \tag{10}$$

2.4 Nash Bargaining

Since all workers and firms are risk neutral, Nash bargaining implies that the wage rate for a worker of skill type i and origin j, w_{ij}, must be such that:

$$(1-\beta)(J_{ij}^E - J_{ij}^U) = \beta(J_{ij}^F - J_i^V). \tag{11}$$

In other words, firms get a share $1-\beta$ and workers get β of the total surplus S_{ij} generated by a match, where

$$S_{ij} = J_{ij}^F + J_{ij}^E - J_{ij}^U - J_i^V,$$

that is,

$$
\begin{aligned}
J_{ij}^F - J_i^V &= (1-\beta)S_{ij}, &(12)\\
J_{ij}^E - J_{ij}^U &= \beta S_{ij}. &(13)
\end{aligned}
$$

2.5 Steady-State Composition of the Labor Force

Recall that I_H and I_L denote the mass of skilled and unskilled immigrants, respectively. Thus, the total mass of skilled (unskilled) workers in the economy is $1-\lambda+I_H$ $(\lambda+I_L)$. Next by equating the flows out of unemployment to the sum of separations and new births, we can find the steady-state employment, and hence the production of each intermediate input (see Appendix A for the details):

$$Y_H = \frac{m(\theta_H)(1-\lambda+I_H)}{n+s_H+m(\theta_H)}, \tag{14}$$

$$Y_L = \frac{m(\theta_L)(\lambda+I_L)}{n+s_L+m(\theta_L)}. \tag{15}$$

Similarly, the steady-state unemployment U_{ij} of each type $i=H,L$ and origin $j=N,I$ is given by:

$$U_{HN} = \frac{(n+s_H)(1-\lambda)}{n+s_H+m(\theta_H)}, \quad U_{HI} = \frac{(n+s_H)I_H}{n+s_H+m(\theta_H)}, \tag{16}$$

$$U_{LN} = \frac{(n+s_L)\lambda}{n+s_L+m(\theta_L)}, \quad U_{LI} = \frac{(n+s_L)I_L}{n+s_L+m(\theta_L)}. \tag{17}$$

Moreover, as mentioned above, the probability that a type i and unemployed worker is native is denoted by ϕ_i and is equal to

$$\phi_H = \frac{U_{HN}}{U_H} = \frac{1-\lambda}{1-\lambda+I_H}, \tag{18}$$

$$\phi_L = \frac{U_{LN}}{U_L} = \frac{\lambda}{\lambda+I_L}, \tag{19}$$

where $U_i = U_{iN}+U_{iI}$, $i=H,L$.

3 Steady-State Equilibrium

Consider next the definition of a steady-state equilibrium for this economy.

Definition. A steady-state equilibrium is a set $\{\theta_i^*,\ p_i^*,\ p_K^*,\ w_{ij}^*,\ Y_i^*,\ K^*,\ U_{ij}^*,\}$, where $i=L,H$ and $j=N,I$, such that

(i) The intermediate input markets clear. In particular, conditions (3) and (4) are satisfied.

(ii) The capital market clears; i.e., condition (5) is satisfied.

(iii) The free entry condition (10) for each skill type i is satisfied.

(iv) The Nash bargaining optimality condition (11) for each skill type i and origin j holds.

(v) The numbers of employed and unemployed workers as well as of filled and unfilled vacancies of each type and origin remain constant; i.e., among others, conditions (14)-(17) are satisfied.

As shown in Appendix A, the steady-state equilibrium values of θ_H and θ_L are given by the following reduced system of equations:

$$\alpha\left\{\alpha+(1-\alpha)\left(\frac{A_H}{A_L\Lambda}\right)^{\rho}\left[xk^{\gamma}+(1-x)\right]^{\frac{\rho}{\gamma}}\right\}^{\frac{1-\rho}{\rho}}=B_L, \tag{20}$$

$$(1-\alpha)(1-x)\left[xk^{\gamma}+(1-x)\right]^{\frac{1-\gamma}{\gamma}}\left\{\alpha\left(\frac{A_L\Lambda}{A_H}\right)^{\rho}\left[xk^{\gamma}+(1-x)\right]^{-\frac{\rho}{\gamma}}+(1-\alpha)\right\}^{\frac{1-\rho}{\rho}}=B_H, \tag{21}$$

where A_i, Λ and k are the employment rate of type i, the ratio of unskilled to skilled labor and the capital to skilled labor ratio, respectively. They are defined as follows

$$A_i\equiv\frac{m(\theta_i)}{n+s_i+m(\theta_i)},\quad \Lambda\equiv\frac{\lambda+I_L}{1-\lambda+I_H},\quad k\equiv\frac{K}{Y_H}=\left[\frac{xB_H}{(1-x)(r+\delta)}\right]^{\frac{1}{1-\gamma}},$$

where

$$B_i\equiv b_i-(1-\phi_i)h_{iI}+\frac{c_i[n+r+s_i+\beta m(\theta_i)]}{(1-\beta)q(\theta_i)},\quad i=L,H.$$

Each of equations (20) and (21) is a zero expected profit condition in the unskilled and skilled input market, respectively. The left-hand-side, which equals p_i, $i=L,H$, is the revenue and the right-hand-side, B_i, the expected cost to an unfilled vacancy of skill type i from being matched randomly with a worker of the same type.

Recall that (1) and (2) imply diminishing marginal products and Edgeworth complementarity between two different inputs, that is, $\partial p_i/\partial Y_i<0$ and $\partial p_i/\partial Y_j>0$ for $i\neq j$. Therefore, an increase in θ_i, which raises the employment and production of input i (Y_i), decreases its price p_i (=marginal product). Also, an increase in θ_i raises the time required to fill a vacant position of type i and hence increases its expected cost B_i. Thus, if, for example, the left-hand-side of (20) is higher than its right-hand-side (i.e., $p_L>B_L$), then it is profitable to post unskilled vacancies and θ_L increases until the equilibrium is restored. Finally, an increase in the tightness in market j (θ_j) raises the employment of input j and thus leads to a higher price of input i, $i\neq j$.

Having determined θ_H^* and θ_L^*, we can get the equilibrium values for the other variables by substituting in the appropriate equations. In particular, the unemployment rates (u_{ij})

follow from equations (16) to (17); for example, the unemployment rate among skilled natives, which is equal to the one among skilled immigrants, is given by $u_{HN} = u_{HI} = (n + s_H)/[n + s_H + m(\theta_H)]$. Finally, the wage rates are given by (see Appendix A)

$$w_{ij} = \frac{[n + r + s_i + m(\theta_i)]\beta p_i + (n + r + s_i)(1 - \beta)(b_i - h_{ij})}{n + r + s_i + \beta m(\theta_i)}. \tag{22}$$

Note that equation (22) can be written as

$$w_{ij} = (1 - \beta)(r + n)J_{ij}^U + \beta p_i, \tag{23}$$

that is, the worker's wage is a linear combination of his outside option ($(r + n)J_{ij}^U$) and his marginal product ($= p_i$) (see Appendix A). Therefore, an increase in tightness θ_i and thus the matching rate $m(\theta_i)$ has two effects on the wage rate of a worker of type i: one negative through the price p_i - an increase in the matching rate raises employment and thus decreases the marginal product and price of input i - and one positive through the outside option - an increase in the matching rate raises the value of search and hence the outside option, which strengthens the worker's bargaining position.

Proposition 1 (Existence and Uniqueness). Under certain parameter restrictions confined in Appendix A, a steady-state equilibrium exists and is unique.

Proof. All formal proofs are presented in Appendix A.

The essence of Proposition 1 can be captured with the help of Figure 2. The equilibrium values of θ_H and θ_L are given by the intersection of the two curves labeled as EP and OH. The EP curve results after combining equations (20) and (21) (it is described by equation A10 given in Appendix A). This curve comprises the set of values of θ_H and θ_L that yield *equal profit* and make firms indifferent between establishing a high-skill and a low-skill vacancy. It has a negative slope since an increase in θ_H lowers the matching rate for high-skill vacancies ($q(\theta_H)$) and thus raises the average time it takes to fill one of them. Put differently, the expected cost of establishing a high-skill vacancy, B_H, goes up, which will decrease the ratio (Y_H/Y_L), in order to restore the relation between p_H and B_H. The decrease in (Y_H/Y_L) will in turn decrease the marginal product of unskilled labor p_L. To offset this, there must be a decrease in the cost of establishing a low-skill vacancy B_L, which requires a decrease in θ_L.[3]

[3]In general the curvature of the EP locus cannot be determined; we draw it as a straight line for simplicity.

The curve OH, on the other hand, is the geometric locus of values of θ_H and θ_L that make the expected profit from establishing a high-skill vacancy equal to zero (it is described by equation 21).[4] It has a positive slope because an increase in θ_H leads to a higher expected cost (B_H) and a lower price (p_H) in the skilled sector. Hence, there must be an increase in θ_L, which will raise the price of the high-skill input and restore the zero-profit condition $p_H = B_H$.

Notice from equation (22) that the wage rate of a native worker who is of type i is higher than that of an immigrant who is of the same skill type. In other words, firms extract higher surplus from immigrants. Therefore, we need to exclude the case where a firm that meets a native worker decides not to form an employment relation and continues to search. As shown in Appendix A, for a meaningful equilibrium where natives get employed, the following condition must hold:

Condition 1 (Precluding the Option to Wait)

$$\frac{c_i}{q(\theta_i)} \geq \frac{(1-\phi_i)(1-\beta)h_{iI}}{[n+r+s_i+\beta m(\theta_i)]}.$$

The left-hand side is the average cost of a vacant position of type i while the right-hand side is the expected net benefit from hiring an immigrant of type i. Condition 1 (written as an equality) establishes the minimum level of market tightness θ_i for a meaningful equilibrium. Given equations (12) and (13), the same condition ensures that $J^E_{ij} \geq J^U_{ij}$, that is, an unemployed worker will not turn down an employment opportunity and continue searching.

4 Equilibrium with Search Frictions

In general, a change in the number of skilled or unskilled immigrants I_i, $i = H, L$, can influence the equilibrium through the impact of such a change on i) prices p_i and ii) expected employment costs B_i. Before analyzing the equilibrium in the general case, where a change in I_i is propagated through both of these channels, it is instructive to examine each case separately. Specifically, we analyze two special cases: first, we set the immigrant search cost h_{iI} equal to zero, so that there is no difference anymore between a native and an immigrant worker of the same skill type. In other words, this assumption implies that $w_{ij} = w_i$ for each j and hence a firm is indifferent between hiring an immigrant

[4] Note that we could have used instead the curve along which the expected profit of establishing a *low-skill* vacancy is zero, as described by equation (20).

and a native worker with the same skills. In this case, a change in I_i has no impact on employment costs B_i; thus, it influences the equilibrium only through its impact on prices. The second special case that we analyze below is the one where $h_{iI} > 0$, but the two intermediate inputs are perfect substitutes ($\rho = 1$). In this case the two input prices are always independent of I_i. Therefore, a change in I_i can affect the labor market outcomes only through its impact on employment cost B_i. Finally, it follows from equations (20) and (21) that our approach exhausts all possible channels of influence, since if $\rho = 1$ and $h_{iI} = 0$, then the equilibrium is independent of the number of immigrants (skilled or unskilled).

4.1 Variable Prices and no Search Costs

Consider first the case where $\rho < 1$ and the search cost h_{iI}, $i = H, L$, is equal to zero. As mentioned above, the latter assumption implies that there is no difference between a native worker and an immigrant of the same type; in particular, $w_{ij} = w_i \ \forall j$. Also, as shown in Appendix A, equation (22), which gives the wage rate for each group, simplifies to

$$w_i = b_i + \frac{\beta}{1-\beta}\frac{c_i}{q(\theta_i)}[n + r + s_i + m(\theta_i)], \quad i = H, L. \tag{24}$$

Proposition 2. If the two intermediate inputs are imperfect substitutes ($\rho < 1$) and there is no search cost ($h_{iI} = 0$) then

$$\frac{d\theta_H}{dI_H} < 0, \ \ \frac{d\theta_L}{dI_H} > 0, \ \ \frac{du_{Hj}}{dI_H} > 0, \ \ \frac{du_{Lj}}{dI_H} < 0, \ \ \frac{dw_{Hj}}{dI_H} < 0 \ \text{ and } \ \frac{dw_{Lj}}{dI_H} > 0, \ \ j = N, I.$$

The effects of a change in I_L have analogous signs.

An increase in the number of skilled immigrants I_H raises the productivity of unskilled labor and lowers that of skilled. Hence, the price of the unskilled input p_L goes up, while the price of the skilled input p_H goes down. Since higher (lower) prices lead to higher (lower) profits, this induces the entry of unskilled jobs and raises the tightness in the unskilled sector θ_L; at the same time, it discourages the entry of skilled jobs and causes the tightness in the skilled sector θ_H to go down. We can demonstrate these effects graphically using Figure 2. An increase in I_H shifts the OH curve to the left (from OH to OH'). On the other hand, since the employment cost does not change and there are only price effects, the EP curve does not shift. Thus, the equilibrium moves from point A to point B; θ_H goes down, while θ_L goes up. Given these changes in the flow probabilities, the rest of the comparative statics follow easily; namely, a decrease in the probability of finding a match raises the unemployment rate among skilled native or immigrant workers (since $u_{HN} = u_{HI}$) and lowers both their marginal product and their outside option and hence their wage (note also that $w_{HN} = w_{HI}$, since in this case native and immigrant workers are identical). The opposite holds for the unskilled workers. Finally, the effects of a change in I_L have a similar interpretation. In fact, notice from equations (20) and (21) that, in this case, the marginal products of the two types of labor depend only on their relative numbers, namely on the ratio of unskilled to skilled labor, $\Lambda = (\lambda + I_L)/(1 - \lambda + I_H)$. Thus, the effects of an increase in I_H, for example, are identical to those of a skill-biased increase in immigration (decrease in Λ).

4.2 Fixed Prices and Search Cost

Next we analyze the other special case where $\rho = 1$ but $h_{iI} > 0$. Here the results are very different from the ones found above. In particular, consider

Proposition 3. If the two intermediate inputs are perfect substitutes and immigrants face a search cost, then a change in I_H has no impact on θ_L, $u_{LN} = u_{LI}$, w_{LN}, and w_{LI}, whereas

$$\frac{d\theta_H}{dI_H} > 0, \quad \frac{du_{Hj}}{dI_H} < 0, \quad \text{and} \quad \frac{dw_{Hj}}{dI_H} > 0, \quad j = N, I.$$

The effects of a change in I_L have analogous signs.

To understand the results summarized in Proposition 3, notice that in this case the two prices are constant: $p_L = \alpha$ and $p_H = (1-\alpha)(1-x)\left[xk^{\gamma} + (1-x)\right]^{\frac{1-\gamma}{\gamma}}$, where, as implied by (2) and (5), k assumes a constant value. On the other hand, the employment cost to a firm of type i, B_i, depends on the relative number of native to total labor of type i, ϕ_i (and not on Λ). This is so because, as can be seen from equation (22), when $h_{iI} > 0 = h_{iN}$, the wage rate of immigrants is lower than that of native workers who are of the same skill type; that is, $w_{iI} < w_{iN}$, $i = H, L$, because immigrants are subject to higher search costs. Intuitively, searching is costlier for immigrants, which forces them to accept lower wages. For a firm, hiring an immigrant is therefore more profitable than hiring a native, given that they are both equally productive. It follows that the increase in the immigrants' share of skilled labor force lowers the expected employment cost in the high-skill sector B_H, by lowering the probability that an unemployed and skilled worker is native (ϕ_H). This spurs high-skill job entry with a concomitant increase in the matching rate and thus the outside option for high-skill workers. Consequently, this leads to an increase in the wage of high-skill native workers w_{HN}, given by equation (22), and a decrease in their unemployment rate $u_{HN} = U_{HN}/1 - \lambda$ (see equation 16). Finally, the market tightness θ_L for low-skill workers is given by (20). Note that if $\rho = 1$ then θ_L is independent of the number of high-skill immigrants. Therefore, the wage rate and the unemployment rate for low-skill workers will remain the same, following an influx of skilled immigrants. This is illustrated graphically in Figure 3. The curve that depicts the locus of points along which profit is zero in the high-skill (low-skill) sector is HH (LL). An increase in the number of high-skill immigrants leaves the second curve unchanged but shifts the first curve to the right (to $H'H'$). Thus, the equilibrium moves from point A to point B; θ_H goes up, whereas θ_L remains the same.

5 General Case

Next we analyze the equilibrium in the general case, where $\rho < 1$ and $h_{iI} > 0$, $i = L, H$. In this general case, a change in I_L or I_H can influence the equilibrium through the impact of such a change on both prices and expected employment costs.

From our analysis above, we can infer that in this general case the impact of an increase in the number of immigrants will be unambiguously positive, both in terms of wages and unemployment, on the native workers whose skills become relatively more scarce, owing to the entry of new immigrants. However, the impact on the natives whose skills become relatively more abundant is in general ambiguous. This is so because the price effect is negative (Proposition 2), whereas the employment cost effect is positive (Proposition 3).

In this section we therefore calibrate the general model to the US data with the aim to quantitatively assess the overall impact of immigration on the labor market outcomes (wages and unemployment rates) for natives of both skill groups. We further use this calibration exercise to provide insights on how immigration affects the total steady-state surplus of the economy, i.e., the total income to natives net of the flow cost of vacancies.[5] We make the assumption that all firms belong to natives, who therefore receive all the net profits. Thus, our measure of net income to natives (labeled as surplus 1) is given by

$$\widetilde{Y} = Y + b_H U_{HN} + b_L U_{LN} - c_H V_H - c_L V_L - w_{HI}(I_H - U_{HI}) - w_{LI}(I_L - U_{LI}),$$

i.e., it is equal to the total flow of output, Y, plus the output-equivalent flow to native

[5] The change in net income is a conventional measure of welfare change in this class of models (see, e.g., Acemoglu 2001).

workers who are not currently employed, $b_H U_{HN} + b_L U_{LN}$, minus the flow costs of job creation for skilled and unskilled vacancies, $c_H V_H$ and $c_L V_L$, respectively, minus the wages paid to currently employed skilled and unskilled immigrants, given by $w_{HI}(I_H - U_{HI})$ and $w_{LI}(I_L - U_{LI})$, respectively. In our simulation exercises below, we also consider an alternative measure of the net income to natives (labeled as surplus 2) that does not include the income enjoyed by the unemployed, that is, $\tilde{Y} - b_H U_{HN} - b_L U_{LN}$.[6]

In what follows we first describe the baseline calibration and then discuss the quantitative predictions of the general model. We end the section with a sensitivity analysis with respect to the production parameters ρ and γ.

5.1 Calibration

For both simplicity and realism (see Blanchard and Diamond, 1991), in our calibration we use a Cobb-Douglas matching function, $M = \xi U_i^{\varepsilon} V_i^{1-\varepsilon}$, which exhibits standard properties. The scale parameter ξ indexes the efficiency of the matching process.

Our model economy is fully characterized by 21 parameters. The interest rate, r, the parameters in the matching function, ξ and ε, the workers' bargaining power, β, the production parameters, ρ, γ, α and x, the job separation rates, s_L and s_H, the capital depreciation rate, δ, the numbers of skilled and unskilled immigrants, I_L and I_H, the population birth rate, n, the share of unskilled labor force, λ, the unemployment flow incomes, b_L and b_H, the vacancy costs, c_L and c_H, and the search costs, h_{LI} and h_{HI}. We choose the parameters of the model to match the US data during the period January 1990 to December 1999. We then simulate the effects of a decade-long increase in the number of immigrants, corresponding to the period 2000-2009. One period in the model economy represents one month, so all the parameters are interpreted monthly. A summary of our calibration is given in Table 1.

First, we calculated the average 30-year treasury constant maturity bond rate over the period 1990-1999 and the average GDP deflator over the same period. The difference between these two figures, which constitutes a measure of the real interest rate, is 4.76%, implying a monthly rate (r) of approximately 0.4%. This is a commonly used value. Second, following common practice, we set the unemployment elasticity of the matching function to $\varepsilon = 0.5$, which is within the range of estimates reported in Petrongolo and Pissarides (2001). Third, following the literature, we postulate the worker's bargaining

[6] We also compute the overall surpluses 1 and 2, which include the wages paid to immigrants.

power to be $\beta = 0.5$, so that the Hosios condition ($\beta = \varepsilon$) is met (see Hosios, 1990). Fourth, as in Krusell et al. (2000), we define as skilled a worker with at least a Bachelor's degree.[7] Moreover, in our baseline calibration we adopt their parameter estimates for the US economy, $\rho = 0.401$ and $\gamma = -0.495$, but we also perform an extensive sensitivity analysis with respect to these parameters.[8] Fifth, using matched monthly data from the basic Current Population Survey (CPS), we estimated the average skilled and unskilled separation rates to be 0.019 and 0.034, respectively.[9] Sixth, data from the Bureau of Economic Analysis give a value of 0.0061 for the monthly depreciation rate of the capital stock.[10] Seventh, for the initial numbers of skilled and unskilled immigrants we set $I_L = 0.089$ and $I_H = 0.036$. Data for these measures come from the Public Use Microdata of the 1990 and 2000 US Censuses. We define as "immigrants" non-citizens and naturalized citizens.[11] Eighth, using also the Public Use Microdata of the 1990 and 2000 US Censuses and applying the same restrictions as in footnote 11, we find the monthly growth rate of the native labor force to be 0.071%. Finally, the percentage of US-born workers without a Bachelor's degree is set to $\lambda = 0.726$, as measured from the March CPS. Thus, the percentage of college graduates ($I_H/(I_L + I_H)$) is slightly higher among immigrants than among native labor force $(1 - \lambda)$ (0.288 vis-à-vis 0.274).

We jointly calibrated the remaining nine parameters by matching nine calibration targets obtained from US data over the period of interest, namely, 1990-1999. More specifically, our first two targets are the average employment rates of workers with at least a Bachelor's degree and of workers with less than a Bachelor's degree. Using data

[7] Our production technology (described in equations 1 and 2) assumes that workers within each of the two skill groups are perfect substitutes to each other. Given that we allow for only two skill groups, this assumption may seem relatively strong. However, a variety of estimates based on US data suggest that given our partition of workers into "high-school equivalents" and "college equivalents", the simple two-skill model that we employ works. Workers of different age and experience within each of these two skill groups tend to be perfect substitutes (see Card, 2009 for an overview of this evidence).

[8] Many recent aggregate time series studies estimate the elasticity of substitution between college and high school graduates to be in the range $1.5 - 2.5$; the implied values for ρ are in the range $0.333 - 0.6$ (see Card 2009).

[9] These measures include employment to unemployment and employment to inactivity transitions. In Appendix B we show that when the employment to inactivity transitions are excluded from our calculations of the separation rates, the results are essentially unaffected (see Table B1).

[10] The definition of capital stock that we used includes nonresidential equipment and software as well as nonresidential structures.

[11] To obtain appropriate values of I_L and I_H we divide the number of immigrants in the data by the native labor force, because in the model the native labor force is normalized to unity. As census data are available only every 10 years, we take the average over the years 1990 and 2000 only. The samples used to compute these and all other relevant measures include only ages 25 to 65, while they exclude those who are not in the labor force (report zero weeks of work, no wage income or are enrolled in school) as well as those who are in the military.

from the March CPS, we found them 0.976 and 0.939, respectively. Moreover, using data also from the March CPS, we estimated the college-plus wage premium to be 61.1%. Our next target is the capital to output ratio, which was computed using data from the Bureau of Economic Analysis (BEA). Specifically, the capital stock is defined as in footnote 10. This variable was then divided by a measure of private output that is equal to the Gross Domestic Product − Gross Housing Value Added − Compensation of Government Employees. This way, we found the value of 1.348 for the capital to output ratio. Our fifth target is the vacancy to unemployment ratio. Using the Conference Board's Help-Wanted Index (HWI), this was found equal to 0.620.[12]

Following Borjas and Friedberg (2009), we define "new immigrants" as those who arrived in the five years prior to the respective Census. Moreover, we calculated hourly earnings as annual wage and salary income, divided by weeks worked per year, divided by hours worked per week. Thus, we can obtain our next two targets which are the native-immigrant wage gap for skilled (−18.8%) and unskilled (−19.0%) workers. Finally, our last two targets are the replacement ratios (ratio of unemployment to employment income) for both skill groups. In our baseline calibration we used Hall and Milgrom's (2008) estimate for the ratio of unemployment to employment income, which includes both unemployment insurance and the value of non-market activity. Their estimate of 0.71 is a standard value commonly used in recent studies.[13] Nevertheless, the typical replacement ratio of unemployment insurance of 0.40 (see Shimer 2005) can be considered as a lower bound for the ratio of unemployment to employment income. In Table B2 in Appendix B, we show that using Shimer's replacement ratio of 0.40 does not alter the results in any significant way.

5.2 Results

Using the Public Use Microdata, we find that over the period January 2000-December 2009 the change in I_L was 0.051 and the change in I_H 0.026, i.e., 5.1% and 2.6% of the *native labor force*, respectively. Moreover, the total increase in the US *labor force* resulting

[12]Data on vacancies from the Job Openings and Labor Turnover Survey (JOLTS) are only available since December 2000. The best available proxy for the number of vacant jobs for the years prior to 2000 is the Conference Board's HWI. We adjusted the HWI to the JOLTS units of measurement using the JOLTS data and then divided by the unemployment rate, as measured from the March CPS files, to obtain the vacancy to unemployment ratio over the period of interest.

[13]See, for instance, Pissarides (2009) and Brugemann and Moscarini (2010).

from international immigration over this period was approximately 6.8%.[14] Crucially, the immigration influx over the period of interest is biased towards skilled labor. More specifically, it follows from the aforementioned data that Λ, the ratio of unskilled to skilled labor, decreased from 2.629 to 2.577.

In Table 2 we summarize the effects of an immigration influx of the same magnitude and composition in terms of skills as the one in the data. We report results obtained from the general model, calibrated to US data as described above, but also, for comparability, from three alternative specifications. In the first specification, we set $h_{LI} = h_{HI} = 0$. There are therefore only price effects in this case (this is the case considered in Proposition 2). In the second specification, we keep the assumption $h_{HI} = 0$, but set $h_{LI} = 1.182$, as calibrated above. Finally, in the last case, we set $h_{LI} = 0$ but set h_{HI} equal to the calibrated value of 4.203.[15]

When natives and immigrants face identical search costs (second column in Table 2) the increase in the number of immigrants causes θ_L to rise and θ_H to fall in line with the results derived in Proposition 2. Because the college-intensive immigration influx raises the ratio of skilled to unskilled workers, the marginal product of skilled workers and thus the price of the skilled labor input falls, while the marginal product and the price of unskilled labor rises, leading to lower job entry in the high-skill sector and higher in the low-skill sector. The unskilled native workers therefore benefit from an increase in both their marginal product and value of outside option, which push their wage up. At the same time, their unemployment rate falls, as their job finding probability increases. The skilled workers, by contrast, undergo a wage decline, as both their marginal product and outside option deteriorate, and an increase in their unemployment rate, as their job finding rate falls.

When we allow for skilled immigrants and natives to have differential search costs (third column), the impact of the same immigration influx on skilled job entry turns from negative to positive and large. In this case, despite the fall in the price of the skilled labor input, the rise in the number of skilled immigrants encourages the entry of skilled jobs by lowering the cost firms expect to pay on average in order to hire a skilled worker. The consequent increase in their job finding rate, causes their unemployment

[14] In conducting their simulation exercises, Borjas and Katz (2007) and Ottaviano and Peri (2012) used an immigrant influx that increased the size of the total workforce by 11.0% and 11.4%, respectively.

[15] Throughout all exercises presented in the Tables 2-8 below, we find Condition 1, which precludes the option of a firm to wait until an immigrant worker arrives, to be satisfied.

rate to fall. However, in determining their wage, the drop in their marginal product dominates the improvement in their job finding rate and thus in their bargaining position in wage setting. Therefore, their wage still falls. Because skilled and unskilled labor are complements in the production of the final good, the presence of differential search costs between immigrant and native skilled workers improves the impact of immigration on the unskilled native workers as well, both in terms of employment and wages. The immigration-induced increase in skilled job entry, and as a consequence in Y_H, leads to an even larger increase in the price of unskilled labor input and therefore to an even larger increase in θ_L.

The same immigration influx has also a more positive impact on natives of both skill types when differential search costs between immigrant and native unskilled workers are introduced (fourth column). In this case, the decline in the expected cost B_L of firms seeking to establish an employment relation with an unskilled worker adds to the increase in the price of the unskilled labor input, causing a much larger increase in unskilled job entry, and as a consequence, a much larger fall in the unemployment rate of unskilled workers. Reasoning as above, the larger increase in the unskilled labor input, Y_L, benefits also the skilled workers. Specifically, the increase in Y_L raises the marginal product of skilled workers, thereby counteracting partially the adverse effect of immigration on the price of the skilled labor input, p_H. The drop in θ_H is therefore smaller in this case compared to the case where immigrants and native unskilled workers are identical.

The results of the general model calibrated to the US data - where immigrants and natives of both skill types face differential search costs and hence have different wages - are summarized in the last column of Table 2. As above, the drop in the expected cost B_L reinforces the effect of the rise in the price of the unskilled labor input on unskilled job entry, leading to a large increase in the tightness prevailing in the unskilled sector. As a result, the unemployment rate of unskilled workers drops by 11.0%. Because the wage of skilled immigrants is also significantly lower than that of skilled natives, the immigration influx causes a large decline also in the expected employment cost of firms seeking to hire skilled workers. Job entry in the skilled sector therefore rises, causing the unemployment rate of skilled workers to fall by 17.26%. In terms of wages, for the reasons explained above the wage of unskilled native workers increases by 0.59%, while that of skilled native workers falls by 0.48%. In all cases considered, the surge in immigration lowers the unemployment rate of natives overall and raises the total income of the economy. With differential search costs, the impact is also positive on the overall wage of native workers although quantitatively small. Hence, the immigration inflow raises the surplus of native workers, mainly because it induces job creation; as a consequence, it lowers their overall unemployment rate and raises the total income of the economy. The largest increase in income and native wage rate and the largest fall in the native unemployment rate occur when immigrants of both types earn lower wages than their competing natives, as the US data dictate. In this case, the native unemployment rate falls by 11.79%, total income increases by 7.41% and the native wage rate increases by 0.15%, leading to an increase in the surplus of natives between 0.6% (surplus1) and 1% (surplus 2).

It is also worth commenting on the impact of the immigration influx on the labor market outcomes for the existing immigrants. Clearly, with identical search costs, immigration has the same consequences, both in terms of wages and unemployment, on workers of the same skill type, irrespective of their origin. Nevertheless, with differential search costs the impact of immigration in terms of wages appears to be more positive on immigrants than on natives. To understand why recall that an increase in market tightness influences the equilibrium wage through two channels: 1) through its impact on the marginal product of labor; an increase in tightness raises employment and decreases the marginal product of labor, thereby lowering the worker's wage; 2) through its impact on the worker's value of outside option; an increase in tightness raises the value of search, thereby strengthening the worker's position in wage setting, and in turn, causing his wage to rise. When search is much costlier for immigrants than for natives, this second channel is much more important for the former, which explains why the impact of an immigration-induced increase in market tightness on their wage is more positive. For these workers, a small increase in their chances of finding a job implies a much larger increase (in percentage terms) in their bargaining power and in turn on their wage.

Notice also in the last two columns of Table 2 that the overall wage of the unskilled decreases, even though the wages of both groups that compose this category (unskilled native and immigrant) go up. We see this, at first sight, paradoxical result in several of the tables that follow. It occurs because the total sum of wages, which in this case is $\lambda w_{LN} + I_L w_{LI}$, goes up by less than the total number of workers, $\lambda + I_L$.

As shown in Appendix B, our results are robust when we change parameters β (second column in Tables B4 and B5) and ε (second column in Tables B6 and B7) and then recalibrate the model to obtain some of the other parameter values as well as when we keep all other parameters the same (Tables B10 and B13). The same is true with respect to changes in unskilled and skilled unemployment income b_L and b_H (see Tables B16 and B19). Finally, Figure C1 in Appendix C presents the dynamic adjustment of several variables in our model. These results are consistent with our stead-state results (details are given in Appendix C).

5.3 Changing the Elasticity of Substitution between Labor and Capital

The results above are derived using the elasticities of substitution between the input factors estimated by Krusell et al. (2000). Nevertheless, in this subsection we examine how robust the general model's predictions are to alternative values for the elasticities of substitution between capital and the skilled and unskilled labor, respectively.

For the nested CES production function, given in equations (1) and (2), the Allen-Hicks elasticities of substitution between unskilled labor Y_L and the other two factors, skilled labor Y_H and capital K, are identical and given by $\sigma_{LK} = \sigma_{LH} = \frac{1}{1-\rho}$. The Allen-Hicks elasticity of substitution between skilled labor and capital is a function of factor shares. Nevertheless, following Krusell et al. (2000) and Ben-Gad (2008), we employ a simplified definition of the elasticity of substitution between skilled labor and capital: $\sigma_{HK} = \frac{1}{1-\gamma}$.

In Table 3 we report the results from the general model for different sets of values for the parameters ρ and γ.[16] As in Ben-Gad (2008), we consider a set where both elasticities are low ($\sigma_{LK} = 1, \sigma_{HK} = 0.5$), a set where both elasticities are high ($\sigma_{LK} = 2, \sigma_{HK} = 1$), and two sets where one elasticity is high and the other low, ($\sigma_{LK} = 1, \sigma_{HK} = 1$) and ($\sigma_{LK} = 2, \sigma_{HK} = 0.5$). The results are qualitatively robust to our choices of σ_{LK} and σ_{HK}. In all cases the impact of the skill-biased immigration that took place in the period 2000-2009 is positive in terms of unemployment on both skilled and unskilled workers, because it leads to higher job entry in both sectors. In terms of wages, it is positive on the unskilled and negative on the skilled native workers. Further, the model's predictions about the impact of immigration on total income and surplus for natives remain the same; skill-biased immigration raises both of them.

Moreover, the effect of the type of immigration analyzed here on unskilled job entry

[16] The rest of the parameters remain the same, as calibrated above. On the contrary, in Table B3 in Appendix B, we change the production parameters ρ and γ and then re-calibrate the model to obtain the other parameter values.

becomes significantly more positive as the elasticity of substitution between skilled labor/capital and unskilled labor declines (i.e., as ρ decreases). Given that skilled labor and capital are complements to each other, the immigration-induced increase in the ratio of skilled to unskilled labor input, $1/\Lambda$, and the resulting increase in capital causes a larger increase in the marginal product of unskilled labor when ρ is small. Consequently, at lower values of ρ the increase in unskilled job entry and the consequent positive effects on the wage and employment of unskilled workers are larger. Similar reasoning explains why the effect of immigration on unskilled job entry becomes more positive as the degree of capital-skill complementarity increases (i.e., as γ decreases). At lower values of γ an increase in Y_H has a larger positive impact on the equilibrium value of capital and therefore the marginal product of the unskilled labor. Finally, Table B3 in Appendix B presents the results of the general model with both differential search costs when we change the values of the production parameters and then re-calibrate the model to obtain some of the other parameter values, as we did above. The results we obtain are similar.

6 Extensions

In this section, we extend the basic model in four different directions. First, we analyze an inflow of immigration with the same skill distribution as in the existing labor force. We call this a *skill-balanced* increase in immigration.[17] Second, we let immigrants be imperfect substitutes for native workers of the same skill type. Third, we consider endogenous skill acquisition on behalf of native workers. Finally, we allow natives and immigrants to be completely different factors both before and after an employment relation commences. Specifically, natives and immigrants search for employment in separate labor markets and are imperfect substitutes to each other in production.

6.1 Skill-Balanced Immigration

The case of skill-balanced immigration is a case rarely considered but nevertheless very close to reality. In fact, as mentioned above, the inflow of immigrants during the period 2000-2009 was more college intensive than the existing US labor force. For example, the average percentage of US citizens with at least a Bachelor's degree during the period 1990-1999 was 27.4%. The same percentage among immigrants was 28.8%. On the other hand,

[17]We are grateful to a referee for suggesting to us this and the last extension.

the percentage of foreign-born labor force with at least a Bachelor's degree that entered in the period 2000-2009 was 33.8%, i.e., more college intensive than the existing stock of natives (the data are from the US Public Use Microdata samples; see also Ottaviano and Peri 2012 for the United States and Docquier, Özden and Peri 2010 for other countries).

With a skill-balanced increase in immigration the ratio of unskilled to skilled (denoted above by Λ) does not change. Hence, if the search cost of immigrants (h_{iI}) is equal to zero, then a balanced increase in immigration will have no impact. Both the price of input i (p_i), which equals the revenue to the firm from employing a worker of skill type i, and the expected cost to the firm from establishing an employment relation (B_i) are independent of the number of immigrants (I_i).

On the other hand, if there is a search cost, then, even with a skill-balanced increase in immigration, the probability that a type i and unemployed worker is native (denoted by ϕ_i, $i = L, H$) goes down. Thus,

Proposition 4. If immigrants face a search cost ($h_{iI} > 0$) and there is no capital stock ($x = 0$), then after a skill-balanced increase in immigration dI

$$\frac{d\theta_H}{dI} > 0, \quad \frac{d\theta_L}{dI} > 0, \quad \frac{du_{HN}}{dI} < 0, \quad \frac{du_{LN}}{dI} < 0, \quad \frac{dw_{Hj}}{dI} > 0 \text{ and } \frac{dw_{Lj}}{dI} > 0, \quad j = N, I$$

where $dI = [(1+I)/(\lambda + I_L)]dI_L = [(1+I)/(1-\lambda+I_H)]dI_H$ and $I = I_L + I_H$.

The intuition is straightforward. A balanced increase in immigration lowers the probability that a type i and unemployed worker is native, which lowers the expected cost from establishing an employment relation, since natives receive higher wages. As a consequence there is firm entry, which lowers unemployment and raises wages.

The consequences of a skill-balanced immigration flow in our calibrated model where capital is allowed to adjust optimally are summarized in Table 4. We consider an increase in immigration that increases the total labor force by 0.077, as above, but leaves the ratio of skilled to unskilled unchanged. To achieve this we increase I_H by 0.021 and I_L by 0.056. Since capital is complementary to skilled labor, as Y_H increases due to firm entry, the marginal product of capital and therefore its equilibrium value also increases. Nevertheless, the increase in capital is smaller than the increase in the number of skilled immigrants and hence the ratio of capital to skilled labor decreases (see the equation that defines k). Thus, on the one hand the expected cost of establishing an employment relation, B_i, drops, but, on the other, the price of each type of intermediate input, p_i, may go down as well. In the case analyzed in Table 4, the former effect dominates on the latter and hence the matching rates for both types of labor increase. Therefore, in line with Proposition 4, a skill-balanced increase in immigration is positive on both skill types in terms of both wages and employment.

Comparing the impact of the 2000-2009 skill-intensive increase (last column of Table 2) to that of the balanced increase, we see that in terms of wages the balanced increase in immigration has a smaller positive impact on unskilled workers. This is to be expected since with a balanced increase the positive impact of a higher ratio of skilled to unskilled labor on the marginal product of unskilled workers disappears. However, in terms of job entry and unemployment, the balanced increase in immigration has a more positive impact on the unskilled workers and less positive on the skilled workers, compared to the 2000-2009 skill-intensive increase. To understand why, notice that the increase in the number of unskilled immigrants is larger and the increase in the number of skilled immigrants is smaller in the balanced increase than in the skill-intensive increase. This implies a larger increase in the probability that a type i and unemployed worker is immigrant for firms directing their search towards unskilled workers and smaller for firms searching for skilled workers (i.e., a larger increase in $1-\phi_L$ and smaller in $1-\phi_H$). For this reason, the fall in the expected employment cost and the resulting increase in job creation is higher in the unskilled and lower in the skilled sector.

6.2 Imperfect Substitution

Next we allow native and immigrant labor of the same type to be imperfect substitutes in production. More specifically, the production function of the final good is still given by (1), where Q is defined in (2). Furthermore, each of the two labor inputs, Y_L and Y_N is another CES sub-aggregate, namely,

$$Y_L = [\psi Y_{LN}^{\eta} + (1-\psi) Y_{LI}^{\eta}]^{1/\eta}, \qquad 1 > \psi > 0, \quad \eta \leq 1, \tag{25}$$

and

$$Y_H = [\zeta Y_{HN}^{\nu} + (1-\zeta) Y_{HI}^{\nu}]^{1/\nu}, \qquad 1 > \zeta > 0, \quad \nu \leq 1, \tag{26}$$

where, for example, Y_{LN} denotes unskilled native labor. Crucially, however, vacancies cannot be opened for immigrants or natives only (see more on this in Subsection 6.4 below).

Clearly, native and immigrant labor of the same type have now different marginal products and hence different prices, p_{ij}:

$$p_{LN} = \alpha\psi Y_{LN}^{\eta-1} Y_L^{\rho-\eta} Y^{1-\rho}, \tag{27}$$

$$p_{HN} = (1-\alpha)(1-x)\zeta Y_{HN}^{\nu-1} Y_H^{\gamma-\nu} Q^{\rho-\gamma} Y^{1-\rho}, \tag{28}$$

$$p_{LI} = \alpha(1-\psi) Y_{LI}^{\eta-1} Y_L^{\rho-\eta} Y^{1-\rho}, \tag{29}$$

$$p_{HI} = (1-\alpha)(1-x)(1-\zeta) Y_{HI}^{\nu-1} Y_H^{\gamma-\nu} Q^{\rho-\gamma} Y^{1-\rho}. \tag{30}$$

The price of capital on the other hand is still given by (5). As before, the marginal products p_{ij} can be expressed as functions of the indicators of the tightness in the labor markets θ_i (see Appendix A).

Next, following the same procedure as the one outlined in Appendix A for the derivation of equations (20)-(22), we arrive at the following two equations that determine θ_H and θ_L:

$$\phi_i p_{iN} + (1-\phi_i) p_{iI} = B_i, \qquad i = L, H, \tag{31}$$

where $h_{ij} = 0$ if $j = N$, as before. The left-hand side of (31) gives the expected benefit to a firm from a match with a worker of skill-type i, whereas the right-hand side gives the expected cost from establishing an employment relation of that type. Free entry requires that the two be equal. Moreover, the wage rate accrued to a worker of skill i and origin j from a match is still given by equation (22), where p_{ij} replaces p_i. Note that in general, the effects of a change in I_L, or I_H, on the matching rates and hence θ_H and θ_L are ambiguous since, without further restrictions, we cannot determine the impact of a change in one of the four labor inputs on the marginal products/prices of the other three. Consider:

Proposition 5. If the two intermediate inputs (Y_H and Y_L) are perfect substitutes ($\rho = 1$), immigrants face a search cost ($h_{iI} > 0$) and $p_{HI} \geqslant p_{HN}$, then a change in I_H has no impact on θ_L, $u_{LN} = u_{LI}$, w_{LN} and w_{LI}, whereas

$$\frac{d\theta_H}{dI_H} > 0, \quad \frac{du_{HN}}{dI_H} < 0, \quad \frac{dw_{HN}}{dI_H} > 0 \text{ and } \frac{dw_{HI}}{dI_H} < 0.$$

Under similar conditions, the effects of a change in I_L have analogous signs.

In the case where native and immigrant workers of the same type were perfect substitutes, immigrants had a lower outside option but the same marginal product as natives. In contrast, in the case analyzed in this subsection, they have a lower outside option and a different marginal product from natives. Hence, an increase, for example, in I_H will decrease the expected cost to an unfilled vacancy from being matched randomly with an unskilled worker, B_H, as before. Nevertheless, it will have an ambiguous effect on the expected benefit from such a match $\phi_H p_{HN} + (1 - \phi_H) p_{HI}$. Given that the probability that the match will be with a native, ϕ_H, decreases, the expected benefit will go up if immigrants are at least as productive as natives, i.e., $p_{HI} \geqslant p_{HN}$. The other results follow easily.

Next, we derive results in this generalized model (with $\rho < 1$) for different values of the parameters η and ν. As an empirical basis for our choices of η and ν we use the estimates reported in Ottaviano and Peri (2012). They first partition workers into groups based on their education and experience characteristics. Then, using a CES aggregator similar to the one in (25), they estimate the elasticity of substitution between natives and immigrants sharing similar education and experience characteristics. Based on their estimates and given our definition of unskilled workers, the elasticity between unskilled immigrant and native workers $\sigma_{LILN} \equiv \frac{1}{1-\eta}$ should range from about 6.5 to about 20, meaning that η should lie somewhere between 0.85 and 0.95. Furthermore, since their results show no evidence of imperfect substitutability between college educated immigrants and natives, we let immigrant and native skilled labor be perfect substitutes. This corresponds to the case where $Y_H = Y_{HN} + Y_{HI}$ replaces (26), so that $p_{HI} = p_{HN}$. Nevertheless, as an additional robustness test, we also consider the case where immigrants and natives of both labor types are imperfect substitutes, as described above, and derive results for values of η and ν between 0.85 and 0.95. Also, in lack of good empirical estimates that can guide our choices of values for ψ and ζ, for the results below we set $\psi = \zeta = 0.75$. This value ensures that, given the other parameters of the model, Condition 1 is satisfied, i.e., the option to wait will never be exercised by firms that search for either skilled or unskilled workers. We keep the rest of the parameter values as described above.

The results in the case where only unskilled immigrant and native labor are imperfects substitutes are shown in Table 5. As can be seen, our previous results are robust to the generalized set-up. More specifically, as before, the skill-biased immigration analyzed here leads to higher job entry in both sectors, raises the wage of unskilled workers and lowers that of skilled native workers. Moreover, immigration raises the surplus accrued to natives, because it raises output and the average wage and lowers the unemployment rate of both skill groups. Also, the smaller the degree of substitutability between native and immigrant unskilled labor (i.e., the lower the value of η), the larger the positive impact of immigration on both labor types. This is not surprising, since a smaller degree of substitutability between unskilled natives and immigrants implies a larger positive impact on the price of the native-unskilled labor input, p_{LN}, following a skill-intensive increase in immigration. It also implies a smaller positive impact on the price of immigrant-unskilled labor input, p_{LI}; nevertheless, since firms are more likely to encounter a native as opposed to an immigrant unskilled worker, the overall increase in the expected benefit to the firm from hiring an unskilled worker (the left-hand-side of equation (31)) is larger, leading to a larger increase in low-skill job entry. Reasoning as above, the resulting larger increase in the unskilled labor input, Y_L, implies a smaller decline in the price of the skilled labor input, p_H, thereby improving also the consequences on skilled natives. In Table 6 (columns 2-4) we see that the same conclusions hold when immigrants and natives of both skill types are imperfect substitutes and ν is fixed to 0.95.[18]

Turning to the impact of imperfect substitutability between immigrant and native skilled workers, as shown in Table 6, the lower ν is, the more positive the impact on skilled native workers is (compare the second column with the last two in Table 6, where $\eta = 0.95$ throughout and ν decreases). In fact, as can be seen in all columns of Table 6, when immigrants and natives of both labor types are imperfect substitutes, the immigration influx has a positive impact on skilled (and unskilled) natives not only in terms of employment, but also in terms of wages. This is because at lower values of ν, the immigration-induced fall in the marginal product of skilled native workers, and therefore the price p_{HN}, is smaller. The skilled immigrants, by contrast, suffer a larger decline in their marginal product as the degree of substitutability between native and immigrant skilled labor falls. Nevertheless, because natives capture a higher share of the skilled labor force, at lower values of ν the immigration-induced decline in the expected benefit to the firm from hiring a skilled worker is smaller. This explains why a low degree of substitutability between immigrants and natives leads to a larger increase in θ_H following the skill-intensive increase in the number of immigrants. Again, due to complementarities, the impact of immigration becomes more positive on both labor types as ν falls. The larger increase in Y_H caused by the larger increase in skilled job entry leads to a larger increase in the price of the unskilled labor input. The consequent larger increase in unskilled job

[18]Card (2009) finds the elasticity of substitution between college-educated natives and immigrants are in the range $16.67 - 34.48$; the implied values for ν are in the range $0.94 - 0.97$.

entry improves the impact of immigration on unskilled native workers in terms of both wages and employment.

Notice also that as the degree of substitutability between native and immigrant workers of the same skill type falls, the wage effect on natives becomes more positive whereas that on competing immigrants becomes less positive. Hence, a high degree of substitutability between immigrants and natives means that the competition effects of additional immigrants fall more heavily on immigrants themselves, thereby lessening the burden on natives.[19] This occurs because as the degree of substitutability between immigrants and natives decreases, the price effect of new immigrants becomes less negative on competing natives and more negative on competing immigrants. To understand why, notice from equations (27) and (29) that the ratio of immigrant to native unskilled labor input, $\frac{Y_{LI}}{Y_{LN}}$, has a positive impact on p_{LN} and negative on p_{LI}. At $\eta = 1$ this ratio disappears, meaning that what matters for how prices respond to immigration is only the ratio of unskilled to skilled labor, Λ; however, at lower values of η the impact becomes more favorable on natives than on previous immigrants. Likewise, from (28) and (30), we see that at lower values of ν, an increase in $\frac{Y_{HI}}{Y_{HN}}$ has a larger positive impact on p_{HN} and negative on p_{HI}. It follows that at smaller values of ν the negative effect of the skilled-intensive immigration influx on w_{HI} through p_{HI} is larger, while the negative effect on w_{HN} through p_{HN} is smaller in absolute value. Likewise, at smaller values of η the positive impact on w_{LI} through p_{LI} is smaller, while that on w_{LN} through p_{LN} is larger in absolute value.

Even though the competition effects of additional immigrants fall more heavily on previous immigrants, the wage of previous immigrants not only increases but increases much more than the wage of natives. As explained above, this is because immigrants have a much lower value of outside option, and thus wage, than natives, owing to their higher search cost. Consequently, the higher availability of jobs has a larger impact in percentage terms on their bargaining position and therefore wage. In the imperfect-substitutes case the percentage impact on the wage of natives becomes even larger because of the shares ψ and ζ that reduce the sizes of immigrant wages significantly.

Finally, Tables B4-B8, B11, B14, B17 and B20 examine the robustness of our results with respect to changes in parameters β, ε, ψ, ζ, b_L and b_H. As before, we analyze the case

[19] The view that the competition effects of additional immigrant inflows are concentrated among immigrants themselves, lessening the negative impact on competing natives due to immigrants and natives being imperfect substitutes, is also supported by evidence reported in Card (2009) and Ottaviano and Peri (2012).

where we change one parameter and keep all other values the same, as well as the case where after changing one parameter we re-calibrate the model to get the other parameter values (details are given in Appendix B).

6.3 Human Capital Accumulation

The next extension that we consider is to allow for endogenous skill acquisition on behalf of native workers. We view this as an interesting case, as in the long run natives may react to any negative pressure from immigrants by adjusting their skill level, while such adjustments cannot take place in the short run.

Specifically, before entering the labor market each agent decides whether to invest in education and become skilled or remain unskilled; that is, investment in human capital/skill is a discrete choice. Native young agents differ with respect to their ability to learn, which in turn determines their cost of acquiring education. Older agents, on the other hand, face an additional cost, which is prohibitive. Thus, older workers never opt for training.[20]

Let the cost of acquiring training be denoted by z and assume that it is distributed uniformly over the closed interval $[0, \overline{z}]$. A native young agent κ will invest in education if the benefit from this decision exceeds the cost, that is, a native young worker κ will invest in education if

$$J^U_{HN} - J^U_{LN} > z^\kappa.$$

Thus, all agents with a cost of education lower than some value z^* will invest in education, where z^* is given by

$$z^* = J^U_{HN} - J^U_{LN}.$$

In this case $1 - \lambda^*$, the fraction of native workers that are skilled, is endogenous and is given by

$$1 - \lambda^* = \frac{z^*}{\overline{z}}. \tag{32}$$

As shown in Appendix A, combining these equations and substituting away J^U_{iN}, $i = L, H$, we get the following equation

$$(1-\lambda)\overline{z} = \frac{1}{n+r}\left\{\frac{\beta m(\theta_H)p_H + (n+r+s_H)b_H}{n+r+s_H+\beta m(\theta_H)} - \frac{\beta m(\theta_L)p_L + (n+r+s_L)b_L}{n+r+s_L+\beta m(\theta_L)}\right\}, \tag{33}$$

which sets the cost to the last worker who receives training equal to the present value of the benefit from a such a decision. Obviously, all workers with a cost lower than the one

[20] For a search and matching model that allows for re-training see Laing, Palivos and Wang (2003).

given by the left-hand side of (33) invest in education. Equations (20), (21) and (33) then determine the equilibrium triplet θ_L^*, θ_H^*, and λ^*. Given these, we can get the equilibrium values for all other variables by substituting in the appropriate equations.

Proposition 6. a) If there is no search cost then the effects of a change in I_L or I_H have the same sign as in Proposition 2 but are smaller in magnitude. b) If the two intermediate labor inputs are perfect substitutes then the effects of a change in I_H have the same sign as in Proposition 3 but are smaller in magnitude. Furthermore,

$$\frac{d\theta_L}{dI_H} > 0, \quad \frac{du_{LN}}{dI_H} < 0, \quad \frac{dw_{LN}}{dI_H} > 0, \quad \frac{dw_{LI}}{dI_H} > 0.$$

An increase in I_L has analogous results.

The intuition behind the results derived in Proposition 6a are the same as that in Proposition 2. Moreover, an increase, for example, in the number of skilled immigrants (which results in a decrease in Λ) lowers the proportion of skilled workers $(1 - \lambda)$, since both the decrease in θ_H and the increase in θ_L that follow diminish the benefit of education. Interestingly, starting from the same equilibrium, with endogenous changes in the skill distribution the decrease in the tightness in the skilled sector θ_H is lower compared to the case where λ is fixed. Similarly, the increase in θ_L is smaller when λ is allowed to adjust. This occurs because the initial effect on prices is mitigated through changes in λ. More specifically, the decrease in Λ is smaller when λ is allowed to adjust, so that the decrease in p_H and increase in p_L are smaller, leading to smaller responses in job entry. In terms of Figure 2, the curve EP remains unchanged but the shift of the curve OH to the left is smaller compared with that in Proposition 2; e.g., the curve shifts to OH' when λ is fixed but only to OH'_λ when λ is endogenously determined. The equilibrium moves from point A to point B when λ is fixed and to point C when λ adjusts optimally. Hence, the changes in both θ_H and θ_L are smaller in absolute value. This has important implications because it makes the benefits of skilled immigration to unskilled native labor (i.e., the decline in the unemployment rate and the increase in the wage rate) smaller and vice versa. Similarly, the losses of (un-) skilled immigration to (un-) skilled native labor (i.e., the increase in the unemployment rate and the fall in the wage rate) are also smaller.

Regarding Proposition 6b, in the case where λ is endogenous, after an entry of skilled immigrant workers, there will be an increase in the matching rate and the wage rate of high-skill workers as well as a decrease in their unemployment rate, as was the case in

Proposition 3. However, starting from the same equilibrium as in the case where λ is fixed, these effects are smaller in magnitude, because the higher availability of skilled jobs (due to the decline in the expected employment cost, B_H) will increase the proportion of natives that choose to become skilled. In turn, the decrease in λ will partially offset the fall in B_H, so that the increase in θ_H is smaller. Graphically in this case the equilibrium can be presented as the intersection of two upward-sloping curves that depict the zero-profit condition in the two sectors, such as $H_\lambda H_\lambda$ and $L_\lambda L_\lambda$ in Figure 3.[21] An increase in the number of skilled immigrants leaves the $L_\lambda L_\lambda$ curve unchanged but shifts the $H_\lambda H_\lambda$ curve to the right (to $H'_\lambda H'_\lambda$). Recall that with fixed λ the equilibrium shifts from point A to point B. Now that λ is endogenous and responds to changes in the matching rates, the equilibrium moves from point A to point C; thus, the increase in θ_H is smaller. Furthermore, in contrast to the case where λ is constant, with endogenous λ, θ_L and hence the matching rate for low-skill workers goes up as well, with a concomitant decrease in the unemployment rates $u_{LN} = u_{LI}$ and an increase in wages w_{LN} and w_{LI}. The reason for the increase in θ_L is that the decrease in λ implies a higher probability that an unemployed unskilled worker is immigrant, which lowers the expected employment cost and spurs entry of low-skill vacancies. Finally, notice that in this case, immigration is beneficial for all groups, low-skill and high-skill, natives and immigrants, since it lowers their unemployment rates and raises their wages.

In Table 7 we examine the consequences of the 2000-2009 immigration influx when there is endogenous skill acquisition on behalf of natives. Allowing for endogenous skill acquisition introduces a new parameter into the model, the upper bound to the cost of acquiring education, $\bar{z}$. The value of this parameter is taken to be 226.321, so that the share of skilled among US-born workers equals 0.274, as above. Since we also keep all other targets the same, the re-calibration of the model with endogenous skill accumulation yields the same values for the rest of the parameters. The skill-intensive increase in immigration raises the ratio of skilled to unskilled labor force, thereby lowering the marginal product of skilled and raising that of unskilled workers. In response to the downward (upward) pressure from immigration on the skilled (unskilled) wage, a higher share of the newly

[21] The reason that these two curves are upward-sloping is simple. Consider, for example, the zero profit condition in the low-skill sector $p_L = B_L$. If the two inputs are perfect substitutes then the price p_L is constant and equal to α. An increase in θ_L will increase the cost of establishing an employment relation B_L. To restore the equilibrium θ_H must increase, so that the outside option for high-skill workers increases and hence there is a decrease in λ, which will decrease B_L. Moreover, it can easily be shown that $H_\lambda H_\lambda$ is steeper than $L_\lambda L_\lambda$.

born native workforce chooses to remain unskilled. The resulting compositional shift in the native labor force towards unskilled workers acts to mitigate the negative (positive) impact of immigrants on the price of skilled (unskilled) input. It also raises (lowers) the expected cost of establishing an employment relation with an unskilled (skilled) worker by lowering (raising) the chances that a searching firm will encounter an immigrant as opposed to a native unskilled (skilled) worker. These counteracting effects lessen the positive effect of skill-biased immigration on the wages and employment of unskilled natives, but also improve the consequences on skilled natives in terms of both employment and wages. Specifically, skilled native workers suffer a smaller decline in their wage and a larger increase in their employment rate. Since the unskilled capture a larger share of the native labor force, the endogenous skill accumulation has a smaller positive impact on the overall surplus of natives, compared with the case were the skill distribution is fixed (compare the last column in Table 2 with the results in Table 7). Finally, Tables B4-B7 examine the robustness of our results with respect to changes in parameters β and ε (details are given in Appendix B).

6.4 Separate Labor Markets for Immigrants and Natives

In the final extension of the basic model, in addition to skill-specific jobs, we also allow for origin-specific vacancies, i.e., vacancies that are suited only for natives or only for immigrants. In other words, firms perform *directed search* towards different types of workers. Hence, there will be four intermediate sectors and four labor markets. By assumption, immigrants cannot search in the market for native jobs and vice versa.

The production side is the same as in Subsection 6.2; see equations (1), (2), (25) and (26). The price of all five inputs, p_K and p_{ij}, $i = L, H$ and $j = N, I$, are still given by equations (5) and (27)-(30), respectively.

Also, in each of the four labor markets unemployed workers and unfilled vacancies match according to a technology $M(U_{ij}, V_{ij})$, where U_{ij} and V_{ij} denote respectively the number of unemployed workers and vacancies of skill type i and origin j. Furthermore, the tightness in each market θ_{ij} is defined as previously, namely, $\theta_{ij} = M(U_{ij}, V_{ij})/U_{ij}$.

The equations that determine the asset values in steady state are the same as before with the exception of (6), which now becomes

$$rJ_{ij}^V = -c_i + q(\theta_{ij}) \left[J_{ij}^F - J_{ij}^V \right] . \tag{34}$$

Moreover, free entry now implies $J_{ij}^V = 0$. Solving the system formed by the free-entry condition, (7)-(9), (12)-(13) and (34), we find that

$$p_{ij} = B_{ij}, \quad B_{ij} \equiv b_i - h_{ij} + \frac{c_i[n + r + s_i + \beta m(\theta_{ij})]}{(1-\beta)q(\theta_{ij})}, \tag{35}$$

where $h_{ij} = 0$ if $j = N$, as before. The marginal products p_{ij} can be expressed as functions of the indicators of the tightness in the labor markets θ_{ij} (see Appendix A). Equations (35) then form a system of four equations that determine the four variables θ_{ij} in terms of I_L, I_H and the other parameters of the model. Having determined θ_{ij}, we can find next the equilibrium wages w_{ij} and unemployment rates u_{ij} by substituting in the appropriate expressions (these follow from equations (16)-(17) and (22) after replacing θ_i with θ_{ij}).

Recall that natives and immigrants search in different labor markets; thus, the number of skilled or unskilled immigrants does not affect the probability that a type i and unemployed worker is native anymore. Consequently, the expected cost of an unfilled vacancy, B_{iN}, which is suited only for a native of type i, remains unchanged following an increase in immigration. In other words, the effect of higher job creation that we described previously disappears. Nevertheless, in general, the effects of a change in I_L, or I_H, on the matching rates are ambiguous since, without further restrictions, we cannot determine the impact of a change in one of the four labor inputs on the marginal products/prices of the other three. Nevertheless, consider:

Proposition 7. If the two intermediate inputs (Y_H and Y_L) are perfect substitutes ($\rho = 1$),

$$\frac{d\theta_{ij}}{dI_\kappa} \begin{cases} < 0 & \text{if} \quad j = I \text{ and } i = \kappa \\ > 0 & \text{if} \quad j = N \text{ and } i = \kappa \\ = 0 & \text{if} \quad i \neq \kappa \end{cases}, \quad i, \kappa = L, H, \; j = I, N.$$

Moreover, $\text{sign}\left(\frac{dw_{ij}}{dI_\kappa}\right) = \text{sign}\left(\frac{d\theta_{ij}}{dI_\kappa}\right)$ and $\text{sign}\left(\frac{du_{ij}}{dI_\kappa}\right) = -\text{sign}\left(\frac{d\theta_{ij}}{dI_\kappa}\right)$.

If $\rho = 1$, then high-skill and low-skill labor inputs are perfect substitutes. Hence, the market for each of these two types of labor is independent of the amount of immigrant labor of the other type. Moreover, high-skill native and immigrant labor inputs are complementary to each other. Thus, an increase in high-skill immigrant labor will decrease the marginal product of high-skill immigrants and increase that of high-skill natives. In the end, this will raise the matching rate of high-skill native workers with a concomitant increase in their wage and a decrease in their unemployment rate. The effects on the existing high-skill immigrants are exactly the opposite. An increase in low-skill immigration will have analogous effects to that of high-skill.

We simulate this alternative setting to obtain results in the more general case where $\rho < 1$. To accommodate the comparison with the previous cases we derive results for values of η and ν between 0.85 and 0.95 and keep the rest of the parameter values unchanged.[22] The results are presented in Table 8. As explained above, when separate markets for immigrants and natives exist, an increase in the number of immigrants has only price effects, because it leaves the expected cost of establishing an employment relation unchanged. This explains why in this case the impact of the skilled-intensive increase in immigration on matching rates is much smaller in magnitude (compare Tables 6 and 8). For the native workers of both types the impact is still positive in terms of both employment and wages. For the unskilled native workers, both the increase in the ratio of skilled to unskilled labor and the increase in the immigrant to native unskilled labor push their marginal product up. As the price of the unskilled-native input increases, firms respond by opening more vacancies suited for unskilled-native workers. On the other hand, there are two countervailing effects on the marginal product of the skilled native workers. First, the increase in the ratio of skilled to unskilled labor that tends to lower it, and second, the increase in the immigrant to native skilled labor that tends to raise it. However, as above, because immigrant and native skilled labor are imperfect substitutes the positive effect dominates. Thus, job creation in the skilled-native market increases.

As discussed above, when immigrants and natives compete for the same jobs the impact of immigration on previous immigrants is positive and large, mainly because of the effect of higher job entry that lowers their unemployment rate and significantly improves their bargaining position and therefore wage. Nevertheless, in the case where there are separate markets, the effect of higher job creation on previous immigrants disappears. The entry of new immigrants does not lower the expected employment cost of firms searching for immigrant labor and thus does not encourage the creation of vacancies suited for immigrants. Instead, as immigrant labor becomes relatively more abundant the price of immigrant labor input falls relative to the price of the native labor input, with negative consequence on the number of jobs available to immigrants and on their

[22]Notice that allowing for native and immigrant labor of the same type to be perfect substitutes to each other does not make sense in this set up. Given that firms can direct their vacancies towards only immigrants or only natives, if the native and immigrant labor were identical then firms would only direct their vacancies towards immigrants, who are willing to accept lower wages. If this were the case then there would be no market for native workers.

wage.[23] As above, a lower degree of substitutability between immigrant and native workers (lower ν or/and η) shifts the competition effects of additional immigrants on immigrants themselves, thereby improving the consequences on both types of native workers, given that they are complements in the production of the final good.

Next, it is worth mentioning that despite the fact that in separate markets the effect of higher job creation that comes through lower expected employment costs is absent, the effect of immigration is still positive on the native workers overall. The entry of new immigrants raises the average wage and lowers the average unemployment rate of native workers. Further, it raises their surplus and the total income of the economy.

Finally, Tables B4-B7, B9, B12, B15, B18 and B21 examine the robustness of our results with respect to changes in parameters β, ε, ψ, ζ, b_L and b_H. As before, we analyze the case where we change one parameter and keep all other values the same, as well as the case where after changing one parameter we re-calibrate the model to get the other parameter values (again, details are given in Appendix B).

7 Conclusions

In this paper we have examined the effects of immigration on the native population in a search and matching model, where search frictions generate unemployment and break the link between marginal products and wages. Within this framework, we have been able to explicitly account for the unemployment and wage effects that come from the impact of immigration on the availability of jobs. Most of the existing contributions to the immigration literature overlook such effects by adopting a Walrasian market-clearing determination of wages. Other features of the model we have developed that deserve attention are: heterogeneity in terms of skills, which allows for the analysis of distributional effects across different skill types; a generalized production technology, which requires both capital and labor and accounts for the effects of immigration on input prices; differential search costs, which can explain the equilibrium wage gap between otherwise identical native and immigrant workers; imperfect substitutability between native and immigrant workers of the same type, which makes the marginal products of these two

[23] The effect on the skilled immigrant workers is unambiguously negative, since both the increase in the ratio of skilled to unskilled labor and the increase in the ratio of the immigrant to unskilled labor lower their marginal product. For the previous unskilled immigrants, on the one hand, the rise in the ratio of skilled to unskilled labor raises their marginal product, but, on the other hand, the rise in the ratio of immigrant to native unskilled labor lowers it. Because immigrant and native labor are imperfect substitutes (i.e., $\eta < 1$) the latter effect is larger so that their marginal product falls.

labor groups different; directed search on behalf of firms, which contrasts with the previous results since the effects of immigration through the employment costs disappear; and finally endogenous skill acquisition on behalf of natives, which gives them the opportunity to react to the negative pressure of immigration.

Within the confines of our basic model we have shown that the influx of skill-biased immigration has two countervailing effects on skilled domestic labor. First, it lowers the marginal product of the skilled labor input, thereby discouraging the creation of skilled jobs. Second, it makes opening vacancies suited for skilled workers more profitable to firms, because firms anticipate that they will be able to pay lower wages to immigrants that have higher search costs. In our calibrated baseline economy, where we let immigrant and native workers of the same type be perfect substitutes in production, we have found that the second effect dominates leading to a higher availability of skilled jobs and lower unemployment among skilled native workers. The higher availability of skilled jobs also strengthens the workers' bargaining position in wage setting, which acts to mitigate the negative effect of the immigration-induced fall in their marginal product on their wages. With regard to unskilled workers, we found that skill-biased immigration raises their wages and lowers their unemployment rate, because of their higher marginal product and the lower employment cost expected by firms. We have shown that these results are robust under various choices of values for the production-function parameters that drive the elasticities of substitution between the three inputs, as well as all labor market institutional parameters. We have also shown that in a calibrated version of the model where natives and immigrants are imperfect substitutes in production, the inflow of skilled immigrants benefits skilled native workers, not only in terms of employment but also in terms of wages.

We believe that our framework is suitable for the examination of a number of interesting issues. For example, the impact of immigration in countries with different labor features and institutions, such as the degree of unionization, the replacement ratio, the efficiency of the matching function and the workers' bargaining power, can be analyzed more systematically. Also, our results apply to the case where immigration is mainly unskilled (possibly illegal) or biased towards unskilled labor. In that case, skilled labor always gains both in terms of wages and unemployment. Unskilled labor, on the other hand, benefits in terms of unemployment but may lose in terms of wages, depending on the degree of substitutability between immigrants and natives. If, in fact, this leads to a negative pressure on unskilled wages but positive on overall income, then it suggests a system of transfers from skilled to unskilled native workers accompanied by a less restrictive immigration policy towards unskilled labor. However, before reaching such a conclusion, one should also take into account the fact that low-income unskilled immigrants are likely to use social programs at higher rates than natives and contribute less to them. In other words, unskilled immigrants may impose a net fiscal burden on the host country. We leave these as possible extensions, which we plan to undertake in the future.

References

[1] Acemoglu, Daron (2001). "Good Jobs versus Bad Jobs," *Journal of Labor Economics* 19, pp. 1-21.

[2] Ben-Gad, Michael (2004). "The Economic Effects of Immigration–A Dynamic Analysis," *Journal of Economic Dynamics and Control* 28, pp. 1825-1845.

[3] Ben-Gad, Michael (2008). "Capital-Skill Complementarity and the Immigration Surplus," *Review of Economic Dynamics* 11, pp. 335-365.

[4] Blanchard, Olivier J. and Peter A. Diamond (1991). "The Aggregate Matching Function," NBER Working Paper No. 3175.

[5] Borjas, George J. (2003). "The Labor Demand Curve is Downward Sloping: Reexamining the Impact of Immigration on the Labor Market," *Quarterly Journal of Economics* 118, pp. 1335-1374.

[6] Borjas, George J. and Rachel M. Friedberg (2009). "Recent Trends in the Earnings of Immigrants to the United States," NBER Working Paper No 15406.

[7] Borjas, George J., Jeffrey Grogger and Gordon Hanson (2008). "Imperfect Substitution between Immigrants and Natives: A Reappraisal," NBER Working Paper No 13887.

[8] Borjas, George J., and Lawrence Katz (2007). "The Evolution of the Mexican-Born Workforce in the United States," in *Mexican Immigration to the United States*, edited by George J. Borjas, National Bureau of Economic Research Conference Report, Cambridge MA.

[9] Bruegemann, Bjoern and Giuseppe Moscarini (2010). "Rent Rigidity, Asymmetric Information, and Volatility Bounds in Labor," *Review of Economic Dynamics* 13, pp. 575-596.

[10] Card, David (2009). "Immigration and Inequality," *American Economic Review* 99, pp. 1–21.

[11] Diamond, Peter A. (1982). "Wage Determination and Efficiency in Search Equilibrium," *Review of Economic Studies* 49, pp. 217-27.

[12] Docquier, Frédéric, Çağlar Özden and Giovanni Peri (2010). "The Wage Effects of Immigration and Emigration," NBER Working Paper No. 16646.

[13] Griliches, Zvi. (1969). "Capital-Skill Complementarity," *Review of Economics and Statistics* 51, pp. 465-468.

[14] Hall, Robert E., and Paul R. Milgrom (2008). "The Limited Influence of Unemployment on the Wage Bargain," *American Economic Review* 98, pp. 1653-1674.

[15] Hazari, Bharat R., and Pasquale M. Sgro (2003). "The Simple Analytics of Optimal Growth with Illegal Migrants," *Journal of Economic Dynamics and Control* 28 , pp.141-151.

[16] Hosios, Arthur (1990). "On the Efficiency of Matching and Related Models of Search and Unemployment," *The Review of Economic Studies* 57, pp. 279-298.

[17] Krusell, Per, Lee E. Ohanian, Jose-Victor Rios-Rull and Giovanni L. Violante (2000). "Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis," *Econometrica* 68, pp. 1029-1053.

[18] Liu, Xiangbo (2010). "On the Macroeconomic and Welfare Effects of Illegal Immigration," *Journal of Economic Dynamics and Control* 34, 2547-2567.

[19] Laing, Derek, Theodore Palivos and Ping Wang (1995). "Learning, Matching and Growth," *Review of Economic Studies*, 62, pp. 115-29.

[20] Laing, Derek, Theodore Palivos and Ping Wang (2003). "The Economics of New Blood," *Journal of Economic Theory* 112, pp. 106-156.

[21] Mortensen, Dale T. and Christopher A. Pissarides (1994). "Job Creation and Job Destruction in the Theory of Unemployment," *Review of Economic Studies* 61, pp. 397–415.

[22] Moy, Hon M. and Chong K. Yip (2006). "The Simple Analytics of Optimal Growth with Illegal Migrants: A Clarification," *Journal of Economic Dynamics and Control* 30, 2469-2475.

[23] NELP (National Employment Law Project) (2002). "Immigrants' Eligibility for Unemployment Compensation," found at http://www.nelp.org/site/publications/P500/.

[24] Ortega, Javier (2000). "Pareto-Improving Immigration in an Economy with Equilibrium Unemployment," *Economic Journal* 110, pp. 92–112.

[25] Ottaviano, Gianmarco I. P., and Giovanni Peri (2012). "Rethinking the Effects of Immigration on Wages," *Journal of the European Economic Association* 10, pp. 152-197.

[26] Palivos, Theodore (2009). "Welfare Effects of Illegal Immigration," *Journal of Population Economics* 22, 131-144.

[27] Petrongolo, Barbara and Christopher Pissarides (2001). "Looking into the Black Box: A Survey of the Matching Function," *Journal of Economic Literature* 31, pp. 390-431.

[28] Pissarides, Christopher (2009). "The Unemployment Volatility Puzzle: Is Wage Stickiness the Answer?," *Econometrica* 77, pp. 1339-1369.

[29] Polgreen, Linnea, and Pedro Silos (2008). "Capital–Skill Complementarity and Inequality: A Sensitivity Analysis," *Review of Economic Dynamics* 11, 302-313.

[30] Shimer, Robert (2005). "The Cyclical Behavior of Equilibrium Unemployment and Vacancies," *American Economic Review*, 95, pp. 25-49.

Table 1: Parameterization of the baseline model: general case

$\varepsilon = 0.5$	Standard, within the range of estimates in Petrongolo and Pissarides (2001).
$\beta = 0.5$	Satisfies the Hosios (1990) condition.
$\rho = 0.401, \gamma = -0.495$	Krusell et al. (2000)
	Measured from the Data:
$r = 0.004$	The monthly interest rate. $*$
$s_H = 0.019, s_L = 0.034,$	The monthly skilled and unskilled separation rates. $**$
$\delta = 0.0061$	The monthly depreciation rate. §
$I_H = 0.036, I_L = 0.089$	The (normalized) number of skilled and unskilled immigrants. †
$n = 0.00071$	The monthly growth rate of the native labor force. †
$\lambda = 0.726$	The share of unskilled labor force. ‡
	Jointly Calibrated to Match:
$\alpha = 0.517$, $x = 0.051$	The employment rates of skilled and unskilled workers:
$c_L = 0.421$, $c_H = 0.556$	0.976 and 0.939. ‡
$b_L = 0.279$, $b_H = 0.449$	The capital-output ratio: 1.348. §
$h_L = 1.182$, $h_H = 4.203$	The college-plus wage premium: 61.1%. ‡
$\xi = 0.714$	The ratio of unemployment to employment income of 0.71% for both skill groups (Hall and Milgrom, 2008).
	The unskilled and skilled native-immigrant wage gap: -19.0% and -18.8%. †
	The vacancy to unemployment ratio: 0.620.⁂

$*$ Federal Reserve Bank of Saint Louis

$**$ Matched data from the Current Population Survey.

§ Bureau of Economic Analysis.

† Public Use Microdata of the 1990 and 2000 Censuses.

‡ March Current Population Survey.

⁂ Conference Board's Help-Wanted Index.

Table 2. The Effects of the 2000-2009 Immigration Influx

(Percentage Changes)

	$h_{HI}=0$ $h_{LI}=0$	$h_{HI}>0$ $h_{LI}=0$	$h_{HI}=0$ $h_{LI}>0$	$h_{HI}>0$ $h_{LI}>0$
	Unskilled Natives			
w_{LN}	0.43	0.53	0.49	0.59
u_{LN}	-0.69	-0.84	-11.01	-11.00
	Unskilled Immigrants			
w_{LI}	same as natives	same as natives	2.87	2.97
u_{LI}	same as natives	same as natives	same as natives	same as natives
	Overall Unskilled			
w_L	same as natives	same as natives	-0.22	-0.11
u_L	same as natives	same as natives	same as natives	same as natives
θ_L	1.50	1.83	23.38	23.36
	Skilled Natives			
w_{HN}	-0.69	-0.70	-0.47	-0.48
u_{HN}	1.13	-17.32	0.76	-17.26
	Skilled Immigrants			
w_{HI}	same as natives	2.74	same as natives	2.93
u_{HI}	same as natives	same as natives	same as natives	same as natives
	Overall Skilled			
w_H	same as natives	-1.50	same as natives	-1.27
u_H	same as natives	same as natives	same as natives	same as natives
θ_H	-2.38	35.42	-1.59	35.29
	Overall Natives			
w_N	-0.01	0.08	0.05	0.15
u_N	-0.38	-2.31	-8.39	-11.79
surplus 1	0.15	0.32	0.43	0.60
surplus 2	0.17	0.47	0.72	1.00
	Overall			
w	0.19	-0.03	-0.18	-0.38
u	-0.60	-2.71	-8.45	-12.10
Y	6.87	7.06	7.24	7.41
surplus 1	6.84	6.69	6.70	6.55
surplus 2	6.87	6.85	6.98	6.95

Notes: The variable w indicates the wage rate, u the unemployment rate, θ the tightness in the labor market, and Y the output of the final good. The subscript L stands for unskilled, H for skilled, N for native and I for immigrant. The term "surplus" refers to total income net of the flow cost of vacancies. The measure "surplus 1" includes the unemployment benefits, whereas the measure "surplus 2" does not.

Table 3. Sensitivity of the Calibration Results with respect to Production Parameters in the General Model ($\boldsymbol{\rho} < 1, \boldsymbol{h_{LI}} > 0, \boldsymbol{h_{HI}} > 0$)

(Percentage Changes)

	$\rho = 0 \quad \gamma = -1$ ($\sigma_{LK} = \sigma_{LH} = 1$, $\sigma_{HK} = 0.5$)	$\rho = 0.5 \quad \gamma = 0$ ($\sigma_{LK} = \sigma_{LH} = 2$, $\sigma_{HK} = 1$)	$\rho = 0.5 \quad \gamma = -1$ ($\sigma_{LK} = \sigma_{LH} = 2$, $\sigma_{HK} = 0.5$)	$\rho = 0 \quad \gamma = 0$ ($\sigma_{LK} = \sigma_{LH} = 1$, $\sigma_{HK} = 1$)
	Unskilled Natives			
w_{LN}	0.73	0.52	0.52	0.75
u_{LN}	-14.75	-10.26	-10.36	-14.29
	Unskilled Immigrants			
w_{LI}	5.46	2.54	2.59	5.14
u_{LI}	same as natives	same as natives	same as natives	same as natives
	Overall Unskilled			
w_L	-0.12	-0.14	-0.15	-0.08
u_L	same as natives	same as natives	same as natives	same as natives
θ_L	31.62	21.73	21.95	30.59
	Skilled Natives			
w_{HN}	-0.50	-0.43	-0.43	-0.53
u_{HN}	-15.13	-17.89	-17.93	-15.16
	Skilled Immigrants			
w_{HI}	1.80	3.38	3.41	1.78
u_{HI}	same as natives	same as natives	same as natives	same as natives
	Overall Skilled			
w_H	-1.17	-1.25	-1.25	-1.20
u_H	same as natives	same as natives	same as natives	same as natives
θ_H	30.89	36.60	36.69	30.96
	Overall Natives			
w_N	0.01	0.16	0.16	0.03
u_N	-14.79	-11.26	-11.35	-14.38
surplus 1	0.55	0.64	0.57	0.65
surplus 2	1.12	1.01	0.95	1.19
	Overall			
w	-0.38	-0.40	-0.40	-0.37
u	-15.13	-11.56	-11.65	-14.72
Y	7.72	7.34	7.35	7.68
surplus 1	6.64	6.53	6.52	6.66
surplus 2	7.21	6.90	6.89	7.19

Notes: See Table 2.

Table 4. The Effects of a Skill-Balanced Immigration

(Percentage Changes)

Unskilled Natives		**Skilled Natives**	
w_{LN}	0.13	w_{HN}	0.26
u_{LN}	-11.54	u_{HN}	-14.91
Unskilled Immigrants		Skilled Immigrants	
w_{LI}	2.52	w_{HI}	3.37
u_{LI}	same as natives	u_{HI}	same as natives
Overall Unskilled		Overall Skilled	
w_L	-0.65	w_H	-0.38
u_L	same as natives	u_H	same as natives
θ_L	24.49	θ_H	30.50
Overall Natives		Overall	
w_N	0.14	w	-0.58
u_N	-11.97	u	-11.97
surplus 1	0.58	surplus 1	6.35
surplus 2	0.98	surplus 2	6.73
		Y	7.18

Notes: See Table 2.

Table 5. Sensitivity of the Calibration Results with respect to the Elasticity of Substitution between Unskilled Natives and Immigrants

(Percentage Changes)

	$\eta = 0.95$ ($\sigma_{LILN} = 20$)	$\eta = 0.90$ ($\sigma_{LILN} = 10$)	$\eta = 0.85$ ($\sigma_{LILN} = 6.67$)
	Unskilled Natives		
w_{LN}	1.48	1.55	1.64
u_{LN}	-14.70	-14.99	-15.29
	Unskilled Immigrants		
w_{LI}	20.69	12.69	6.36
u_{LI}	same as natives	same as natives	same as natives
	Overall Unskilled		
w_L	-3.24	-3.08	-2.92
u_L	same as natives	same as natives	same as natives
θ_L	31.69	32.32	32.99
	Skilled Natives		
w_{HN}	-1.58	-1.49	-1.40
u_{HN}	-18.96	-19.04	-19.12
	Skilled Immigrants		
w_{HI}	2.92	3.08	3.24
u_{HI}	same as natives	same as natives	same as natives
	Overall Skilled		
w_H	-2.52	-2.44	-2.34
u_H	same as natives	same as natives	same as natives
θ_H	38.82	38.99	39.16
	Overall Natives		
w_N	0.17	0.24	0.32
u_N	-15.17	-15.43	-15.71
surplus 1	0.66	0.73	0.80
surplus 2	1.40	1.49	1.59
	Overall		
w	-2.75	-2.63	-2.50
u	-15.50	-15.77	-16.05
Y	5.70	5.85	6.01
surplus 1	4.34	4.46	4.59
surplus 2	5.01	5.15	5.31

Notes: See Table 2.

Table 6. Sensitivity of the Calibration Results with respect to the Elasticity of Substitution between Skilled and Unskilled Natives and Immigrants

(Percentage Changes)

	$\eta = 0.95$ $\nu = 0.95$ $(\sigma_{LILN} = 20)$ $(\sigma_{HIHN} = 20)$	$\eta = 0.90$ $\nu = 0.95$ $(\sigma_{LILN} = 10)$ $(\sigma_{HIHN} = 20)$	$\eta = 0.85$ $\nu = 0.95$ $(\sigma_{LILN} = 6.67)$ $(\sigma_{HIHN} = 20)$	$\eta = 0.95$ $\nu = 0.90$ $(\sigma_{LILN} = 20)$ $(\sigma_{HIHN} = 10)$	$\eta = 0.95$ $\nu = 0.85$ $(\sigma_{LILN} = 20)$ $(\sigma_{HIHN} = 6.67)$
	Unskilled Natives				
w_{LN}	0.21	0.28	0.36	0.27	0.33
u_{LN}	-16.45	-16.78	-17.15	-16.56	-16.68
	Unskilled Immigrants				
w_{LI}	35.38	21.35	11.64	36.35	37.39
u_{LI}	same as natives	same as natives	same as natives	same as natives	same as natives
	Overall Unskilled				
w_L	-4.68	-4.53	-4.36	-4.62	-4.55
u_L	same as natives	same as natives	same as natives	same as natives	same as natives
θ_L	35.69	36.44	37.25	35.94	36.20
	Skilled Natives				
w_{HN}	0.20	0.29	0.39	0.28	0.39
u_{HN}	-22.05	-22.14	-22.24	-22.20	-22.36
	Skilled Immigrants				
w_{HI}	41.27	42.42	43.67	25.20	13.67
u_{HI}	same as natives	same as natives	same as natives	same as natives	same as natives
	Overall Skilled				
w_H	-6.05	-5.95	-5.85	-5.87	-5.69
u_H	same as natives	same as natives	same as natives	same as natives	same as natives
θ_H	45.27	45.46	45.66	45.58	45.90
	Overall Natives				
w_N	0.13	0.20	0.28	0.19	0.27
u_N	-17.06	-17.37	-17.70	-17.18	-17.30
surplus 1	0.51	0.58	0.65	0.57	0.65
surplus 2	1.52	1.62	1.73	1.60	1.69
	Overall				
w	-5.09	-4.97	-4.83	-4.99	-4.88
u	-17.40	-17.71	-18.04	-17.52	-17.64
Y	3.83	3.99	4.16	3.94	4.07
surplus 1	2.07	2.18	2.31	2.16	2.27
surplus 2	2.91	3.06	3.22	3.02	3.14

Notes: See Table 2.

Table 7. The Effects of the 2000-2009 Immigration Influx with Endogenous Human Capital Accumulation

(Percentage Changes)

Unskilled Natives		**Skilled Natives**	
w_{LN}	0.37	w_{HN}	-0.13
u_{LN}	-10.78	u_{HN}	-17.65
Unskilled Immigrants		**Skilled Immigrants**	
w_{LI}	2.66	w_{HI}	3.42
u_{LI}	same as natives	u_{HI}	same as natives
Overall Unskilled		**Overall Skilled**	
w_L	-0.33	w_H	-0.92
u_L	same as natives	u_H	same as natives
θ_L	22.89	θ_H	36.10
Overall Natives		**Overall**	
w_N	0.02	w	-0.48
u_N	-11.46	u	-11.81
surplus 1	0.47	surplus 1	6.45
surplus 2	0.86	surplus 2	6.83
λ	0.32	Y	7.30

Notes: See Table 2.

Table 8. The Effects of the 2000-2009 Immigration Influx - Separate Labor Markets for Immigrants and Natives

(Percentage Changes)

	$\eta = 0.95$ $\nu = 0.95$ $(\sigma_{LILN} = 20)$ $(\sigma_{HIHN} = 20)$	$\eta = 0.90$ $\nu = 0.95$ $(\sigma_{LILN} = 10)$ $(\sigma_{HIHN} = 20)$	$\eta = 0.85$ $\nu = 0.95$ $(\sigma_{LILN} = 6.67)$ $(\sigma_{HIHN} = 20)$	$\eta = 0.95$ $\nu = 0.90$ $(\sigma_{LILN} = 20)$ $(\sigma_{HIHN} = 10)$	$\eta = 0.95$ $\nu = 0.85$ $(\sigma_{LILN} = 20)$ $(\sigma_{HIHN} = 6.67)$
	Unskilled Natives				
w_{LN}	0.23	0.31	0.41	0.30	0.38
u_{LN}	-1.38	-2.11	-3.11	-1.85	-2.44
θ_{LN}	3.40	5.25	7.87	4.56	6.06
	Unskilled Immigrants				
w_{LI}	-2.84	-5.69	-8.34	-2.73	-2.59
u_{LI}	0.11	0.24	0.39	0.10	0.10
θ_{LI}	-0.23	-0.50	-0.80	-0.22	-0.20
	Overall Unskilled				
w_L	-4.89	-4.77	-4.65	-4.83	-4.75
u_L	-6.29	-7.06	-8.10	-6.76	-7.36
	Skilled Natives				
w_{HN}	0.01	0.11	0.23	0.09	0.18
u_{HN}	-0.07	-1.08	-2.48	-0.97	-2.23
θ_{HN}	0.15	2.48	5.72	2.22	5.19
	Skilled Immigrants				
w_{HI}	-3.74	-3.59	-3.41	-7.16	-10.38
u_{HI}	0.06	0.06	0.05	0.13	0.20
θ_{HI}	-0.12	-0.11	-0.11	-0.25	-0.40
	Overall Skilled				
w_H	-6.42	-6.33	-6.23	-6.30	-6.18
u_H	-7.34	-8.38	-9.79	-8.28	-9.58
	Overall Natives				
w_N	0.11	0.20	0.29	0.19	0.28
u_N	-1.12	-1.91	-2.99	-1.67	-2.40
surplus 1	0.31	0.39	0.49	0.38	0.46
surplus 2	0.54	0.81	1.19	0.74	1.01
	Overall				
w	-5.33	-5.24	-5.14	-5.24	-5.13
u	-6.66	-7.48	-8.60	-7.22	-7.96
Y	3.33	3.66	4.10	3.57	3.88
surplus 1	2.23	2.35	2.47	2.32	2.42
surplus 2	2.60	2.93	3.35	2.84	3.14

Notes: See Table 2.

Figure1. The Structure of the Basic Model

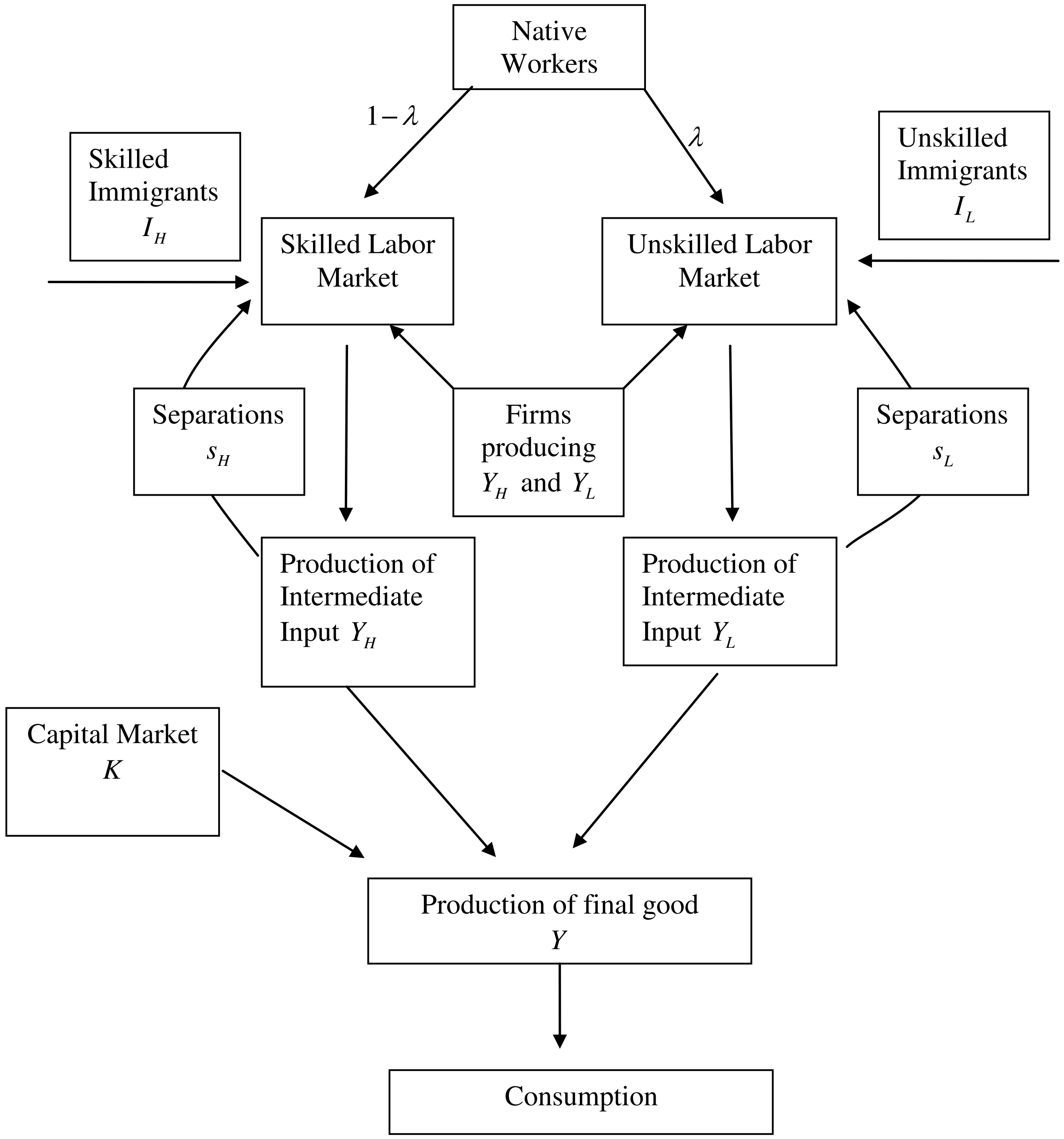


Figure 2. Existence and Uniqueness in the Basic Model – An Increase in High-Skill Immigration when There Are No Search Costs with and without Endogenous Skill Acquisition

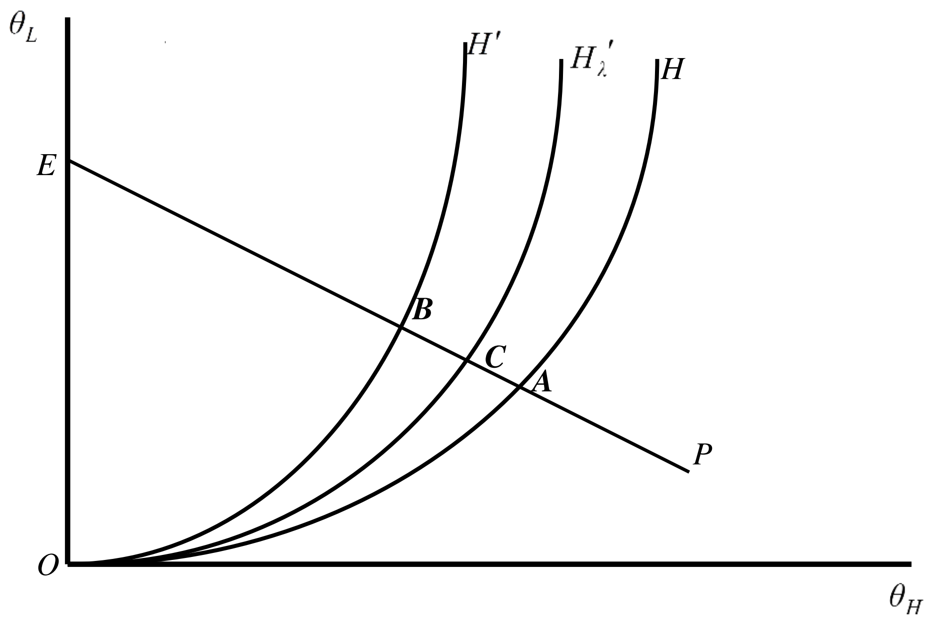
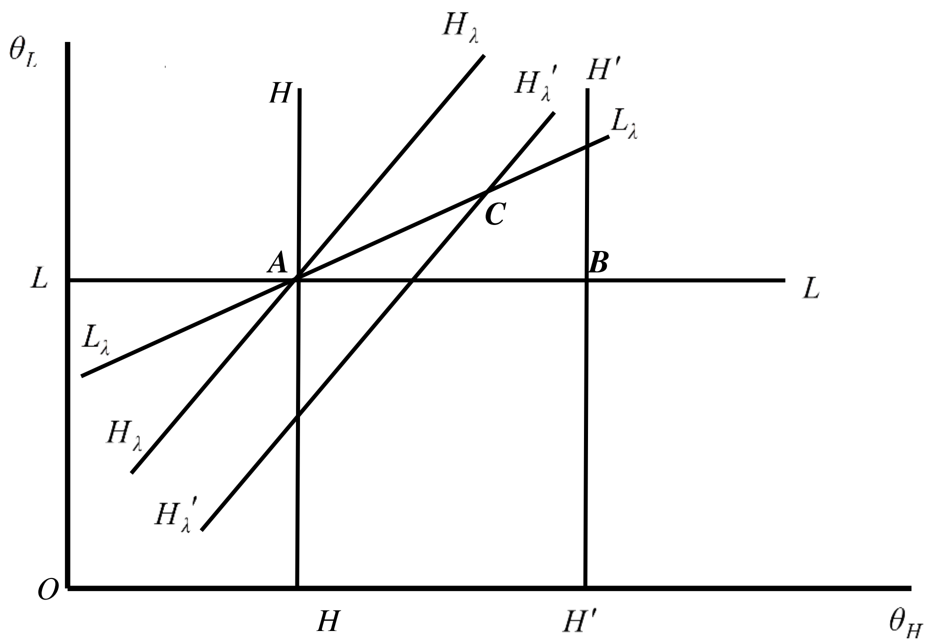


Figure 3. An Increase in High-Skill Immigration when There Are Search Costs and Perfect Substitutability with and without Endogenous Skill Acquisition



Appendix A: Derivations and Proofs

(A major portion of this Appendix is not intended for publication)

Derivation of equations (14)-(17). The change in the number of unemployed skilled workers ($U_H = U_{HN} + U_{HI}$) is given by the difference between the sum of new births ($n(1-\lambda+I_H)$) and break-ups ($s_H Y_H$) and the sum of deaths (nU_H) and matches ($m(\theta_H)U_H$) of skilled workers; that is,

$$\dot{U}_H = n(1-\lambda+I_H) + s_H Y_H - [nU_H + m(\theta_H)U_H],$$

where a dot over a variable denotes its time derivative. Setting $\dot{U}_H$ equal to zero and using the identity $Y_H + U_H = 1-\lambda+I_H$ yields equation (14) in the main text. The other equations follow similarly.

Derivation of the system of equations (20)-(22). Using (1) and (2), equations (3), (4) and (5) can be written as

$$p_L = \alpha\left\{\alpha + (1-\alpha)\left[x\left(\frac{K}{Y_H}\right)^{\gamma} + (1-x)\right]^{\frac{\rho}{\gamma}}\left(\frac{Y_H}{Y_L}\right)^{\rho}\right\}^{\frac{1-\rho}{\rho}}, \tag{A1}$$

$$p_H = (1-\alpha)(1-x)\left[x\left(\frac{K}{Y_H}\right)^{\gamma} + (1-x)\right]^{\frac{1-\gamma}{\gamma}}\left\{\frac{\alpha\left(\frac{Y_H}{Y_L}\right)^{-\rho}}{\left[x\left(\frac{K}{Y_H}\right)^{\gamma} + (1-x)\right]^{\frac{\rho}{\gamma}}} + (1-\alpha)\right\}^{\frac{1-\rho}{\rho}}, \tag{A2}$$

and

$$p_K = (1-\alpha)x\left[x + (1-x)\left(\frac{K}{Y_H}\right)^{-\gamma}\right]^{\frac{1-\gamma}{\gamma}}\left\{\frac{\alpha\left(\frac{Y_H}{Y_L}\right)^{-\rho}}{\left[x\left(\frac{K}{Y_H}\right)^{\gamma} + (1-x)\right]^{\frac{\rho}{\gamma}}} + (1-\alpha)\right\}^{\frac{1-\rho}{\rho}}, \tag{A3}$$

respectively. Taking the ratio of (A2) to (A3) we have

$$\frac{p_H}{p_K} = \frac{1-x}{x}\left(\frac{K}{Y_H}\right)^{1-\gamma}, \quad \text{where} \quad p_K = r+\delta. \tag{A4}$$

Moreover, taking the ratio of equations (14) and (15), we get

$$\frac{Y_H}{Y_L} = \frac{m(\theta_H)[n+s_L+m(\theta_L)](1-\lambda+I_H)}{m(\theta_L)[n+s_H+m(\theta_H)](\lambda+I_L)}. \tag{A5}$$

Combining (7), (10) and (12) we obtain

$$S_{ij} = \frac{1}{1-\beta}\frac{p_i - w_{ij}}{n+r+s_i}. \tag{A6}$$

Next, subtracting (8) from (9) and using (13) and (A6) yields the expression for the wage rates (equation 22). Moreover, substitute (22) in (A6) to get

$$S_{ij} = \frac{p_i - b_i + h_{ij}}{n + r + s_i + \beta m(\theta_i)}. \tag{A7}$$

Substituting (12) and (A7) in (6), after taking into account the free entry condition (10), yields

$$p_i = B_i, \quad \text{where} \quad B_i \equiv b_i - (1 - \phi_i)h_{iI} + \frac{c_i[n + r + s_i + \beta m(\theta_i)]}{(1-\beta)q(\theta_i)} \tag{A8}$$

and by assumption $h_{iN} = 0$ for $i = H, L$. Combining equations (A1), (A5) and (A8) yields (20), where the expression for k follows from (A4) and (A8). Similarly, combining (A2), (A5) and (A8) yields (21).

Derivation of equation (23). Substituting (13) and (A7) in (8) we get

$$(r+n)J_{ij}^U = \frac{\beta m(\theta_i)p_i + (n + r + s_i)(b_i - h_{ij})}{n + r + s_i + \beta m(\theta_i)}. \tag{A11}$$

Next rewrite (22) taking into account (A11) to obtain (23).

Proof of Proposition 1. Combining equations (20) and (21), we arrive at the following equation

$$\frac{\left(\frac{B_L}{\alpha}\right)^{\frac{\rho}{1-\rho}} - \alpha}{1-\alpha} = \frac{\alpha}{\left[\frac{B_H}{(1-\alpha)(1-x)}\left[xk^\gamma + (1-x)\right]^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\rho}{1-\rho}} - (1-\alpha)}, \tag{A9}$$

where B_L, B_H and k are defined in the main text. Simple differentiation shows that B_H and k are both increasing functions of θ_H. On the other hand, B_L is an increasing function of θ_L. Rearranging equation (A9) we obtain

$$X = \frac{\alpha\Psi}{\Psi - (1-\alpha)}, \tag{A10}$$

where

$$X \equiv \left(\frac{B_L}{\alpha}\right)^{\frac{\rho}{1-\rho}} \quad \text{and} \quad \Psi \equiv \left[\frac{B_H}{(1-\alpha)(1-x)}\left[xk^\gamma + (1-x)\right]^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\rho}{1-\rho}}.$$

Equation (A10) defines a locus of θ_H and θ_L along which a firm is indifferent between opening a low-skill and a high-skill vacancy. This locus, which is labeled EP in Figure 2, has negative slope:

$$\frac{d\theta_L}{d\theta_H}|_{EP} = \frac{-\frac{\alpha(1-\alpha)}{[\Psi-(1-\alpha)]^2}\frac{d\Psi}{dB_H}\frac{dB_H}{d\theta_H}}{\frac{dX}{dB_L}\frac{dB_L}{d\theta_L}} < 0.$$

Moreover, equation (21) defines a locus of θ_H and θ_L along which a high-skill vacancy has zero expected profit. This locus, which is labeled as OH in Figure 2, has the following properties:

$$\lim_{\theta_H \to 0} \theta_L = 0, \quad \lim_{\theta_H \to \overline{\theta_H}} \theta_L = \infty, \text{ where } \overline{\theta_H} < \infty, \quad \frac{d\theta_L}{d\theta_H}|_{OH} = \frac{\frac{dB_H}{d\theta_H} - \frac{\partial p_H}{\partial \theta_H}}{\frac{\partial p_H}{\partial \theta_L}} > 0,$$

where p_H is equal to the (LHS) of (21) and hence $\partial p_H/\partial\theta_H < 0$. Equations (21) and (A10) determine the equilibrium values of θ_H and θ_L. To ensure an intersection of the EP and OH

curves in the positive orthant we must impose conditions that guarantee that the intercept of the EP curve is positive. One can easily show that $\Psi_0 \equiv \lim_{\theta_H \to 0} \Psi(\theta_H) < \infty$ and $X_0 \equiv \lim_{\theta_L \to 0} X(\theta_L) < \infty$. Moreover,

$$\lim_{\theta_L \to \infty} X(\theta_L) = \begin{cases} \infty & \text{if} \quad \rho > 0 \\ 0 & \text{if} \quad \rho < 0 \end{cases} \quad \text{and} \quad \frac{dX(\theta_L)}{d\theta_L} = \begin{cases} > 0 & \text{if} \quad \rho > 0 \\ < 0 & \text{if} \quad \rho < 0 \end{cases}.$$

Given these properties, existence and uniqueness is ensured if

$$0 < (X_0)^{\frac{1}{\rho}} < \left[\frac{\alpha \Psi_0}{\Psi_0 - (1-\alpha)} \right]^{\frac{1}{\rho}}.$$

Condition 1. A firm that meets a native worker of type i will decide to establish an employment relation if $J_{iN}^F \geq J_i^V$. Using equations (7) and (10) then it must be the case that $p_i \geq w_{iN}$, which using equation (22) can be written as $p_i \geq b_i$. Finally, using equation (A8) we get the condition given in the main text.

Derivation of equation (24). If $h_{ij} = 0$ then equation (22) implies that $w_{ij} = w_i$ and equation (7) that $J_{ij}^F = J_i^F \ \forall j$. It follows then from equations (6) and (10) that

$$J_i^F = \frac{c_i}{q(\theta_i)}.$$

On the other hand, (7) and (10) imply

$$J_i^F = \frac{p_i - w_i}{(n + r + s_i)}.$$

Combining the last two equations yields

$$w_i = p_i - (n + r + s_i) \frac{c_i}{q(\theta_i)}, \quad i = H, L,$$

and, after using (A8), (24).

Proof of Proposition 2. Differentiating equations (21) and (A10) we obtain

$$\frac{d\theta_H}{dI_H} = \frac{-\frac{1}{\rho} \frac{dX}{dB_L} \frac{dB_L}{d\theta_L} \frac{\partial p_H}{\partial \Lambda} \frac{\partial \Lambda}{\partial I_H}}{D_1} < 0 \quad \text{and} \quad \frac{d\theta_L}{dI_H} = \frac{\frac{1}{\rho} \frac{\alpha(1-\alpha)}{[\Psi - (1-\alpha)]^2} \frac{d\Psi}{dB_H} \frac{dB_H}{d\theta_H} \frac{\partial p_H}{\partial \Lambda} \frac{\partial \Lambda}{\partial I_H}}{D_1} > 0,$$

where

$$D_1 = \frac{1}{\rho} \frac{dX}{dB_L} \frac{dB_L}{d\theta_L} \left(\frac{dp_H}{d\theta_H} - \frac{\partial B_H}{\partial \theta_H} \right) - \frac{1}{\rho} \frac{\alpha(1-\alpha)}{[\Psi - (1-\alpha)]^2} \frac{d\Psi}{dB_H} \frac{dB_H}{d\theta_H} \frac{\partial p_H}{\partial \theta_L} < 0.$$

The results regarding the unemployment variables (u_{HN} and u_{LN}) and the wage rates (w_H and w_L) follow immediately from equations (16)-(17) and (24). Finally, the results regarding a change in I_L follow similarly.

Proof of Proposition 3. If $\rho = 1$ then equation (20) and (21) become independent of each other. More specifically, (20) simplifies to $\alpha = B_L$, which determines θ_L as a function of I_L alone. Similarly, equation (21) simplifies to $(1-\alpha)(1-x)\left[xk^\gamma + (1-x)\right]^{\frac{1-\gamma}{\gamma}} = B_H$, which determines

θ_H as a function of I_H (recall that equations (2) and (5) imply that k assumes a constant value). Simple differentiation then shows that

$$\frac{d\theta_H}{dI_H} = \frac{1-\lambda}{(1-\lambda+I_H)^2}\frac{h_{LH}}{D_2} > 0,$$

where

$$D_2 = \frac{c_H}{1-\beta}\frac{\beta m'(\theta_H)q(\theta_H) - q'(\theta_H)[n+r+s_H+\beta m(\theta_H)]}{[q(\theta_H)]^2} > 0$$

The results regarding the unemployment variables (u_{Hj} and u_{Lj}) and the wage rates (w_{Hj} and w_{Lj}) follow immediately from equations (16)-(17) and (22). Finally, the results regarding a change in I_L follow similarly after differentiating (20).

Proof of Proposition 4. The proof is very similar to that of Proposition 3 and thus omitted.

Expressing the marginal products in Subsection 6.2 as functions of θ_i's. Using equations (1), (2), (25) and (26), we find Y/Y_L as a function of θ_i. Specifically,

$$\frac{Y}{Y_L} = \left[\alpha + (1-\alpha)\left(\frac{Q}{Y_L}\right)^{\rho}\right]^{\frac{1}{\rho}},$$

$$\frac{Q}{Y_L} = \left[x\left(\frac{K}{Y_H}\right)^{\gamma} + (1-x)\right]^{\frac{1}{\gamma}}\frac{Y_H}{Y_L},$$

$$\frac{K}{Y_H} = \frac{k}{\left[\zeta + (1-\zeta)\left(\frac{Y_{HI}}{Y_{HN}}\right)^{\nu}\right]^{1/\nu}} = \frac{k}{\left[\zeta + (1-\zeta)\left(\frac{I_H}{1-\lambda}\right)^{\nu}\right]^{1/\nu}}$$

where

$$k \equiv \frac{K}{Y_{HN}}, \quad \frac{Y_H}{Y_L} = \frac{\left[\zeta + (1-\zeta)\left(\frac{I_H}{1-\lambda}\right)^{\nu}\right]^{1/\nu}}{\left[\psi + (1-\psi)\left(\frac{I_L}{\lambda}\right)^{\eta}\right]^{1/\eta}}\frac{A_H}{A_L}\frac{1-\lambda}{\lambda},$$

since, in steady state, $Y_{LN}= A_L\lambda$, $Y_{LI}= A_L I_L$, $Y_{HN}= A_H(1-\lambda)$, and $Y_{HI}= A_H I_H$ (recall that $A_i= m(\theta_i)/[n+s_i+m(\theta_i)]$). Moreover, using (5) and (28), we have

$$\frac{p_K}{p_{HN}} = \frac{x}{(1-x)\zeta}\frac{k^{\gamma-1}}{\left(\frac{Y_H}{Y_{HN}}\right)^{\gamma-\nu}}$$

or

$$k = (p_{HN})^{\frac{1}{1-\gamma}}\left[\frac{x}{(1-x)\zeta(r+\delta)}\right]^{\frac{1}{1-\gamma}}\left(\frac{Y_H}{Y_{HN}}\right)^{\frac{\gamma-\nu}{\gamma-1}}$$

or

$$k = (p_{HN})^{\frac{1}{1-\gamma}}\left[\frac{x}{(1-x)\zeta(r+\delta)}\right]^{\frac{1}{1-\gamma}}\left(\zeta + (1-\zeta)\left(\frac{I_H}{1-\lambda}\right)^{\nu}\right)^{\frac{\gamma-\nu}{(\gamma-1)\nu}}.$$

Also,

$$\frac{Y_L}{Y_{LN}} = \left[\psi + (1-\psi)\left(\frac{Y_{LI}}{Y_{LN}}\right)^{\eta}\right]^{\frac{1}{\eta}} = \left[\psi + (1-\psi)\left(\frac{I_L}{\lambda}\right)^{\eta}\right]^{\frac{1}{\eta}}.$$

Using all the above equations, we can express, through consecutive substitutions, p_{LN} as a function of the matching rates $m(\theta_i)$ and hence the tightness prevailing in each market θ_i.

Notice, from equation (29), that to express p_{LI} as a function of the matching rates we need only one additional ratio

$$\frac{Y_L}{Y_{LI}} = \left[\psi\left(\frac{Y_{LI}}{Y_{LN}}\right)^{-\eta} + (1-\psi)\right]^{\frac{1}{\eta}} = \left[\psi\left(\frac{I_L}{\lambda}\right)^{-\eta} + (1-\psi)\right]^{\frac{1}{\eta}}$$

since

$$\frac{Y_{LI}}{Y_{LN}} = \frac{I_L}{\lambda}.$$

Similarly, for p_{HN} we need to compute the following ratios

$$\frac{Y}{Q} = \left[\alpha\left(\frac{Q}{Y_L}\right)^{-\rho} + (1-\alpha)\right]^{\frac{1}{\rho}},$$

$$\frac{Q}{Y_H} = \left[x\left(\frac{K}{Y_H}\right)^{\gamma} + (1-x)\right]^{\frac{1}{\gamma}},$$

$$\frac{Y_H}{Y_{HN}} = \left[\zeta + (1-\zeta)\left(\frac{Y_{HI}}{Y_{HN}}\right)^{\nu}\right]^{\frac{1}{\nu}} = \left[\zeta + (1-\zeta)\left(\frac{I_H}{1-\lambda}\right)^{\nu}\right]^{\frac{1}{\nu}}.$$

Finally, to express p_{HI} as a function of the matching rates we need only one additional ratio

$$\frac{Y_H}{Y_{HI}} = \left[\zeta\left(\frac{Y_{HI}}{Y_{HN}}\right)^{-\nu} + (1-\zeta)\right]^{\frac{1}{\nu}} = \left[\zeta\left(\frac{I_H}{1-\lambda}\right)^{-\nu} + (1-\zeta)\right]^{\frac{1}{\nu}}.$$

Proof of Proposition 5. If $\rho = 1$ then the two equations described by (31) become independent of each other. To find the effect of a change in I_H on θ_H differentiate (31) when $i = H$, using the equations that express p_{ij} as functions of θ_i (derived above). The results regarding the unemployment variables (u_{Hj} and u_{Lj}) and the wage rates (w_{Hj} and w_{Lj}) follow immediately from equations (16)-(17) and (22).

Derivation of equation (33). Combining equations (A11) and (32), we get (33).

Proof of Proposition 6. We illustrate the results regarding the effects of a change in I_H. The effects of a change in I_L follow similarly. Consider first the effect of a change in θ_i on λ. Substituting (20) and (21) in (33) yields

$$(1-\lambda)\overline{z}(r+n) = b_H - b_L + \frac{\beta}{1-\beta}(c_H\theta_H - c_L\theta_L). \tag{A12}$$

Differentiating (A12) we obtain

$$\frac{d\lambda}{d\theta_H} = -\frac{1}{\overline{z}(r+n)}\frac{\beta}{1-\beta}c_H < 0 \text{ and } \frac{d\lambda}{d\theta_L} = \frac{1}{\overline{z}(r+n)}\frac{\beta}{1-\beta}c_L > 0.$$

a) Next differentiate equations (21) and (A10) to get

$$\frac{d\theta_H}{dI_H} = \frac{-\frac{1}{\rho}\frac{dX}{dB_L}\frac{dB_L}{d\theta_L}\frac{\partial p_H}{\partial \Lambda}\frac{\partial \Lambda}{\partial I_H}}{D_3} < 0 \text{ and } \frac{d\theta_L}{dI_H} = \frac{\frac{\alpha(1-\alpha)}{[\Psi-(1-\alpha)]^2}\frac{d\Psi}{dB_H}\frac{dB_H}{d\theta_H}\frac{\partial p_H}{\partial \Lambda}\frac{\partial \Lambda}{\partial I_H}}{D_3} > 0,$$

where

$$D_3 = \frac{1}{\rho}\frac{dX}{d\theta_L}\left(\frac{\partial p_H}{\partial \theta_H} + \frac{\partial p_H}{\partial \lambda}\frac{d\lambda}{d\theta_H} - \frac{\partial B_H}{\partial \theta_H}\right) - \frac{1}{\rho}\frac{\alpha(1-\alpha)}{[\Psi-(1-\alpha)]^2}\frac{d\Psi}{d\theta_H}\left(\frac{\partial p_H}{\partial \theta_L} + \frac{\partial p_H}{\partial \lambda}\frac{d\lambda}{d\theta_H}\right) < 0.$$

Comparing these derivatives with the ones derived in Proposition 2, it follows that, starting from the same equilibrium, the effect of a change in I_H is smaller, in absolute value, on both θ_H and θ_L when λ is endogenously determined. The other results follow immediately from equations (16)-(17) and (24).

b) If $\rho = 1$ equations (20) and (21) simplify to $\alpha = B_L$ and $(1-\alpha)(1-x)\left[xk^{\gamma} + (1-x)\right]^{\frac{1-\gamma}{\gamma}} = B_H$, where, as implied by (2) and (5), k is constant. Simple differentiation shows that

$$\frac{d\theta_H}{dI_H} = \frac{-1}{D_4}\left[\frac{\partial B_L}{\partial \phi_L}\frac{\partial \phi_L}{\partial \lambda}\frac{\partial \lambda}{\partial \theta_L} + \frac{\partial B_L}{\partial \theta_L}\right]\frac{\partial B_H}{\partial \phi_H}\frac{\partial \phi_H}{\partial I_H} > 0, \quad \frac{d\theta_L}{dI_H} = \frac{-1}{D_4}\frac{\partial B_L}{\partial \phi_L}\frac{\partial \phi_L}{\partial \lambda}\frac{\partial \lambda}{\partial \theta_H}\frac{\partial B_H}{\partial \phi_H}\frac{\partial \phi_H}{\partial I_H} > 0,$$

where

$$D_4 = \frac{\partial B_L}{\partial \phi_L}\frac{\partial \phi_L}{\partial \lambda}\frac{\partial \lambda}{\partial \theta_L}\frac{\partial B_H}{\partial \theta_H} + \frac{\partial B_L}{\partial \theta_L}\frac{\partial B_H}{\partial \phi_H}\frac{\partial \phi_H}{\partial \lambda}\frac{\partial \lambda}{\partial \theta_H} + \frac{\partial B_H}{\partial \theta_H}\frac{\partial B_L}{\partial \theta_L} > 0.$$

Straightforward algebra shows that

$$\frac{d\theta_H}{dI_H}|_{\lambda \text{ fixed}} > \frac{d\theta_H}{dI_H}|_{\lambda \text{ variable}}.$$

The results regarding the unemployment variables and the wage rates follow immediately from equations (16)-(17) and (22).

Expressing the marginal products in Subsection 6.4 as functions of θ_{ij}'s. The procedure is similar to that outlined above for the case considered in Subsection 6.2, i.e., the case where immigrants and natives are imperfect substitutes but search in the same market. Using equations (1), (2), (25) and (26), we find Y/Y_L as a function of θ_i. Specifically,

$$\frac{Y}{Y_L} = \left[\alpha + (1-\alpha)\left(\frac{Q}{Y_L}\right)^{\rho}\right]^{\frac{1}{\rho}},$$

$$\frac{Q}{Y_L} = \left[x\left(\frac{K}{Y_H}\right)^{\gamma} + (1-x)\right]^{\frac{1}{\gamma}}\frac{Y_H}{Y_L},$$

$$\frac{K}{Y_H} = \frac{k}{\left[\zeta + (1-\zeta)\left(\frac{Y_{HI}}{Y_{HN}}\right)^{\nu}\right]^{1/\nu}} = \frac{k}{\left[\zeta + (1-\zeta)\left(\frac{A_{HI}}{A_{HN}}\right)^{\nu}\left(\frac{I_H}{1-\lambda}\right)^{\nu}\right]^{1/\nu}}$$

where

$$k \equiv \frac{K}{Y_{HN}}, \quad A_{ij} \equiv \frac{m(\theta_{ij})}{n + s_i + m(\theta_{ij})},$$

and

$$\frac{Y_H}{Y_L} = \frac{\left[\zeta\left(A_{HN}(1-\lambda)\right)^{\nu} + (1-\zeta)\left(A_{HI}I_H\right)^{\nu}\right]^{1/\nu}}{\left[\psi\left(A_{LN}\lambda\right)^{\eta} + (1-\psi)\left(A_{LI}I_L\right)^{\eta}\right]^{1/\eta}},$$

since, in steady state,

$$Y_{LN} = A_{LN}\lambda, \quad Y_{LI} = A_{LI}I_L, \quad Y_{HN} = A_{HN}(1-\lambda), \quad \text{and} \quad Y_{HI} = A_{HI}I_H.$$

Moreover, using (5) and (28), we have

$$\frac{p_K}{p_{HN}} = \frac{x}{(1-x)\zeta}\frac{k^{\gamma-1}}{\left(\frac{Y_H}{Y_{HN}}\right)^{\gamma-\nu}}$$

or

$$k = (p_{HN})^{\frac{1}{1-\gamma}}\left[\frac{x}{(1-x)\zeta(r+\delta)}\right]^{\frac{1}{1-\gamma}}\left(\frac{Y_H}{Y_{HN}}\right)^{\frac{\gamma-\nu}{\gamma-1}}$$

or

$$k = (p_{HN})^{\frac{1}{1-\gamma}}\left[\frac{x}{(1-x)\zeta(r+\delta)}\right]^{\frac{1}{1-\gamma}}\left(\zeta + (1-\zeta)\left(\frac{A_{HI}}{A_{HN}}\right)^{\nu}\left(\frac{I_H}{1-\lambda}\right)^{\nu}\right)^{\frac{\gamma-\nu}{(\gamma-1)\nu}}.$$

Also,

$$\frac{Y_L}{Y_{LN}} = \left[\psi + (1-\psi)\left(\frac{Y_{LI}}{Y_{LN}}\right)^{\eta}\right]^{\frac{1}{\eta}} = \left[\psi + (1-\psi)\left(\frac{A_{LI}}{A_{LN}}\right)^{\eta}\left(\frac{I_L}{\lambda}\right)^{\eta}\right]^{\frac{1}{\eta}}.$$

Finally, using all the above equations, we can express, through consecutive substitutions, p_{LN} as a function of the matching rates $m(\theta_{ij})$ and hence the tightness prevailing in each market θ_{ij}.

Notice, from equation (29), that to express p_{LI} as a function of the matching rates we need only one additional ratio

$$\frac{Y_L}{Y_{LI}} = \left[\psi\left(\frac{Y_{LI}}{Y_{LN}}\right)^{-\eta} + (1-\psi)\right]^{\frac{1}{\eta}} = \left[\psi\left(\frac{A_{LI}}{A_{LN}}\right)^{-\eta}\left(\frac{I_L}{\lambda}\right)^{-\eta} + (1-\psi)\right]^{\frac{1}{\eta}}$$

since

$$\frac{Y_{LI}}{Y_{LN}} = \frac{A_{LI}}{A_{LN}}\frac{I_L}{\lambda}.$$

Similarly, for p_{HN} we need to compute the following ratios

$$\frac{Y}{Q} = \left[\alpha\left(\frac{Q}{Y_L}\right)^{-\rho} + (1-\alpha)\right]^{\frac{1}{\rho}}$$

$$\frac{Q}{Y_H} = \left[x\left(\frac{K}{Y_H}\right)^{\gamma} + (1-x)\right]^{\frac{1}{\gamma}}$$

$$\frac{Y_H}{Y_{HN}} = \left[\zeta + (1-\zeta)\left(\frac{Y_{HI}}{Y_{HN}}\right)^{\nu}\right]^{\frac{1}{\nu}} = \left[\zeta + (1-\zeta)\left(\frac{A_{HI}}{A_{HN}}\right)^{\nu}\left(\frac{I_H}{1-\lambda}\right)^{\nu}\right]^{\frac{1}{\nu}}.$$

Finally, to express p_{HI} as a function of the matching rates we need only one additional ratio

$$\frac{Y_H}{Y_{HI}} = \left[\zeta\left(\frac{Y_{HI}}{Y_{HN}}\right)^{-\nu} + (1-\zeta)\right]^{\frac{1}{\nu}} = \left[\zeta\left(\frac{A_{HI}}{A_{HN}}\right)^{-\nu}\left(\frac{I_H}{1-\lambda}\right)^{-\nu} + (1-\zeta)\right]^{\frac{1}{\nu}}.$$

Proof of Proposition 7. If $\rho = 1$, then the markets for high-skill and low-skill workers are independent. This follows from the four equations (35), which form two independent systems consisting of two equations each. Moreover, each system describes the interdependence between native and immigrant workers of the same skill. Simple differentiation yields the results regarding θ_{ij}. The effects on the unemployment and the wage rates follow then immediately from equations (16)-(17) and (22), respectively, where θ_{ij} replaces θ_i.

Appendix B: Further Sensitivity Analysis

(not intended for publication)

In this Appendix we present further sensitivity analysis to show that our results are not sensitive to any of the assumed or borrowed values from the literature as well as to our measure of separation rates.

SEPARATION RATES: s_H ANDand s_L

The separation rates we used in our simulations include transitions from employment to both unemployment and inactivity. Next we also examine how the results would change if we define job separations as transitions to unemployment only. Based on matched data from the CPS we find that the monthly transition rate from employment to unemployment for skilled workers is 0.006 and for unskilled workers is 0.014. In Table B1 we show that the results in all the specifications are essentially unchanged when we calibrate the general model using these values for the separations rates (s_H and s_L, respectively) (compare columns 2, 3, 4, and 5 in Table B1 with the last column in Table 2, Table 7, column 2 in Table 6 and column 2 in Table 8, respectively).

REPLACEMENT RATIO

We also examine whether the results would change if we replaced our targeted replacement ratio of 0.71, with Shimer's replacement ratio of 0.40. As mentioned above, the first includes both unemployment insurance and the value of non-market activity, while the latter includes only unemployment insurance. In Table B2 we show that results do not change in any significant way (again compare columns 2, 3, 4, and 5 in Table B2 with the last column in Table 2, Table 7, column 2 in Table 6 and column 2 in Table 8, respectively). Higher value of the replacement ratio tend to amplify the response of job creation as shown in the tables. This is because higher replacement ratio means smaller net profits to the firms, so that shocks have a larger impact in percentage terms on net profits and thus on job creation.

Production elasticity parameters: ρ and γ

Next we examine how the results would change if the parameters of the general model were jointly calibrated assuming values for the production elasticity parameters ρ and γ different from those in Krusell et al. (2000). The results of this test are summarized in Table B3. We calibrate the parameters of the general model for each of the different sets of values in the table. Comparing the results in Table B3 with those reported in the last column of Table 2 shows that our results are not sensitive to our choices of values for these parameters.

Bargaining power: β

In Tables B4 and B5 we show that our results are not qualitatively sensitive to changes in the value of β, the workers' bargaining power. We calibrate the parameters of the general model at $\beta = 0.35$ and $\beta = 0.65$ and then derive results for all the specifications using the new parameter values.

Unemployment elasticity of the matching function: ε

Likewise, in Tables B6 and B7 we show that our results are not qualitatively sensitive to changes in the value of ε. Again, we calibrate the parameters of the general model at ε=0.35 and ε=0.65 and show that the results in all the specifications are qualitatively unaffected.

Sensitivity of Calibration Results with respect to ψ, ζ, β, ε, b_L and b_H.

We also examine the sensitivity of the results presented in the main text. In contrast to the results presented above here we do not re-calibrate; instead, we keep all other parameters as given in Table 1.

In Tables B8 and B9 we examine how robust our results are to changes in the values of ψ and ζ in the imperfect-substitutes and separate-markets models, respectively. Given that we do not re-calibrate we cannot use values less than 0.72, because the condition regarding the option to wait ceases to be satisfied. Also, we cannot use values higher than 0.85 because either the skilled or the unskilled immigrant wage turns negative. By increasing ψ and ζ we lower the wages of immigrants while the search cost remains the same. This is why we get negative immigrant wages. The results are not sensitive to changes in these parameter values within the specified range.

In our benchmark calibration we follow common practice in taking the bargaining power parameter, β, to be equal to 0.5. In Tables B10-B12 we show the results do not change in any fundamental way when we use alternative values for β. Also, as shown in Tables B13-B15 in all the specifications the results are qualitatively robust to our choices of values for ε.

Finally, in Tables B16-B18 and B19-B21, we examine the sensitivity of the results with respect to changes in the unemployment income of unskilled (b_L) and skilled workers (b_H), respectively. At higher values of b_i the wage and expected employment cost of type i are higher. This explains why the response of job creation to immigration is higher at higher values of b_i.

Appendix C: Transitional Dynamics

(not intended for publication)

Figure C1 presents the dynamic adjustment in our basic model. The experiment is the following. We let the number of skilled and unskilled immigrants increase by 0.022% and 0.042%, respectively, of the native labor force each month for a period of 10 years. Thus, the total skilled and unskilled immigration is 2.6% and 5.1%, just as during the period 2000-2009 in the United States. As shown in Figure C1, the simulation results of the dynamic model are in accord with the steady-steady results that are presented in the last column of Table 2. Job creation increases in both sectors and unemployment falls for both skill groups. The unskilled-native wage increases because of both higher θ_L (outside option) and higher p_L. The skilled native wage falls because p_H falls. Also, once the immigration shock ceases to exist the economy settles quickly to the new steady-state values.

Initially, when the stock of immigrants is still small, the response of job creation to immigration is larger (the slopes of θ_L and θ_H are steeper). This suggests that the marginal benefit of additional immigrants on the receiving country is larger when the number of existing immigrants is small. (Note that the increase in p_L is steeper at the beginning; this may also contribute to the steeper response of job creation). When immigrants stop entering the country, job creation in both sectors starts decreasing. This is because firms no longer benefit from lower employment costs. As soon as immigrants stop entering then the probability that an unemployed worker is immigrant stops increasing. So, firms start reducing the number of vacancies they post and unemployment starts increasing. Subsequently, once unemployment is high enough, firms benefit from higher arrival rates of unemployed workers and thus lower vacancy costs, so vacancies start increasing slightly. Eventually, vacancies settle to a level that is higher than their initial level. For this reason, once immigrants stop entering, the tightness in each of the two markets starts falling, but never goes below its initial level. Accordingly, the unemployment rates keep falling as new immigrants enter country, start increasing when immigrants stop entering, and eventually settle to levels lower than their initial levels.

Wages follow a similar pattern. For example, the wages of unskilled natives increase faster at the beginning and then slow down. Subsequently, when the inflow of immigrants disappears, wages start falling because the workers' outside option starts deteriorating. However, because tightness eventually settles to a higher level, the workers' value of outside option remains higher than what it was before immigrants started entering. Thus, their wages settle to a higher level than their original level. On the other hand, the wages of skilled natives settle at a lower level than the initial one, because of the increase in the ratio of skilled to unskilled labor (skill-biased immigration influx).

Table B1. Sensitivity of the Calibration Results with respect to the Separation Rates

(Percentage Changes)

	General Model	General Model Endogenous Human Capital	Imperfect Substitutes $\eta = \nu = 0.95$	Separate Markets $\eta = \nu = 0.95$
	Unskilled Natives			
w_{LN}	0.60	0.40	0.23	0.23
u_{LN}	-10.40	-10.19	-16.04	-1.35
θ_{LN}	22.08	21.63	34.93	3.30
	Unskilled Immigrants			
w_{LI}	2.83	2.54	33.04	-2.86
u_{LI}	same as natives	same as natives	same as natives	0.13
θ_{LI}	same as natives	same as natives	same as natives	-0.27
	Overall Unskilled			
w_L	-0.12	-0.32	-4.69	-4.88
u_L	same as natives	same as natives	same as natives	-6.16
	Skilled Natives			
w_{HN}	-0.44	-0.12	0.22	0.01
u_{HN}	-15.75	-16.13	-21.77	-0.05
θ_{HN}	32.21	32.99	44.77	0.12
	Skilled Immigrants			
w_{HI}	2.63	3.08	43.02	-3.80
u_{HI}	same as natives	same as natives	same as natives	0.09
θ_{HI}	same as natives	same as natives	same as natives	-0.17
	Overall Skilled			
w_H	-1.28	-0.96	-6.10	-6.39
u_H	same as natives	same as natives	same as natives	-7.20
	Overall Natives			
λ		0.30		
w_N	0.17	0.06	0.14	0.11
u_N	-11.08	-10.77	-16.69	-1.11
surplus 1	0.78	0.66	0.75	0.46
surplus 2	1.16	1.03	1.79	0.70
	Overall			
w	-0.39	-0.48	-5.12	-5.32
u	-11.38	-11.11	-17.02	-6.54
Y	7.38	7.27	3.85	3.28
surplus 1	6.64	6.54	2.26	2.35
surplus 2	7.01	6.90	3.11	2.70

Notes: The table shows results when we set $s_L = 0.014$ and $s_H = 0.006$ and then recalibrate the model to obtain some of the other parameter values as described in Sub-section 5.1.

Table B2. Sensitivity of the Calibration Results with respect to the Targeted Replacement Ratio

(Percentage Changes)

	General Model	General Model Endogenous Human Capital	Imperfect Substitutes $\eta = \nu = 0.95$	Separate Markets $\eta = \nu = 0.95$
	Unskilled Natives			
w_{LN}	0.70	0.48	0.56	0.30
u_{LN}	-7.61	-7.45	-9.14	-0.30
θ_{LN}	16.17	15.84	19.69	0.67
	Unskilled Immigrants			
w_{LI}	2.44	2.15	17.40	-3.15
u_{LI}	same as natives	same as natives	same as natives	0.10
θ_{LI}	same as natives	same as natives	same as natives	-0.20
	Overall Unskilled			
w_L	-0.08	-0.31	-4.60	-4.56
u_L	same as natives	same as natives	same as natives	-3.92
	Skilled Natives			
w_{HN}	-0.45	-0.10	0.20	-0.11
u_{HN}	-13.83	-14.15	-16.45	0.11
θ_{HN}	28.29	28.95	33.75	-0.24
	Skilled Immigrants			
w_{HI}	2.32	2.80	29.77	-4.12
u_{HI}	same as natives	same as natives	same as natives	0.06
θ_{HI}	same as natives	same as natives	same as natives	-0.12
	Overall Skilled			
w_H	-1.34	-0.99	-6.31	-6.21
u_H	same as natives	same as natives	same as natives	-5.80
	Overall Natives			
λ		0.32		
w_N	0.24	0.12	0.39	0.14
u_N	-8.39	-8.12	-10.00	-0.24
surplus 1	0.78	0.65	0.92	0.35
surplus 2	0.95	0.81	1.25	0.37
	Overall			
w	-0.38	-0.48	-5.09	-5.02
u	-8.70	-8.46	-10.33	-4.46
Y	7.26	7.15	3.34	2.90
surplus 1	6.63	6.52	2.17	2.14
surplus 2	6.79	6.68	2.38	2.13

Notes: The table shows results when we set our targeted replacement ratio to 0.40. We keep all other targets the same and recalibrate the general model as described in Sub-section 5.1.

Table B3. Sensitivity of the Calibration Results with respect to Production Parameters in the General Model

(Percentage Changes)

	$\rho=0 \quad \gamma=-1$ ($\sigma_{LK}=\sigma_{LH}=1$, $\sigma_{HK}=0.5$)	$\rho=0.5 \quad \gamma=0$ ($\sigma_{LK}=\sigma_{LH}=2$, $\sigma_{HK}=1$)	$\rho=0.5 \quad \gamma=-1$ ($\sigma_{LK}=\sigma_{LH}=2$, $\sigma_{HK}=0.5$)	$\rho=0 \quad \gamma=0$ ($\sigma_{LK}=\sigma_{LH}=1$, $\sigma_{HK}=1$)
	Unskilled Natives			
w_{LN}	0.84	0.52	0.53	0.83
u_{LN}	-11.17	-10.96	-10.96	-11.16
	Unskilled Immigrants			
w_{LI}	3.30	2.88	2.88	3.29
u_{LI}	same as natives	same as natives	same as natives	same as natives
	Overall Unskilled			
w_L	0.15	-0.18	-0.18	0.15
u_L	same as natives	same as natives	same as natives	same as natives
θ_L	23.70	23.27	23.27	23.69
	Skilled Natives			
w_{HN}	-0.89	-0.38	-0.38	-0.88
u_{HN}	-17.12	-17.29	-17.29	-17.12
	Skilled Immigrants			
w_{HI}	2.42	3.06	3.05	2.43
u_{HI}	same as natives	same as natives	same as natives	same as natives
	Overall Skilled			
w_H	-1.69	-1.16	-1.16	-1.68
u_H	same as natives	same as natives	same as natives	same as natives
θ_H	35.01	35.36	35.36	35.01
	Overall Natives			
w_N	0.14	0.15	0.15	0.14
u_N	-11.92	-11.76	-11.76	-11.91
surplus 1	0.60	0.59	0.60	0.59
surplus 2	1.00	1.00	1.00	0.99
	Overall			
w	-0.39	-0.38	-0.38	-0.39
u	-12.23	-12.07	-12.07	-12.22
Y	7.41	7.41	7.41	7.41
surplus 1	6.55	6.55	6.56	6.54
surplus 2	6.95	6.95	6.95	6.94

Notes: The table shows results when we change the values of ρ and γ and then recalibrate the general model to obtain some of the other parameter values as described in Sub-section 5.1.

Table B4. Calibration Results with $\beta = 0.35$

(Percentage Changes)

	General Model	General Model Endogenous Human Capital	Imperfect Substitutes $\eta = \nu = 0.95$	Separate Markets $\eta = \nu = 0.95$
	Unskilled Natives			
w_{LN}	0.66	0.45	0.31	0.22
u_{LN}	-8.30	-8.05	-13.53	-1.29
θ_{LN}	17.63	17.09	29.80	3.07
	Unskilled Immigrants			
w_{LI}	2.45	2.14	22.36	-2.90
u_{LI}	same as natives	same as natives	same as natives	0.23
θ_{LI}	same as natives	same as natives	same as natives	-0.47
	Overall Unskilled			
w_L	-0.12	-0.33	-4.68	-4.80
u_L	same as natives	same as natives	same as natives	-5.67
	Skilled Natives			
w_{HN}	-0.44	-0.09	0.21	-0.02
u_{HN}	-14.22	-14.64	-21.20	0.14
θ_{HN}	29.08	29.95	43.66	-0.30
	Skilled Immigrants			
w_{HI}	2.35	2.84	45.83	-3.88
u_{HI}	same as natives	same as natives	same as natives	0.12
θ_{HI}	same as natives	same as natives	same as natives	-0.24
	Overall Skilled			
w_H	-1.32	-0.97	-6.17	-6.36
u_H	same as natives	same as natives	same as natives	-6.81
	Overall Natives			
λ		0.32		
w_N	0.22	0.10	0.20	0.10
u_N	-9.04	-8.70	-14.34	-1.03
surplus 1	0.64	0.51	0.58	0.31
surplus 2	0.96	0.82	1.59	0.48
	Overall			
w	-0.40	-0.49	-5.14	-5.25
u	-9.35	-9.04	-14.69	-6.06
Y	7.29	7.17	3.83	3.18
surplus 1	6.50	6.39	2.08	2.20
surplus 2	6.81	6.69	2.87	2.42

Notes: The table shows results when we set $\beta = 0.35$ and then recalibrate the general model to obtain some of the other parameter values as described in Subsection 5.1.

Table B5. Calibration Results with $\beta = 0.65$

(Percentage Changes)

	General Model	General Model Endogenous Human Capital	Imperfect Substitutes $\eta = \nu = 0.95$	Separate Markets $\eta = \nu = 0.95$
		Unskilled Natives		
w_{LN}	0.51	0.29	0.18	0.23
u_{LN}	-13.57	-13.38	-17.83	-1.42
θ_{LN}	28.78	28.38	38.31	3.65
		Unskilled Immigrants		
w_{LI}	3.43	3.13	36.22	-2.76
u_{LI}	same as natives	same as natives	same as natives	0.06
θ_{LI}	same as natives	same as natives	same as natives	-0.11
		Overall Unskilled		
w_L	-0.12	-0.34	-4.61	-5.02
u_L	same as natives	same as natives	same as natives	-6.65
		Skilled Natives		
w_{HN}	-0.50	-0.16	0.17	0.03
u_{HN}	-19.49	-19.86	-22.47	-0.27
θ_{HN}	39.86	40.61	46.03	0.63
		Skilled Immigrants		
w_{HI}	3.35	3.83	37.04	-3.65
u_{HI}	same as natives	same as natives	same as natives	0.03
θ_{HI}	same as natives	same as natives	same as natives	-0.06
		Overall Skilled		
w_H	-1.22	-0.87	-6.00	-6.56
u_H	same as natives	same as natives	same as natives	-7.76
		Overall Natives		
λ		0.32		
w_N	0.08	-0.04	0.09	0.12
u_N	-14.32	-14.02	-18.37	-1.18
surplus 1	0.56	0.43	0.46	0.30
surplus 2	1.04	0.90	1.41	0.62
		Overall		
w	-0.38	-0.48	-5.02	-5.47
u	-14.63	-14.36	-18.69	-7.02
Y	7.52	7.41	3.77	3.52
surplus 1	6.60	6.49	2.08	2.26
surplus 2	7.07	6.96	2.90	2.82

Notes: The table shows results when we set $\beta = 0.65$ and then recalibrate the general model to obtain some of the other parameter values as described in Sub-section 5.1.

Table B6. Calibration Results with $\varepsilon = 0.35$

(Percentage Changes)

	General Model	General Model Endogenous Human Capital	Imperfect Substitutes $\eta = \nu = 0.95$	Separate Markets $\eta = \nu = 0.95$
	Unskilled Natives			
w_{LN}	0.55	0.31	0.25	0.25
u_{LN}	-7.56	-7.40	-11.32	-1.04
θ_{LN}	22.95	22.46	34.87	3.43
	Unskilled Immigrants			
w_{LI}	2.24	1.93	16.88	-3.10
u_{LI}	same as natives	same as natives	same as natives	0.08
θ_{LI}	same as natives	same as natives	same as natives	-0.22
	Overall Unskilled			
w_L	-0.25	-0.48	-4.74	-4.78
u_L	same as natives	same as natives	same as natives	-5.13
	Skilled Natives			
w_{HN}	-0.55	-0.18	0.07	-0.04
u_{HN}	-11.97	-12.26	-15.23	0.26
θ_{HN}	35.00	35.85	44.65	-0.79
	Skilled Immigrants			
w_{HI}	1.83	2.34	23.15	-4.29
u_{HI}	same as natives	same as natives	same as natives	0.04
θ_{HI}	same as natives	same as natives	same as natives	-0.12
	Overall Skilled			
w_H	-1.50	-1.13	-6.43	-6.46
u_H	same as natives	same as natives	same as natives	-6.12
	Overall Natives			
λ		0.34		
w_N	0.10	-0.03	0.13	0.12
u_N	-8.12	-7.83	-11.77	-0.82
surplus 1	0.52	0.39	0.48	0.33
surplus 2	0.81	0.66	1.13	0.45
	Overall			
w	-0.55	-0.65	-5.24	-5.26
u	-8.42	-8.16	-12.10	-5.52
Y	7.24	7.12	3.44	3.05
surplus 1	6.37	6.25	1.92	2.08
surplus 2	6.64	6.52	2.37	2.18

Notes: The table shows results when we set $\varepsilon = 0.35$ and then recalibrate the general model to obtain some of the other parameter values as described in Sub-section 5.1.

Table B7. Calibration Results with $\varepsilon = 0.65$

(Percentage Changes)

	General Model	General Model Endogenous Human Capital	Imperfect Substitutes $\eta = \nu = 0.95$	Separate Markets $\eta = \nu = 0.95$
	Unskilled Natives			
w_{LN}	0.63	0.42	0.17	0.22
u_{LN}	-14.57	-14.29	-21.81	-1.80
θ_{LN}	23.76	23.31	36.68	3.82
	Unskilled Immigrants			
w_{LI}	3.69	3.39	69.93	-2.63
u_{LI}	same as natives	same as natives	same as natives	0.14
θ_{LI}	same as natives	same as natives	same as natives	-0.22
	Overall Unskilled			
w_L	0.02	-0.19	-4.61	-5.20
u_L	same as natives	same as natives	same as natives	-7.22
	Skilled Natives			
w_{HN}	-0.41	-0.08	0.37	0.06
u_{HN}	-22.63	-23.11	-29.09	-0.77
θ_{HN}	35.57	36.34	45.97	1.50
	Skilled Immigrants			
w_{HI}	3.98	4.45	64.78	-3.37
u_{HI}	same as natives	same as natives	same as natives	0.08
θ_{HI}	same as natives	same as natives	same as natives	-0.12
	Overall Skilled			
w_H	-1.04	-0.71	-5.61	-6.68
u_H	same as natives	same as natives	same as natives	-8.47
	Overall Natives			
λ		0.30		
w_N	0.19	0.08	0.12	0.11
u_N	-15.57	-15.22	-22.57	-1.57
surplus 1	0.67	0.54	0.55	0.29
surplus 2	1.18	1.05	1.98	0.84
	Overall			
w	-0.22	-0.31	-4.92	-5.63
u	-15.89	-15.56	-22.92	-7.60
Y	7.58	7.47	4.29	3.95
surplus 1	6.74	6.64	2.23	2.36
surplus 2	7.26	7.15	3.55	3.33

Notes: The table shows results when we set $\varepsilon = 0.65$ and then recalibrate the general model to obtain some of the other parameter values as described in Sub-section 5.1.

Table B8. Sensitivity with respect to the Production Parameters ψ and ζ in the Imperfect-Substitutes Model

(Percentage Changes)

	$\psi = 0.75$ $\zeta = 0.75$	$\psi = 0.80$ $\zeta = 0.75$	$\psi = 0.75$ $c = 0.80$	$\psi = 0.80$ $\zeta = 0.80$
	Unskilled Natives			
w_{LN}	0.21	0.39	0.06	0.23
u_{LN}	-16.45	-14.85	-15.90	-14.36
	Unskilled Immigrants			
w_{LI}	35.38	93.76	30.61	72.85
u_{LI}	same as natives	same as natives	same as natives	same as natives
	Overall Unskilled			
w_L	-4.68	-5.02	-4.83	-5.17
u_L	same as natives	same as natives	same as natives	same as natives
θ_L	35.69	32.13	34.48	31.04
	Skilled Natives			
w_{HN}	0.20	-0.06	0.46	0.20
u_{HN}	-22.05	-21.57	-21.28	-20.82
	Skilled Immigrants			
w_{HI}	41.27	35.56	133.83	99.19
u_{HI}	same as natives	same as natives	same as natives	same as natives
	Overall Skilled			
w_H	-6.05	-6.30	-6.51	-6.76
u_H	same as natives	same as natives	same as natives	same as natives
θ_H	45.27	44.28	43.68	42.71
	Overall Natives			
w_N	0.13	0.16	0.13	0.16
u_N	-17.06	-15.61	-16.49	-15.09
surplus 1	0.51	0.53	0.51	0.53
surplus 2	1.52	1.40	1.46	1.34
	Overall			
w	-5.09	-5.38	-5.37	-5.65
u	-17.40	-15.94	-16.83	-15.42
Y	3.83	3.35	3.47	3.01
surplus 1	2.07	1.79	1.81	1.53
surplus 2	2.91	2.47	2.57	2.15

Notes: The table shows results of the model where immigrants and natives of the same type are imperfect substitutes in production when we change the values of ψ and ζ. We keep all other parameter values the same (see Table 1).

Table B9. Sensitivity with respect to the Production Parameters ψ and ζ in the Separate-Markets Model

(Percentage Changes)

	$\psi = 0.75$ $\zeta = 0.75$	$\psi = 0.80$ $\zeta = 0.75$	$\psi = 0.75$ $\zeta = 0.80$	$\psi = 0.80$ $\zeta = 0.80$
	Unskilled Natives			
w_{LN}	0.23	0.33	0.10	0.20
u_{LN}	-1.38	-1.32	-0.50	-0.71
θ_{LN}	3.40	3.10	1.22	1.66
	Unskilled Immigrants			
w_{LI}	-2.84	-3.03	-3.04	-3.25
u_{LI}	0.11	0.08	0.12	0.09
θ_{LI}	-0.23	-0.17	-0.25	-0.19
	Overall Unskilled			
w_L	-4.89	-5.20	-4.96	-5.30
u_L	-6.29	-5.93	-5.34	-5.27
	Skilled Natives			
w_{HN}	0.01	-0.22	0.18	-0.03
u_{HN}	-0.07	1.37	-0.95	0.14
θ_{HN}	0.15	-3.05	2.09	-0.31
	Skilled Immigrants			
w_{HI}	-3.74	-4.04	-3.90	-4.19
u_{HI}	0.06	0.07	0.04	0.05
θ_{HI}	-0.12	-0.13	-0.09	-0.10
	Overall Skilled			
w_H	-6.42	-6.51	-6.84	-6.97
u_H	-7.34	-5.76	-7.96	-6.75
	Overall Natives			
w_N	0.11	0.09	0.13	0.09
u_N	-1.12	-0.78	-0.58	-0.56
surplus 1	0.31	0.28	0.28	0.26
surplus 2	0.54	0.39	0.41	0.34
	Overall			
w	-5.33	-5.55	-5.53	-5.78
u	-6.66	-6.05	-6.00	-5.73
Y	3.33	2.72	2.84	2.35
surplus 1	2.23	1.89	1.95	1.62
surplus 2	2.60	2.04	2.15	1.70

Notes: The table shows results of the model where immigrants and natives search in different labor markets when we change the values of ψ and ζ. We keep all other parameter values the same (see Table 1).

Table B10. Sensitivity of the Calibration Results with respect to the Bargaining Share in the General Model

(Percentage Changes)

	$\beta = 0.8$	$\beta = 0.7$	$\beta = 0.6$	$\beta = 0.5$	$\beta = 0.4$
	Unskilled Natives				
w_{LN}	0.44	0.49	0.54	0.59	0.64
u_{LN}	-10.39	-10.65	-10.84	-11.00	-11.17
	Unskilled Immigrants				
w_{LI}	1.42	1.88	2.37	2.97	3.75
u_{LI}	same as natives	same as natives	same as natives	same as natives	same as natives
	Overall Unskilled				
w_L	0.11	0.05	-0.02	-0.11	-0.22
u_L	same as natives	same as natives	same as natives	same as natives	same as natives
θ_L	23.36	23.30	23.31	23.36	23.45
	Skilled Natives				
w_{HN}	-0.48	-0.49	-0.49	-0.48	-0.46
u_{HN}	-17.20	-17.21	-17.23	-17.26	-17.30
	Skilled Immigrants				
w_{HI}	1.09	1.61	2.20	2.93	3.90
u_{HI}	same as natives	same as natives	same as natives	same as natives	same as natives
	Overall Skilled				
w_H	-0.87	-1.00	1.13	-1.27	-1.43
u_H	same as natives	same as natives	same as natives	same as natives	same as natives
θ_H	35.97	35.61	35.41	35.29	35.23
	Overall Natives				
w_N	0.04	0.07	0.11	0.15	0.19
u_N	-11.28	-11.49	-11.65	-11.79	-11.93
surplus 1	0.59	0.57	0.57	0.60	0.64
surplus 2	1.37	1.17	1.06	1.00	0.97
	Overall				
w	-0.13	-0.20	-0.28	-0.38	-0.51
u	-11.58	-11.80	-11.96	-12.10	-12.24
Y	7.94	7.69	7.53	7.41	7.31
surplus 1	6.94	6.80	6.68	6.55	6.42
surplus 2	7.72	7.39	7.16	6.95	6.74

Notes: The table shows results of the general model when we change the value of the bargaining share. We keep all other parameter values the same (see Table 1).

Table B11. Sensitivity of the Calibration Results with respect to the Bargaining Share in the Imperfect-Substitutes Model

(Percentage Changes)

	$\beta = 0.8$	$\beta = 0.7$	$\beta = 0.6$	$\beta = 0.5$	$\beta = 0.4$
			Unskilled Natives		
w_{LN}	0.03	0.11	0.17	0.21	0.26
u_{LN}	-15.04	-15.63	-16.07	-16.45	-16.81
			Unskilled Immigrants		
w_{LI}	4.37	9.20	17.20	35.38	152.77
u_{LI}	same as natives	same as natives	same as natives	same as natives	same as natives
			Overall Unskilled		
w_L	-4.27	-4.38	-4.51	-4.68	-4.90
u_L	same as natives	same as natives	same as natives	same as natives	same as natives
θ_L	35.25	35.34	35.49	35.69	35.97
			Skilled Natives		
w_{HN}	0.39	0.30	0.25	0.20	0.17
u_{HN}	-22.06	-22.04	-22.04	-22.05	-22.09
			Skilled Immigrants		
w_{HI}	8.19	13.86	22.86	41.27	113.81
u_{HI}	same as natives	same as natives	same as natives	same as natives	same as natives
			Overall Skilled		
w_H	-5.21	-5.50	-5.76	-6.05	-6.38
u_H	same as natives	same as natives	same as natives	same as natives	same as natives
θ_H	46.50	45.87	45.50	45.27	45.14
			Overall Natives		
w_N	0.04	0.07	0.10	0.13	0.15
u_N	-15.85	-16.36	-16.74	-17.06	-17.39
surplus 1	0.45	0.46	0.48	0.51	0.55
surplus 2	2.34	1.94	1.69	1.52	1.40
			Overall		
w	-4.59	-4.73	-4.90	-5.09	-5.34
u	-16.18	-16.69	-17.07	-17.40	-17.73
Y	4.78	4.34	4.05	3.83	3.65
surplus 1	2.74	2.50	2.29	2.07	1.81
surplus 2	4.33	3.74	3.30	2.91	2.51

Notes: The table shows results of the model where immigrants and natives of the same type are imperfect substitutes in production when we change the value of the bargaining share. We keep all other parameter values the same (see Table 1).

Table B12. Sensitivity of the Calibration Results with respect to the Bargaining Share in the Separate-Markets Model

(Percentage Changes)

	$\beta = 0.8$	$\beta = 0.7$	$\beta = 0.6$	$\beta = 0.5$	$\beta = 0.4$
			Unskilled Natives		
w_{LN}	0.25	0.24	0.23	0.23	0.22
u_{LN}	-1.17	-1.24	-1.31	-1.38	-1.47
θ_{LN}	3.44	3.34	3.34	3.40	3.50
			Unskilled Immigrants		
w_{LI}	-2.31	-2.46	-2.63	-2.84	-3.14
u_{LI}	0.11	0.11	0.11	0.11	0.11
θ_{LI}	-0.23	-0.23	-0.23	-0.23	-0.23
			Overall Unskilled		
w_L	-5.00	-4.89	-4.86	-4.89	-4.97
u_L	-5.91	-6.05	-6.17	-6.29	-6.42
			Skilled Natives		
w_{HN}	0.04	0.03	0.02	0.01	0.00
u_{HN}	-0.38	-0.26	-0.16	-0.07	0.02
θ_{HN}	1.00	0.64	0.38	0.15	-0.05
			Skilled Immigrants		
w_{HI}	-3.10	-3.28	-3.49	-3.74	-4.11
u_{HI}	0.06	0.06	0.06	0.06	0.06
θ_{HI}	-0.12	-0.12	-0.12	-0.12	-0.12
			Overall Skilled		
w_H	-6.57	-6.41	-6.38	-6.42	-6.52
u_H	-7.65	-7.54	-7.43	-7.34	-7.25
			Overall Natives		
w_N	0.13	0.12	0.12	0.11	0.11
u_N	-1.00	-1.03	-1.07	-1.12	-1.19
surplus 1	0.25	0.27	0.29	0.31	0.33
surplus 2	0.69	0.60	0.56	0.54	0.53
			Overall		
w	-5.46	-5.33	-5.30	-5.33	-5.42
u	-6.41	-6.49	-6.57	-6.66	-6.76
Y	3.91	3.62	3.45	3.33	3.23
surplus 1	2.65	2.50	2.37	2.23	2.06
surplus 2	3.51	3.12	2.85	2.60	2.36

Notes: The table shows results of the model where immigrants and natives search in different labor markets when we change the value of the bargaining share. We keep all other parameter values the same (see Table 1).

Table B13. Sensitivity of the Calibration Results with respect to the Matching Elasticity in the General Model

(Percentage Changes)

	$\epsilon = 0.1$	$\epsilon = 0.3$	$\epsilon = 0.5$	$\epsilon = 0.7$
	Unskilled Natives			
w_{LN}	0.48	0.53	0.59	0.64
u_{LN}	-2.13	-6.48	-11.00	-15.75
	Unskilled Immigrants			
w_{LI}	0.92	1.83	2.97	4.40
u_{LI}	same as natives	same as natives	same as natives	same as natives
	Overall Unskilled			
w_L	-0.28	-0.20	-0.11	-0.01
u_L	same as natives	same as natives	same as natives	same as natives
θ_L	22.34	22.80	23.36	24.05
	Skilled Natives			
w_{HN}	-0.69	-0.60	-0.48	-0.34
u_{HN}	-3.35	-10.20	-17.26	-24.52
	Skilled Immigrants			
w_{HI}	-0.07	1.50	2.93	4.25
u_{HI}	same as natives	same as natives	same as natives	same as natives
	Overall Skilled			
w_H	-1.99	-1.63	-1.27	-0.90
u_H	same as natives	same as natives	same as natives	same as natives
θ_H	34.33	34.82	35.29	35.77
	Overall Natives			
w_N	0.03	0.09	0.15	0.21
u_N	-2.33	-7.02	-11.79	-16.71
surplus 1	0.39	0.48	0.60	0.73
surplus 2	0.46	0.71	1.00	1.34
	Overall			
w	-0.73	-0.56	-0.38	-0.21
u	-2.55	-7.29	-12.10	-17.05
Y	6.94	7.16	7.41	7.71
surplus 1	6.12	6.33	6.55	6.80
surplus 2	6.17	6.54	6.95	7.42

Notes: The table shows result of the general model when we change the value of the matching elasticity parameter. We keep all other parameter values the same (see Table 1).

Table B14. Sensitivity of the Calibration Results with respect to the Matching Elasticity in the Imperfect-Substitutes Model

(Percentage Changes)

	$\epsilon = 0.1$	$\epsilon = 0.3$	$\epsilon = 0.5$	$\epsilon = 0.7$
	Unskilled Natives			
w_{LN}	0.30	0.27	0.21	0.10
u_{LN}	-3.22	-9.74	-16.45	-23.51
	Unskilled Immigrants			
w_{LI}	-0.72	9.00	35.38	393.29
u_{LI}	same as natives	same as natives	same as natives	same as natives
	Overall Unskilled			
w_L	-4.54	-4.60	-4.68	-4.77
u_L	same as natives	same as natives	same as natives	same as natives
θ_L	33.94	34.65	35.69	37.29
	Skilled Natives			
w_{HN}	-0.11	0.00	0.20	0.55
u_{HN}	-4.24	-12.96	-22.05	-31.68
	Skilled Immigrants			
w_{HI}	0.23	19.48	41.27	68.91
u_{HI}	same as natives	same as natives	same as natives	same as natives
	Overall Skilled			
w_H	-7.10	-6.63	-6.05	-5.29
u_H	same as natives	same as natives	same as natives	same as natives
θ_H	43.54	44.33	45.27	46.45
	Overall Natives			
w_N	0.14	0.14	0.13	0.10
u_N	-3.39	-10.17	-17.06	-24.24
surplus 1	0.43	0.46	0.51	0.60
surplus 2	0.58	0.96	1.52	2.36
	Overall			
w	-5.33	-5.21	-5.09	-4.96
u	-3.61	-10.46	-17.40	-24.62
Y	2.89	3.28	3.83	4.65
surplus 1	1.78	1.91	2.07	2.27
surplus 2	1.72	2.21	2.91	3.92

Notes: The table shows result of the model where immigrants and natives of the same type are imperfect substitutes in production when we change the value of the matching elasticity parameter. We keep all other parameter values the same (see Table 1).

Table B15. Sensitivity of the Calibration Results with respect to the Matching Elasticity in the Separate-Markets Model

(Percentage Changes)

	$\epsilon = 0.1$	$\epsilon = 0.3$	$\epsilon = 0.5$	$\epsilon = 0.7$
	Unskilled Natives			
w_{LN}	0.29	0.26	0.23	0.22
u_{LN}	-0.37	-0.98	-1.38	-1.93
θ_{LN}	3.95	3.64	3.40	4.25
	Unskilled Immigrants			
w_{LI}	-3.22	-3.00	-2.84	-2.64
u_{LI}	0.02	0.06	0.11	0.15
θ_{LI}	-0.22	-0.22	-0.23	-0.22
	Overall Unskilled			
w_L	-4.52	-4.61	-4.89	-5.65
u_L	-1.99	-4.73	-6.29	-7.46
	Skilled Natives			
w_{HN}	-0.12	-0.07	0.01	0.08
u_{HN}	0.16	0.32	-0.07	-1.35
θ_{HN}	-1.68	-1.12	0.15	2.67
	Skilled Immigrants			
w_{HI}	-6.60	-4.63	-3.74	-3.22
u_{HI}	0.01	0.04	0.06	0.08
θ_{HI}	-0.13	-0.13	-0.12	-0.11
	Overall Skilled			
w_H	-7.00	-6.56	-6.42	-7.00
u_H	-2.51	-5.55	-7.34	-9.17
	Overall Natives			
w_N	0.13	0.12	0.11	0.11
u_N	-0.28	-0.75	-1.12	-1.80
surplus 1	0.39	0.34	0.31	0.30
surplus 2	0.42	0.42	0.54	1.20
	Overall			
w	-5.27	-5.19	-5.33	-6.03
u	-2.28	-5.08	-6.66	-7.95
Y	2.80	2.97	3.33	4.57
surplus 1	1.85	2.06	2.23	2.39
surplus 2	1.71	2.09	2.60	3.92

Notes: The table shows result of the model where immigrants and natives search in different labor markets when we change the value of the matching elasticity parameter. We keep all other parameter values the same (see Table 1).

Table B16. Sensitivity of the Calibration Results with respect to the Unemployment Income of the Unskilled Workers in the General Model

(Percentage Changes)

	$b_L = 0.1$	$b_L = 0.2$	$b_L = 0.25$	$b_L = 0.28$	$b_L = 0.35$
	Unskilled Natives				
w_{LN}	0.72	0.67	0.62	0.59	0.44
u_{LN}	-6.86	-8.69	-10.04	-11.00	-14.48
	Unskilled Immigrants				
w_{LI}	1.96	2.38	2.72	2.97	3.95
u_{LI}	same as natives	same as natives	same as natives	same as natives	same as natives
	Overall Unskilled				
w_L	0.08	0.00	-0.07	-0.11	-0.27
u_L	same as natives	same as natives	same as natives	same as natives	same as natives
θ_L	14.37	18.33	21.24	23.36	31.02
	Skilled Natives				
w_{HN}	-0.61	-0.56	-0.51	-0.48	-0.35
u_{HN}	-17.14	-17.19	-17.23	-17.26	-17.36
	Skilled Immigrants				
w_{HI}	2.72	2.81	2.88	2.93	3.13
u_{HI}	same as natives	same as natives	same as natives	same as natives	same as natives
	Overall Skilled				
w_H	-1.40	-1.34	-1.30	-1.27	-1.14
u_H	same as natives	same as natives	same as natives	same as natives	same as natives
θ_H	35.04	35.15	35.23	35.29	35.50
	Overall Natives				
w_N	0.21	0.19	0.16	0.15	0.07
u_N	-8.45	-9.88	-10.98	-11.79	-14.80
surplus 1	0.65	0.63	0.61	0.60	0.52
surplus 2	0.81	0.89	0.95	1.00	1.18
	Overall				
w	-0.27	-0.32	-0.36	-0.38	-0.47
u	-8.71	-10.17	-11.28	-12.10	-15.13
Y	7.20	7.28	7.36	7.41	7.63
surplus 1	6.65	6.61	6.58	6.55	6.47
surplus 2	6.80	6.86	6.91	6.95	7.13

Notes: The table shows result of the general model when we change the unemployment income of the unskilled workers. We keep all other parameter values the same (see Table 1).

Table B17. Sensitivity of the Calibration Results with respect to the Unemployment Income of the Unskilled Workers in the Imperfect-Substitutes Model

(Percentage Changes)

	$b_L = 0.1$	$b_L = 0.2$	$b_L = 0.25$	$b_L = 0.28$	$b_L = 0.30$
	Unskilled Natives				
w_{LN}	0.63	0.50	0.35	0.21	0.06
u_{LN}	-7.85	-11.12	-14.01	-16.45	-18.89
	Unskilled Immigrants				
w_{LI}	7.06	14.79	24.41	35.38	50.31
u_{LI}	same as natives	same as natives	same as natives	same as natives	same as natives
	Overall Unskilled				
w_L	-4.29	-4.43	-4.56	-4.68	-4.80
u_L	same as natives	same as natives	same as natives	same as natives	same as natives
θ_L	16.60	23.75	30.20	35.69	41.27
	Skilled Natives				
w_{HN}	-0.13	-0.02	0.09	0.20	0.32
u_{HN}	-21.75	-21.86	-21.97	-22.05	-22.14
	Skilled Immigrants				
w_{HI}	37.55	38.94	40.19	41.27	42.40
u_{HI}	same as natives	same as natives	same as natives	same as natives	same as natives
	Overall Skilled				
w_H	-6.39	-6.28	-6.16	-6.05	-5.92
u_H	same as natives	same as natives	same as natives	same as natives	same as natives
θ_H	44.64	44.88	45.09	45.27	45.46
	Overall Natives				
w_N	0.34	0.27	0.20	0.13	0.05
u_N	-9.98	-12.53	-14.95	-17.06	-19.23
surplus 1	0.74	0.67	0.59	0.51	0.42
surplus 2	1.05	1.21	1.37	1.52	1.68
	Overall				
w	-4.89	-4.96	-5.03	-5.09	-5.15
u	-10.25	-12.84	-15.28	-17.40	-19.58
Y	3.24	3.44	3.64	3.83	4.04
surplus 1	2.19	2.17	2.12	2.07	2.00
surplus 2	2.41	2.57	2.74	2.91	3.09

Notes: The table shows result of the model where immigrants and natives of the same type are imperfect substitutes in production when we change the unemployment income of the unskilled workers. We keep all other parameter values the same (see Table 1).

Table B18. Sensitivity of the Calibration Results with respect to the Unemployment Income of the Unskilled Workers in the Separate-Markets Model

(Percentage Changes)

	$b_L = 0.1$	$b_L = 0.2$	$b_L = 0.25$	$b_L = 0.28$	$b_L = 0.30$
	Unskilled Natives				
w_{LN}	0.33	0.31	0.28	0.23	0.16
u_{LN}	-0.25	-0.47	-0.84	-1.38	-2.33
θ_{LN}	0.53	1.05	1.94	3.40	6.52
	Unskilled Immigrants				
w_{LI}	-2.89	-2.83	-2.82	-2.84	-2.86
u_{LI}	0.09	0.10	0.10	0.11	0.12
θ_{LI}	-0.18	-0.20	-0.21	-0.23	-0.24
	Overall Unskilled				
w_L	-4.31	-4.43	-4.61	-4.89	-5.44
u_L	-3.61	-4.49	-5.35	-6.29	-7.60
	Skilled Natives				
w_{HN}	-0.15	-0.12	-0.07	0.01	0.13
u_{HN}	0.84	0.74	0.51	-0.07	-2.20
θ_{HN}	-1.86	-1.65	-1.14	0.15	5.25
	Skilled Immigrants				
w_{HI}	-3.92	-3.89	-3.84	-3.74	-3.57
u_{HI}	0.07	0.06	0.06	0.06	0.05
θ_{HI}	-0.13	-0.13	-0.13	-0.12	-0.11
	Overall Skilled				
w_H	-6.39	-6.40	-6.41	-6.42	-6.53
u_H	-6.23	-6.38	-6.67	-7.34	-9.65
	Overall Natives				
w_N	0.13	0.13	0.12	0.11	0.10
u_N	0.12	-0.14	-0.53	-1.12	-2.31
surplus 1	0.32	0.32	0.31	0.31	0.30
surplus 2	0.31	0.33	0.39	0.54	1.09
	Overall				
w	-4.86	-4.96	-5.11	-5.33	-5.78
u	-4.37	-5.02	-5.75	-6.66	-8.17
Y	2.88	2.95	3.08	3.33	4.09
surplus 1	2.22	2.24	2.24	2.23	2.21
surplus 2	2.23	2.29	2.39	2.60	3.31

Notes: The table shows result of the model where immigrants and natives search in different labor markets when we change the unemployment income of the unskilled workers. We keep all other parameter values the same (see Table 1).

Table B19. Sensitivity of the Calibration Results with respect to the Unemployment Income of the Skilled Workers in the General Model (Percentage Changes)

	$b_H = 0.2$	$b_H = 0.35$	$b_H = 0.40$	$b_H = 0.45$	$b_H = 0.50$
	Unskilled Natives				
w_{LN}	0.56	0.57	0.58	0.59	0.60
u_{LN}	-10.97	-10.99	-11.00	-11.00	-11.01
	Unskilled Immigrants				
w_{LI}	2.92	2.95	2.96	2.97	2.98
u_{LI}	same as natives	same as natives	same as natives	same as natives	same as natives
	Overall Unskilled				
w_L	-0.14	-0.12	-0.12	-0.11	-0.10
u_L	same as natives	same as natives	same as natives	same as natives	same as natives
θ_L	23.29	23.33	23.34	23.36	23.38
	Skilled Natives				
w_{HN}	-0.37	-0.42	-0.45	-0.48	-0.52
u_{HN}	-13.25	-15.41	-16.29	-17.26	-18.40
	Skilled Immigrants				
w_{HI}	1.91	2.44	2.67	2.93	3.24
u_{HI}	same as natives	same as natives	same as natives	same as natives	same as natives
	Overall Skilled				
w_H	-1.15	-1.21	-1.24	-1.27	-1.30
u_H	same as natives	same as natives	same as natives	same as natives	same as natives
θ_H	27.02	31.47	33.29	35.29	37.66
	Overall Natives				
w_N	0.16	0.15	0.15	0.15	0.14
u_N	-11.23	-11.52	-11.65	-11.79	-11.97
surplus 1	0.64	0.62	0.61	0.60	0.58
surplus 2	0.97	0.99	0.99	1.00	1.01
	Overall				
w	-0.37	-0.38	-0.38	-0.38	-0.39
u	-11.56	-11.84	-11.96	-12.10	-12.27
Y	7.36	7.39	7.40	7.41	7.43
surplus 1	6.59	6.57	6.56	6.55	6.54
surplus 2	6.92	6.93	6.94	6.95	6.96

Notes: The table shows result of the general model when we change the unemployment income of the skilled workers. We keep all other parameter values the same (see Table 1).

Table B20. Sensitivity of the Calibration Results with respect to the Unemployment Income of the Skilled Workers in the Imperfect-Substitutes Model

(Percentage Changes)

	$b_H = 0.2$	$b_H = 0.35$	$b_H = 0.40$	$b_H = 0.45$	$b_H = 0.50$
	Unskilled Natives				
w_{LN}	0.16	0.19	0.20	0.21	0.23
u_{LN}	-16.36	-16.41	-16.42	-16.45	-16.47
	Unskilled Immigrants				
w_{LI}	34.72	35.06	35.21	35.38	35.60
u_{LI}	same as natives	same as natives	same as natives	same as natives	same as natives
	Overall Unskilled				
w_L	-4.73	-4.70	-4.69	-4.68	-4.66
u_L	same as natives	same as natives	same as natives	same as natives	same as natives
θ_L	35.51	35.61	35.65	35.69	35.75
	Skilled Natives				
w_{HN}	0.48	0.35	0.28	0.20	0.10
u_{HN}	-15.62	-18.95	-20.40	-22.05	-24.10
	Skilled Immigrants				
w_{HI}	18.87	28.94	34.29	41.27	51.55
u_{HI}	same as natives	same as natives	same as natives	same as natives	same as natives
	Overall Skilled				
w_H	-5.85	-5.95	-5.99	-6.05	-6.11
u_H	same as natives	same as natives	same as natives	same as natives	same as natives
θ_H	31.93	38.82	41.84	45.27	49.54
	Overall Natives				
w_N	0.18	0.16	0.14	0.13	0.10
u_N	-16.29	-16.67	-16.85	-17.06	-17.35
surplus 1	0.63	0.57	0.55	0.51	0.46
surplus 2	1.49	1.51	1.51	1.52	1.53
	Overall				
w	-5.07	-5.08	-5.09	-5.09	-5.10
u	-16.65	-17.02	-17.19	-17.40	-17.68
Y	3.73	3.78	3.80	3.83	3.86
surplus 1	2.14	2.11	2.09	2.07	2.04
surplus 2	2.84	2.87	2.89	2.91	2.93

Notes: The table shows result of the model where immigrants and natives of the same type are imperfect substitutes in production when we change the unemployment income of the skilled workers. We keep all other parameter values the same (see Table 1).

Table B21. Sensitivity of the Calibration Results with respect to the Unemployment Income of the Skilled Workers in the Separate-Markets Model

(Percentage Changes)

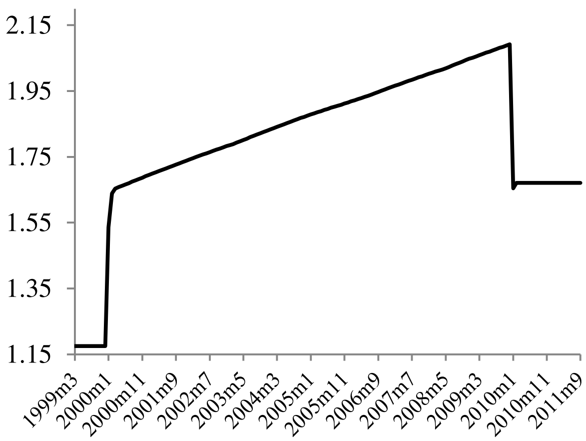
	$b_H = 0.2$	$b_H = 0.35$	$b_H = 0.40$	$b_H = 0.45$	$b_H = 0.50$
	Unskilled Natives				
w_{LN}	0.20	0.21	0.21	0.23	0.25
u_{LN}	-1.04	-1.11	-1.18	-1.38	-2.37
θ_{LN}	2.50	2.70	2.88	3.40	6.21
	Unskilled Immigrants				
w_{LI}	-2.87	-2.86	-2.86	-2.84	-2.81
u_{LI}	0.11	0.11	0.11	0.11	0.10
θ_{LI}	-0.23	-0.23	-0.23	-0.23	-0.21
	Overall Unskilled				
w_L	-4.84	-4.85	-4.86	-4.89	-5.12
u_L	-5.86	-5.95	-6.04	-6.29	-7.49
	Skilled Natives				
w_{HN}	0.05	0.04	0.03	0.01	0.00
u_{HN}	-0.04	-0.07	-0.09	-0.07	0.25
θ_{HN}	0.09	0.16	0.21	0.15	-0.72
	Skilled Immigrants				
w_{HI}	-3.77	-3.75	-3.74	-3.74	-3.70
u_{HI}	0.05	0.06	0.06	0.06	0.06
θ_{HI}	-0.11	-0.11	-0.12	-0.12	-0.13
	Overall Skilled				
w_H	-5.94	-6.05	-6.15	-6.42	-7.63
u_H	-5.82	-6.56	-6.93	-7.34	-7.48
	Overall Natives				
w_N	0.12	0.12	0.12	0.11	0.06
u_N	-0.96	-1.00	-1.03	-1.12	-1.53
surplus 1	0.31	0.31	0.31	0.31	0.30
surplus 2	0.47	0.48	0.50	0.54	0.79
	Overall				
w	-5.17	-5.21	-5.24	-5.33	-5.79
u	-6.25	-6.35	-6.44	-6.66	-7.41
Y	3.13	3.18	3.22	3.33	3.91
surplus 1	2.22	2.23	2.23	2.23	2.22
surplus 2	2.45	2.48	2.51	2.60	3.10

Notes: The table shows result of the model where immigrants and natives search in different labor markets when we change the unemployment income of the skilled workers. We keep all other parameter values the same (see Table 1).

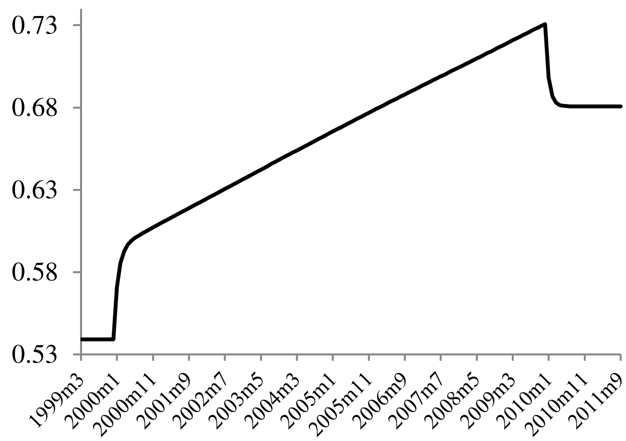
Figure C1. Dynamic Adjustment

Labor market tightness

Tightness in the skilled market

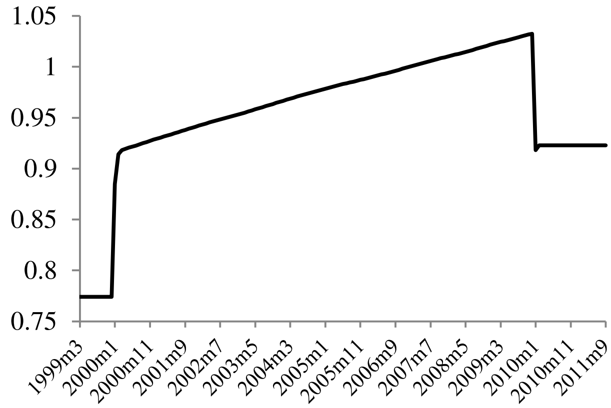


Tightness in the unskilled market

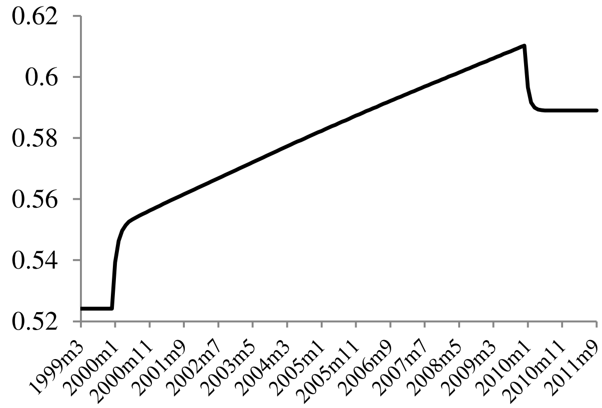


Matching rates

The skilled matching rate

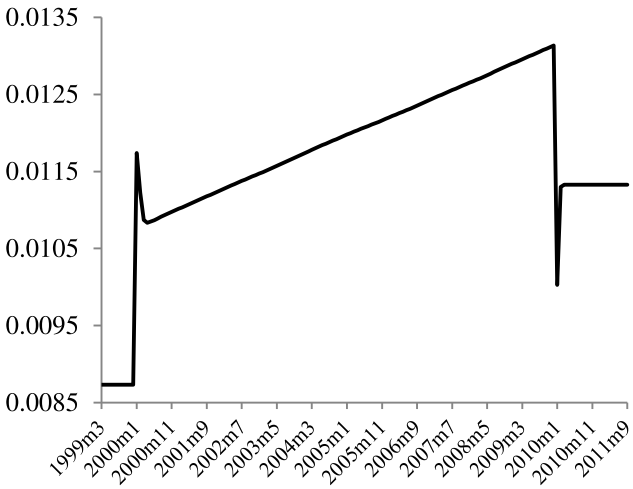


The unskilled matching rate

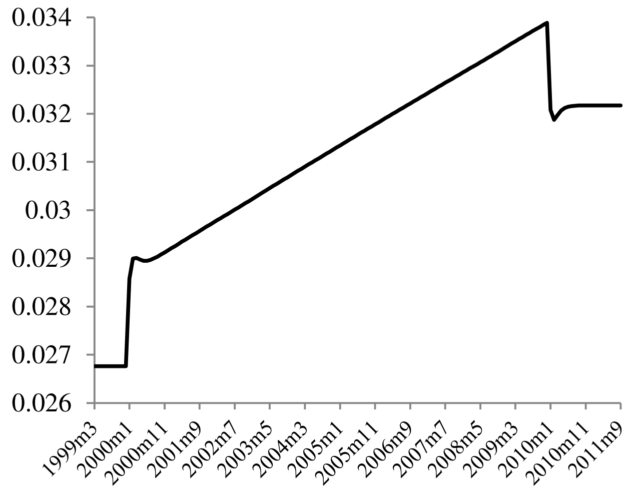


Vavancies

Skilled vacancies

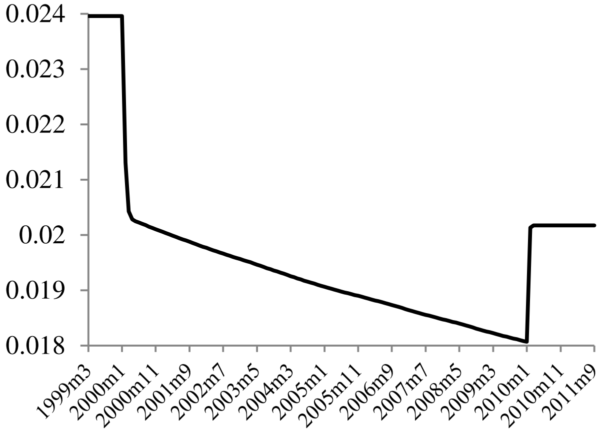


Unskilled vacancies

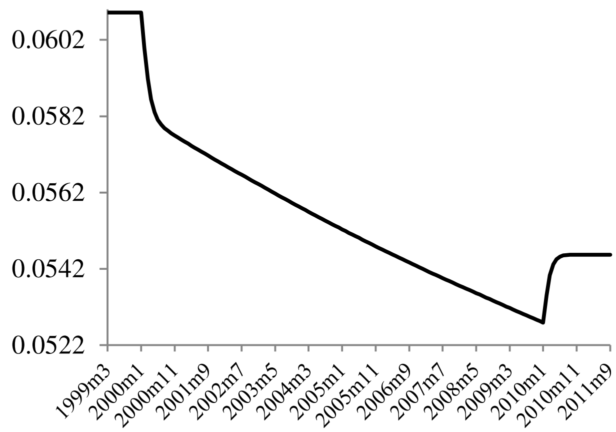


Unemployment rates

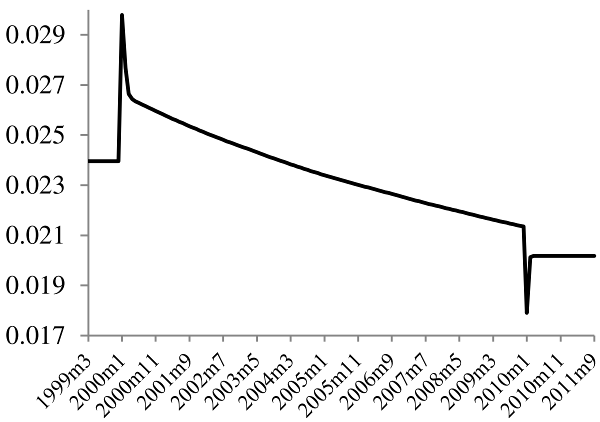
The skilled-native unemployment rate



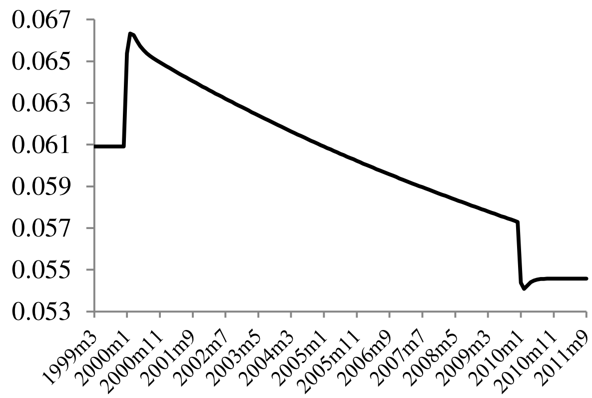
The unskilled-native unemployment rate



The skilled-immigrant unemployment rate

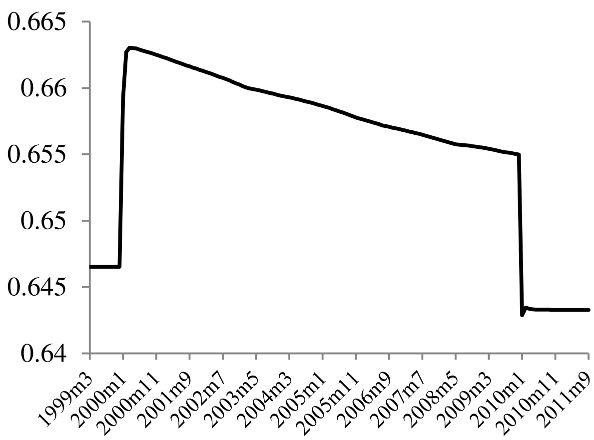


The unskilled-immigrant unemployment rate

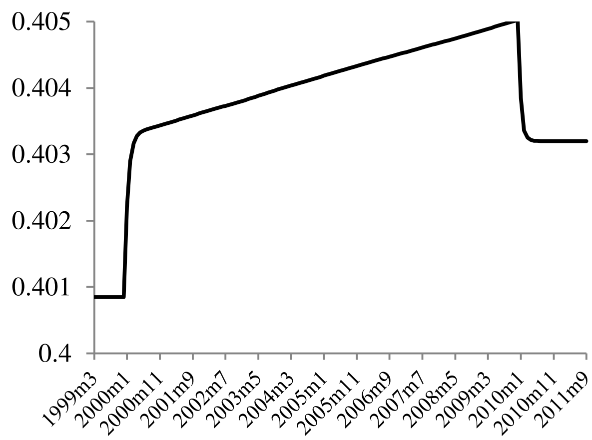


Wages

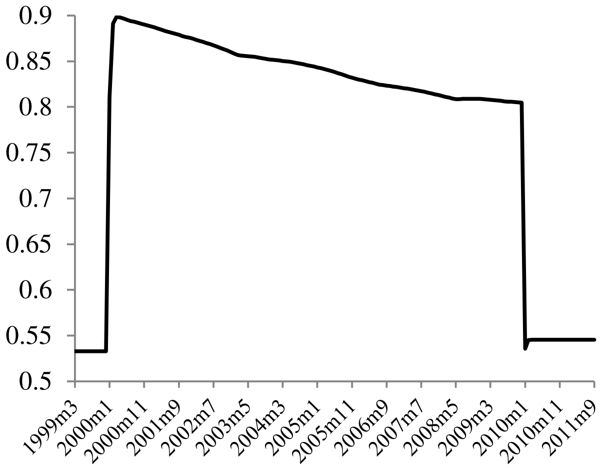
The skilled-native wage



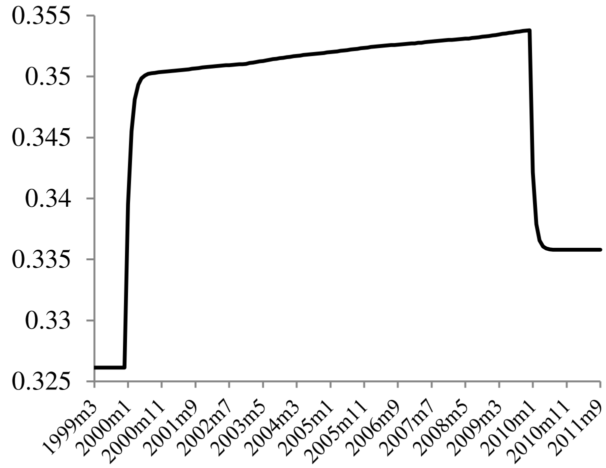
The unskilled-native wage



The skilled-immigrant wage

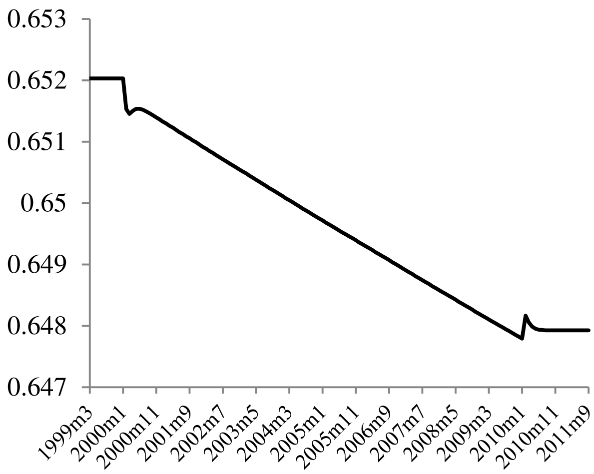


The unskilled-immigrant wage

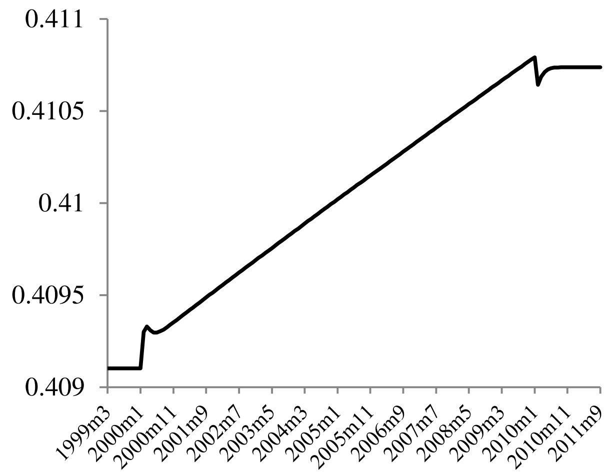


Prices

The price of the skilled input

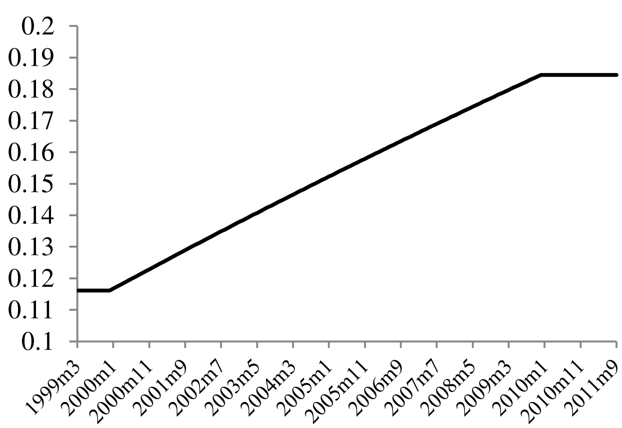


The price of the unskilled input

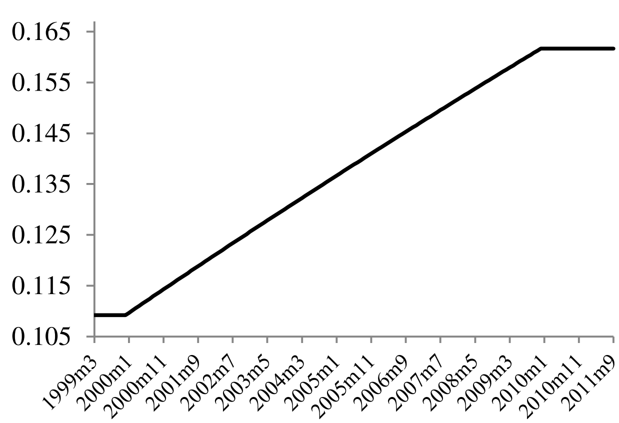


Probability that an unemployed worker is immigrant

Proportion of immigrants in the skilled labor force



Proportion of immigrants in the unskilled labor force



Total income and capital