

A SEARCH-EQUILIBRIUM APPROACH TO THE EFFECTS OF IMMIGRATION ON LABOR MARKET OUTCOMES*

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We analyze the impact of the U.S. skill-biased immigration influx that took place between 2000 and 2009 within a search and matching model that allows for skill heterogeneity, differential search cost, and capital-skill complementarity. We find that although the skill-biased immigration raised the overall net income to natives, it had distributional effects. Specifically, unskilled native workers gained in terms of both employment and wages. Skilled native workers, however, gained in terms of employment but lost in terms of wages. Nevertheless, in an extension where skilled natives and immigrants are imperfect substitutes, even the skilled wage rises.

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 et al. (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 is now well understood, imperfect substitution between native and immigrant labor can generate a positive effect on native wages.

This article aspires to contribute to the debate regarding the impact of immigration by following a different approach. We conduct our analysis within a search and matching model of the labor market (e.g., Diamond, 1982; Mortensen and Pissarides, 1994). In this class of models, unemployment exists due to search frictions, and job entry responds endogenously to market incentives. 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 of 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 setup skill heterogeneity 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

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capital as an independent factor of production serves as an additional channel of adjustment to immigration-induced changes in labor supply. Fourth, we adopt 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 U.S. economy and find that the impact of the *skill-biased* increase in immigration that took place between 2000 and 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.

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 search framework 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, since there is only one labor type, his analysis overlooks both the negative effect 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, 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 2000–09, 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, whereas, in an extension of the model, 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 article 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 case, we assume that there are no differences in search costs between otherwise identical native and immigrant workers. In the second case, 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. Section 6 presents the results of several extensions and Section 7 concludes.²

2. THE MODEL

We construct a search and matching model with two intermediate inputs and one final consumption good. Time is continuous. 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, whereas that of immigrants is denoted by I and is determined exogenously. The mass of jobs, however, is determined endogenously as part of the equilibrium. All agents are risk neutral and discount the future at the interest rate r . The rest of this section offers a detailed description of the model.

2.1. Workers and Firms. Workers are either skilled (H) or unskilled (L).³ Let λ be the fraction of native workers that are unskilled (in the benchmark version of the model λ is 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 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 nonstorable. 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; Krusell et al., 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:

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

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

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 and the skilled input (Y_H) are nested together in the subaggregate input Q given

² The working paper version of the article (Chassamboulli and Palivos, 2012) presents detailed proofs of the propositions, the extensions of the model, the sensitivity analysis, and the dynamic adjustment of the equilibrium.

³ We use the terms skilled (unskilled) and high (low) skill interchangeably.

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; Polgreen and Silos, 2008). If either ρ or γ equals 0, 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,

$$(3) \quad p_L = \alpha Y_L^{\rho-1} Y^{1-\rho},$$

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

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 plus its depreciation rate (δ). Thus,

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

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, and linearly homogeneous 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 $m'(\theta_i) > 0$ and $q'(\theta_i) < 0$.

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 Chassamboulli and Palivos, 2012). A vacant firm bears a recruitment cost c_i , specific to its type. This is measured in units of final output, which melts away in keeping the vacancy. However, an unemployed worker of type i receives a flow of income b_i , which captures the opportunity cost of employment. There is no cross-skill matching. High-skill workers direct their search toward the high-skill sector and low-skill workers toward 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 et al. (1995, 2003).

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 . 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.⁴ More generally, however, h_{ij} may denote a difference in the outside option b_i . Henceforth, we assume that $h_{iN} = 0 < h_{iI}$, 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 or unemployed and a vacancy is either filled or unfilled. We denote the present discounted value associated with each state by J_{ij}^κ , where $i = H, L$ denotes the skill type (high skill or low skill), $j = N, I$ denotes the origin (native or immigrant), and $\kappa = V, U, F, E$, indicates the state (vacant firm, unemployed worker, filled job, employed worker). Then in steady state,

$$(6) \quad rJ_i^V = -c_i + q(\theta_i) [\phi_i J_{iN}^F + (1 - \phi_i) J_{iI}^F - J_i^V],$$

$$(7) \quad rJ_{ij}^F = p_i - w_{ij} - (s_i + n) [J_{ij}^F - J_i^V],$$

$$(8) \quad (r + n)J_{ij}^U = b_i - h_{ij} + m(\theta_i) [J_{ij}^E - J_{ij}^U],$$

$$(9) \quad (r + n)J_{ij}^E = w_{ij} - s_i [J_{ij}^E - J_{ij}^U],$$

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,

$$(10) \quad J_i^V = 0.$$

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

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

In other words, firms get a share $1 - \beta$ and workers get β of the total surplus S_{ij} generated by a match, where $S_{ij} = J_{ij}^F + J_{ij}^E - J_{ij}^U - J_i^V$.

⁴ 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, e.g., NELP, 2002 (accessed December 23, 2009)).

2.5. *Steady-State Composition of the Labor Force.* Recall that I_H and I_L denote the mass of skilled and unskilled immigrants. 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:

$$(12) \quad Y_H = \frac{m(\theta_H)(1 - \lambda + I_H)}{n + s_H + m(\theta_H)}, \quad Y_L = \frac{m(\theta_L)(\lambda + I_L)}{n + s_L + m(\theta_L)}.$$

Similarly, the steady-state unemployment U_{ij} of each type i and origin j is given by

$$(13) \quad U_{HN} = \frac{(n + s_H)(1 - \lambda)}{n + s_H + m(\theta_H)}, \quad U_{HI} = \frac{(n + s_H)I_H}{n + s_H + m(\theta_H)},$$

$$(14) \quad U_{LN} = \frac{(n + s_L)\lambda}{n + s_L + m(\theta_L)}, \quad U_{LI} = \frac{(n + s_L)I_L}{n + s_L + m(\theta_L)}.$$

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

$$\phi_H = \frac{U_{HN}}{U_H} = \frac{1 - \lambda}{1 - \lambda + I_H}, \quad \phi_L = \frac{U_{LN}}{U_L} = \frac{\lambda}{\lambda + I_L},$$

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; that is, 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; that is, conditions (12)–(14) are satisfied.

It can be shown that the steady-state equilibrium values of θ_H and θ_L are given by the following reduced system of equations:

$$(15) \quad \alpha \left\{ \alpha + (1 - \alpha) \left(\frac{A_H}{A_L \Lambda} \right)^\rho [xk^\gamma + (1 - x)]^{\frac{\rho}{\gamma}} \right\}^{\frac{1-\rho}{\rho}} = B_L,$$

$$(16) \quad (1 - \alpha)(1 - x) [xk^\gamma + (1 - x)]^{\frac{1-\gamma}{\gamma}} \left\{ \alpha \left(\frac{A_L \Lambda}{A_H} \right)^\rho [xk^\gamma + (1 - x)]^{-\frac{\rho}{\gamma}} + (1 - \alpha) \right\}^{\frac{1-\rho}{\rho}} = B_H,$$

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:

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

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 (15) and (16) 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 (15) 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 (13)–(14); for example, the unemployment rate among skilled natives, which is equal to the one among skilled immigrants, is given by $u_{HN} = u_{HH} = (n + s_H) / [n + s_H + m(\theta_H)]$. Finally, the wage rates are given by

$$(17) \quad w_{ij} = \frac{[n + r + s_i + m(\theta_i)]\beta p_i + (n + r + s_i)(1 - \beta)(b_i - h_{ij})}{n + r + s_i + \beta m(\theta_i)}.$$

Note that equation (17) can be written as

$$(18) \quad w_{ij} = (1 - \beta)(r + n)J_{ij}^U + \beta p_i,$$

that is, the worker's wage is a convex combination of his outside option ($(r + n)J_{ij}^U$) and his marginal product (= p_i). 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). *A steady-state equilibrium exists and is unique.*

The essence of Proposition 1 can be captured with the help of Figure 1. 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 (15) and (16). 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

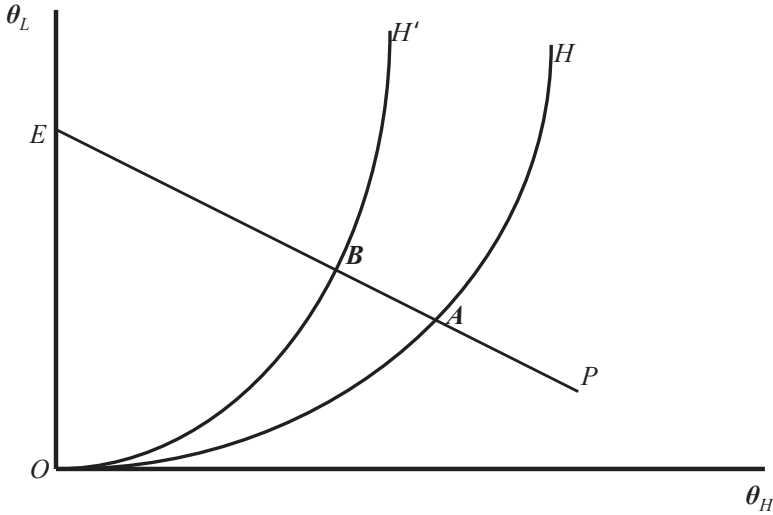


FIGURE 1

EXISTENCE AND UNIQUENESS—AN INCREASE IN HIGH-SKILL IMMIGRATION WHEN THERE ARE NO SEARCH COSTS

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) 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 .⁵

The curve OH , however, is the locus of values of θ_H and θ_L that make the expected profit from establishing a high-skill vacancy equal to zero (described by Equation 16). 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 (17) 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. The following condition suffices for that:

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 whereas 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 that firms and workers get a constant share of the surplus S_{ij} , the same condition ensures that $J_{ij}^E \geq J_{ij}^U$, that is, an unemployed worker will not turn down an employment opportunity and continue searching.

⁵ In general, the curvature of the EP locus cannot be determined; we draw it as a straight line for simplicity.

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 and a native worker with the same skills. In this case, a change in I_i has no impact on employment cost 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 (15) and (16) 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.

4.1. Variable Prices and No Search Costs. Consider first the case where $\rho < 1$ and the search cost, h_{iI} , is equal to zero. The latter assumption implies that there is no difference between a native worker and an immigrant of the same type; in particular, $w_{ij} = w_i \forall j$.

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

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

The effects of a change in I_L have analogous signs.

An increase in I_H raises the productivity of unskilled labor and lowers that of skilled. Hence, p_L goes up, whereas p_H goes down. Since higher (lower) prices lead to higher (lower) profits, this induces the entry of unskilled jobs and raises θ_L ; at the same time, it discourages the entry of skilled jobs and lowers θ_H . We can demonstrate these effects graphically using Figure 1. An increase in I_H shifts the OH curve to the left (from OH to OH'). However, since the employment cost does not change, the EP curve does not shift. Thus, the equilibrium moves from point A to point B ; θ_H goes down, whereas θ_L goes up. Given these changes, 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 ($w_{HN} = w_{HI}$ in this case). 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 (15) and (16) 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

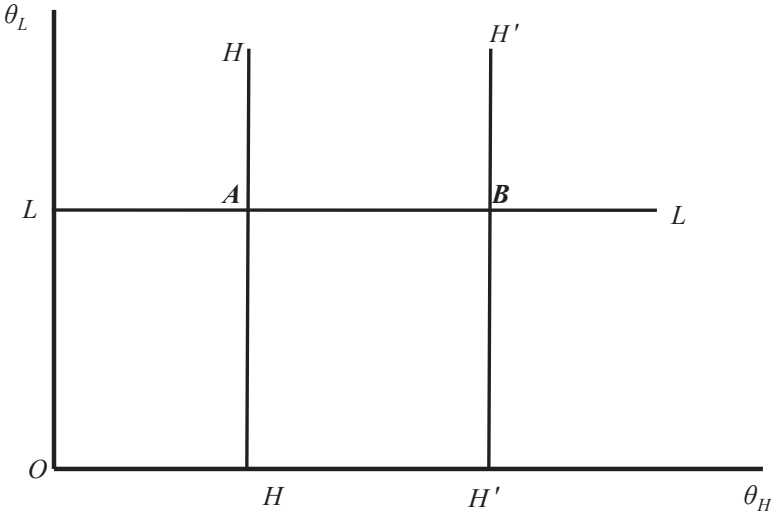


FIGURE 2

AN INCREASE IN HIGH-SKILL IMMIGRATION WHEN THERE ARE SEARCH COSTS AND PERFECT SUBSTITUTABILITY

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_{Lj} , and w_{Lj} , 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 $p_H = (1 - \alpha)(1 - x) [xk^\gamma + (1 - x)]^{\frac{1-\gamma}{\gamma}}$, where, as implied by (2) and (5), k assumes a constant value. However, 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, when $h_{iI} > 0 = h_{iN}$, the wage rate of immigrants is lower than that of native workers of the same skill type; that is, $w_{iI} < w_{iN}$, because immigrants are subject to higher search costs (see Equation (17)). 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 (17), and a decrease in their unemployment rate $u_{HN} = U_{HN}/1 - \lambda$ (see Equation 13). Finally, the market tightness θ_L for low-skill workers is given by (15). Note that if $\rho = 1$, then θ_L is independent of I_H . 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 2. Along the curve HH (LL) profit is zero in the high-skill (low-skill) sector. An increase in I_H 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 $h_{il} > 0$. 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 employment, 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 U.S. 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, that is, the total income to natives net of the flow cost of vacancies.⁶ 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

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

that is it is equal to the total flow of output, Y , plus the output-equivalent flow to unemployed native workers, $b_H U_{HN} + b_L U_{LN}$, minus the flow costs of vacancies, $c_H V_H + c_L V_L$, minus the wages paid to employed immigrants, $w_{HI}(I_H - U_{HI}) + w_{LI}(I_L - U_{LI})$. 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, $\tilde{Y} - b_H U_{HN} - b_L U_{LN}$.

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), 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 U.S. 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 2000–09. 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 and the average GDP deflator over the period 1990–99. 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 (ε) to 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 power (β) to be 0.5, so that the Hosios condition ($\beta = \varepsilon$) is met (Hosios, 1990). Fourth, as in Krusell et al. (2000), we define as skilled a worker with at least a

⁶ The change in net income is a conventional measure of welfare change in this class of models (see, e.g., Acemoglu, 2001).

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)
<i>Measured from the data:</i>	
$r = 0.004$	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.‡
<i>Jointly calibrated to match:</i>	
$\alpha = 0.517, x = 0.051$	The employment rates of skilled and unskilled workers: 0.976 and 0.939.‡
$c_L = 0.421, c_H = 0.556$	The capital-output ratio: 1.348.§
$b_L = 0.279, b_H = 0.449$	The college-plus wage premium: 61.1%.‡
$h_L = 1.182, h_H = 4.203$	The ratio of unemployment to employment income of 0.71% for both skill groups (Hall and Milgrom, 2008).
$\xi = 0.714$	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.

Bachelor's degree.⁷ Moreover, in our baseline calibration we adopt their parameter estimates for the U.S. 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 (BEA) 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 (PUM) of the 1990 and 2000 US Censuses. We define as "immigrants" noncitizens and naturalized citizens.¹¹ Eighth, using also

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 U.S. 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 ages 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 time series studies find 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 0.3–0.6 (see Card, 2009).

⁹ These measures include employment to unemployment and employment to inactivity transitions. In Chassamboulli and Palivos (2012), we show that when the employment to inactivity transitions are excluded from our calculations of the separation rates, the results are essentially unaffected.

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 25–65, while they exclude those who are not in the labor force (report zero weeks of work or no wage income or are enrolled in school) as well as those who are in the military.

PUM 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 U.S.-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 U.S. data over the period of interest, namely, 1990–99. 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 from the March CPS, we found them to be 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 BEA data. 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 GDP—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 (e.g., see Pissarides, 2009; Brügemann and Moscarini, 2010). 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 Chassamboulli and Palivos (2012), we show that using Shimer's replacement ratio of 0.40 does not alter the results in any significant way.

5.2. Results. Using PUM, we find that the change in I_L and I_H between January 2000 and December 2009 was 0.051 and 0.026, respectively, that is, 5.1% and 2.6% of the *native labor force*. Moreover, the total increase in the U.S. *labor force* resulting from international immigration over this period was 6.8%.¹³ Crucially, the immigration influx over the period of interest is biased toward skilled labor. More specifically, it follows from the aforementioned data that Δ , the ratio of unskilled to skilled labor, decreased from 2.629 to 2.577.¹⁴

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 as described above, but also, for comparability, from three alternative specifications. In the first, we set $h_{LL} = h_{HI} = 0$; hence, there are only price effects (this is the case considered in Proposition 2). In the second specification, we keep the assumption $h_{HI} = 0$,

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 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.

¹⁴ On this reversal of the traditional immigration movement, see also Ottaviano and Peri (2012) for the United States and Docquier et al. (2010) for other countries.

TABLE 2
THE EFFECTS OF THE 2000–2009 IMMIGRATION INFLUX (CHANGES IN PERCENTAGE POINTS)

	$h_{HI} = 0$ $h_{LI} = 0$	$h_{HI} > 0$ $h_{LI} = 0$	$h_{HI} = 0$ $h_{HI} > 0$	$h_{HI} > 0$ $h_{LI} > 0$
<i>Unskilled natives</i>				
w_{LN}	0.17	0.21	0.20	0.24
u_{LN}	-0.06	-0.07	-0.64	-0.64
<i>Unskilled immigrants</i>				
w_{LI}	Same as natives	Same as natives	0.94	0.98
u_{LI}	Same as natives	Same as natives	Same as natives	Same as natives
θ_L	0.39	0.48	14.04	14.14
<i>Skilled natives</i>				
w_{HN}	-0.44	-0.45	-0.30	-0.31
u_{HN}	0.05	-0.38	0.03	-0.38
<i>Skilled immigrants</i>				
w_{HI}	Same as natives	1.44	Same as natives	1.56
u_{HI}	Same as natives	Same as natives	Same as natives	Same as natives
θ_H	-0.76	49.33	-0.53	49.57
<i>Overall natives</i>				
w_N	-0.01	0.04	0.02	0.07
u_N	-0.03	-0.16	-0.45	-0.57
Surplus 1	0.07	0.15	0.20	0.28
Surplus 2	0.07	0.21	0.33	0.46

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.

but set $h_{LI} = 1.182$, as calibrated above. Finally, in the last case, we set $h_{LI} = 0$ and 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 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, whereas the marginal product and the price of unskilled labor rise, 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 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 expected cost of hiring a skilled worker. The consequent increase in their job finding rate causes their unemployment rate to fall. However, the drop in their marginal product dominates the improvement in their job finding rate, and thus their bargaining position in wage setting weakens. 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, in terms of both employment and wages. The immigration-induced increase in skilled job entry, and as

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

a consequence in Y_H , leads to an even larger increase in the price of the 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 U.S. 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 0.64 percentage points. 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 0.38 percentage points. In terms of wages, for the reasons explained above, the wage of unskilled native workers increases by 0.24 percentage points, whereas that of skilled native workers falls by 0.31 percentage points.

In all cases considered, the surge in immigration lowers the unemployment rate of natives overall and raises the total native income. 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. 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 U.S. data dictate. In this case, the native unemployment rate falls by 0.57 percentage points and the native wage rate increases by 0.07 percentage points, leading to an increase in the surplus of natives between 0.28 (surplus 1) and 0.46 (surplus 2) percentage points.

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 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.

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

TABLE 3
 SENSITIVITY OF THE CALIBRATION RESULTS WITH RESPECT TO PRODUCTION PARAMETERS IN THE GENERAL MODEL
 ($\rho < 1, h_{LI} > 0, h_{HI} > 0$) (CHANGES IN PERCENTAGE POINTS)

	$\rho = 0 \gamma = -1$ ($\sigma_{Lk} = \sigma_{LH} = 1,$ $\sigma_{HK} = 0.5$)	$\rho = 0.5 \gamma = 0$ ($\sigma_{Lk} = \sigma_{LH} = 2,$ $\sigma_{HK} = 1$)	$\rho = 0.5 \gamma = -1$ ($\sigma_{Lk} = \sigma_{LH} = 2,$ $\sigma_{HK} = 0.5$)	$\rho = 0 \gamma = 0$ ($\sigma_{Lk} = \sigma_{LH} = 1,$ $\sigma_{HK} = 1$)
<i>Unskilled natives</i>				
w_{LN}	0.24	0.22	0.22	0.26
u_{LN}	-0.99	-0.57	-0.58	-0.94
<i>Unskilled immigrants</i>				
w_{LI}	1.37	0.89	0.90	1.33
u_{LI}	Same as natives	Same as natives	Same as natives	Same as natives
θ_L	14.08	14.13	14.12	14.11
<i>Skilled natives</i>				
w_{HN}	-0.37	-0.27	-0.26	-0.40
u_{HN}	-0.31	-0.40	-0.40	-0.31
<i>Skilled immigrants</i>				
w_{HI}	1.17	1.70	1.71	1.15
u_{HI}	Same as natives	Same as natives	Same as natives	Same as natives
θ_H	49.50	49.64	49.64	49.46
<i>Overall natives</i>				
w_N	0.01	0.08	0.07	0.01
u_N	-0.80	-0.53	-0.53	-0.77
Surplus 1	0.25	0.31	0.27	0.30
Surplus 2	0.49	0.47	0.44	0.53

NOTES: See Table 2.

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), 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 . 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 2000–09 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. Furthermore, the model's prediction regarding the positive impact of immigration on native surplus remains valid.

6. EXTENSIONS

Next we comment briefly on three extensions of the model (details on these and more extensions are in Chassamboulli and Palivos, 2012). First, we let immigrants be imperfect substitutes for native workers of the same type and hence have different marginal products and different prices. When we let just unskilled immigrants be imperfect substitutes for unskilled natives, we find our previous results to be robust. 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, it raises the overall surplus accrued to natives.

When immigrants and natives of both labor types are imperfect substitutes, then 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 so because at lower values of the elasticity of substitution, the immigration-induced fall in the marginal product of skilled native workers 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, the wage of existing immigrants not only increases but increases much more than the wage of natives. As 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.

Next, we 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; such adjustments cannot take place in the short run. Specifically, before entering the labor market we let each agent decide whether to invest in education and become skilled or remain unskilled. Native young agents differ with respect to their ability to learn, which in turn determines their cost of acquiring education.

We find that a skill-intensive increase in immigration, such as the one that took place from 2000 to 2009, 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 born native workforce chooses to remain unskilled. The resulting compositional shift in the native labor force toward 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 (negative) effects of skill-biased immigration on the wages and employment of unskilled (skilled) natives. 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.

In the final extension of the basic model, we assume imperfect substitutability, as above, but, in addition to skill-specific jobs, we also allow for origin-specific vacancies, that is, vacancies that are suited only for natives or only for immigrants. Hence, there are four intermediate sectors and four labor markets. By assumption, immigrants cannot search in the market for native jobs and vice versa. Thus, the number of skilled or unskilled immigrants does not affect the probability that a type i and unemployed worker is native anymore. Consequently, there will be only price effects and the impact of the skilled-intensive increase in immigration on the matching rates is in general much smaller in magnitude.

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. Hence, 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 sector increases.

In contrast to the case where immigrants and natives compete for the same jobs, when 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 its price falls relative to the

price of the native labor input, with negative consequence on the number of jobs available to immigrants and on their wage.

7. CONCLUSIONS

In this article, 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 our model 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 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.

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