The Dynamic Effects of Immigration

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Abstract

I examine the welfare effects of immigration on United States workers. I build a dynamic search and matching model in which immigrants and natives differ according to their outside options, separation rates, wealth holdings and skill composition. Immigration affects native-born welfare by i) altering the skill composition of the labor force, ii) lowering the expected hiring cost of firms, and iii) altering the rate of return on wealth. I demonstrate that the transition period, during which the economy adjusts to immigration, involves both higher returns to wealth and inferior labor market conditions in comparison to the long run steady state. Accounting for transition dynamics therefore shifts the welfare effects of immigration in favor of wealthy households at the expense of workers.

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1 Introduction

Restrictions on labor movements between countries are arguably the largest policy distortions in the international economy. Wage differentials for observably identical workers can exceed 1000% across different national markets (Clemens et al., 2008), compared to price wedges that rarely exceed 74% for goods, and 15% for financial instruments (Clemens, 2011). Estimates of the increase in world GDP caused by the removal of labor market barriers range from 66% (Iregui, 2005) to 127% (Klein and Ventura, 2007) - three orders of magnitude larger than the equivalent removal of trade or capital flow barriers.

Despite these enormous potential gains to world income, and a dramatic expansion in international migration over the last 20 years, more than 96% of humanity remain in their country of birth (International Organization for Migration, 2013). Host countries continue to restrict migrant entry out of public concern for the adverse effect of immigration on the welfare of native-born citizens (Mayda, 2006).[1] Understanding these welfare consequences is therefore not just important to native-born workers, but also to the substantial proportion of the world population who wish to migrate.

In this article, I examine the impact of immigration on the labor market outcomes and welfare of native-born workers in a dynamic model with labor market search frictions (Diamond, 1982; Mortensen and Pissarides, 1994) and endogenous wealth accumulation. Migrants and natives differ according to their outside options (Chassamboulli and Palivos, 2014), separation rates (Battisti et al., 2014), skill composition (Borjas, 2003) and wealth holdings.

Within this theoretical framework, immigration affects native welfare via three primary channels - the *price* channel, the *hiring cost* channel, and the *capital surplus* channel. The *price* channel reflects standard classical factor demand theory. Immigration alters the skill composition of the labor force and the resulting factor returns which, in a competitive setting, affects wages. I demonstrate that this impact on wages is maintained in my non-Walrasian labor market setup, and that the changes in relative productivities also alter the hiring incentives of firms and therefore employment.

The *hiring cost* channel is novel to the immigration literature (Chassamboulli and Palivos, 2013). Immigrants have lower outside options than their native counterparts and are therefore willing to accept lower wages. Because firms cannot ex-ante distinguish between native and immigrant workers when posting job vacancies, immigration increases the likelihood that a given vacancy is eventually filled by an immigrant, and therefore decreases the expected wage to be paid by a firm. The resulting increase in firm surplus promotes hiring activity, which improves the labor market conditions of both immigrants and the native-born through an

[1] For example, 47% of Americans and 64% of Britons viewed migration as more of a problem than an opportunity in 2013 (Transatlantic Trends, 2013, p. 14).

increase in employment and the bargaining positions of workers.

The *capital surplus* channel is related to the concept of the "immigration surplus" identified by Borjas (1995). In the absence of a perfectly elastic capital stock, immigration generates higher rates of return to capital and lower marginal products of labor, thereby benefiting the owners of capital at the expense of workers.[2] I demonstrate that this channel allows wealthier households to benefit more from immigration than their less wealthy counterparts, who rely primarily on labor income.

To my knowledge, this article is the first to simultaneously consider each of these three channels within the same model. Ben-Gad (2004) and Moy and Yip (2006) employ neoclassical growth frameworks with homogeneous labor to investigate the *capital surplus* channel. Ben-Gad (2008) extends Ben-Gad (2004) by incorporating skill heterogeneity to further examine the redistributive *price* channel across skill groups. More recently, Chassamboulli and Palivos (2013, 2014) and Battisti et al. (2014) have examined the effects of immigration within a search and matching framework with skill heterogeneity. These frameworks incorporate the *price* and *hiring cost* channels but do not speak to the *capital surplus* channel.

In order to accommodate the *capital surplus* channel, I compute the full transition dynamics of the economy as it adjusts to new levels of immigration. While Ben-Gad (2008) accounts for transition dynamics in a neoclassical framework, this article is the first to do so in a setting with labor market frictions. The literature traditionally derives welfare implications by comparing pre- and post-migration steady states within static frameworks (Borjas, 1995, 1999) or by ignoring transition dynamics within dynamic frameworks (Liu, 2010; Chassamboulli and Palivos, 2013, 2014; Battisti et al., 2014). There are two issues with this approach. The first is that the transition to the new steady state can involve periods in which wages and unemployment deviate substantially from their eventual steady state values. Ignoring these deviations potentially ignores significant fluctuations in labor income that could alter welfare conclusions based solely on steady state values. The second issue is that the resulting steady state levels of asset holdings, and therefore consumption, inherently depend on the transition dynamics in an economy with heterogeneous wealth holders (Mendoza and Tesar, 1998). The literature therefore necessarily makes simplifying assumptions such as not allowing immigrants to accumulate wealth (Palivos, 2009; Liu, 2010) or forcing savings to be sent abroad (Moy and Yip, 2006). These assumptions completely eliminate the redistributive effect of the *capital surplus* channel.

The transition dynamics crucially depend on the elasticity of the aggregate capital stock. I therefore investigate the welfare consequences of immigration under two extreme scenarios - an *open* economy in which

[2] Borjas (1999) estimates that this channel redistributes approximately 2% of output from workers to owners of capital within a static model, although Ben-Gad (2004) demonstrates that accounting for transition dynamics reduces this estimate by a factor of three.

domestic asset markets are fully open to foreign capital flows and a *closed* economy in which the aggregate capital stock is fully determined by the wealth accumulation decisions of domestic households. The dynamics of the *closed* economy are more protracted than the *open* economy dynamics because the aggregate capital stock in a *closed* economy is less reactive to the changes in factor prices caused by immigration. The marginal productivities of labor, which are increasing in the level of the capital stock, are therefore lower during the *closed* economy transition than the *open* economy transition. As a result, the *closed* economy creates inferior labor market outcomes - in the form of lower wages and higher unemployment - in comparison to the *open* economy over the adjustment period. Offsetting these negative labor market effects are the increased rates of return to capital that occur in the *closed* economy over the adjustment period. In other words, the *capital surplus* channel plays a more important role in the *closed* economy.

An additional contribution of this article is a methodological one. I adopt the preference specification of Greenwood et al. (1988) which ensures that the disutility derived from employment is independent of household wealth. This allows the coefficient on the disutility of labor to be consistent with the interpretation of an "outside option" that is common in the search and matching literature with risk neutral agents. To my knowledge, I am the first to exploit this particular implication of these preferences within a search and matching model with risk averse agents. The assumption facilitates both the steady state and transition analysis by allowing labor market dynamics, which would otherwise depend on household wealth (Krusell et al., 2010), to be computed separately from wealth dynamics.

I calibrate the model to match key features of the United States economy over the previous decade, including unemployment rates, wage premiums, wealth holdings, population shares and job finding rates for each worker type using data from the Current Population Survey and the Survey of Income and Program Participation. I simulate the effects of immigration by increasing the size of the labor force by 1% through an increase in the stock of either high skill or low skill immigrants. I do not model the migration decision itself, and instead assume that the number of migrants can be completely determined by policy - a realistic assumption for the United States.

My baseline calibration implies that the *price* channel dominates the *hiring cost* channel in the determination of wages. An influx of low (high) skill migrants always reduces the wages of low (high) skill workers. My baseline calibration also implies that employment outcomes are instead driven by the *hiring cost* channel. Immigration reduces unemployment for all workers, regardless of skill type.

Low (high) skill immigration improves the welfare of high (low) skill workers and reduces welfare for low (high) skill workers, both in the long run and after accounting for transition dynamics. For both skill types, long run welfare in the *closed* economy is higher than in the *open* economy because the temporary increase in asset returns incentivizes a higher level of long run wealth holdings, which is reflected in higher consumption given that the long run labor market conditions are equivalent in both cases.

For both skill types, however, the transition in the *closed* economy setting is costly. The improvement in asset returns over the adjustment period does not offset the worsening labor market conditions. Long run welfare therefore always dominates the measure of total welfare that accounts for the transition dynamics.

Finally, I find that the wealthier high skill households prefer the *closed* economy setting because the baseline calibration implies that the increase in asset returns more than compensates for the relative decline in labor market conditions in comparison to the *open* economy setting. Low skill households, on the other hand, prefer the *open* economy setting. Because low skill households have lower wealth holdings than their high skill counterparts, labor income plays a more dominant role in their consumption decisions. Thus, the increased asset returns in the closed economy do not compensate for the more protracted labor market adjustments.

This article is related to a vast empirical literature that examines the impact of immigration on the labor market outcomes of the host country by either exploiting variation in immigration stocks across local labor markets (Altonji and Card, 1991; Pischke and Velling, 1997), national level labor supply variation across education and experience groups (Grossman, 1982; Borjas, 2003), or natural immigration experiments (Card, 1990; Hunt, 1992). Unfortunately, a consistent conclusion still evades the profession. For example, Borjas (2003) and Borjas et al. (2008) find a large negative wage effect of immigration on natives, whereas Card (2009) and Ottaviano and Peri (2012) find a small and often positive effect. I build on a more recent related literature that seeks to answer this question within a general equilibrium framework (Ben-Gad, 2004, 2008; Liu, 2010; Chassamboulli and Palivos, 2013, 2014).

This article proceeds as follows. In section 2, I describe the theoretical model. In section 3, I describe the calibration procedure and the data sources used to inform the calibration. In section 4, I analyze the mechanisms through which migrants impact the labor market and native welfare. I present the results of the calibrated quantitative model in section 5. I conclude in section 6.

2 Model

There are four types of representative households, each consisting of a continuum of workers of the same type. Workers are either native-born (N) or immigrants (I) and each worker has either high (H) or low (L) skill. Members of each household pool their income in order to insure each other against individual employment risks. Consumption and investment decisions are therefore made at the level of the household.

I denote the measure of type ij workers as Q_{ij}, where $i \in \{H, L\}$ denotes the skill level and $j \in \{N, I\}$ the nativity of each worker. I normalize the total measure of workers to unity, $\sum_{ij} Q_{ij} = 1$. Immigration is modeled as an exogenous increase in the total measure of workers through an increase in either Q_{HI} or Q_{LI}. Time is discrete. All decisions are dynamic and time subscripts are omitted for notational clarity. Where appropriate, recursive notation is used to distinguish contemporary from future variables.

Production The final output numeraire good Y is produced by a representative firm using capital K and a composite input Z according to the following production function

$$Y = AK^{\alpha} Z^{1-\alpha} \tag{1}$$

where A is total factor productivity, α is the capital share of output and Z is a CES aggregate of different types of labor. The Cobb-Douglas functional form in (1) implicitly assumes that physical capital has the same degree of substitutability with each type of labor contained in Z. This structure coincides with the majority of the literature (Borjas, 2003; Ottaviano and Peri, 2012; Battisti et al., 2014).[3]

The composite input good Z is produced using an intermediate low-skilled good Y_L and an intermediate high-skilled good Y_H defined by

$$Z = \left(\gamma Y_L^{\rho} + (1-\gamma) Y_H^{\rho}\right)^{1/\rho}$$

where $-\infty < \rho \leq 1$ is a function of the elasticity of substitution σ_{HL} between the two skill groups ($\rho = 1 - 1/\sigma_{HL}$) and γ is a productivity parameter that determines the income share of the low-skilled good (Card and Lemieux, 2001). The breakdown of skill types is not an innocuous assumption. Different aggregation levels of education imply vastly different wage elasticities in the empirical literature, and as (Borjas, 2014, p. 127) states, "there is no convincing evidence on how best to pool" the intermediate goods in this setup. Nevertheless, the recognition that migration differentially impacts different skill groups is a key feature of the empirical literature and the dual decomposition should be viewed as a minimalist assumption.[4]

The representative firm rents capital from workers and purchases the intermediate goods from perfectly competitive firms that produce using linear functions of labor according to the following production func-

[3]There are, however, a number of empirical studies that find that physical capital is more complementary toward high skill labor than toward low skill labor (Griliches, 1969; Berndt and Christensen, 1974; Denny and Fuss, 1977; Krusell et al., 2000). Chassamboulli and Palivos (2014) utilize these observations in order to simulate a larger immigration surplus from high skill immigration than from low skill immigration.

[4]This structure is identical to that used in Battisti et al. (2014) and similar to the structure used in Chassamboulli and Palivos (2014). Dustmann et al. (2013) avoid the aggregation issue altogether by assessing the impact of immigration along the entire wage distribution.

tions

$$Y_i = E_{iN} + E_{iI}, \quad i \in \{L, H\} \tag{2}$$

where E_{ij} is the measure of employed workers of type ij, with $i \in \{L, H\}$ indexing skills (low and high) and $j \in \{N, I\}$ distinguishing native from immigrant workers.

Embedded within Equation (2) is the implicit assumption that native-born and immigrant workers within each skill-level are perfect substitutes. Much of the disagreement in the empirical literature on the effect of migration on wages can be reduced to a disagreement regarding the degree to which migrants and natives of a given skill level are substitutable in production.[5] For example, Borjas et al. (2008) and Aydemir and Borjas (2007) estimate an effectively infinite elasticity and conclude that equally skilled natives and immigrants are perfect substitutes in their findings of a negative effect of migration on wages. The positive wage effects in Ottaviano and Peri (2012), on the other hand, are a result of their empirical findings that natives and immigrants are not perfect substitutes in production even within a skill group. However, Borjas et al. (2012) go on to show that the elasticity of substitution of around 20 estimated by Ottaviano and Peri (2012) was a result of an unusual regression specification which, once corrected, results in an elasticity close to infinity. I side with Borjas et al. (2012) and, indeed, with Battisti et al. (2014) in assuming that natives and migrants are perfect substitutes.

The intermediate goods market is perfectly competitive so prices reflect their marginal contribution to the production of the final good. In particular,

$$p_L = AK^{\alpha}(1-\alpha)\gamma Y_L^{\rho-1}\left[\gamma Y_L^{\rho} + (1-\gamma)Y_H^{\rho}\right]^{(1-\alpha-\rho)/\rho} \tag{3}$$

$$p_H = AK^{\alpha}(1-\alpha)(1-\gamma)Y_H^{\rho-1}\left[\gamma Y_L^{\rho} + (1-\gamma)Y_H^{\rho}\right]^{(1-\alpha-\rho)/\rho} \tag{4}$$

Because the labor market is not competitive, the equilibrium prices of the intermediate goods are not equal to wages. This creates total non-zero profits for the representative intermediate goods firm of

$$d = p_H Y_H + p_L Y_L - E_{LN}w_{LN} - E_{LI}w_{LI} - E_{HN}w_{HN} - E_{HI}w_{HI} - \kappa_L v_L - \kappa_H v_H \tag{5}$$

where w_{ij} is the wage played to worker type ij, κ_i is the cost of posting a vacancy to labor market i and v_i is the total number of vacancies posted to labor market i. Profits are paid out as dividends to households, who are the shareholders, as explained below.

Finally, the final good firm rents capital on competitive markets at a price that reflects its marginal prod-

[5] See Ottaviano and Peri (2012) and Borjas (2014) for a discussion.

uct

$$r = \alpha A \left(\frac{Z}{K} \right)^{1-\alpha} \tag{6}$$

Labor Markets There is a separate labor market for each skill type (H and L). Intermediate-good firms post skill-specific vacancies which do not distinguish between natives and immigrants, as usually required by law. The supply of each type of worker is given exogenously and natives and immigrants of the same skill-type compete for the same jobs. Four types of workers therefore compete in just two labor markets. The total supply of workers in labor market i is given by $Q_i = Q_{iN} + Q_{iI}$, $i \in \{H, L\}$. Immigration represents an exogenous change in the number of foreign-born workers, Q_{iI}.

The number of matches formed in each period is a standard function of the number of vacancies posted and the number of unemployed workers in each market. Defining labor market tightness as $\theta_i = v_i/U_i$, the matching function yields the vacancy-filling rate $\mu_i = \mu(\theta_i)$ and the job-finding rate $f_i = f(\theta_i)$ as

$$\mu_i = \xi \theta_i^{-\epsilon}, \quad f_i = \xi \theta_i^{1-\epsilon} \tag{7}$$

where ϵ and ξ have the usual respective interpretations of matching function elasticity and efficiency. Existing matches separate at the exogenous rate s_{ij}, which may differ between natives and immigrants as well as across skill-types. This assumption is required to generate differential rates of unemployment across worker types that are observed in the data (Battisti et al., 2014). The law of motion of employment is

$$E'_{ij} = (1 - s_{ij})E_{ij} + f_i(Q_{ij} - E_{ij}) \tag{8}$$

The level of employment of type ij next period is equal to the sum of this period's employed workers that do not separate, and this period's unemployed workers who successfully find an employment match.

Firm Value Functions The resulting equations governing the value to a firm producing good i of an open vacancy V_i and of a filled job J_{ij} are as follows

$$V_i = -\kappa_i + q\Big[(1 - \mu_i)V'_i + \mu_i\Big((1 - \phi_i)J'_{iN} + \phi_i J'_{iI}\Big)\Big] \tag{9}$$

$$J_{ij} = p_i - w_{ij} + q\Big(s_{ij}V'_i + (1 - s_{ij})J'_{ij}\Big) \tag{10}$$

where κ_i is the cost of posting a vacancy in labor market i. The discount rate of the firm is q, which is the marginal rate of substitution of anyone with positive holdings of the firm, as explained below. The variable

$\phi_i = U_{iI}/(U_{iI} + U_{iN})$ denotes the probability that any given filled vacancy is filled by an immigrant, which is defined as the share of immigrants among those searching for a job. An open vacancy is turned into a filled job at the rate μ_i.

Equation (9) demonstrates that the value to the firm of posting a vacancy in market i is equal to the probability of becoming matched with a worker in that market multiplied by the expected discounted gain from such an event less the cost of posting a vacancy. Importantly, the value of an open vacancy has no index j because firms cannot discriminate between native and immigrant workers when posting vacancies, as required by law. Equation (10) demonstrates that the value of a match to the firm is equal to the sum of the contemporary production surplus of that match and the discounted expected value of the match persisting next period given that the match will separate with probability s_{ij}.

Free entry of firms implies that, in equilibrium, $V_i = 0$ for all i, which implies the following job creation condition

$$\kappa_i = q\mu_i\Big((1-\phi_i)J'_{iN} + \phi_i J'_{iI}\Big) \tag{11}$$

Firms post vacancies until the cost of doing so is equal to the discounted expected value of the surplus gained from posting a vacancy.

Asset Markets Households transfer wealth across time by investing in two assets: capital k which is used as an input for production, and equity x, which is a claim to the firm's profit. Because both forms of wealth holdings are risk free, no arbitrage equates the returns to each asset which, after normalizing the total amount of equity to one, yields the following relationship

$$1 + r' - \delta = \frac{d' + p'}{p}$$

where r is the return to capital and d is the dividend paid to the holders of equity, as given by Equation (5). Since capital and equity are equivalent from the household's viewpoint, the composition of the investment portfolio is irrelevant. I therefore simplify the asset structure by defining a composite asset a according to

$$a = (1 + r - \delta)k + (p + d)x$$

The price of the asset, q, is defined according to

$$q = 1/(1 + r' - \delta)$$

which is the inverse of the gross return to capital holdings or, equivalently, equity holdings. Simple algebra then implies that the following household budget constraint

$$C_{ij} + k'_{ij} + px'_{ij} = (1 + r - \delta)k_{ij} + (p + d)x_{ij} + E_{ij}w_{ij}$$

can be reduced to

$$C_{ij} + qa'_{ij} = a_{ij} + E_{ij}w_{ij}$$

This setup, which is equivalent to the asset structure proposed by Krusell et al. (2010), determines the appropriate firm discount rate in the presence of heterogeneous households.

In the closed economy, aggregation implies that

$$\sum_{ij} a_{ij} = (1 + r - \delta)K + (p + d) \tag{12}$$

where K is the aggregate capital stock used in production according to Equation (1). In the open economy, I make the standard small open economy assumption that the aggregate capital stock adjusts in order to satisfy Equation (13) in all time periods.

$$r^* = \alpha \frac{Y}{K} \tag{13}$$

where r^* is an exogenously set world interest rate.

Households Although individual workers face unemployment risk, households of each type are comprised of a continuum of such workers who pool their income. Investment and consumption decisions are therefore made at the level of the household. The optimization problem of household ij is

$$W_{ij}(a_{ij}; \omega) = \max_{a'_{ij}, C_{ij}} \log\left(C_{ij} - b_{ij}E_{ij}\right) + \beta W_{ij}(a'_{ij}; \omega') \tag{14}$$

subject to

$$C_{ij} + qa'_{ij} = a_{ij} + E_{ij}w_{ij} \quad \text{and} \quad a_{ij} \geq 0, \quad \text{given} \;\; a_{ij}(0)$$

where C_{ij} is total consumption of the household, ω represents the aggregate state which consists of all aggregate variables relevant to household decision making and $a_{ij}(0)$ is initial wealth holdings. The household chooses this period's consumption and next period's wealth holdings subject to its budget constraint and taking the evolution of employment as given according to Equation (8). The household receives labor income from its employed workers and asset income from wealth.

The choice of preferences is a special case of those described by by Greenwood et al. (1988). This specification allows an interpretation of b_{ij} as a worker's "outside option" in a manner that is consistent with the job search literature. The outside option is crucial in determining the total surplus of an employer-employee match, and therefore the dynamics of the labor market. In a canonical search model with linear preferences, the outside option can be interpreted as either the amount of utility sacrificed by a worker in gaining employment, or as a monetary unemployment benefit. Within the context of risk averse households, however, the equivalence between these interpretations breaks down. In particular, the amount of utility sacrificed in gaining employment depends on the marginal rate of substitution between leisure and consumption which in general depends on the wealth of a household. Similarly, the amount of utility derived from a monetary unemployment benefit will depend on the marginal utility of consumption, which also depends on wealth. As Krusell et al. (2010) demonstrate, the resulting labor market dynamics therefore depend on the distribution and level of wealth within the economy. The particular specification of preferences in Equation (14) ensures that the disutility derived from labor is independent of wealth, which is a well-known property of Greenwood et al. (1988) preferences.

The value to household ij of an extra worker is given by

$$W_{ij}^{E}(a_{ij};\omega) = \left(C_{ij} - b_{ij}E_{ij}\right)^{-1}\left(w_{ij} - b_{ij}\right) + \beta(1 - s_{ij} - f_i)W_{ij}^{E}(a'_{ij};\omega')$$

The transition of an additional worker from a state of unemployment to employment yields an immediate utility-adjusted benefit from the wage net of the outside option as well as an additional benefit derived from the implications for having another worker in the next period.

Wage Determination Wages are determined through bilateral Nash bargaining between households and the intermediate good firm, which divides the total surplus from an employment match between the two parties according to the following rule.

$$\max_{w_{ij}} \left(W_{ij}^{E}\right)^{1-\eta} \left(J_{ij}\right)^{\eta} \tag{15}$$

where $\eta \in (0,1)$ represents the bargaining power of the worker. The solution to (16) yields the following wage equation

$$w_{ij} = \eta \left(p_i + q f_i J'_{ij}\right) + (1-\eta) b_{ij} \tag{16}$$

which has the usual interpretation that the wage is equal to a weighted average of the worker's contribution to production and the outside option, where the weights are determined by the household's bargaining power. In the case where the household has no bargaining power ($\eta = 0$), the wage is simply the minimum amount required to incentivize the household to provide another worker, which is the outside option b_{ij}. In the case where the household has full power in wage negotiations ($\eta = 1$), the wage reflects the total amount of surplus to the firm generated by the match.

Equilibrium A competitive equilibrium in the *closed* economy consists of a set of allocations for each household $\{C_{ij}(t), a_{ij}(t)\}_{t=o}^{\infty}$, a set of prices $\{r(t), q(t), p(t), p_i(t), w_{ij}(t)\}_{t=0}^{\infty}$, a set of production stocks $\{K(t), Z(t), Y_i(t)\}_{t=0}^{\infty}$, a set of profits and vacancies $\{d(t), v_i(t)\}_{t=0}^{\infty}$, a set of matching rates $\{f_i(t), \mu_i(t)\}$, a set of employment and unemployment stocks $\{E_{ij}, U_{ij}\}_{t=0}^{\infty}$ and a set of labor market tightness measures $\{\theta_i\}_{t=0}^{\infty}$ such that

1. Given the prices, the profits, and the job finding rates, the allocations $\{C_{ij}(t), a_{ij}(t)\}$ solve the optimization problem of household ij.
2. Given the prices and the vacancy matching rates, the aggregate inputs and the vacancies solve the firms problem, where the profits are determined by (5).
3. The intermediate input markets clear. In particular, Equations (3) and (4) are satisfied.
4. The matching rates are determined by (7).
5. The Nash bargaining condition, (16), that determines wages is satisfied
6. The free entry condition (11) for each skill type i is satisfied.
7. The numbers of employed and unemployed workers satisfy (8).
8. Capital markets clear so that the sum of individual asset holdings is consistent with the aggregate capital stock. In particular, Equation (12) is satisfied.

A competitive equilibrium in the *open* economy coincides with that of a closed economy except that the capital market clearing condition 8 is replaced by

8′. Open capital markets ensure that the aggregate capital stock immediately adjusts to satisfy Equation (13) in all time periods.

Welfare I quantify the welfare effects of immigration in terms of compensating consumption differentials (Lucas, 2003). In particular, I define λ_{ij} as the percentage change in initial consumption of household ij that would leave the utility of that household unaffected by immigration. More formally, λ_{ij} solves

$$\sum_{t=0}^{\infty} \beta^t \log(\bar{C}_{ij}(1+\lambda_{ij}) - b_{ij}\bar{E}_{ij}) = \sum_{t=0}^{\infty} \beta^t \log(C_{ij}(t) - b_{ij}E_{ij}(t)) \tag{17}$$

where $\bar{C}_{ij}$ and $\bar{E}_{ij}$ are the initial steady state values of consumption and employment, respectively. A positive value of λ_{ij} corresponds to a welfare gain from immigration. In the presentation of the quantitative results in sections 4 and 5, I also present the steady state welfare gains λ^*_{ij} defined as the solution to

$$\sum_{t=0}^{\infty} \beta^t \log(\bar{C}_{ij}(1+\lambda_{ij}) - b_{ij}\bar{E}_{ij}) = \sum_{t=0}^{\infty} \beta^t \log(C^*_{ij} - b_{ij}E^*_{ij}) \tag{18}$$

where C^*_{ij} and E^*_{ij} are the long run steady state values of consumption and employment, respectively. The values of λ_{ij} and λ^*_{ij} differ because the former incorporates the welfare effects of the transition dynamics whereas the latter does not. Sections 4 and 5 demonstrate that, in general, the transition dynamics are costly so that $\lambda_{ij} < \lambda^*_{ij}$.

Computation Because of household heterogeneity, a one-to-one mapping between a household-level state variable a_{ij} and the aggregate state, which includes aggregate capital, does not exist. Because household decisions rely on the aggregate state, the evolution of which must be consistent with the decisions of other households, the model cannot be solved analytically. I use the following shooting algorithm to solve for the transition dynamics which ensures that the value of the post immigration experiment steady state asset holding positions are consistent with the asset-accumulation dynamics of the pre-reform equilibrium and the dependency of the wealth distribution on initial asset holdings (Mendoza and Tesar, 1998; Gorodnichenko et al., 2012).

For a given calibration, the resulting steady state values of labor market variables after an immigration shock can be determined analytically. This is a result of the preferences described in Equation (14) which ensure that the disutility derived from employment is independent of a household's wealth, and therefore also independent of the transition dynamics. The final steady state values of aggregate capital $\bar{K}$ and labor market tightness variables, $\bar{\theta}_L$ and $\bar{\theta}_H$, can be derived analytically.

The computation algorithm for the *closed* economy is as follows.

1. For a given sufficiently long number of time periods T, choose a sequence of aggregate capital stocks $\mathbf{K} = \{K_0, \cdots, K_T = \bar{K}\}$.
2. Choose a sequence of market tightness parameters for both the low-skill and high-skill labor markets $\Theta_L = \{\theta_{L0}, \cdots, \theta_{LT} = \bar{\theta}_L\}$, $\Theta_H = \{\theta_{H0}, \cdots, \theta_{HT} = \bar{\theta}_H\}$.
3. Calculate the resulting sequence of job finding and vacancy filling probabilities using Equation (7), employment stocks using Equation (8), factor prices using Equations (1)-(4) and firm value functions using Equation (10).
4. Using the values calculated in step 3, determine whether the job-creation conditions (11) are satisfied. If not, update Θ_L and Θ_H and return to step 3. Otherwise, proceed to step 5.
5. Use the sequence of wages and asset returns to solve each household's optimization problem. Check that the sum of all resulting household asset holdings are consistent with the level of the aggregate capital stock in each period according to (12). If not, update $\mathbf{K}$ and return to step 1. Repeat until convergence.

The computation algorithm for the *open* economy is simpler as it does not require the *outer* aggregate capital loop.

1. Choose a sequence of market tightness parameters for both the low-skill and high-skill labor markets $\Theta_L = \{\theta_{L0}, \cdots, \theta_{LT} = \bar{\theta}_L\}$, $\Theta_H = \{\theta_{H0}, \cdots, \theta_{HT} = \bar{\theta}_H\}$.
2. Calculate the resulting sequence of job finding and vacancy filling probabilities using Equation (7), employment stocks using Equation (8). Calculate the resulting aggregate level of capital using (6) and the assumption that r remains constant in each period. Calculate the resulting factor prices using Equations (1)-(4) and firm value functions using Equation (10).
3. Using the values calculated in step 2, determine whether the job-creation conditions (11) are satisfied. If not, update Θ_L and Θ_H and return to step 2. Repeat until convergence.

3 Data and Calibration

Section 4 demonstrates that the direction and size of the effects of immigration on the labor market and welfare crucially depend on the parameter values. In order to generate quantitative results for the effect of immigration, I calibrate the model to match key features of the United States economy over the last decade. I define a time period as one quarter.

The model is characterized by 23 parameters which consist of the preference parameters $\{\beta, b_{ij}\}$, the labor force numbers $\{Q_{ij}\}$, the production parameters $\{A, \rho, \alpha, \gamma\}$, the matching function parameters $\{\xi, \epsilon\}$, the workers' bargaining power η, the capital depreciation rate δ, the initial shares of wealth $\{a_{ij}(0)\}$, the vacancy posting costs $\{\kappa_i\}$ and the separation rates $\{s_{ij}\}$. I partition the parameters into two sets - $\Theta_1 = \{Q_{ij}, \beta, \rho, \alpha, \kappa_H, \delta, \epsilon, \eta, A, b_{iI}, a_{ij}(0)\}$ and $\Theta_2 = \{\kappa_L, b_{iH}, s_{ij}, \xi, \gamma\}$. I calibrate the parameters in Θ_1 by either directly matching values with an empirical counterpart, by taking values common in the literature, or by normalization. I jointly calibrate the parameters in Θ_2 using moment matching.

I set the risk free steady state rate of return in the model equal to the real interest rate calculated by Chassamboulli and Palivos (2014) who use an inflation adjusted measure of the 30-year treasury constant maturity bond rate of 4.76% per annum, which implies a quarterly discount factor of $\beta = 0.988$. In the case of the open economy, I fix the world interest rate at this level. I set the elasticity of the matching function, ϵ, equal to 0.5, which is a commonly used value within the range of estimates reported in Pissarides and Petrongolo (2001). I then set the Nash bargaining parameter η equal to 0.5 in accordance with the efficiency condition proposed by Hosios (1990).

The elasticity of substitution between high and low skilled workers crucially depends on the definition of each skill group. For example, Card (2009) finds that workers with less than a high school education are perfect substitutes for those with a high school education, regardless of age and experience. On the other hand, the elasticity of substitution between workers with and without a college education has consistently been estimated to be around 2 (Katz and Murphy, 1992; Angrist, 1995; Johnson, 1997; Ottaviano and Peri, 2012). I therefore define high skill to be those workers who have completed college, and set $\rho = 1 - \frac{1}{\sigma_{HL}} = 0.5$, which corresponds to an elasticity of substitution of $\sigma_{HL} = 2$.

I set the quarterly value of depreciation δ equal to 0.0182 which is equivalent to the monthly rate of 0.0061 in Chassamboulli and Palivos (2014). I set the capital share of income α equal to the standard 0.33. I choose the labor force shares Q_{ij} to match their empirical counterparts. Using monthly (January 2005 - December 2014) microdata from the Current Population Survey (CPS) downloaded from IPUMS (see Flood et al. (2015)), I calculate the share of the US labor force of each type, which is plotted in Figure 1.[6]

[6] I define immigrants as those who were born outside of the United States. A detailed description of the construction of this

[Insert Figure 1 about here]

Low-skilled native workers account for the majority of the United States labor force at an average of 57.0% over the sample period, followed by high-skilled natives at 26.1%, low skilled immigrants at 11.9% and high skilled immigrants at 5%. I directly match the values of Q_{ij} to these figures after normalizing the total population $\sum_{ij} Q_{ij} = 1$.

I estimate the respective wealth shares of each worker type, $\bar{a}_{ij}(0)$, using the 2008 Survey of Income and Program Participation (SIPP), which consists of a short, rotating panel made up of 8 to 12 waves of data collected every 4 months for up to 36,700 households in the United States. Each wave of the survey contains both core questions that are common to each wave and topical questions about a particular topic that are not updated in each wave. I use waves 4, 7 and 10, which contains information on both household assets (in the topical module) and the birthplace and education level of the respondent (in the core) over the 2009 to 2011 period. As explained by Cobb-Clark and Hildebrand (2006), more commonly used datasets containing wealth and asset information are less appropriate for considering the allocation of wealth across immigrant and skill groups.[7] The Survey of Consumer Finances, for example, does not identify foreign-born individuals whereas the design of the Panel Study of Income Dynamics does not include any immigrants who arrived in the United States after 1968.[8]

Table 1 presents the wealth shares of each worker type in each wave of the 2008 SIPP. On average between 2009 and 2011, native high skilled workers owned 86.7% of household wealth, followed by 8.5% for High skilled immigrants, 3.6% for low skilled natives and just 1.2% for low skilled immigrants. Note that the distribution of wealth is more skewed toward high skilled workers than these figures suggest, given that high skilled workers make up a lower amount of the United States labor force than their low-skilled counterparts, as demonstrated in Figure 1.

[Insert Table 1 about here]

I normalize the high-skill vacancy posting cost κ_H to one and I set A in order to normalize steady state output, Y, to one. Finally, I normalize the native outside options b_{iN} to zero. This simplifies the interpretation of the welfare results because it ensures that native born welfare is fully determined by consumption fluctuations rather than a combination of consumption and labor supply fluctuations.

The parameters in $\Theta_2 = \{b_{iN}, s_{ij}, \gamma, \kappa_L, \xi\}$ are jointly determined by 9 moment matching conditions. I demonstrate in Appendix A that the moment matching procedure can be reduced to a system of nine

data is available upon request.

[7] Ben-Gad (2008) calibrates his model using the Survey of Consumer Finances to identify the ratio of wealth between high and low skilled workers. He does not, however, distinguish between native born and immigrant wealth.

[8] Although in 1990 the PSID added 2,000 Latino households consisting of families originally from Mexico, Puerto Rico, and Cuba.

simultaneous equations in nine unknowns which allows me to exactly match the nine moments. A subjective weighting of each moment is therefore not required.

The first three moments are the respective ratios of the wages of each worker type with respect to the wages of high skill natives over the 2005 to 2015 period. Using data from the outgoing rotation groups of the CPS, Figure 2 plots the time series of nominal hourly wages (left hand panel) as well as the resulting ratios with respect to high skilled native wages (right hand panel). It demonstrates two main points. The first is that within each skill group, native born workers earn a premium over their immigrant counterparts. Similarly, within nativity groups, high skilled workers earn a premium over their low skilled counterparts. The wage ratio with respect to high skilled natives is, on average over the 2005 to 2015 period, 0.9618 for high-skilled immigrants, 0.651 for low-skilled natives and 0.588 for low skilled immigrants.

[Insert Figure 2 about here]

Unemployment rates of each worker type are the next four moment targets. Using CPS data, Figure 3 plots the trend of unemployment rates for each group over the last decade. Each group experienced a noticeable peak in late 2009 as a result of the global financial crisis. Over the entire 10 year period, high skilled natives experienced an average unemployment rate of 3.4% while high skilled immigrants experiences a rate of 4.5%. Low skilled workers regardless of nativity faced a much higher unemployment rate of 8.7% for native workers. Interestingly, low-skilled immigrants experienced a lower average unemployment rate of 8.1%.

[Insert Figure 3 about here]

Finally, I target the respective job finding rates within each labor market. Using matched CPS data, I calculate instantaneous job finding rates which account for aggregation bias using the methodology of Shimer (2012). Figure 4 plots the series of job finding rates for high skilled (solid line) and low skilled (dashed line) workers over the last decade. Over the entire period, high skilled workers have benefited from higher job finding rates of 0.27 compared to 0.245 for low skill workers.

[Insert Figure 4 about here]

The calibration results and targets are summarized in Table 2.

[Insert Table 2 about here]

4 Analysis

In this section, I analyze the theoretical mechanisms through which immigration affects the labor market and welfare outcomes of native workers. I isolate each mechanism using special cases of the parameter values.

4.1 Basic Model

In this section, I equate the outside options and separation rates of all workers ($b_{ij} = 0$, $s_{ij} = s_{HN}$). I also assume that high and low skill workers are perfect substitutes ($\rho = 1$), have equal productivity ($\gamma = 0.5$) and that hiring costs are homogeneous across labor markets ($\kappa_L = \kappa_H = 1$). Production is therefore reduced to a standard Cobb-Douglas model with homogeneous labor and the effect of immigration is to simply increase the supply of that labor. Table 3 lists the percentage changes for key variables in response to a 1% increase in the labor force caused by either low skill immigration (columns 1 - 2) or high skill immigration (columns 3 - 4) under the assumption that all workers hold the same amount of wealth. Because wealth holdings and the accumulation of aggregate capital plays a large role in determining the welfare effects in this model, I distinguish between two extreme scenarios regarding the degree to which domestic asset markets are open to foreign capital flows. Columns 1 and 3 represent an *open* economy that is fully open to foreign capital flows, in which case the return to asset holdings is unaffected by domestic factors. Columns 2 and 4 represent a *closed* economy in which the aggregate capital stock is fully determined by the asset accumulation decisions of domestic households.

[Insert Table 3 about here]

Table 3 demonstrates that an influx of immigrants of either skill level has no effect on wages, unemployment or goods prices in the long run after capital adjusts to leave factor prices unaltered. A general property of this model is that the steady state values of the labor market variables do not depend on the transition dynamics. This is a direct consequence of the Greenwood et al. (1988) preferences specified in Equation (14), which ensure that worker outside options, and therefore labor market dynamics are not affected by household wealth. The steady state outcomes of these labor market variables do not, however, fully determine the overall welfare effects. This is because consumption decisions, which ultimately affect welfare, depend on asset accumulation as well as the dynamics of labor market variables.

Columns 1 and 3 of Table 3 show that when capital immediately adjusts to leave asset returns unaltered, the present value of labor income is also unaltered and therefore utility is unaffected by immigration, either on impact or in the long run. Thus, the welfare implications derived from a static neoclassical model with a perfectly elastic supply of capital coincide with my framework under the assumptions of this section when capital markets are open to foreign investment.

However, when the economy is *closed*, the immigration-induced increase in labor supply temporarily increases the marginal product of capital and therefore the rate of return to wealth holdings. This incentivizes households to accumulate wealth. Columns 2 and 4 demonstrate that there is a long-run welfare gain equal to a 0.24% permanent increase in the level of initial consumption as a result of the accumulation of wealth over the transition period. This long run welfare gain, however, is almost completely offset by the reduction in labor income as labor market conditions temporarily worsen over the transition.[9] Table 3 demonstrates that the transition costs reduce the welfare gain by 99% (0.24 vs 0.0006). In this scenario, the effect of immigration on the welfare of native born workers is similar in an open or closed economy.

Figure 5, which plots the adjustment path of labor market tightness, unemployment and wages of native workers in response to an immigration-induced 1% increase in the total labor force, helps to illustrate why the welfare results differ between the open and the closed economy cases. The red dashed lines illustrate the behavior of variables in the *open* economy, where capital immediately adjusts to equate asset returns. Because labor is homogeneous, the constant rate of return on capital implies a constant marginal product of labor. There is therefore no change in the hiring incentives of firms or wages.

[**Insert Figure 5 about here**]

The blue solid lines represent the *closed* economy. Immigration reduces the marginal product of labor because the aggregate capital stock is sluggish to respond. This reduces the bargaining position of workers, which negatively impacts wages and unemployment until steady prices are restored. Why, then, is the overall welfare gain to natives positive (6×10^{-4}), despite the reduction in the preset value of labor income? Because households also generate asset income. Over the transition, the temporary increase in asset returns caused by the immigration-induced increase in the marginal product of capital more than makes up for the loss in labor earnings.

4.2 Capital Surplus Channel - Heterogeneous Wealth Holdings

Table 4 presents the equivalent results to Table 3 with the exception that household wealth shares are consistent with the empirical observations presented in section 3. The neutral long run effects on the labor market are unaltered because of the preference specification in Equation (14) that ensures that each worker's outside option is independent of wealth. However, when the economy is *closed*, the welfare effects of immigration are affected by initial wealth holdings. In particular, the long run welfare gains (0.41% vs 0.11%) and total welfare gains (0.17% vs -0.13%) are now much larger for high-skilled native households. High skilled native households begin with a much larger share of national wealth, as demonstrated in Table 1, which means that they are less reliant upon labor income. Therefore, the reduction in the present value of

[9] This difference in long run utility gain between closed and open economies has been examined in the context of capital tax reforms by Mendoza and Tesar (1998).

labor income caused by immigration can be "buffered" by a sufficiently large amount of wealth. The labor income of low skilled households, however, dominates asset income which results in a welfare loss for these households.

[Insert Table 4 about here]

4.3 Price Channel - Imperfect Substitution between Skill Groups

In this section, I analyze the case in which all workers remain identical in terms of outside options ($b_{ij} = 0$), separation rates, ($s_{ij} = s_{HN}$) and productivity ($\gamma = 0.5$) but that high and low skill workers are no longer perfect substitutes ($\rho = 0.5$), despite hiring costs remaining the same across labor markets ($\kappa_L = \kappa_H = 1$). Under this scenario, immigration affects the relative skill composition of the labor force, and therefore alters the relative prices of each intermediate good p_i. Equation (19) presents the steady state value to a firm of an employment match with worker ij.

$$J_{ij} = \frac{(1-\eta)(p_i - b_{ij})}{1 - \beta(1 - s_{ij} - \eta f_i)} \tag{19}$$

Equation (19) demonstrates that an increase in p_i increases the value to the firm of a match in labor market i, which incentivizes hiring and leads to more employment in that labor market. The improvement in workers' bargaining positions also positively influences wages. The corresponding results in Table 5 are consistent with this insight. Low skill immigration (columns 1 - 2) increases (decreases) the wages of high (low) skill workers by 0.44% (0.33%), which are reflected in similar changes to goods prices. This is the redistributive effect of skill-biased immigration that is predicted by classical factor demand theory (Borjas, 2014). In a competitive setup, the effect on prices and wages coincide, but the labor search frictions in the model create a wedge between these goods and labor prices. Nevertheless, these results are consistent with long run wage elasticities of 0.3 - 0.4 that are estimated within competitive frameworks (Borjas, 2003; Ben-Gad, 2008).

[Insert Table 5 about here]

The non-Walrasian labor market framework also allows the analysis of unemployment effects. The change in producer surplus caused by the price effects of immigration also alter the vacancy posting decisions of firms. Thus, low skill immigration reduces (increases) high (low) skill unemployment. As a result of these labor market changes, low skill immigration unsurprisingly increases (reduces) the present value of labor income for high (low) skill workers. For both types of workers, labor income is superior in the *open* economy because a more responsive aggregate capital stock leads to higher levels of the marginal products of labor over the transition period. Figure 6, which plots the transition dynamics of labor market variables in response low skill immigration, demonstrates this point. The *open* economy responses exhibit higher levels of wages and lower levels of unemployment over the transition period. Note that, in contrast to Figure 5, the red dashed line that represents the economy with open capital flows is not a flat line. Within an environment with two skill groups, a constant rate of return to capital no longer implies a constant marginal product of labor. Instead, the relative marginal products adjust according to the skill composition of the employed labor force. Because search frictions ensure that employment stocks adjust gradually, so too do marginal products and therefore wages and unemployment.

[Insert Figure 6 about here]

High (low) skill households experience welfare gains (losses), both in the long run and after accounting for transition costs. Long run welfare gains are always higher in the *closed* economy compared to the *open* economy because the wealth accumulation over the transition period results in higher levels of asset income in the long run while long run labor income are unaltered across the *closed* and *open* economies. The total welfare effects, however, depend on whether the reduction in the present vale of labor market earnings are offset by higher asset returns over the transition period.

The qualitative results are reversed in columns 3 - 4. High skill immigration worsens (improves) the labor market outcomes of high (low) skill workers. As a result, high (low) skill households experience welfare losses (gains). The magnitudes of the changes induced by high skill immigration are larger than low skill immigration. This is because the population of high skilled workers is much smaller than low skilled workers, as presented in Section 3 and Figure 1. As a result, a 1% increase in the labor force that arises out of an increase in high skill workers distorts the skill composition of the labor force to a larger degree.

4.4 Hiring Cost Channel - Heterogeneous Workers

In this section, I analyze the case in which high and low skill workers are perfect substitutes ($\rho = 1$) but where workers differ according to their outside options (b_{ij}) and separation rates (s_{ij}).[10] Under these assumptions, an increase in the number of immigrants increases the probability, ϕ_i, that a given vacancy within each labor market is filled by an immigrant. Native workers command a wage premium over their immigrant counterparts due to having higher outside options. This means that an increased likelihood of hiring an immigrant lowers the expected wage to be paid by a firm and therefore raises the expected value of posting a vacancy. Firms are incentivized to post vacancies, which increases employment and wages via

[10] Because equilibrium conditions cannot be satisfied with equal productivity and hiring costs within each labor market, I also set γ and κ_L to their respective calibrated values.

an increase in the worker's bargaining position. Chassamboulli and Palivos (2014) and Battisti et al. (2014) study this *hiring cost* channel within a static setting.

Table 6 demonstrates that a low-skill immigration-induced 1% increase in the labor force (columns 1 - 2) lowers the expected cost of hiring in the low skill market and, through its effect on hiring incentives, lowers long run unemployment by 0.37%. The tighter labor market conditions increase the bargaining position of low skill workers, which also results in higher (0.04%) long run wages. Wages and unemployment in the high skill market are unaffected in the long run because there is no skill-composition effect of the type explored in section 4.3, and the likelihood of hiring an immigrant is unchanged in the high skill market.

[Insert Table 6 about here]

Figure 7, which presents the transition dynamics of the labor market variables in response to low skill immigration, demonstrates that the neutral long run labor market effects mask substantial short run fluctuations in the *closed* economy. The relatively sluggish response of capital in comparison to the *open* economy keeps the marginal product of labor below its steady state level. This reduces the surplus to firms in the high skill market, which temporarily raises unemployment and reduces wages. Thus, the present value of labor earnings for high skill workers decreases, as demonstrated in Table 6. In the *open* economy, however, the high skill labor market is unaffected, and behaves as it does in the case of the basic model presented in section 4.1. The reduction in the marginal product of labor over the transition period is dominated by the reduction in hiring costs for low skill workers. Thus, low skill labor earnings increases.

[Insert Figure 7 about here]

The qualitative welfare impacts of immigration reflect the labor earnings effects. In particular, low (high) skill immigration reduces welfare for high (low) skill workers in the *closed* economy, as the *capital surplus* gains from wealth holdings are outweighed by the negative impact on labor earnings. However, the hiring cost effect ensures that low (high) skill households benefit from low (high) skill immigration. Finally, the welfare of high (low) skill workers is unaffected by (low) high skill immigration in the *open* economy.

5 Results

Table 7 presents the main results. Low skill immigration improves the long run wages of high skill workers by 0.45% and reduces the long run wages of low skill workers by 0.27%. These figures can be interpreted as long run wage elasticities and are roughly consistent with the wage elasticity estimates of between -0.3 and -0.4 in frameworks with competitive labor markets (Borjas, 2003; Ben-Gad, 2008), as well as the empirical literature. For example, in their meta analysis of 344 estimates of the impact of immigration on wages, Longhi et al. (2005) find an average elasticity of -0.12. Thus, it is the traditional *price* channel that dominates the *hiring cost* channel in wage setting, which is also reflected in the magnitudes of the corresponding changes to goods prices. I find that high skilled immigration reduces the long run wages of high skilled workers by 0.91% and improves the wages of low-skilled workers by 0.67%. As discussed in section 4.3, the larger elasticities caused by high skill immigration are a result of differences in the size of the respective labor forces. Table 2 records that high skill workers only account for approximately 30% of the labor force. Thus, for a given immigration-induced increase in the population, the skill composition of the labor force is more dramatically affected if that increase is comprised of high skill workers.

[Insert Table 7 about here]

Immigration, regardless of its skill composition, lowers long run unemployment. I find a long run "unemployment elasticity" of between -0.04 and -0.30, which indicates that the *hiring cost* channel dominates the *price* channel in the determination of employment. Low skill immigration, for example, lowers the productivity of low skill workers which is reflected in a reduction in low skill wages. However, this reduction in productivity is offset by a corresponding reduction in hiring cost, which, on balance, promotes hiring activity. These findings are also somewhat consistent with the empirical literature. In their meta analysis of 165 estimates of the impact of immigration on employment, Longhi et al. (2006) find that employment of the native born reduces by an average of 0.03% in the US, and -0.84% in countries other than the US, but with a range from -3.9% to 6.2%. In the United States there appears to be a small net job creation effect, which is consistent with my findings, while European labour markets have a 'crowding out' effect.

In the cases where immigration reduces wages but improves employment, it is the former that dominates in terms of the present value of labor earnings, calculated by discounting labor income by the steady state return on wealth. For example, low skill immigration reduces the present value of labor earnings for low skilled households by 0.12% in the *open* economy, despite also reducing the long run unemployment rate of low skill workers by 0.30%.

I now turn toward the welfare effect of capital stock elasticity. As the economy responds to an immigration influx, there is a transition period during which the labor market adjusts to its new steady state equilibrium. The dynamic response of labor market variables to low skill immigration is presented in Figure 8, which demonstrates that the dynamics crucially depend on the responsiveness of the aggregate capital stock. The relatively sluggish response of the capital stock in the *closed* economy through heightened domestic savings ensures a longer transition period than in an *open* economy, in which capital is constantly imported to leave its rate of return constant. The economy takes approximately one decade (40 quarters) to reach the steady state in the *open* economy compared to around 40 years (160 quarters) in the *closed* economy. These transition periods are consistent with those found in the neoclassical framework of Ben-Gad (2008), which indicates that capital frictions are more important than labor market frictions in determining the long run adjustment of the economy to immigration.

[Insert Figure 8 about here]

Not only is the transition period more protracted in the *closed* economy, but labor productivity in any given period is lower in comparison to the *open* economy. Consequently, wages are always lower, and unemployment always higher in any given period following immigration until the steady state is reached in the *closed* economy. The present value of labor earnings is therefore always lower in a *closed* economy. Table 7 shows that, for example, low skill immigration raises the present value of high skill household labor earnings by 0.45% in an *open* economy but just 0.31% in a *closed* economy. The ultimate effect on welfare, however, also depends on how wealth income changes between the *open* and *closed* economies. The welfare results across columns 1 and 2 demonstrate that high skill households benefit from low skill immigration to a much larger degree in the *closed* economy (0.30% vs 0.17%). This indicates that the gains from asset income over the more protracted transition period offset the corresponding reductions in labor income. However, the opposite is true for the less wealthy low skill households. Because low skill households derive a larger proportion of their income from labor, any gains in asset returns are more than offset by the corresponding reduction in labor earnings. Thus, low skill households experience a welfare gain from high skill immigration of 0.67% in the *open* economy compared to just 0.50% in the *closed* economy.

6 Conclusion

Current migration policies are among the largest economic distortions in the world economy. Driving these policies are concerns for the welfare effects of immigration on native-born workers. Understanding these effects is therefore crucial not just for native-born workers, but also for the substantial proportion of the world population who wish to migrate.

In this article, I examine the welfare effects of immigration within a general equilibrium framework calibrated to match key features of the United States economy over the last decade. I construct a fully dynamic search and matching model in which migrants and natives differ according to their outside options, separation rates, wealth holdings and skill composition.

Migrants affect native-born welfare by shifting the skill composition of the labor force, by lowering the hiring cost of firms, by temporarily raising the rates of returns to wealth holdings, and by temporarily lowering the average marginal product of labor. I find that immigration of one skill type lowers the long run wages of that skill type, raises the long run wages of the other skill type, and reduces the long run unemployment rates for all workers. The overall effect of the changes in labor market conditions caused by high (low) skill immigration is to reduce the discounted present value of labor income for high (low) skill households and increase the discounted present value of labor income for low (high) skill workers.

The magnitude of the changes in the present value of labor earnings crucially depends on the responsiveness of the aggregate capital stock to immigration. I find that an open economy, in which capital is constantly imported to leave its rate of return constant, significantly improves the impact of immigration on labor earnings in comparison to a closed economy in which the response of the capital stock is relatively sluggish. The closed economy, however, exhibits higher rates of return to wealth.

I find that low (high) skill immigration results in a welfare loss for high (low) skill native households and a welfare gain for low (high) skill native households. The welfare of high skill households, which are wealthier than their low skill counterparts, is improved in a closed economy in comparison to the open economy. On the other hand, the less wealthy low skill households prefer the open economy because labor rather than wealth is their dominant source of income. By computing the full transition dynamics of the economy as it adjusts to immigration, this article suggests that wealth holdings are a key determinant of the welfare effects of immigration.

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Tables

Table 1: Wealth Shares

	2009	2010	2011	Mean
Native High Skill	0.873	0.868	0.863	0.867
Native Low Skill	0.038	0.036	0.034	0.036
Immigrant High Skill	0.078	0.085	0.091	0.085
Immigrant Low Skill	0.012	0.012	0.012	0.012

Source: Own construction using data from the 2008 Panel of the Survey of Income and Program Participation. 2009 data extracted from the Topical Module in Wave 4, 2010 data from Wave 7 and 2011 data from Wave 10. Measure of wealth is the variable THHTNW, a household level variable defined as the sum of all assets less unsecured debt. Assets include home equity, net equity in vehicles, real estate equity, business equity, interest earning assets, equity in stock and mutual funds, and retirement accounts, such as IRA, KEOGH and 401(k) savings accounts. Debt includes credit card balances and amount owing on vehicles. Immigrants are defined as those not born in the United States which is denoted by the variable EBORNUS in the core module of each wave. High skill level is defined by those with a bachelors degree and above, as denoted in the EEDUCATE variable in the core module of each wave. *Note*: Rows may not sum to one due to rounding.

Table 2: Parameterization Results

Parameter	Data Source
<u>Normalization</u>	
$\kappa_L = 1$, $b_{HN} = b_{LN} = 0$	Normalization
$\epsilon = 0.5$, $\eta = 0.5$	Pissarides and Petrongolo (2001), Hosios (1990)
$\rho = 0.5$	Katz and Murphy (1992), Ottaviano and Peri (2012)
$\alpha = 0.33$	Standard Value
<u>Direct Match</u>	
$\beta = 0.9884$	4.76% annual risk free rate, Chassamboulli and Palivos (2014)
$\delta = 0.0182$	0.0061 monthly rate, Chassamboulli and Palivos (2014)
$Q_{HN} = 0.261$, $Q_{LN} = 0.570$ $Q_{HI} = 0.051$, $Q_{LI} = 0.119$	Average labor force shares (2005 - 2015), Current Population Survey
$a_{HN}(0) = 0.867$, $a_{LN}(0) = 0.036$ $a_{HI}(0) = 0.085$, $a_{LI}(0) = 0.012$	Waves 4, 7 and 10 of the 2008 panel of the Survey of Income and Program Participation
<u>Method of Moments</u>	
$s_{HN} = 0.0095$, $s_{HI} = 0.0127$ $s_{LN} = 0.0233$, $s_{LI} = 0.0216$ $\xi = 0.3629$, $\kappa_L = 0.2571$ $b_{HI} = -0.3222$, $b_{LI} = -0.5302$ $\gamma = 0.4781$	Unemployment rates: $u_{HN} = 0.034$, $u_{HI} = 0.045$, $u_{LN} = 0.087$, $u_{LI} = 0.081$ Wage premiums: $\frac{w_{HI}}{w_{HN}} = 0.9618$, $\frac{w_{LN}}{w_{HN}} = 0.651$, $\frac{w_{LI}}{w_{HN}} = 0.588$ Job finding rates: $f_H = 0.2329$, $f_L = 0.213$

Source: Parameter A is normalized to set steady state output equal to one. A time period is one quarter. High-skilled workers in the CPS data are defined as those with at least a college education (educ99>= 15). Immigrants are defined as those workers born outside of the United States (bpl≠ 9900). To be included within the counts, a worker must be classified as within the labor force and over 16. See Table 1 for description of SIPP variables.

Table 3: Basic Model - Effects of a 1% immigration-induced increase in the labor force in an economy with homogeneous labor ($\rho = 1$, $s_{ij} = s$, $b_{ij} = 0$), homogeneous production ($\kappa_H = \kappa_L$, $\gamma = 0.5$) and per capita wealth holdings ($a_{ij}/Q_{ij} = a/Q$)

	Low Skill Immigration		High Skill Immigration	
	Open (1)	Closed (2)	Open (3)	Closed (4)
Long-Run Labor Market				
Native High Skill Wage (w_{HN})	0		0	
Native Low Skill Wage (w_{LN})	0		0	
Native High Skill Unemployment (u_{HN})	0		0	
Native Low Skill Unemployment (u_{LN})	0		0	
High Skill Good Price (p_H)	0		0	
Low Skill Good Price (p_L)	0		0	
Present Value Earnings				
Native High Skill Labor Income	0	-0.14	0	-0.14
Native Low Skill Labor Income	0	-0.14	0	-0.14
Welfare				
Native High Skill Long Run Welfare Gain (λ^*_{HN})	0	0.24	0	0.24
- Transition Cost	-0	-0.24	-0	-0.24
Native High Skill Welfare Gain (λ_{HN})	0	6×10^{-4}	0	6×10^{-4}
Native Low Skill Long Run Welfare Gain (λ^*_{LN})	0	0.24	0	0.24
- Transition Cost	-0	-0.24	-0	-0.24
Native Low Skill Welfare Gain (λ_{LN})	0	6×10^{-4}	0	6×10^{-4}

Source: Model Simulation. Each entry corresponds to the percentage change in that row's variable under the assumption of that column. The percentage changes are in response to an influx of immigrants that increases the total labor force by 1%. Columns 1 and 2 represent the case where all new immigrants are low-skilled. Columns 3 and 4 represent the case where all new immigrants are high-skilled. Capital is assumed to flow freely from abroad in order to keep the return on capital constant in columns 1 and 3. In columns 2 and 4, the aggregate capital stock is fully determined by domestic wealth accumulation. The "Long-run" effects are the resulting percentage changes once the long run steady state is achieved. The compensating differential under "On Impact" are the percentage changes in the period in which the influx of new immigrants occur, which therefore accounts for the transition costs.

Table 4: Capital Surplus Channel (Basic Model with Calibrated Wealth Holdings) - Effects of a 1% immigration-induced increase in the labor force in an economy with homogeneous labor ($\rho = 1$, $s_{ij} = s$, $b_{ij} = 0$), homogeneous production ($\kappa_H = \kappa_L$, $\gamma = 0.5$) and calibrated per capita wealth holdings (a_{ij}/Q_{ij})

	Low Skill Immigration		High Skill Immigration	
	Open	Closed	Open	Closed
	(1)	(2)	(3)	(4)
Long-Run Labor Market				
Native High Skill Wage (w_{HN})	0		0	
Native Low Skill Wage (w_{LN})	0		0	
Native High Skill Unemployment (u_{HN})	0		0	
Native Low Skill Unemployment (u_{LN})	0		0	
High Skill Good Price (p_H)	0		0	
Low Skill Good Price (p_L)	0		0	
Present Value Earnings				
Native High Skill Labor Income	0	-0.14	0	-0.14
Native Low Skill Labor Income	0	-0.14	0	-0.14
Welfare				
Native High Skill Long Run Welfare Gain (λ^*_{HN})	0	0.41	0	0.41
- Transition Cost	-0	-0.24	-0	-0.24
Native High Skill Welfare Gain (λ_{HN})	0	0.17	0	0.17
Native Low Skill Long Run Welfare Gain (λ^*_{LN})	0	0.11	0	0.11
- Transition Cost	-0	-0.24	-0	-0.24
Native Low Skill Welfare Gain (λ_{LN})	0	-0.13	0	-0.13

Source: Model Simulation. Each entry corresponds to the elasticity of that row's variable with respect to immigration under the assumption of that column. Columns 1 and 2 represent the case where all new immigrants are low-skilled. Columns 3 and 4 represent the case where all new immigrants are high-skilled. Capital is assumed to flow freely from abroad in order to keep the return on capital constant in columns 1 and 3. In columns 2 and 4, the aggregate capital stock is fully determined by domestic wealth accumulation.

Table 5: Price Channel - Effects of a 1% immigration-induced increase in the labor force in an economy with imperfect substitution between high and low skilled goods ($\rho = 0.5 < 1$), homogeneous workers ($s_{ij} = s$, $b_{ij} = 0$), homogeneous production ($\kappa_H = \kappa_L$, $\gamma = 0.5$) and homogeneous wealth holdings ($a_{ij}/Q_{ij} = a/Q$)

	Low Skill Immigration		High Skill Immigration	
	Open	Closed	Open	Closed
	(1)	(2)	(3)	(4)
Long-Run Labor Market				
Native High Skill Wage (w_{HN})	0.44		-0.96	
Native Low Skill Wage (w_{LN})	-0.30		0.66	
Native High Skill Unemployment (u_{HN})	-0.22		0.48	
Native Low Skill Unemployment (u_{LN})	0.15		-0.33	
High Skill Good Price (p_H)	0.43		-0.93	
Low Skill Good Price (p_L)	-0.18		0.40	
Present Value Earnings				
Native High Skill Labor Income	0.43	0.31	-0.95	-1.12
Native Low Skill Labor Income	-0.29	-0.41	0.66	0.48
Welfare				
Native High Skill Long Run Welfare Gain (λ^*_{HN})	0.36	0.55	-0.79	-0.53
- Transition Cost	-0	-0.21	-0	-0.29
Native High Skill Welfare Gain (λ_{HN})	0.36	0.34	-0.79	-0.82
Native Low Skill Long Run Welfare Gain (λ^*_{LN})	-0.23	-0.01	0.51	0.83
- Transition Cost	-0	-0.21	-0	-0.29
Native Low Skill Welfare Gain (λ_{LN})	-0.23	-0.21	0.51	0.53

Source: Model Simulation. Each entry corresponds to the elasticity of that row's variable with respect to immigration under the assumption of that column. Columns 1 and 2 represent the case where all new immigrants are low-skilled. Columns 3 and 4 represent the case where all new immigrants are high-skilled. Capital is assumed to flow freely from abroad in order to keep the return on capital constant in columns 1 and 3. In columns 2 and 4, the aggregate capital stock is fully determined by domestic wealth accumulation.

Table 6: Hiring Cost Channel - Effects of a 1% immigration-induced increase in the labor force in an economy with perfect substitution between high and low skilled goods ($\rho = 1$), heterogeneous workers (s_{ij}, b_{ij}), homogeneous production ($\gamma = 0.5$) and homogeneous wealth holdings ($a_{ij}/Q_{ij} = a/Q$)

<table>
<tr><th></th><th colspan="2">Low Skill Immigration</th><th colspan="2">High Skill Immigration</th></tr>
<tr><th></th><th>Open
(1)</th><th>Closed
(2)</th><th>Open
(3)</th><th>Closed
(4)</th></tr>
<tr><td><u>Long-Run Labor Market</u></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Native High Skill Wage (w_{HN})</td><td colspan="2">0</td><td colspan="2">0.04</td></tr>
<tr><td>Native Low Skill Wage (w_{LN})</td><td colspan="2">0.04</td><td colspan="2">0</td></tr>
<tr><td>Native High Skill Unemployment (u_{HN})</td><td colspan="2">0</td><td colspan="2">-0.59</td></tr>
<tr><td>Native Low Skill Unemployment (u_{LN})</td><td colspan="2">-0.37</td><td colspan="2">0</td></tr>
<tr><td>High Skill Good Price (p_H)</td><td colspan="2">0</td><td colspan="2">0</td></tr>
<tr><td>Low Skill Good Price (p_L)</td><td colspan="2">0</td><td colspan="2">0</td></tr>
<tr><td><u>Present Value Earnings</u></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Native High Skill Labor Income</td><td>0</td><td>-0.15</td><td>0.24</td><td>0.09</td></tr>
<tr><td>Native Low Skill Labor Income</td><td>0.17</td><td>0.02</td><td>0</td><td>-0.15</td></tr>
<tr><td><u>Welfare</u></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Native High Skill Long Run Welfare Gain (λ^*_{HN})</td><td>0</td><td>0.18</td><td>0.14</td><td>0.39</td></tr>
<tr><td>- Transition Cost</td><td>-0</td><td>-0.21</td><td>-0</td><td>-0.25</td></tr>
<tr><td>Native High Skill Welfare Gain (λ_{HN})</td><td>0</td><td>-0.05</td><td>0.14</td><td>0.14</td></tr>
<tr><td>Native Low Skill Long Run Welfare Gain (λ^*_{LN})</td><td>0.08</td><td>0.32</td><td>0</td><td>0.20</td></tr>
<tr><td>- Transition Cost</td><td>-0</td><td>-0.21</td><td>-0</td><td>-0.25</td></tr>
<tr><td>Native Low Skill Welfare Gain (λ_{LN})</td><td>0.08</td><td>0.09</td><td>0</td><td>-0.04</td></tr>
</table>

Source: Model Simulation. Each entry corresponds to the elasticity of that row's variable with respect to immigration under the assumption of that column. Columns 1 and 2 represent the case where all new immigrants are low-skilled. Columns 3 and 4 represent the case where all new immigrants are high-skilled. Capital is assumed to flow freely from abroad in order to keep the return on capital constant in columns 1 and 3. In columns 2 and 4, the aggregate capital stock is fully determined by domestic wealth accumulation.

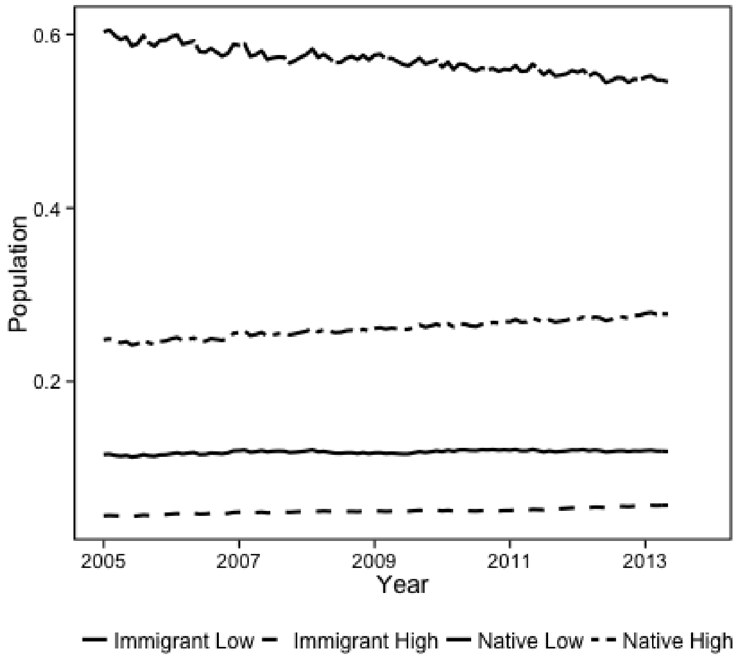
Table 7: Main Quantitative Results - Effects of a 1% immigration-induced increase in the labor force for the calibrated economy.

	Low Skill Immigration		High Skill Immigration	
	Open	Closed	Open	Closed
	(1)	(2)	(3)	(4)
Long-Run Labor Market				
Native High Skill Wage (w_{HN})	0.45		-0.91	
Native Low Skill Wage (w_{LN})	-0.27		0.67	
Native High Skill Unemployment (u_{HN})	-0.21		-0.04	
Native Low Skill Unemployment (u_{LN})	-0.30		-0.29	
High Skill Good Price (p_H)	0.43		-0.91	
Low Skill Good Price (p_L)	-0.19		0.40	
Present Value Earnings				
Native High Skill Labor Income	0.45	0.31	-0.74	-0.92
Native Low Skill Labor Income	-0.12	-0.25	0.69	0.50
Welfare				
Native High Skill Long Run Welfare Gain (λ^*_{HN})	0.17	0.51	-0.55	-0.08
- Transition Cost	-0	-0.21	-0	-0.30
Native High Skill Welfare Gain (λ_{HN})	0.17	0.30	-0.55	-0.38
Native Low Skill Long Run Welfare Gain (λ^*_{LN})	-0.12	-0.03	0.67	0.80
- Transition Cost	-0	-0.21	-0	-0.30
Native Low Skill Welfare Gain (λ_{LN})	-0.12	-0.24	0.67	0.50

Source: Model Simulation. Each entry corresponds to the elasticity of that row's variable with respect to immigration under the assumption of that column. Columns 1 and 2 represent the case where all new immigrants are low-skilled. Columns 3 and 4 represent the case where all new immigrants are high-skilled. Capital is assumed to flow freely from abroad in order to keep the return on capital constant in columns 1 and 3. In columns 2 and 4, the aggregate capital stock is fully determined by domestic wealth accumulation.

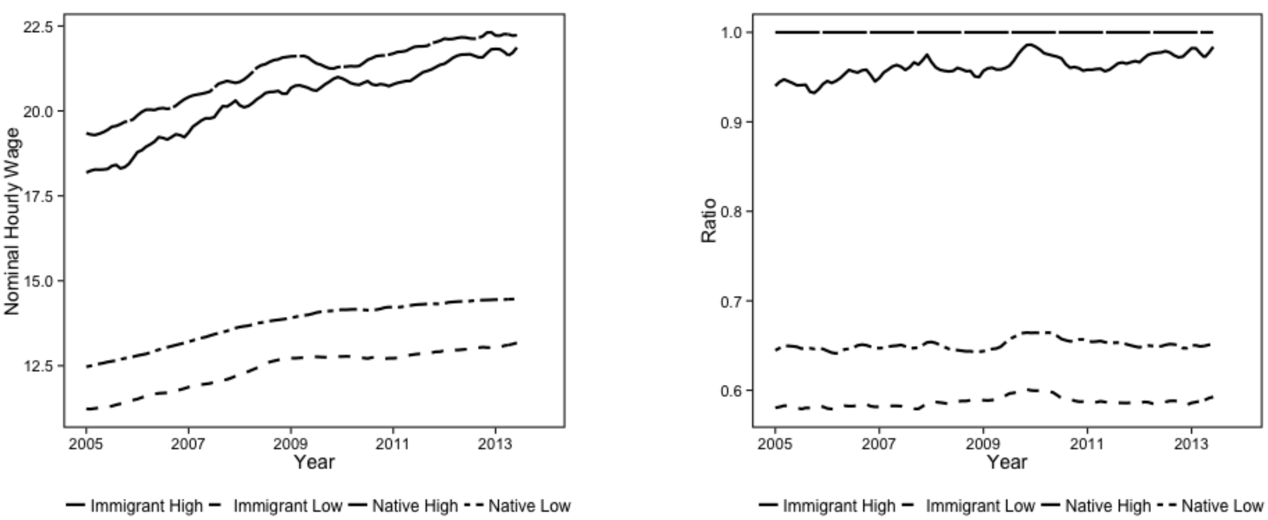
Figures

Figure 1: Labor Force Shares



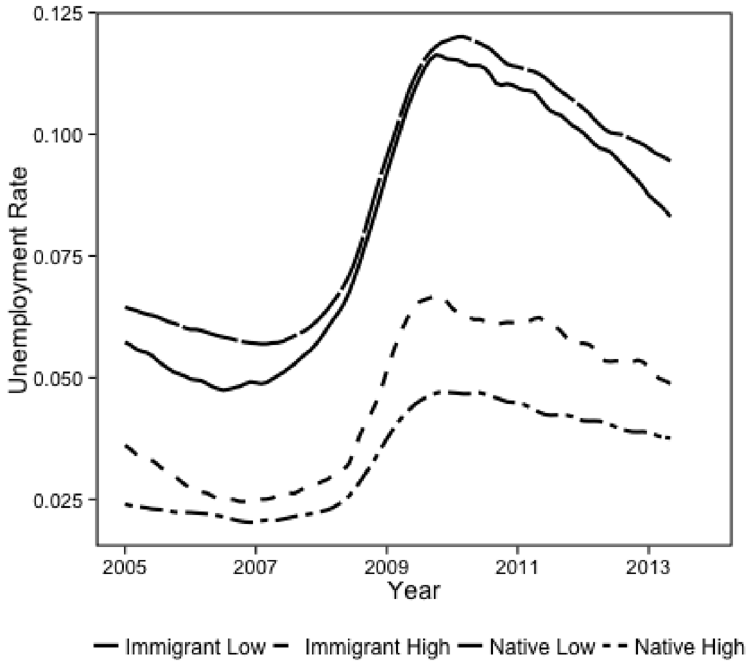
Notes: Own illustration using data from the January 2005 to December 2014 publicly available monthly samples from the Current Population Survey provided by IPUMS. High-skilled workers are defined as those with at least a college education (educ99 >= 15). Immigrants are defined as those workers born outside of the United States ($bpl \neq 9900$). To be included within the counts, a worker must be classified as within the labor force.

Figure 2: Nominal Hourly Wage (LHS) and Hourly Wage as proportion of Native High Skilled Wage (RHS)



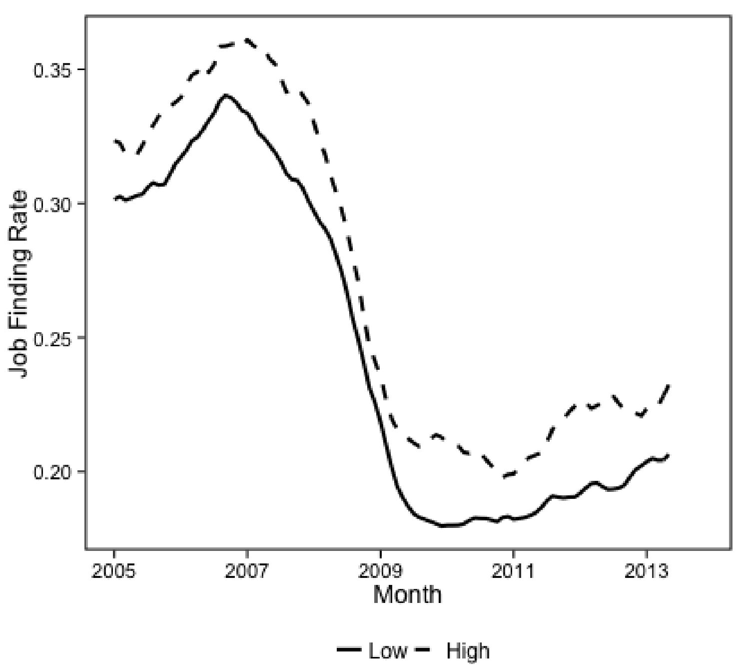
Source: Own illustration using data from the outgoing rotation group of each monthly sample in the Current Population Survey between January 2005 to December 2014. Data provided by IPUMS. High-skilled workers are defined as those with at least a college education (educ99 >= 15). Immigrants are defined as those workers born outside of the United States ($bpl \neq 9900$). Variable used is hourly wage.

Figure 3: Unemployment Rates



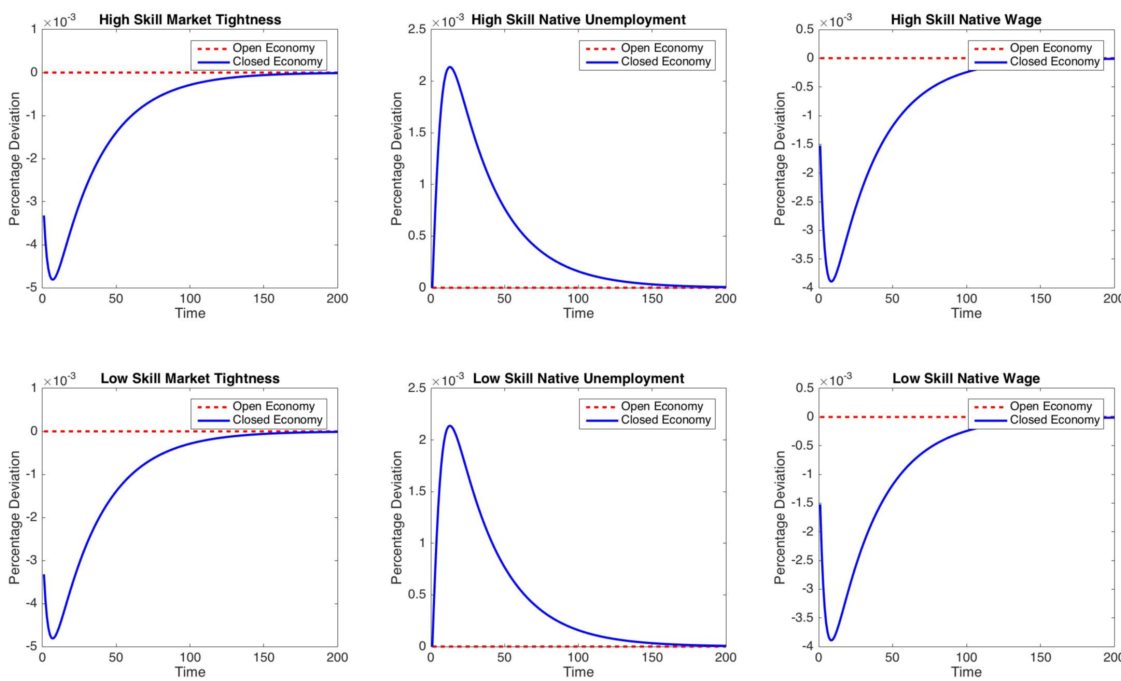
Notes: Own illustration using data from the January 2005 to December 2014 publicly available monthly samples from the Current Population Survey provided by IPUMS. High-skilled workers are defined as those with at least a college education (educ99 >= 15). Immigrants are defined as those workers born outside of the United States ($bpl \neq 9900$). To be included within the counts, a worker must be classified as within the labor force.

Figure 4: Monthly Job Finding Probabilities



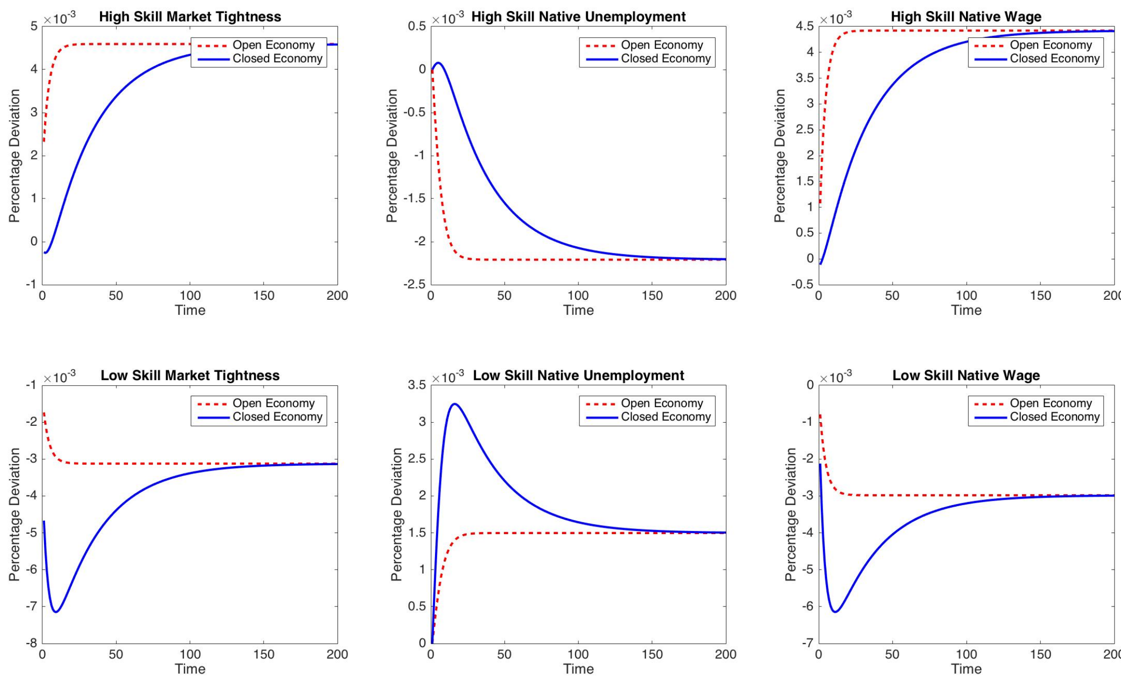
Notes: Own illustration using matched data from the January 2005 to December 2014 publicly available monthly samples from the Current Population Survey provided by IPUMS. High-skilled workers are defined as those with at least a college education (educ99 >= 15). Missing observations are assumed to be missing at random.

Figure 5: Basic Model - Labor Market Transition Dynamics from Immigration with Homogeneous Labor, Perfect Intermediate Good Substitution



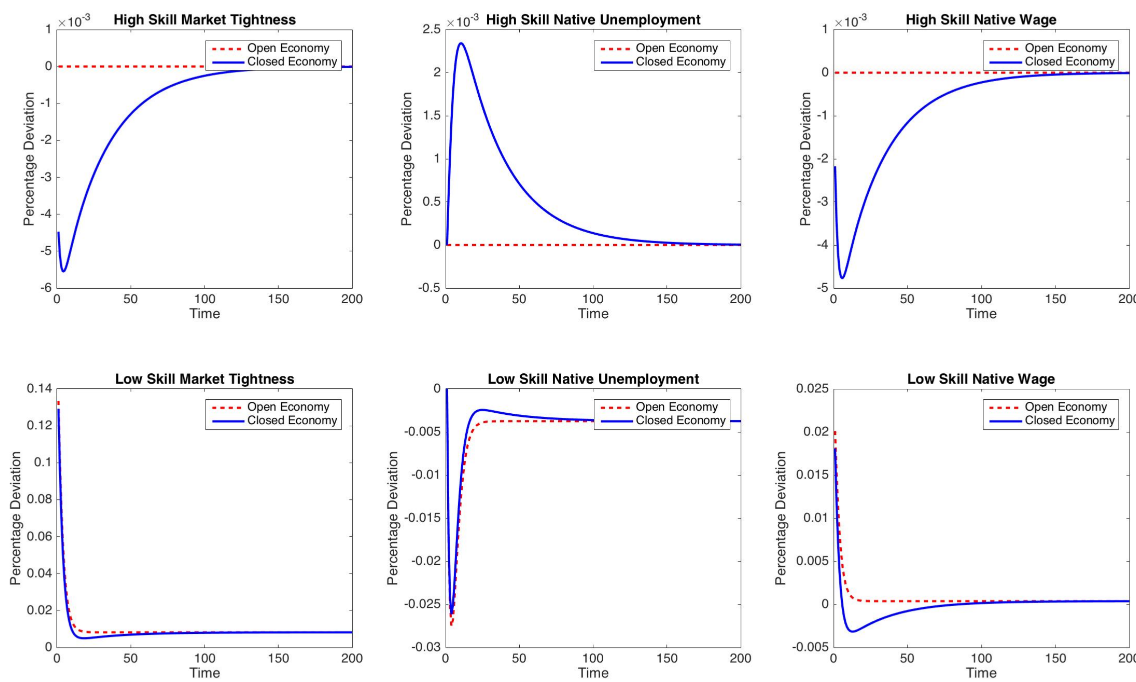
Notes: Own illustration. Simulation from an experiment in which the stock of high-skill immigrants increases by 1% of the total labor force at time 0. Calibration is a special case in which high and low skill goods are perfect substitutes ($\rho = 1$), and all workers are homogeneous so that worker separation rates ($s_{ij} = s$), outside options ($b_{ij} = 0$). Solid blue lines represent the behavior of variables in an economy where capital is determined solely by the capital accumulation decisions of resident household. Red dashed lines represent an economy open to foreign capital flows.

Figure 6: Price Channel - Labor Market Transition Dynamics from a 1% low-skill immigration-induced increase in the labor force in an economy with imperfect substitution between high and low skilled goods ($\rho = 0.5 < 1$), homogeneous workers ($s_{ij} = s$, $b_{ij} = 0$) and homogeneous production ($\kappa_H = \kappa_L$, $\gamma = 0.5$)



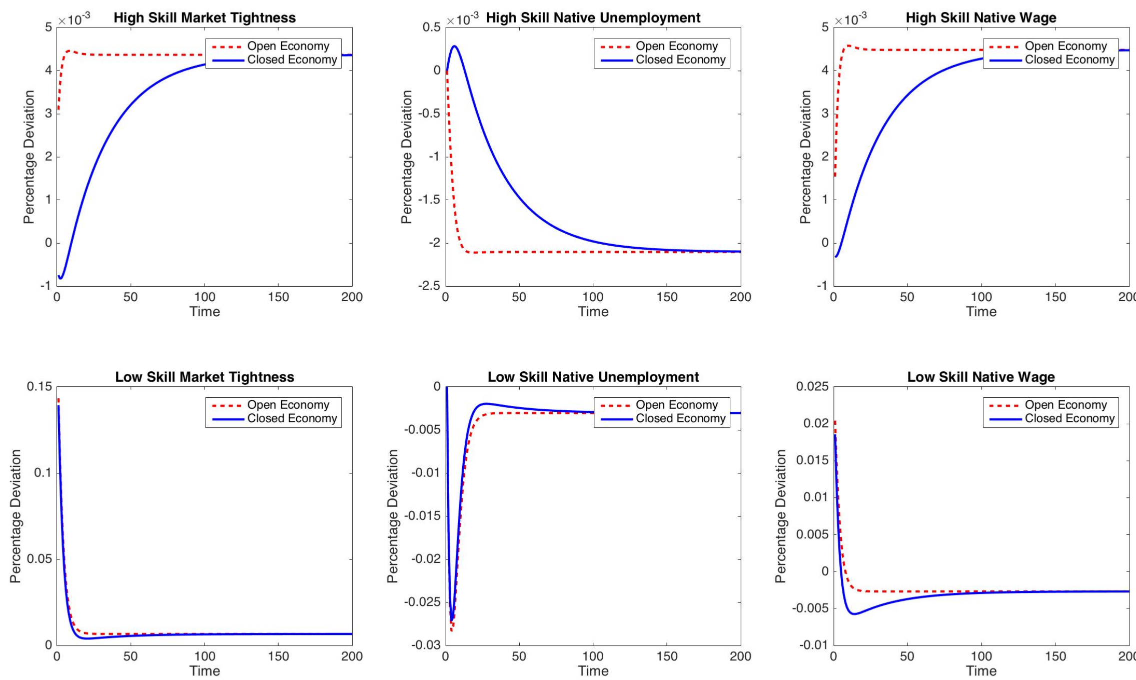
Notes: Own illustration. Simulation from an experiment in which the stock of high-skill immigrants increases by 1% of the labor force. Solid blue lines represent the behavior of variables in an economy where capital is determined solely by the capital accumulation decisions of resident household. Red dashed lines represent an economy open to foreign capital flows.

Figure 7: Hiring Cost Channel - Labor Market Transition dynamics from a 1% low-skill immigration-induced increase in the labor force in an economy with perfect substitution between high and low skilled goods ($\rho = 1$), heterogeneous workers (s_{ij}, b_{ij}) and homogeneous production ($\gamma = 0.5$)



Notes: Own illustration. Simulation from an experiment in which the stock of low-skill immigrants is increased by 1% of the labor force. Solid blue lines represent the behavior of variables in an economy where capital is determined solely by the capital accumulation decisions of resident household. Red dashed lines represent an economy open to foreign capital flows.

Figure 8: Calibrated Model - Labor Market Transition dynamics from a 1% low-skill immigration-induced increase in the United States labor force



Notes: Own illustration. Simulation from an experiment in which the stock of low-skill immigrants is increased by 1% of the labor force. Calibration is described in section 3. Solid blue lines represent the behavior of variables in an economy where capital is determined solely by the capital accumulation decisions of resident household. Red dashed lines represent an economy open to foreign capital flows.

A Description of Moment Matching Calibration Procedure

The task of the procedure is to find values of the nine parameters in $\Theta_2 = \{b_{iN}, s_{ij}, \gamma, \kappa_L, \xi\}$ in order to match nine moments. The set of moments are three ratios of the wages of each worker type with respect to the wage of the high skilled native worker ($\frac{w_{ij}}{w_{HN}}$), four unemployment rates (one for each type of worker, u_{ij}), and two job finding rates (one for each labor market, f_i). The data sources for each moment are discussed in section 3.

For given values of the parameters in Θ_2 and the externally calibrated parameters in Θ_1, one can sequentially calculate the following steady state values. The targeted unemployment rates can be used to calculate the stocks of employed and unemployed workers according to the following equations.

$$\begin{aligned} U_{ij} &= Q_{ij} \cdot u_{ij} \\ E_{ij} &= Q_{ij} \cdot (1 - u_{ij}) \end{aligned}$$

Production stocks and the resulting prices of intermediate goods follow directly according to

$$\begin{aligned} Y_i &= E_{iN} + E_{iI} \\ Z &= \left(\gamma Y_L^\rho + (1-\gamma) Y_H^\rho\right)^{1/\rho} \\ K &= \alpha \frac{Y}{r} \\ p_L &= A K^\alpha (1-\alpha) \gamma Y_L^{\rho-1} \left[\gamma Y_L^\rho + (1-\gamma) Y_H^\rho\right]^{(1-\alpha-\rho)/\rho} \\ p_H &= A K^\alpha (1-\alpha)(1-\gamma) Y_H^{\rho-1} \left[\gamma Y_L^\rho + (1-\gamma) Y_H^\rho\right]^{(1-\alpha-\rho)/\rho} \end{aligned}$$

Using the targeted job finding probabilities, the firm value functions and the resulting wages can be calculated according to the following equations.

$$J_{ij} = \frac{(1-\eta)(p_i - b_{ij})}{1 - \beta(1 - s_{ij} - \eta f_i)} \tag{20}$$

$$w_{ij} = \eta \left(p_i + q f_i J_{ij}\right) + (1-\eta) b_{ij} \tag{21}$$

Finally, one can calculate the implied vacancy filling probabilities by

$$\theta_i = \left(\frac{f_i}{\xi}\right)^{1/(1-\epsilon)} \tag{22}$$

$$\mu_i = f_i/\theta_i \tag{23}$$

The preceding equations yield values which allow me to confirm whether the following nine equations are satisfied.

$$s_{ij}E_{ij} = f_i U_{ij} \qquad \text{for } ij \in \{HN, HI, LN, LI\} \tag{24}$$

$$w_{ij} = \left(\frac{w_{ij}}{w_{HN}}\right) w_{HN} \qquad \text{for } ij \in \{HI, LN, LI\} \tag{25}$$

$$\kappa_i = \beta\mu_i\left(\phi_i J_{iI} + (1-\phi_i)J_{iN}\right) \qquad \text{for } i \in \{H, L\} \tag{26}$$

I choose values of the parameters in Θ_2 in order to satisfy equations (24)-(26). Because the matching procedure can be reduced to a set of nine simultaneous equations in nine unknowns, the system is perfectly identified and each moment can be matched exactly. The results and moments of this procedure are summarized in Table 2.