Macroeconomic Dynamics, **26**, 2022, 1264–1301. Printed in the United States of America.
doi:10.1017/S1365100520000553

IMMIGRATION, ENDOGENOUS SKILL BIAS OF TECHNOLOGICAL CHANGE, AND WELFARE ANALYSIS

GONCA SENEL
Bowdoin College

This paper investigates the long-run effects of immigration on wages and welfare in a model with endogenous technology choice (ETC) where firms are allowed to choose their optimal skill intensity from a menu of available technologies. I embed the ETC framework into the Auerbach and Kotlikoff model (1987) that features a large set of overlapping generations, a rich collection of population dynamics, and a social security system. I calibrate the model to match with the U.S. data and evaluate the effect of ETC with the help of two experiments. In the first experiment, I increase the share of high-skilled immigrants and compare the wage and welfare predictions of the model with ETC to a standard model where the skill intensities in production technology are fixed. In the standard model, since the skill intensities are constant, increase in the supply of high-skilled labor leads to a decrease in high-skilled wages and an increase in low-skilled wages. On the other hand, in the model with ETC, negative supply-side effects are counterbalanced by an increase in the intensity of the more abundant high-skilled labor, leading to a smaller decrease in their wages. The discrepancy between wage predictions of these two models is also reflected in the welfare: while the model with ETC predicts an increase in both high- and low-skilled natives' welfare, the standard model would predict a decrease in the welfare of the high skilled and a larger increase in the welfare of the low skilled. In the second experiment, I examine the effects of an increase in low-skilled immigration and find that in this case, since the initial production technology is low-skilled intensive, the ETC effects are smaller. These results imply that if ETC is ignored, both in the short run and long run, wage and welfare analyses of immigration will be incomplete, and even misleading.

Keywords: Immigration, Endogenous Technology Choice, Endogenous Skill Intensity, Welfare Analysis

1. INTRODUCTION

The United States, with its long immigration history, has experienced significant inflows of immigrants in recent decades. In 1970, only 4.7% of the population

I am grateful to Lee E. Ohanian for his invaluable guidance and support, and to Gadi Barlevy, Bob Barsky, Marco Bassetto, Francisco Buera, Nida Cakir, Jeffrey Campbell, Mariacristina De Nardi, Hesna Genay, Francois Guorio, Ergys Islamaj, Alejandro Justiniano, Ethan Lewis, and Giovanni Peri for insightful discussions and comments. An online appendix is available at http://www.goncasenel.com/uploads/2/4/8/1/24818900/senel_immigration_online_appendix.pdf. All errors are mine. Address correspondence to: Gonca Senel, Department of Economics, Bowdoin College, 9700 College Station, Brunswick, ME 04011-8497, USA. gsenel@bowdoin.edu. Phone: (424) 832-4247. Fax: (207) 725-3168.

 1469-8056/20

was foreign born, but by 2010, immigrants' share has increased to 13% of the total population. Immigrants have substantial economic and political impacts, and whether immigration is a remedy for the solvency of the social security system or an additional burden for the US government is still an ongoing debate attracting a substantial amount of empirical and theoretical research.

The vast majority of existing empirical literature focuses on the labor market outcomes of immigration through the analysis of relative wages and unemployment. Many studies like Card (2001), Friedberg (2001), Card and Lewis (2007), and Card (2009), among others, find that even though immigration creates substantial changes in the demographics of the US population, its effects on wages and unemployment are minimal.[1] Moreover, in numerous empirical studies like Beaudry et al. (2010), Doms and Lewis (2006), Lewis (2011a), and Peri (2012), insignificant labor market effects of immigration are attributed to the endogenous technology choice (ETC) of firms. These studies document that the local labor supply affects the skill intensity of the firms' production technology in the direction of the more abundant type of labor.[2,3] However, even though empirical literature recognizes the importance of ETC in assessing the effects of immigration, the theoretical literature ignores this aspect by assuming that the skill intensity of the production technology is exogenous and fixed over time. In this case, since the intensity of the production technology is fixed, when the relative supply of a specific type of labor increases, the decrease in the relative wage is larger and more significant. Therefore, omitting the ETC in theoretical models distorts the wage predictions by creating larger supply-side effects. Furthermore, due to the discrepancy between the wage predictions of these models and the empirical findings, the resulting long-run welfare analysis would be incomplete, and even misleading.

The aim of this paper is to address this issue and contribute to the existing literature in two ways. First, this paper reconciles the findings of the empirical literature and theoretical models by introducing a novel mechanism into a model with a social security system in order to study the long-run welfare effects of immigration. Specifically, I embed the ETC into the Auerbach and Kotlikoff model (1987), which is the pioneer Computable General Equilibrium model, with a large set of overlapping generations. To the best of my knowledge, this is the first study to explore the long-run welfare effects of immigration in a model with ETC. Furthermore, another aspect that differentiates this paper from the existing literature is that the model features a rich demographic structure, which allows the analysis of immigration on the US population both in the short run and the long run.[4]

In this paper, the model representation of the ETC of firms is based on the literature pioneered by Acemoglu (1998, 2002a, 2002b) and Caselli and Coleman (2006).[5] I conduct my analysis with parameter values that are calibrated for the US economy. Regarding immigration policy, I assume that at the initial state, each year, 2% of the existing immigrant population[6] enters into the economy as new immigrants. Furthermore, the share of the new high-skilled and low-skilled immigrants is assumed to be the same and equal to 1% so that in the stationary population distribution, they constitute 12% of the population, which is close to the immigrants' population share in the United States. Given the initial setting, I conduct two experiments to explore the effect of ETC in the case of a change in high-skilled and low-skilled immigration policy. In these experiments, the aim is to show how a permanent but small change in the immigration policy can lead to significant results with regard to wages and long-run welfare.

In the first experiment, I increase the share of incoming high-skilled immigrants to 2% of the existing immigrants while keeping the incoming low-skilled immigrants' share at 1%. Even though the increase in high-skilled immigration is small, the resulting changes in ETC create significant effects on skill intensity, wages, and consumption decisions of individuals, whereas the effects on individual labor and asset decisions are less significant. Specifically, I find that in the model with ETC, high-skilled wages decrease by only 6.53%, while low-skilled wages go up by only 7.05%, whereas a model without ETC would predict a 16.35% decrease in high-skilled wages and a 21.02% increase in low-skilled wages. The discrepancy between the two models is due to the ETC of firms. Specifically, the increase in high-skilled labor supply increases the high-skilled labor intensity of the firms' production function by 38.14% and reduces the low-skilled labor intensity by 35.53%. This leads to an increase in high-skilled demand, which counterbalances the negative effect of an increase in the supply of the high skilled. Considering the welfare effects of an increase in high-skilled immigration, the model with ETC predicts that high-skilled immigration will increase the welfare of both high-skilled and low-skilled workers, while the standard model without ETC predicts that the welfare of high-skilled workers will decrease, and there will be a positive and larger effect on the welfare of low-skilled workers.

In this framework, high-skilled immigration has two opposite effects on the welfare of high-skilled workers, both in the models with and without ETC. First, high-skilled immigration increases the share of the working-age population, which consequently reduces the contribution rate at which workers pay into the social security system. The decline in contribution rate raises the workers' net income regardless of the skill type, which leads to higher consumption and welfare. On the contrary, as a result of an increase in the supply of high-skilled workers, high-skilled wages go down, which reduces the consumption and the welfare of high-skilled workers. In the model without ETC, the magnitude of the decrease in high-skilled wages due to the increase in high-skilled labor supply is larger than the increase in the net income driven by the decrease in the contribution rate. Therefore, the welfare of high-skilled workers goes down. However, in the new model with ETC, firms can choose from a menu of technologies, and therefore, when the supply of high-skilled labor increases, firms are able to change their production technology in order to increase the intensity of high-skilled workers in their production function. As a result, in the model with ETC, the decrease in high-skilled wages due to the increase in high-skilled supply is small enough to be counterbalanced by the increase in net income driven by the decrease in contribution rate, creating a welfare gain for the high-skilled workers. Therefore, in the case of high-skilled immigration, there is a significant discrepancy between the welfare predictions for the high-skilled workers in a standard model without ETC and the model with ETC. Considering the low-skilled workers, I find that in both models, high-skilled immigration affects low-skilled workers' welfare positively due to increase in their wages and decrease in the contribution rate.

In the second experiment, I assume that the share of incoming low-skilled immigrants is increased to 2% of the existing immigrants while high-skilled immigrants' share is kept at 1%. In this case, the ETC effect is found to be less significant. The underlying reason is that due to the larger share of low-skilled workers in the initial steady state, the initial production technology is low-skilled-intensive. Therefore, the change in production technology due to low-skilled immigration is smaller. Moreover, in the case of low-skilled immigration, since immigrants have a higher probability of having high-skilled children, increase in the supply of low-skilled immigrants ultimately increases the supply of high-skilled natives. Therefore, in the long run, high-skilled wages start to fall due to the positive supply effect. Considering the welfare effect of the increase in low-skilled immigrants, for both models, the lifetime utility of both high-skilled and low-skilled immigrants increases. This implies that even though ETC creates significant results in the case of high-skilled immigration, it has no significant effects in the case of low-skilled immigration, especially when the initial production technology is low-skilled-intensive due to the initial abundant supply of low-skilled workers.

The rest of this paper is structured as follows. Section 2 constructs the proposed model. Section 3 summarizes the calibration of the model, and Sections 4 and 5 examine the model with respect to high-skilled and low-skilled immigration. Section 6 concludes.

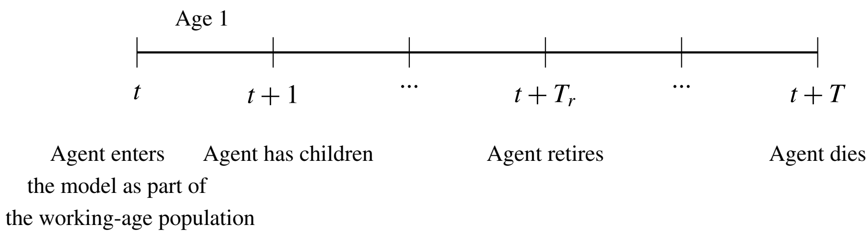
2. THE MODEL

I analyze the long-run effects of immigration using an overlapping generations model à la Auerbauch and Kotlikoff (1987) that features heterogeneous individuals, firms, government, and the social security system.[7] Different from the existing literature, I show the effects of immigration in a model with ETC, where firms are allowed to choose their optimal technology from a set of available technologies, the so-called "technology frontier" following Caselli and Coleman (2006). In this case, as the relative supply of high-skilled and low-skilled labor changes due to immigration, firms can choose production technologies among those that use the more abundant type of labor more productively.

In this setting, the model includes the following agents where the problem of each agent is explained in the following sections: (a) heterogeneous individuals, (b) firms, (c) government, and (d) pension funds.

2.1. Individuals

I use an overlapping generations framework with T number of periods, where T is set equal to 70, and each period corresponds to 1 year.



At each date t, a new generation enters into the population as a member of the working-age population. Specifically, an individual enters into the model as a 1 year old, corresponding to a real age of 21. An individual can only have children at the age of 2, corresponding to a real age of 22. Since the model only includes working-age individuals, the children of these individuals enter the model 21 years later.

There are no bequest motives in this model, and the individual starts her life with zero assets. At age 1, she starts supplying labor in exchange for wage income, and she continues working till the retirement age $T_r = 45$ in this model, which corresponds to the real age of 65. She allocates her resources between consumption and savings (asset holdings) after paying income taxes and contributions to the social security system. At the age of 45 (corresponding to a real age of 65), the individual retires and starts receiving social security benefits and lives for an additional 25 years and dies at the age of 70 with zero assets. Furthermore, there is age-dependent uncertainty concerning the survival of individuals from one period to the next where $\lambda_{i,i+1}$ is the conditional survival probability at age i.[8] Survival probabilities change with age and are given exogenously. There are accidental bequests in this model, and in the case of death before the age of 70, assets of the deceased individual are confiscated by the government and distributed as a lump-sum transfer among the individuals who survived. Overall, even though the lifespan of an individual is uncertain owing to unexpected death, in each period, a constant fraction of agents dies, and there is no aggregate uncertainty.

Individuals are heterogeneous with respect to their age, nativity, and educational attainment (skill). In the model, age, nativity, and the skill of an individual determine the productivity, fertility, and the intergenerational skill transmission. There are two types of individuals with respect to nativity: native and immigrant, where natives are denoted by n and immigrants are denoted by m. There are two types of individuals with respect to educational attainment: high skilled and low skilled, where high skilled are denoted by h and low skilled are denoted by l. An agent with age $i \in \{1, .., 70\}$, nativity $j \in \{m, n\}$, and skill level $s \in \{h, l\}$ is denoted by (i, j, s). The productivity of an individual is age-, nativity-, and skill-dependent,

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press

whereas the fertility and intergenerational skill transmission of an individual is nativity- and skill-dependent.

2.1.1. Individual's problem. An agent who was born at time t with nativity j and skill level s will maximize her expected lifetime utility by solving the following problem with respect to her sequence of assets $a_{t+i}(i,j,s)$, labor supply $l_{t+i-1}(i,j,s)$, and consumption $c_{t+i-1}(i,j,s)$ for $i \in \{1,..,T+1\}$:

$$\max \quad \frac{(c_t^{\gamma}(1,j,s)(1-l_t(1,j,s))^{(1-\gamma)})^{1-\eta}}{1-\eta} + \sum_{i=2}^{T} \beta^{i-1} \left(\prod_{z=1}^{i-1} \lambda_{z,z+1} \right) \frac{(c_{t+i-1}^{\gamma}(i,j,s)(1-l_{t+i-1}(i,j,s))^{(1-\gamma)})^{1-\eta}}{1-\eta}, \quad (1)$$

where the maximization is subject to the constraints:

$$b_{t+i-1}(i,j,s) + (1-\tau_w-\tau_b)w_{t+i-1}(s)e(i,j,s)l_{t+i-1}(i,j,s) + (1+(1-\tau_r)r_{t+i-1})a_{t+i-1}(i,j,s) + tr_{t+i-1} = c_{t+i-1}(i,j,s) + a_{t+i}(i,j,s)$$

$$b_{t+i-1}(i,j,s) = 0 \text{ for } 1 \le i \le 44$$
$$l_{t+i-1}(i,j,s) = 0 \text{ for } i \ge 45$$
$$a_{t+T+1}(i,j,s) = 0$$

Till the age of 45, an individual supplies $l(i,j,s)$ units of labor and receives $(1-\tau_w-\tau_b)w(s)e(i,j,s)l(i,j,s)$, where $w(s)$ is the skill-specific wage rate, $e(i,j,s)$ is the age, nativity and skill-specific efficiency, τ_w is the wage-income tax rate, and τ_b is the pension fund contribution rate. In return for her asset holdings, namely $a_{t+i-1}(i,j,s)$, the individual receives $(1+(1-\tau_r)r_{t+i-1})a_{t+i-1}(i,j,s)$ where $r_{t+i-1}(i,j,s)$ is the return on assets and τ_r is the capital-income tax. Furthermore, the individual receives lump-sum transfers denoted by tr_{t+i-1}. There is uncertainty in the lifespan of each individual, and $\lambda_{z,z+1}$ denotes the conditional probability of survival from age z to age $z+1$. If the individual survives till the age of 45, she retires and starts receiving the pension payments denoted by $b_t(i,j,s)$.

2.1.2. Population dynamics. In this model, the aim is to capture as many features of the evolution of the US population as possible. This helps us obtain an accurate measure of labor supply with different skill levels that will determine the ETC of firms. Therefore, the model includes a rich set of variables like fertility rates, skill transmissions, survival uncertainty, and immigration policy that will govern the evolution of the population, hence the labor supply.

Changes in immigration policy have both direct and indirect effects on the long-run population distribution. The direct effect is through increases in the relative supply of either high-skilled or low-skilled labor. The indirect effect of immigration comes from the change in population distribution as a result of

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press

immigrants having different fertility rates and skill-heredity probabilities (the probability of transferring the parent's skill level to the descendant). Therefore, in this model, the steady-state distribution of the population with respect to age, skill, and nativity is determined by the following factors: (a) fertility of individuals, (b) intergenerational skill transmission between parents and their children, and (c) immigration policy.

Fertility of Individuals

In this model, $\varphi(j, s)$ denotes the number of children per person with nativity $j \in \{m, n\}$ and skill level $s \in \{h, l\}$. In order to keep the evolution of the population simple, I assume that both immigrants and natives are fertile only at the real age of 22 (which corresponds to age 2 in the model) so that an individual who enters the model at time t will have children at time $t + 1$, and their children will enter into the model 21 years later. Therefore, since there is a 21-year lag for the introduction of the children into the model, even though the direct effect of immigration is experienced immediately after the policy change, the indirect effects would be experienced later on the transition path.

Intergenerational Skill Transmission

All children, regardless of their parents' nativity, are assumed to be native. The transmission of skills from parents to children is assumed to follow a Markov process where $\Pi(j, s, s')$ denotes the probability that a parent with nativity j and skill s will have a child with skill level s'. The transition matrices with respect to natives and immigrants are represented by the matrices below:

$$\Pi_n = \begin{bmatrix} \pi(n, l, l) & \pi(n, l, h) \\ \pi(n, h, l) & \pi(n, h, h) \end{bmatrix}$$

$$\Pi_m = \begin{bmatrix} \pi(m, l, l) & \pi(m, l, h) \\ \pi(m, h, l) & \pi(m, h, h) \end{bmatrix}$$

The first matrix represents the skill transmission for the natives while the second matrix represents the skill transmission for the immigrants. As an example, $\pi(n, l, h)$ specifies the probability that a low-skilled native parent will have a high-skilled child. This also implies that $\pi(n, l, l) = (1 - \pi(n, l, h))$ should hold.

Immigration Policy

In the model, the immigration policy, which is represented by $\psi(h, l)$, determines the number of new high-skilled and low-skilled immigrants and is defined as a percentage of the total number of immigrants already residing in the country. Therefore, $\psi(h, l)$ is defined by the pair $[\psi(1, m, h), \psi(1, m, l)]$ where $\psi(1, m, h)$ and $\psi(1, m, l)$ specify the percentages of new high-skilled and low-skilled immigrant population, respectively. Immigrants are assumed to enter the model only at age 1 (corresponding to the real age of 21). I assume that this value was initially 1% for both skill levels.[9,10]

Law of Motion for Population

At time t, the total number of individuals with age i, nativity j, and skill level s is represented by $P_t(i, j, s)$ where $i \in \{1, .., 70\}$, nativity $j \in \{m, n\}$, and skill level $s \in \{h, l\}$. Given immigration policy $\psi(h, l) = [\psi(1, m, h), \psi(1, m, l)]$, fertility rates $\varphi(j, s)$, skill transition probabilities $\pi(j, s, s')$, and survival probabilities $\lambda_{i,i+1}$, the evolution of the population is explained below.

- Evolution of newborns: All newborns are considered as natives. Since the model only includes the working-age population, children who are born at time t will enter the model 21 periods later at time t+21.

$$P_{newborn,t}(n, h) = \sum_{j,s} \varphi(j, s)P_t(2, j, s)\pi(j, s, H) \quad (2)$$

$$P_{newborn,t}(n, l) = \sum_{j,s} \varphi(j, s)P_t(2, j, s)(1 - \pi(j, s, H)) \quad (3)$$

- Evolution of native population: There are age-specific survival probabilities that determine the number of native individuals who will survive to the next period.

$$P_t(i + 1, n, s) = \lambda_{i,i+1}P_{t-1}(i, n, s)\,; \;\; i \in \{1, .., 69\}\,, \;\; s \in \{l, h\} \quad (4)$$

- Evolution of immigrant population: For the immigrants already residing in the country, age-specific survival probabilities determine the number of immigrants who will survive to the next period. Moreover, we assume that age-specific survival probabilities are the same for natives and immigrants. The population of new immigrants who enter the economy at age 1 is determined by the immigration policy and the total number of immigrants already residing in the country.

$$P_t(i + 1, m, s) = \lambda_{i,i+1}P_{t-1}(i, m, s)\,; \;\; i \in \{1, .., 69\}\,, \;\; s \in \{l, h\} \quad (5)$$

$$P_t(1, m, s) = \psi(1, m, s) \sum_{i=2}^{70} \sum_{s \in \{l,h\}} P_t(i, m, s) \quad (6)$$

2.2. Firms

The firm's problem is to choose optimal capital K_t, high-skilled labor H_t, and low-skilled labor L_t to maximize its profit, given the rental rate of capital r_t, skill-specific wage rates $w_t(s)$, and the depreciation rate δ. Moreover, in the model with ETC, besides capital and labor choices, firms are allowed to choose the optimal productivity levels for their high-skilled and low-skilled labor—denoted by $\Phi_{H,t}$ and $\Phi_{L,t}$, respectively, from a menu of production technologies called "technology frontier" described as in Caselli and Coleman (2006). The firm's problem in the case with ETC is described below:[11]

$$\max_{\Phi_{H,t}\Phi_{L,t}K_t,L_t,H_t} \{K_t^{\alpha}[A_t^{\frac{\sigma-1}{\sigma}}(\Phi_{H,t}H_t)^{\frac{\sigma-1}{\sigma}} + A_t^{\frac{\sigma-1}{\sigma}}(\Phi_{L,t}L_t)^{\frac{\sigma-1}{\sigma}}]^{(\frac{\sigma}{\sigma-1})(1-\alpha)}$$
$$- (r_t + \delta)K_t - w_t(l)L_t - w_t(h)H_t\}, \quad (7)$$

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press

subject to

$$\Phi_{H,t}^{\omega} + \kappa \Phi_{L,t}^{\omega} \leq B, \quad \textbf{(8)}$$

where A_t is exogenous labor augmenting the productivity process with deterministic growth rate g. σ is the elasticity of substitution between high-skilled and low-skilled labor, and α is the capital share. In the problem with ETC, besides K_t, H_t, and L_t, firms choose optimal $\Phi_{H,t}$ and $\Phi_{L,t}$ from the technology frontier characterized by Equation (8). On this frontier, there is a trade-off between increasing low-skill versus high-skill productivity. Parameters κ and ω govern the degree of the trade-off while parameter B specifies the height of the technology frontier. In order to ensure that there is an interior solution for $\Phi_{H,t}$ and $\Phi_{L,t}$, I assume $\omega > \sigma - 1$.[12]

This model features two main characteristics of the microfounded ETC models: the trade-off between the high-skill-augmenting versus low-skill-augmenting technologies and the relationship between the relative supply of skills and the type of the technology that will be used optimally.[13] The details of the technology frontier and its relationship with the microfounded ETC models is discussed in detail in Online Appendix B.3.4.

2.3. Government

The government collects taxes (T_t) in order to finance its expenditures (G_t) and transfers (Tr_t). Since there is survival uncertainty in the model, assets of the individuals unexpectedly deceased before the age of 70 are confiscated as accidental bequests (T_{Bt}) and redistributed by the government. Taxes are collected in the form of labor income and capital income taxes, as follows:

$$T_t = \tau_w w_t(l) L_t + \tau_w w_t(h) H_t + \tau_r r_t K_t, \quad \textbf{(9)}$$

where L_t is the aggregate low-skilled labor, H_t is the aggregate high-skilled labor, and K_t is the aggregate capital.

Since the economy is growing exogenously at rate g, I assume that transfers grow at the same rate:

$$Tr_t = (1+g)^t \sum_{i,j,s} tr_t P_t(i,j,s). \quad \textbf{(10)}$$

Government spending is a constant fraction $\bar{y}$ of the aggregate output:

$$G_t = \bar{y} Y_t. \quad \textbf{(11)}$$

All accidental bequests are seized by the government:

$$Beq_t = \sum_i \sum_j \sum_s a_t(i+1,j,s) P_{t-1}(i,j,s)(1-\lambda_{i,i+1}). \quad \textbf{(12)}$$

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press

In equilibrium, transfers (Tr_t) will be set such that the government keeps a balanced budget at each period:

$$T_t + Beq_t = G_t + Tr_t. \quad (13)$$

2.4. Pension Funds

In order to measure the long-run welfare effects of ETC in the United States, I include a social security system where individuals are entitled to receive social security payments when they retire.[14] The social security system is pay-as-you-go. All social security contributions are collected by the social security authority and redistributed to retirees.[15] Pensions are skill- and nativity-specific and are defined as a constant fraction (ζ) of net labor income:

$$b_t(i,j,s) = \begin{cases} 0 & i < 45 \\ \zeta(1-\tau_w-\tau_b)w_t(s)e(j,s) & i \geq 45. \end{cases}$$

In equilibrium, the contribution rate τ_b is set such that pension funds keep a balanced budget in each period:

$$\sum_{i\geq 45}\sum_j\sum_s \zeta(1-\tau_w-\tau_b)w_t(s)e(i,j,s)P_t(i,j,s) = \sum_{i<45}\sum_j\sum_s \tau_b w_t(s)e(i,j,s)l_t(i,j,s)P_t(i,j,s). \quad (14)$$

2.5. Competitive Equilibrium

In this section, I define the competitive equilibrium and the stationary equilibrium of the model. Given age (i), nativity (j), and skill (s), the state variables for each individual are initial asset holdings (a) and the efficiency levels (e). The aggregate state of the economy at time t is defined by the distribution of the population (P) with respect to age, nativity, and skill, as well as the total assets and the labor efficiencies.

DEFINITION 1. *Given the initial distribution of assets a_0, population P_0, government transfers tr_t, and government expenditures G_t, the tax rates τ_b, τ_w, τ_r, fertility rates $\varphi(j,s)$, skill heredity probabilities $\pi(j,s,s')$, survival probabilities $\lambda_{i,i+1}$, and immigration policy $\psi(1,m,s)$, a competitive equilibrium for this economy is a sequence of wages $\{w(s)\}$, interest rates $\{r\}$, aggregate labor $\{H,L\}$, capital $\{K\}$, taxes $\{T\}$, transfers $\{Tr\}$, contribution rate $\{\tau_b\}$, individual's labor, consumption, savings decisions $\{l(i,j,s), c(i,j,s), a(i,j,s)\}$, and the population distribution $\{P(i,j,s)\}$ such that at each time t:*

- *$l(i,j,s), c(i,j,s), a(i,j,s)$ solve the individual's problem.*
- *K, H, L, Φ_H, Φ_L solve the firm's problem.*

- *The goods market clears:*

$$Y = I + G + \sum_{i,j,s} P(i,j,s)c(i,j,s) \tag{15}$$

- *The labor market clears:*

$$H_t = \sum_{i\in(2,3)} \sum_{j\in(n,m)} l_t(i,j,h)e(i,j,h)P_t(i,j,h) \tag{16}$$

$$L_t = \sum_{i\in(2,3)} \sum_{j\in(n,m)} l_t(i,j,l)e(i,j,l)P_t(i,j,l) \tag{17}$$

- *Aggregate capital is equal to aggregate private wealth:*

$$K_t = \sum_{i\in(2,3)} \sum_{j\in(n,m)} \sum_{s\in(l,h)} a_t(i,j,s)P_t(i,j,s) \tag{18}$$

- *Transfers balance the government's budget (Equation (13) holds).*
- *The pension contribution rate balances the social security balance (Equation (14) holds).*

DEFINITION 2. *A stationary equilibrium is a competitive equilibrium in which per capita variables as well as prices and policies are constant, and aggregate variables grow at the constant growth rate of the Hicks-neutral technology (g) and the population (g_{pop}).*[16]

3. MODEL PARAMETERS

Model parameters are summarized in Table 1.[17]

4. EXPERIMENT I: INCREASE IN HIGH-SKILLED LABOR

In this model, immigration policy is defined as the share of new immigrants entering the United States as a percentage of the immigrant population already residing in the country. Each year, a constant fraction of the existing immigrants enter the economy as part of the working-age population. Furthermore, it is assumed that immigrants can only immigrate at the age of 21, which corresponds to age 1 in this model.

At the initial steady state, immigration policy is such that each year 2% of the existing immigrants enter the economy as new immigrants where half of these immigrants are high skilled while the other half are low skilled. In this case, immigration policy can be represented by $\psi(s)$, where $s \in \{h, l\}$ so that $\psi(L) = 1\%$ and $\psi(H) = 1\%$.

Given this setting, the aim of this section is to explore the long-run effects of permanent changes in the immigration policy. In the first experiment, I assume that at time 1, the immigration policy changes permanently, and the share of new high-skilled immigrants as a percentage of existing immigrants is doubled from 1% to 2%, while the percentage of new low-skilled immigrants is kept at the

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press

TABLE 1. Model parameters

Definition	Notation	Value	Source
Individual			
Efficiency units for worker at age $i \in \{1, .., 70\}$ nativity $j \in \{m, n\}$ and skill level $s \in \{h, l\}$	$e(i, j, s)$	See text	ACS (2000–2007)
Conditional survival probability at age i	$\lambda_{i,i+1}$	See text	National Vital Statistics (2000–2007)
Time discount factor	β	0.99	Corresponds to a capital/output ratio of approximately 2.4
Relative risk aversion	η	2	Imrohoroglu et al. (2017), Heer (2001)
Share of consumption in utility function	γ	0.32	Resulting average labor supply = 0.3
Number of children per person with nativity j and skill s	$\varphi(j, s)$	See text	National Center for Health Statistics, CPS, ACS
Population of parents with nativity j and skill s	$P(2, j, s)$	See text	Stationary distribution given the fertility rates, intergenerational mobility matrices, and immigration policy
Probability that a parent of nativity j and skill s will have a high-skilled child	$\pi(j, s)$	See text	GSS (1977–2016)
Government			
Amount of transfers from government	tr_t		Adjusted to sustain a balanced budget for the government
Wage income tax	τ_w	0.28	Trabant and Uhlig (2010)
Capital income tax	τ_r	0.36	Trabant and Uhlig (2010)
Government expenditures percent of GDP	$\bar{y}$	0.195	Heer and Irmen (2014)
Social security system			
Contribution rate	τ_b		Adjusted to sustain a balanced budget for pension system
Replacement rate	ζ	0.5	Heer and Irmen (2014)

TABLE 1. Continued

Definition	Notation	Value	Source
Producer			
Intensity of high-skilled workers in production	Φ_H		Calculated using $\frac{H}{L}$ ratio and given technology frontier
Intensity of low-skilled workers in production	Φ_L		Calculated using $\frac{H}{L}$ ratio and given technology frontier
Degree of substitutability between high- and low-skilled-augmenting technologies	ω	0.589	See text
Trade-off between high- and low-skilled-augmenting technologies	κ	1.476	See text
Height of the technology frontier	B	17.816	See text
Elasticity of substitution between high-skilled and low-skilled labor	σ	1.5	Krusell et al (2000)
Share of capital in production	α	0.33	
Depreciation rate of capital	δ	0.055	De Nardi et al. (1999)
Growth rate of Hicks-neutral productivity (A)	g	0.016	De Nardi et al. (1999)

initial rate. In this case, the new immigration policy becomes: $\psi(L) = 1\%$ and $\psi(H) = 2\%$.

Given the immigration policy described above, in the following sections, first, I examine the changes in the population distribution, steady-state values for the economy aggregates as well as the individual's saving, consumption, and labor decisions. Next, I analyze the transition dynamics of the economy to gauge the long-run effects of the ETC.

4.1. Steady-State Analysis

This section seeks to address the effect of a permanent immigration policy change on the steady state of the economy. Furthermore, in this section, in order to assess the effect of ETC, I compare a model without ETC with one with ETC. The results show that in the model with ETC, capital and output levels are higher than the model without ETC. Furthermore, in the model with ETC, as firms increase the efficiency of the more abundant high-skilled workers at the expense of low-skilled worker efficiency, high-skilled wages decrease only slightly while low-skilled wages experience a more modest increase.

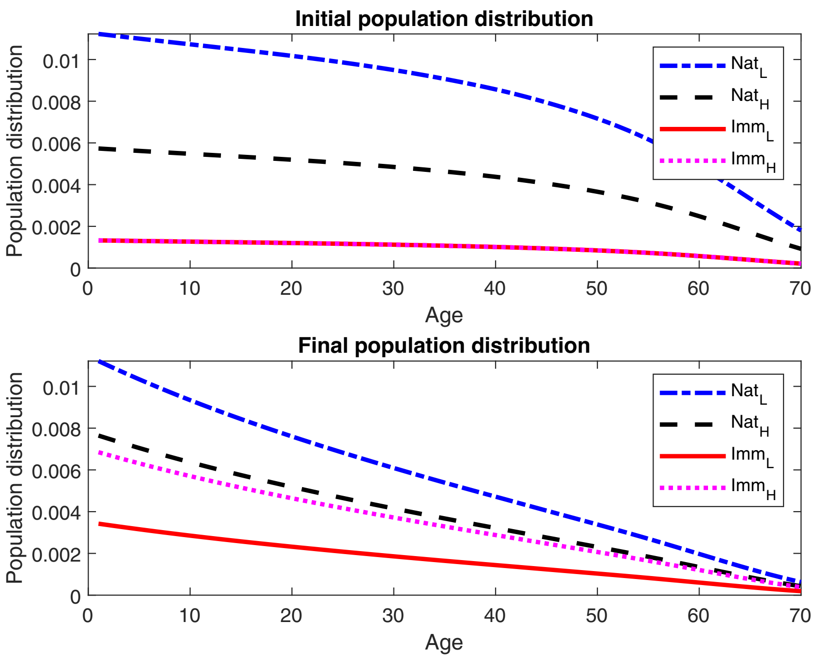
4.1.1. Population dynamics. Figure 1 illustrates the initial and final distribution of total population with respect to nativity and skill. In Figure 1, in the final steady state, as more immigrants enter into the economy, due to their higher fertility rates as compared to natives, the share of young population goes up. Specifically, in the final steady state, the median age of the population, including the child population, decreases from 37 to 30. Moreover, the median age of the population excluding the children who are below the age of 21 decreases from 27 (47 in real age) to 20 (40 in real age), implying an increase in the working-age population relative to retirees.

Table 2 illustrates the distribution of total population with respect to nativity, skill, and labor market participation. First, compared to the initial distribution, the share of immigrants increases from 12% to 32% of the total population. Furthermore, the share of working-age population increased from 75% to 82% so that there are more people paying into the social security system, which reduces the individual contribution rate, τ_b. In addition, the share of immigrants in the working-age population increased from 5% to 10% for the low-skilled workers and to 20% for the high skilled. In this case, even though the share of new low-skilled immigrants is still 1%, in the final steady state, increase in the number of existing immigrants creates higher population share for the low-skilled immigrants. Furthermore, even though the share of working-age low-skilled natives has declined significantly by 11%, the percentage of high-skilled natives has declined only by 1%. Since immigrants are more fertile and have a higher probability of having high-skilled children, in the final steady state, the share of working-age high-skilled natives does not change much.[18]

TABLE 2. Population distribution with respect to labor market participation

	Initial distribution			Final distribution	
	Low skilled	High skilled		Low skilled	High skilled
Natives			Natives		
Working age	0.435	0.222	Working age	0.325	0.221
Retired	0.137	0.070	Retired	0.061	0.041
Immigrants			Immigrants		
Working age	0.051	0.051	Working age	0.099	0.198
Retired	0.016	0.016	Retired	0.019	0.037

Notes: This table illustrates the population distribution of workers with respect to their labor force participation, nativity, and skill level before and after the immigration policy change. The left table reports the population distribution before the immigration policy change, and the right table reports the population distribution after the immigration policy change. In each table, the first two rows show the share of the natives, while the third and fourth rows show the share of the immigrants.



Notes: This figure illustrates the population distribution of workers with respect to their nativity and skill level before and after the immigration policy change. Nat_L represents the share of low-skilled natives, Nat_H represents the share of high-skilled natives, whereas Imm_L represents share of the low-skilled immigrants, and Imm_H represents the share of high-skilled immigrants. The upper panel shows the initial population distribution before the policy change, and the lower panel shows the final population distribution after the policy change.

FIGURE 1. Population distribution.

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press

TABLE 3. Steady states of the models with and without ETC

	Steady states		
	Initial steady state	Final steady state (without ETC)	Final steady state (with ETC)
Variable	$\sigma = 1.5$	$\sigma = 1.5$	$\sigma = 1.5$
K_{ss}	91.716	105.296	106.850
H_{ss}	0.081	0.123	0.124
L_{ss}	0.140	0.122	0.120
Tr_{ss}	3.370	3.807	3.863
Beq_{ss}	0.907	0.878	0.891
$\tau_{b,ss}$	0.101	0.064	0.064
$w_{H,ss}$	166.516	139.288	155.639
$w_{L,ss}$	88.176	106.716	94.391
r_{ss}	0.083	0.086	0.086
$\Phi_{H,ss}$	43.923	43.923	60.675
$\Phi_{L,ss}$	19.679	19.679	12.686
Y_{ss}	38.414	45.010	45.674
C_{ss}	18.160	22.065	22.390
K_{ss}/Y_{ss}	2.388	2.339	2.339
$K_{ss}/(H_{ss}+L_{ss})$	2.388	2.339	2.339
$K_{ss}/(w_{H,ss}H_{ss}+w_{L,ss}L_{ss})$	3.564	3.492	3.492

Notes: This table shows the steady-state outcomes of the models with and without ETC, given $\sigma = 1.5$. The first column reports the initial steady-state values, and the second column reports the final steady-state values when the skill-intensity levels are constant and equal to the initial steady-state levels. Lastly, the third column reports the final steady-state values when the firms are allowed to change their skill intensities. K_{ss} is the steady-state level of capital, H_{ss} is the steady-state level of high-skilled workers, L_{ss} is the steady-state level of low-skilled labor, Tr_{ss} is the steady-state level of transfers, Beq_{ss} is the steady-state level of accidental bequests, $\tau_{b,ss}$ is the steady-state level of contribution rate, $w_{H,ss}$ is the steady-state level of high-skilled wages, $w_{L,ss}$ is the steady-state level of low-skilled wages, r_{ss} is the steady-state level of interest rates, $\Phi_{H,ss}$ is the skill intensity of high-skilled workers in the production function, $\Phi_{L,ss}$ is the skill intensity of the low-skilled workers in the production function, Y_{ss} is the steady-state level of output, C_{ss} is the steady-state level of consumption, K_{ss}/Y_{ss} is the steady-state level of capital-output ratio, $K_{ss}/(H_{ss}+L_{ss})$ is the steady-state level of capital–labor ratio, $K_{ss}/(w_{H,ss}H_{ss}+w_{L,ss}L_{ss})$ is the steady-state level of capital–labor income ratio.

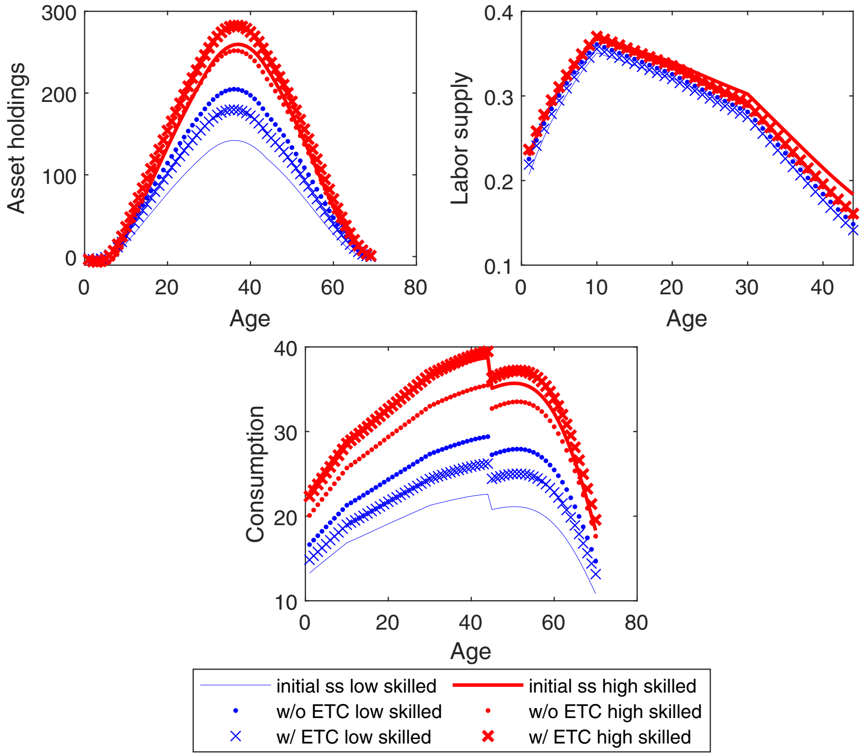
4.1.2. Economy aggregates. In the literature, elasticity of substitution between high-skilled and low-skilled labor, namely σ, ranges between 1.1 and 2. In this paper, I calculate the steady-state outcomes for σ values that are equal to 1.1, 1.5, and 1.9.[19] In the analysis below, I consider the case where $\sigma = 1.5$, which is reported in Table 3.[20] The first column of Table 3 shows the results at the initial steady state. The second column shows the final steady-state results with the new immigration policy in a model without ETC. In this model, firms cannot change their production technologies after immigration policy change. Specifically, in the case without ETC, firms have fixed efficiency levels for the high-skilled and low-skilled workers, namely Φ_H and Φ_L, which are equal to the optimal levels of the initial steady state. In the last column, which is labeled as "with ETC," constant efficiency assumption is relaxed so that in the final steady state, the firms can choose the optimal efficiency levels for their high-skilled and low-skilled workers in their production function. Therefore, for each given σ, the efficiency levels are the same in Column 1 and Column 2, whereas in Column 3, firms choose a production technology so that the more abundant high-skilled labor is used more efficiently at the expense of less efficient low-skilled labor. Therefore, in Column 3, Φ_H is higher and Φ_L is lower than the previous columns.

First, when the supply of high-skilled workers goes up, the high-skilled workers constitute a larger share of the population, which leads to an increase in H and a relative decrease in L. Due to the relative decrease in the supply of low-skilled labor, low-skilled wages go up whereas high-skilled wages go down. However, as we compare the scenario without ETC (Column 2) with the scenario where firms are allowed to choose their optimal technologies (Column 3), the decline in high-skilled wages and increase in low-skilled wages are lower in magnitude in the case with ETC. The underlying reason is that the increase in the efficiency of high-skilled workers due to ETC increases firm's demand for high-skilled labor, which increases the high-skilled wages, creating a counterbalancing effect, consequently mitigating the negative effect of the increase in the high-skilled labor supply. Similarly, decrease in the efficiency of low-skilled workers has a negative effect on low-skilled wages due to decline in firms' demand for low-skilled labor, alleviating the increase in low-skilled wages.

In the final steady state, as the share of the working age population goes up due to immigration, the contribution rate, namely τ_b, declines for each worker. Therefore, in the final steady state in both models with and without ETC, the economy creates more capital. Moreover, the inflow of high-skilled workers has an indirect positive effect on the aggregate capital as high-skilled workers have higher wages, and they save a larger share of their income. Comparing the models with and without ETC, increase in the aggregate capital is more pronounced when ETC is allowed in the model. In this case, since high-skilled workers do not experience a considerable decrease in their wages, their savings do not change significantly.

Lastly, due to the increase in K and H, total output, Y, is higher in the final steady state, more so in the case with ETC. With respect to consumption, as the contribution rate τ_b decreases, there are more resources available for the working-age population, which increases the aggregate consumption.

4.1.3. Individuals' choices at the steady states. In this section, I investigate the effect of high-skilled immigration on the asset holdings, labor choice, and consumption decisions of individuals. There are two factors that affect the individual decisions. First, due to the increase in immigration rate, the decline in the contribution rate (τ_b) increases the net income of the workers. Second, increase in high-skilled immigration increases low-skilled wages and decreases high-skilled wages. The magnitude of these changes depends on whether the ETC is embedded into the model or not. Therefore, increase in high-skilled immigrants has a positive effect on the net income of the low skilled, regardless of the model. However, for the high skilled, when ETC is also taken into account, the decrease



Notes: This figure shows the workers' asset holding, labor, and consumption decisions at different steady states with respect to their age and skill levels. The first panel of the figure illustrates the results with respect to natives' asset-holding decisions. The second panel of the figure illustrates the results with respect to natives' labor decisions. The third panel of the figure shows the results with respect to natives' consumption decisions. The red lines represent high-skilled workers, and the blue lines represent low-skilled workers. The straight line illustrates the results at the initial steady state, whereas the dotted line illustrates the results at the final steady state where skill intensities are constant at the initial steady-state levels. Lastly, the cross line illustrates the results at the final steady state where the skill intensities change due to endogenous technology choice.

FIGURE 2. Asset holding, labor supply, and consumption profiles with respect to age.

in high-skilled wages is smaller, and together with the decline in τ_b, the net effect of high-skilled immigration is positive.

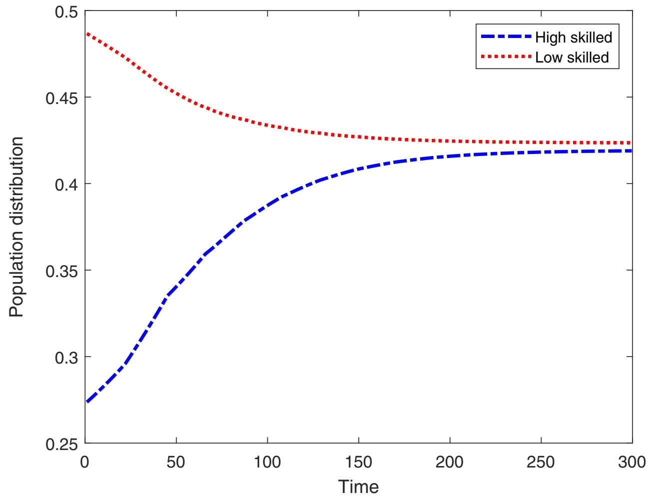
The first panel of Figure 2 shows the asset-holding decisions of the natives in the initial and final steady states with respect to their skill levels.[21] First, comparing the initial and final steady states, low-skilled workers save more as their net income increases due to the decrease in the contribution rate as well as the increase in low-skilled wages. On the contrary, for the high skilled, in the model without ETC, the decrease in high-skilled wages is more substantial, and despite the decrease in the contribution rate, the net income goes down, and high-skilled workers save less. However, in the model with ETC, since high-skilled wages decrease only slightly and together with the decrease in the contribution rate, the overall effect on high-skilled savings is positive even though it is a small effect.

The second panel of Figure 2 illustrates the changes in the labor supply of natives with respect to age and skill level. The results show that due to the increase in interest rates in the final steady state, the labor supply is tilted clockwise so that workers work more in their earlier years. Moreover, low-skilled workers increase their labor supply in the final steady state as the low-skilled wages are higher, especially in the model without ETC. On the contrary, high-skilled workers increase their labor only in the model with ETC since the decline in high-skilled wages is less significant. Overall, these effects are very small, and the models with and without ETC reveal similar results.

Consumption decisions are shown in the third panel of Figure 2. First, low-skilled consumption increases significantly as a result of an increase in low-skilled wages. Moreover, the increase in low-skilled consumption is less in the model with ETC as a result of a more modest increase in the low-skilled wages. Regarding high-skilled workers, in the model without ETC, high-skilled individuals consume less as their wages decline significantly due to the increase in high-skilled immigration. On the contrary, in the model with ETC, due to a slight decline in their wages, high-skilled workers' consumption in the final steady state is close to their initial steady-state levels, and for high-skilled retirees, consumption is even higher than the initial steady-state levels.

4.2. Transition

In this section, I show the transition path for 300 years for the economy where at time 1 the share of high-skilled immigrants, which is defined as a percentage of the existing immigrants, increases to 2%, while the new low-skilled immigrants' share is kept at 1%.[22] Regarding this experiment, due to the permanent change in the immigration policy, there is a continuous inflow of high-skilled and low-skilled immigrants into the economy, and it takes 150 years for the population to converge to the new stationary distribution.[23] The results show that as a result of new immigration policy, the supply of high-skilled workers (H) on the transition path goes up while it goes down for the low skilled (L). The change in H and L occurs gradually as more high-skilled immigrants enter into the economy. In the model without ETC, Φ_H and Φ_L are constants on the transition path. On the contrary, in the model with ETC, due to the gradual increase in H relative to L, Φ_H increases gradually while Φ_L decreases as firms choose to increase the efficiency of the high skilled at the expense of reducing the efficiency of low-skilled workers. As will be described in the following sections, 50% of the endogenous technological change occurs in the first 50 years of transition, and the skill intensities converge to their steady-state levels when the population reaches its stationary distribution.



Notes: This figure shows the share of high-skilled and low-skilled workers on the transition path. The red dotted line illustrates the share of low-skilled workers, while the blue dashed line illustrates the share of high-skilled workers.

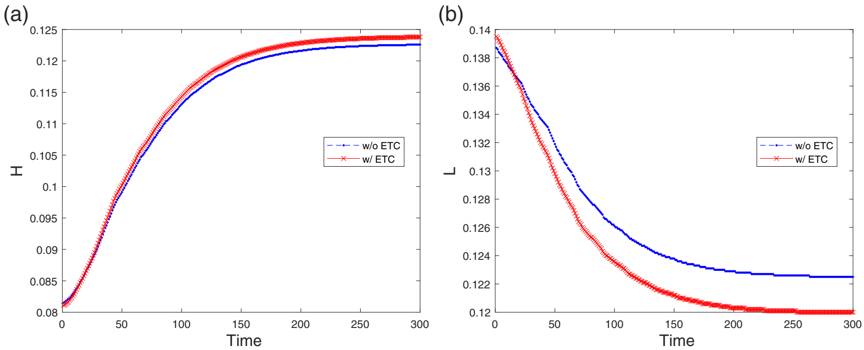
FIGURE 3. Share of high- and low-skilled workers on the transition path.

In the following sections, I investigate the effect of the change in immigration policy on population dynamics, aggregate labor, firms' efficiency choices, prices, economy aggregates, government and pension budgets, as well as long term capital ratios. Lastly, I conclude this section with the welfare analysis.

4.2.1. Population dynamics. Figure 3 shows the law of motion for the high-skilled and low-skilled working-age population. On the transition path, the share of high-skilled workers is going up while the share of low-skilled workers is going down. There are two reasons for this behavior. First, increase in high-skilled immigrants increases the share of high-skilled workers, as expected. Second, since immigrants have higher fertility rates and their probability of having a high-skilled child is also higher, in the long run, there is an additional inflow of high-skilled workers into the economy.

4.2.2. Aggregate labor. The evolution of high-skilled and low-skilled population together with workers' labor supply decisions determine the total supply of H and L in the economy. As can be seen in Figure 4, total high-skilled labor goes up while low-skilled labor drops significantly. This is mainly due to the increase in the share of high-skilled workers in the population. Furthermore, when the ETC is introduced into the model, high-skilled workers supply more labor, and low-skilled workers reduce their labor share. The underlying reason is that, in the

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press



Notes: This figure shows the aggregate high-skilled and low-skilled labor supply on the transition path. The left figure shows the high-skilled labor supply, while the right figure shows the low-skilled labor supply. The blue dash-dotted line shows the results in the model without ETC, and the red cross line shows the results in the model with ETC.

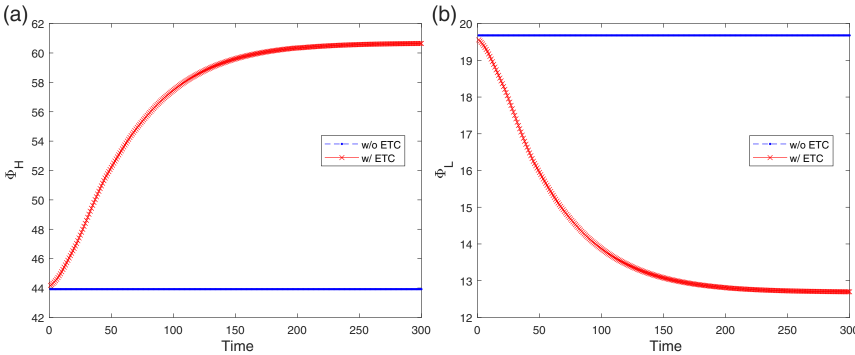
FIGURE 4. Aggregate labor on the transition path. (a) High-skilled labor. (b) Low-skilled labor.

model with ETC, due to the increase in high-skilled efficiency, demand for the high-skilled goes up while it is the opposite for the low-skilled, which reflects on the wages and eventually on the labor supply decisions. Specifically, in the model with ETC, since the high-skilled wage does not decline by as much as it does in the model without ETC, high-skilled workers do not reduce their labor significantly, resulting in a higher high-skilled aggregate labor level.

Considering individual labor supply decisions of the low-skilled, in the model without ETC, as a result of the increase in wages, low-skilled workers increase their labor. However, because the relative mass of low-skilled workers goes down, the population effect dominates the individual labor choice effect, and the aggregate low-skilled labor goes down. In the model with ETC, as a result of a more modest increase in wages, low-skilled workers increase their labor supply less than the case without ETC, so that aggregate low-skilled labor supply is lower than the model without ETC.

4.2.3. Firm's efficiency choice. The supply of H and L determines the efficiency levels Φ_H and Φ_L as illustrated in Figure 5. As H increases and L decreases, Φ_H increases and Φ_L decreases in the model with ETC. Since the evolution of H and L is gradual, Φ_H and Φ_L also change gradually, converging to a new steady state. On the transition path, approximately 50% of the technological change is achieved within the first 50 years. Moreover, as the population converges to its stationary distribution,[24] the skill intensities converge to their new steady-state values. Lastly, as can be seen in the figure, when the ETC is not considered, the efficiency levels are fixed at the initial levels.

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press



Notes: This figure shows high-skilled and low-skilled labor efficiencies on the transition path. The left figure shows high-skilled labor efficiency, while the right figure shows the low-skilled labor efficiency. The blue dash-dotted line shows the results in the model without ETC, and the red cross line shows the results in the model with ETC.

FIGURE 5. Labor efficiencies on the transition path. (a) Φ_H: High-skilled efficiency. (b) Φ_L: Low-skilled efficiency.

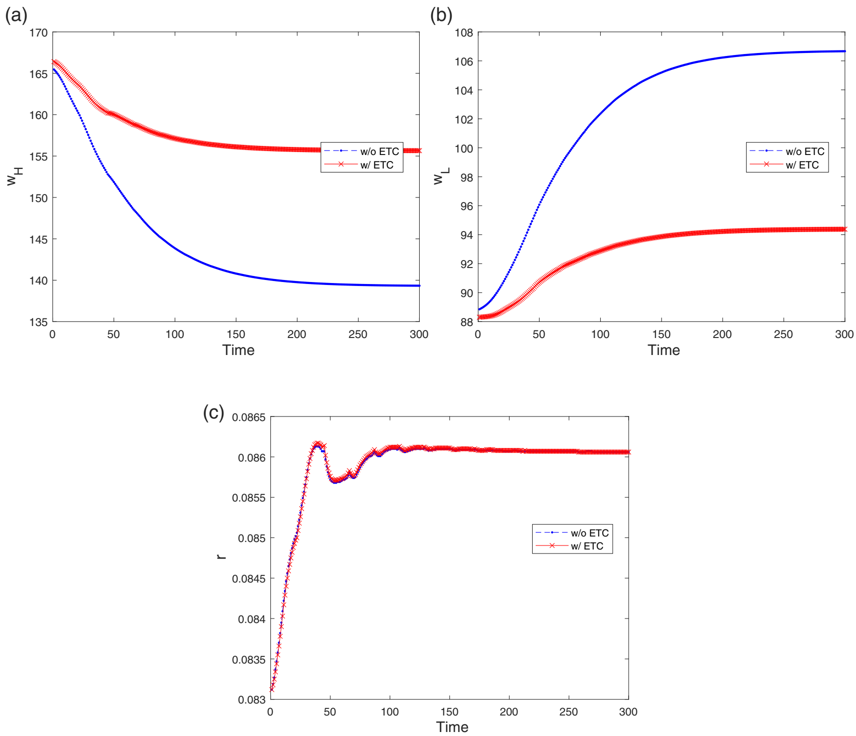
4.2.4. Prices. Together with the aggregate supply of H and L, changes in Φ_H and Φ_L reflect on the wage profiles for high-skilled and low-skilled workers as illustrated in Figure 6.[25] In the model with ETC, increase in H has two opposite effects on wages. First, it depresses high-skilled wages due to the increase in high-skilled labor supply. However, an increase in H also increases the skill intensity of production for the high skilled, Φ_H, which pushes up high-skilled wages. Therefore, the positive demand-side effect due to the increase in the skill intensity of the production function alleviates the adverse wage effect of the increase in supply. On the contrary, in the model without ETC, since technological change is muted, the positive effect of the increase in Φ_H is not present, and the only effect that reflects on the high-skilled wage is the negative supply effect of an increase in H. Accordingly, the decrease in high-skilled wages is more significant in the case without ETC.

For low-skilled workers, allowing for ETC mitigates the positive wage effect as firms reduce the intensity of low-skilled workers in production for the sake of increasing the intensity of the high skilled.

In both of the models, interest rates increase as the demand for capital increases. However, there is no effect of ETC on the interest rates.

4.2.5. Economy aggregates. Figure 7 shows the economy aggregates on the transition path. The initial effect of immigration on the aggregate capital is negative because immigrants are assumed to enter the workforce without any initial capital. However, when the share of working-age population starts to go up, τ_b decreases, more resources become available for individuals to save, and in equilibrium, aggregate capital goes up. Furthermore, in the model with ETC, high-skilled

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press



Notes: This figure shows the aggregate prices on the transition path. Figure (a) shows the high-skilled wages, while Figure (b) shows the low-skilled wages. Figure (c) shows the interest rates. The blue dash-dotted line shows the results in a model without ETC, and the red cross line shows the results in the model with ETC.

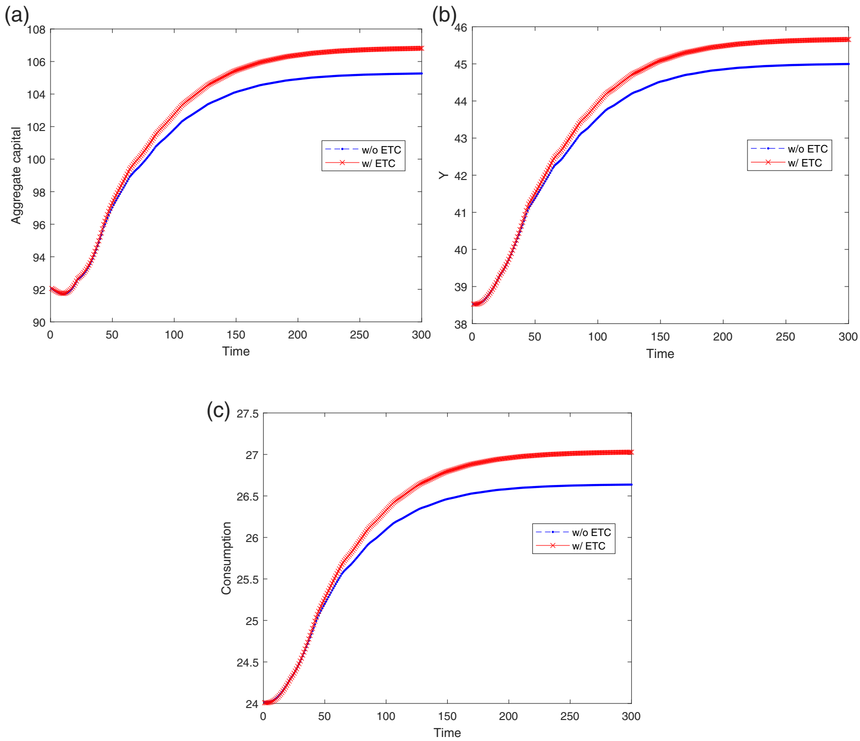
FIGURE 6. Aggregate prices on the transition path. (a) High-skilled wages. (b) Low-skilled wages. (c) Interest rates.

workers save even more as the decline in wages are smaller, and they have a higher share of the population so that total capital increases more than the model without ETC. Accordingly, increase in the capital reflects on the increase in output, and output is also higher in the final steady state. Therefore, the model without ETC underestimates the aggregate capital, the aggregate consumption, as well as the aggregate output.

4.2.6. Capital ratios. Figure 8 illustrates the capital ratios on the transition path. In the final steady state, the capital-to-labor ratio goes up, more so in the model with ETC since high-skilled workers save more. On the other hand, capital-to-labor income and capital-to-output ratios decline at the same rate in scenarios with and without ETC. Capital output ratio, namely K/Y, can be written as:

$$\frac{K}{Y} = \frac{K_t^{1-\alpha}}{A_t[(\Phi_{H,t}H_t)^{\frac{\sigma-1}{\sigma}} + (\Phi_{L,t}L_t)^{\frac{\sigma-1}{\sigma}}]^{(\frac{\sigma}{\sigma-1})(1-\alpha)}}. \quad \textbf{(19)}$$

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press

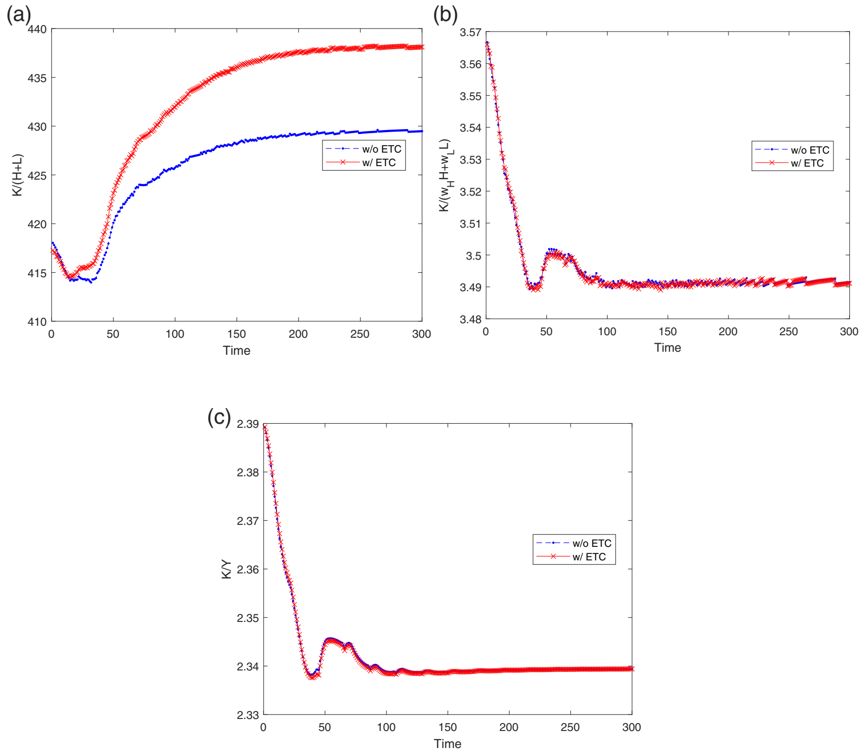


Notes: This figure shows the economy aggregates on the transition path. Figure (a) shows the aggregate capital, while Figure (b) shows the aggregate output. Figure (c) shows the aggregate consumption. The blue dash-dotted line shows the results in the model without ETC, and the red cross line shows the results in the model with ETC.

FIGURE 7. Economy aggregates on the transition path. (a) Aggregate capital. (b) Aggregate output. (c) Aggregate consumption.

In this equation, K/Y is a function of capital per effective unit of labor, which decreases as a result of an increase in high-skilled labor as more immigrants enter into the economy. Moreover, this decrease is present not only with ETC but also in the model without ETC, implying that the main source of the decrease in K/Y is immigration and its effects on the median age. Therefore, in the new steady state, decrease in capital per worker implies that the efficiency of the capital goes up in terms of its unit production.

4.2.7. Government and pension system budget. Figure 9 illustrates the government transfers and pension payments. On the transition path, as more high-skilled immigrants enter the economy, total transfers increase. Furthermore, increase in transfers is more significant in the model with ETC because increase in high-skilled wages leads to more accidental bequests, which eventually leads to higher government revenues. Lastly, as mentioned before, due to the increase in the



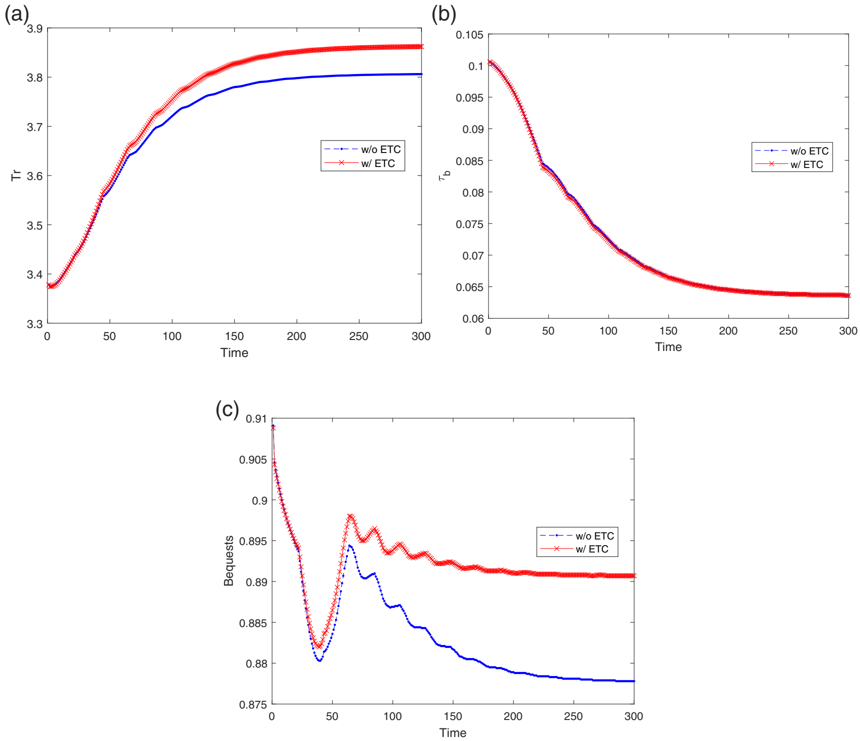
Notes: This figure shows the capital ratios on the transition path. Figure (a) shows the capital–labor ratio while Figure (b) shows the capital–labor income ratio. Figure (c) shows the capital–output ratio. The blue dash-dotted line shows the results in the model without ETC and red cross line shows the results in a model with ETC.

FIGURE 8. Capital ratios on the transition path. (a) Capital–labor ratio. (b) Capital–labor income ratio. (c) Capital–output ratio.

share of the working-age population, in both models (with and without ETC), contribution rates are lower in the final steady state.

4.2.8. Welfare effects of high-skilled immigration. In this section, I explore the long-run welfare effects of immigration within the context of ETC. Specifically, I use two measures, equivalent variation (EV) and consumption equivalent variation (CEV), to quantify the changes in the welfare of individuals who are born on the transition path. Given the total lifetime utility u_0 at the initial steady state, where u_0 is defined as $v(p_0, c(w_0)) = u_0$, with initial steady-state prices p_0, consumption profile $c(w_0)$, and initial level of wealth w_0,[26] for an individual who is born at time 1 after the change in the immigration policy, and who has lifetime utility $u_1 = v(p_1, w_1)$, which is defined with respect to the prices and wealth at time 1, the EV is defined as the amount of initial wealth required to acquire u_1, keeping the prices fixed at the initial steady-state values:

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press



Notes: This figure shows the government and pension system budget on the transition path. Figure (a) shows the government transfers. Figure (b) shows the pension payment share. Figure (c) shows the aggregate accidental bequests. The blue dash-dotted line shows the results in the model without ETC, and the red cross line shows the results in the model with ETC.

FIGURE 9. Government and pension system budget on the transition path. (a) Government transfers. (b) Pension payment share. (c) Accidental bequests.

$$v(p_0, c(w_0 + EV)) = u_1.$$

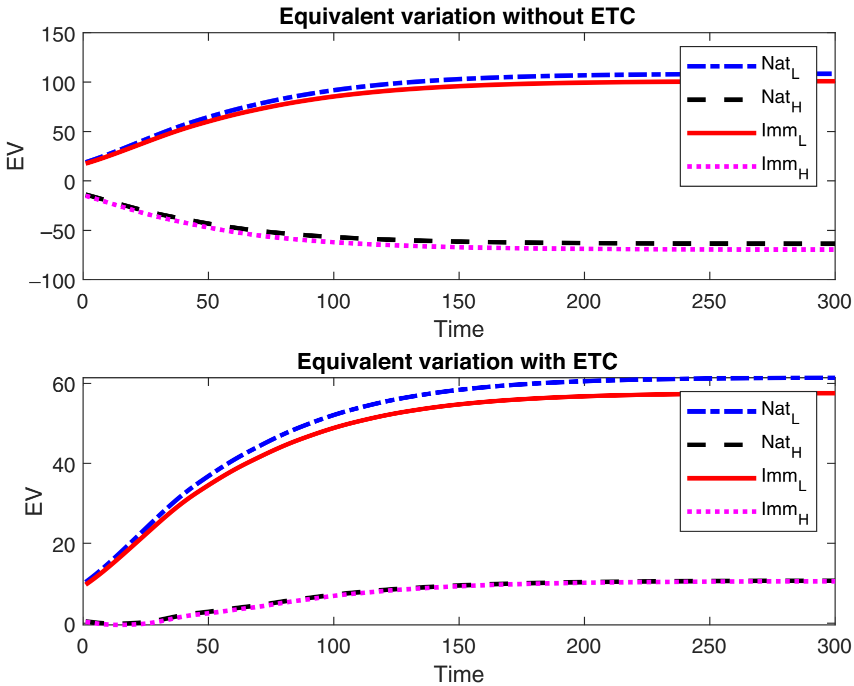
Similarly, the CEV is defined as the percentage increase in initial steady-state consumption levels required to acquire u_1, keeping the prices fixed at the initial steady-state values:

$$v(p_0, c(w_0)(1 + CEV)) = u_1.$$

When the signs of EV and CEV are positive, it means that the lifetime utility of the individual is higher than the initial steady-state values, while a negative EV or a negative CEV implies that the welfare of the individual has gone down after the immigration policy.

Figures 10 and 11 illustrate the effects of the increase in high-skilled immigration on the welfare of individuals with respect to each nativity and skill group, using EV and CEV measures, respectively. The upper panel of each figure shows

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press

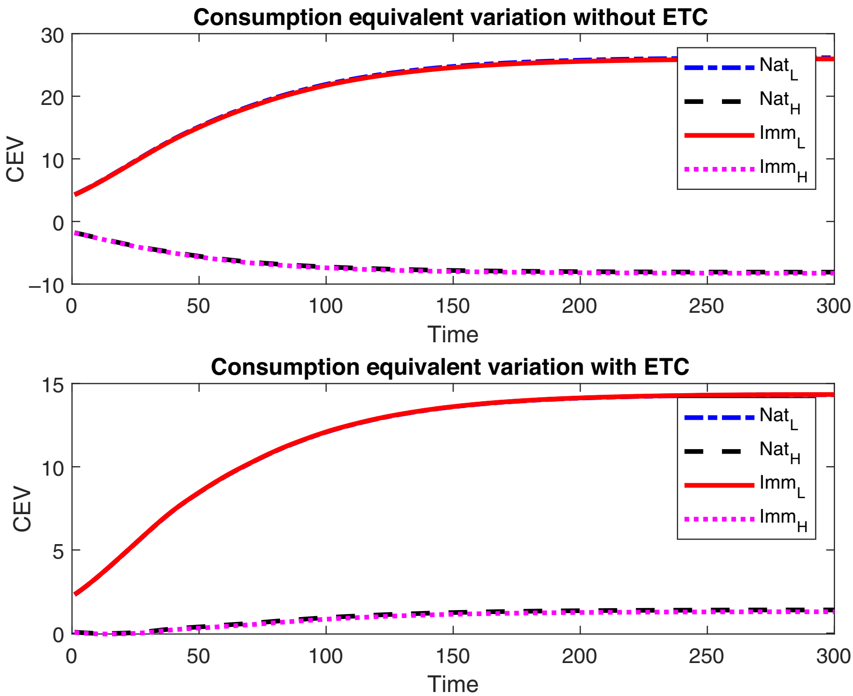


Notes: This figure shows the equivalent variation (EV) on the transition path with respect to nativity and skill. EV is measured in terms of the level of the consumption good. The upper panel shows EV in the model without ETC, while the lower panel shows EV in the model with ETC. Nat_L shows the EV of low-skilled natives and is represented by a blue dashed line, Nat_H shows the EV of high-skilled natives and is represented by a black dashed line, whereas Imm_L shows the EV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the EV of high-skilled immigrants and is represented by a magenta dashed line.

FIGURE 10. Equivalent variation on the transition path.

the welfare implications of the model without ETC, while the lower panel shows the results when ETC is introduced into the model. As expected, for each nativity and skill group, EV and CEV measures display similar effects on their welfare after the immigration policy change. First, in the model without ETC, the effect of the change in the immigration policy is positive for low-skilled workers while it has an opposite effect on the high-skilled workers. Due to the increase in low-skilled wages, low-skilled workers increase their consumption and labor supply at the same time. In the model, the positive effect of consumption is stronger than the negative effect of the increase in labor, pushing up the lifetime utility for the low-skilled. Regarding high-skilled workers, there are two factors that counteract with each other and determine the overall effect on their welfare. First, as a result of high-skilled immigration, high-skilled wages go down, and workers reduce their consumption as their income falls. Conversely, as more immigrants enter into the economy, the pension system contribution rate τ_b goes down, increasing the net income and the consumption of high-skilled workers. In the model without ETC,

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press



Notes: This figure shows the consumption equivalent variation (CEV) on the transition path with respect to nativity and skill. CEV is measured in terms of the percentage of the consumption good. The upper panel shows the CEV in the model without ETC, while the lower panel shows the CEV in the model with ETC. Nat_L shows the CEV of low-skilled natives and is represented by a blue dashed line, Nat_H shows the CEV of high-skilled natives and is represented by a black dashed line, whereas Imm_L shows the CEV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the CEV of high-skilled immigrants and is represented by a magenta dashed line.

FIGURE 11. Consumption equivalent variation on the transition path.

the negative effect of the decline in wages is larger than the positive effect of the decline in the contribution rate τ_b, so that the welfare of the high-skilled goes down significantly as compared to the initial steady state illustrated by a negative EV and a negative CEV in the figures. Comparing natives with immigrants, due to the differences in their productivities, welfare losses of high-skilled immigrants are higher than their native counterparts, while among low-skilled workers, low-skilled natives have higher gains.

Considering the lower panel, interestingly, the welfare effect of the immigration policy on high-skilled workers is positive in the model with ETC. In this case, as the high-skilled wages do not decrease as much as in the model without ETC, and due to the positive effect of the decline in the contribution rate (τ_b), after the immigration policy change, high-skilled workers increase their consumption and reduce their labor, and the total effect on their lifetime utility is positive.

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press

Furthermore, in the model with ETC, since there is a reallocation between low-skilled and high-skilled wages, the effect of the immigration policy change on the low-skilled is still positive, but less than before.

Lastly, in this experiment, since the technology frontier plays a vital role in the analysis, in Online Appendix C.3, I conduct tests to explore the conditions under which these results are robust with respect to two potential sources of variation in the parameters. The first relates to the elasticity of substitution between high-skilled and low-skilled workers. The second source of variation comes from the characterization of high-skilled workers. The robustness tests suggest that the main results are not driven by the variation in the elasticity of substitution. Moreover, the results are not influenced when the technology frontier is estimated using primary or secondary education as the threshold.

5. EXPERIMENT II: INCREASE IN LOW-SKILLED LABOR

In this section, I analyze the effects of an increase in low-skilled immigration. Specifically, in this experiment, the share of new low-skilled immigrants is doubled from 1% to 2% of existing immigrants while keeping the percentage of new high-skilled immigrants at 1% so that $\psi(H) = 1\%$ and $\psi(L) = 2\%$.[27]

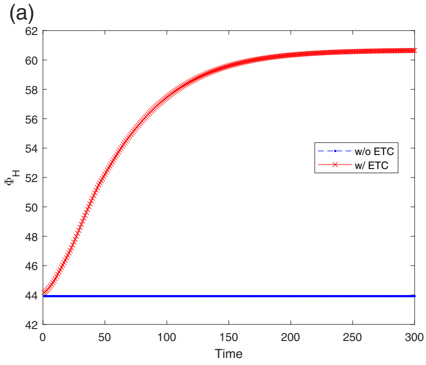
In the following analysis, I primarily focus on the technology, wage, and welfare effects of low-skilled immigration on the transition path.[28] Furthermore, while analyzing the changes in prices due to the change in immigration policy, I compare the short-run wage predictions of the model with the empirical findings of Ottaviano and Peri (2012).[29]

5.1. Transition

5.1.1. Firm's efficiency choice. Figure 12 illustrates the changes in the efficiency levels Φ_H and Φ_L on the transition path. The efficiency level for the high-skilled goes down for approximately 50 periods and then starts to rise, while it is the opposite for low-skilled labor. There are two reasons for these short-run and long-run differences. First, in the short run, initial increase in L and initial decrease in H leads to an increase in Φ_L and a decrease in Φ_H. However, in the long run, the supply of H starts to increase as immigrants start to have more children who are high-skilled. In this case, it becomes more profitable for firms to use H more efficiently so that they start to increase Φ_H at the expense of a decrease in Φ_L. Considering the overall effect on the efficiency levels, in the final steady state, Φ_L is higher than its initial steady-state value, while it is the opposite for Φ_H. Lastly, as expected, when the ETC is not allowed, the efficiency levels are fixed at the initial levels.

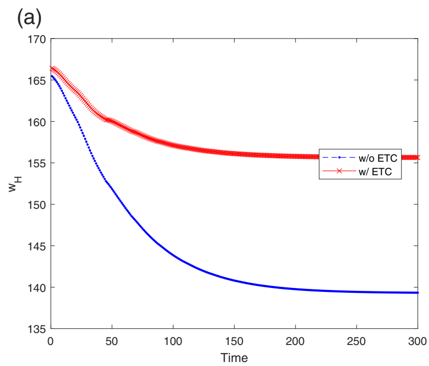
5.1.2. Wages. Figure 13 shows the changes in wages on the transition path. In the model with ETC, wages are determined by the aggregate high-skilled (H) and low-skilled (L) labor supplies as well as the skill intensities, Φ_H and Φ_L.[30]

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press



Notes: This figure shows the high-skilled and low-skilled labor efficiencies on the transition path. The left figure shows the high-skilled labor efficiency, while the right figure shows the low-skilled labor efficiency. The blue dash-dotted line shows the results in the model without ETC, and the red cross line shows the results in the model with ETC.

FIGURE 12. Labor efficiencies on the transition path. (a) Φ_H: High-skilled efficiency. (b) Φ_L: Low-skilled efficiency.

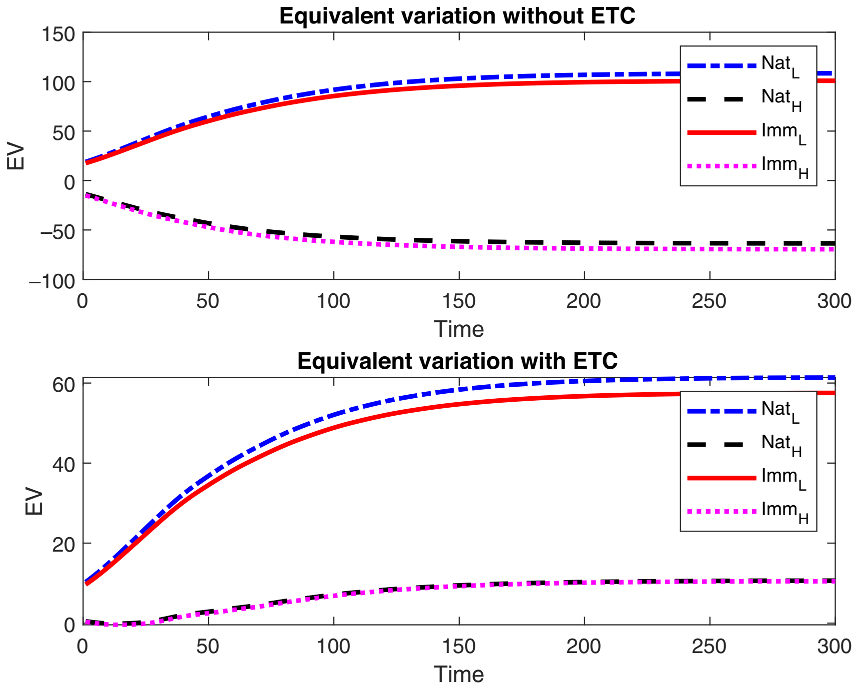


Notes: This figure shows the aggregate prices on the transition path. Figure (a) shows high-skilled wages, while Figure (b) shows low-skilled wages. The blue dash-dotted line shows the results in the model without ETC, and the red cross line shows the results in the model with ETC.

FIGURE 13. Wages. (a) High-skilled wages. (b) Low-skilled wages.

On the contrary, in the model without ETC, aggregate supplies of H and L are the only factors that determine high-skilled and low-skilled wages. In the model with ETC, an increase in L depresses low-skilled wages, while an increase in Φ_L (resulting from an increase in L) counteracts this effect and raises low-skilled wages. However, in the case without ETC, the positive effect of the increase in Φ_L is not present, and the only effect that reflects on the low-skilled wage is the negative supply effect of the increase in L. Accordingly, the decrease in low-skilled wages is more significant in the case without ETC. On the flip side, for high-skilled workers, as H initially decreases, high-skilled wages go up. However,

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press



Notes: This figure shows the equivalent variation (EV) on the transition path with respect to nativity and skill. The upper panel shows EV in the model without ETC, while the lower panel shows EV in the model with ETC. Nat_L shows the EV of low-skilled natives and is represented by a blue dashed line, Nat_H shows the EV of high-skilled natives and is represented by a black dashed line, whereas Imm_L shows the EV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the EV of high-skilled immigrants and is represented by a magenta dashed line.

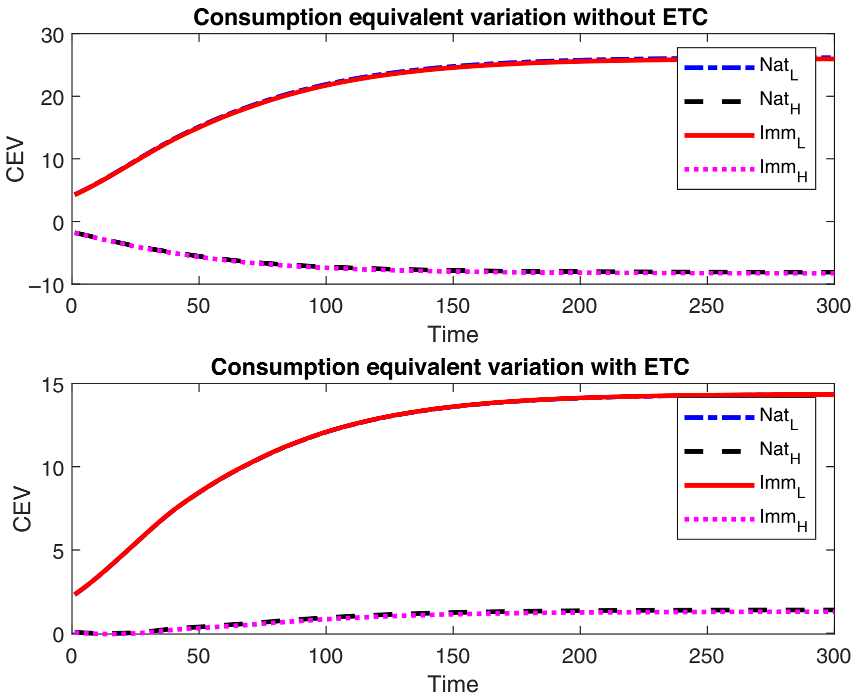
FIGURE 14. Equivalent variation on the transition path.

the increase in wages is less pronounced in the case with ETC when firms decrease Φ_H as H becomes scarcer.

Furthermore, considering the model in the long run, when H starts to increase as immigrants have more high-skilled children, high-skilled wages start to decline. In the case with ETC, the change in high-skilled wages is such that the short-run increase in wages is less than the long-run decrease so that overall, high-skilled wages are 0.17% lower than their initial steady-state values. This implies that high-skilled wages are almost identical in the initial and final steady states. Moreover, in the model without ETC, initial increase in high-skilled wages are higher (compared to the model with ETC) so that the long-run effect of the immigration policy on high-skilled wages is still positive.

5.1.3. Welfare effects of low-skilled immigration. Figures 14 and 15 illustrate the effects of the increase in low-skilled immigration on the welfare of individuals

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press



Notes: This figure shows the CEV on the transition path with respect to nativity and skill. CEV is measured in terms of the percentage of the consumption good. The upper panel shows the CEV in the model without ETC, while the lower panel shows the CEV in the model with ETC. Nat_L shows the CEV of low-skilled natives and is represented by a blue dashed line, Nat_H shows the CEV of high-skilled natives and is represented by a black dashed line, whereas Imm_L shows the CEV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the CEV of high-skilled immigrants and is represented by a magenta dashed line.

FIGURE 15. Consumption equivalent variation on the transition path.

with respect to each nativity and skill group, using the EV and CEV measures, respectively. The upper panel of each figure shows the welfare implications of the model without ETC, while the lower panel shows the results when ETC is introduced into the model. As expected, for each nativity and skill group, EV and CEV measures reveal similar welfare effects after the immigration policy change. First, in the case of low-skilled immigration, the effect of the change in the immigration policy is positive for both high-skilled and low-skilled workers. Due to the decrease in τ_b, both types of workers increase their consumption, and their overall welfare increases. Comparing high-skilled natives and immigrants, due to their higher productivity, the welfare gains of high-skilled immigrants are higher. On the contrary, considering low-skilled workers, low-skilled natives have higher gains as their productivity is slightly higher.

With regard to the lower panel, the welfare effect of the immigration policy is still positive for both high-skilled and low-skilled workers. However, this

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press

time, due to the increase in low-skilled efficiency and wages, there is a reallocation of welfare from high skilled to low skilled so that the welfare gains for the low skilled in the model with ETC is higher while it is reversed for the high skilled. Moreover, since initial population is low-skilled-abundant, the initial low-skilled intensity of the production technology is high, and it is easier to readjust the technology frontier as a result of additional incoming low-skilled workers. However, this also means that the gains from readjustment is smaller as the initial technology frontier is already low-skilled-intensive.[31]

6. CONCLUSION

In this study, I investigate the long-run wage and welfare effects of immigration in a model with ETC where firms are allowed to choose the optimal skill intensity of their production from a menu of available technologies, which is called the "technology frontier" a la Caselli and Coleman (2006). I embed the ETC structure into the Auerbach and Kotlikoff (1987) model with a large set of overlapping generations and a rich demographic structure to analyze the long-run welfare effects of immigration.

In the first experiment, in order to analyze the effect of an increase in high-skilled immigrants, the share of new high-skilled immigrants is increased from 1% to 2% of the existing immigrants, while keeping the share of low-skilled immigrants at 1%. In the model with ETC, change in the immigration policy creates less significant effects on wages as the negative supply-side effects are counterbalanced by an increase in the intensity of the more abundant high-skilled labor, leading to a smaller decrease in their wages. Specifically, in the long run, the model with ETC predicts that high-skilled wages decrease only by 6.53%, while low-skilled wages go up only by 7.05%. On the contrary, the model without ETC predicts a 16.35% decrease in high-skilled wages and a 21.02% increase in low-skilled wages. Furthermore, the model with ETC predicts that high-skilled immigration will increase the welfare of both high-skilled and low-skilled natives, while the model without ETC predicts that the welfare of high-skilled natives will decrease, and there will be a positive and larger effect on the welfare of the low-skilled. In the model with ETC, since high-skilled wages do not decrease as much, and due to the positive effect of the decline in the contribution rate, high-skilled workers increase their consumption and reduce their labor, and the total effect on their lifetime utility is positive. Furthermore, in the model with ETC, due to the reallocation of wages from low skilled to high skilled, for the low skilled, the effect of the immigration policy change is still positive, but smaller.

In the second experiment, I investigate the long-run welfare effects of low-skilled immigration. In this experiment, the share of new low-skilled immigrants is increased from 1% to 2% of existing immigrants while keeping the share of high-skilled immigrants at 1%. First, as immigrants have a higher probability of having high-skilled children, increase in the supply of low-skilled immigrants

https://doi.org/10.1017/S1365100520000553 Published online by Cambridge University Press

also increases the supply of high-skilled natives. Therefore, in the long run, high-skilled wages start to fall as the supply of high-skilled workers goes up. In the case with ETC, the overall effect on high-skilled wages is insignificant and negative as the high-skilled wages go down by 0.18%, while the effect on low-skilled wages is a 1.85% decline. In the model without ETC, increase in low-skilled immigration creates a 3.33% decline in low-skilled wages and a 1.22% increase in high-skilled wages. Therefore, since the initial economy is low-skilled abundant, and the production technology is already low-skilled-intensive, the effect of ETC is smaller in the case of an increase in low-skilled immigration. Considering the welfare effects of the increase in low-skilled immigrants, in both models, the welfare of both high-skilled and low-skilled immigrants increases. However, in the model with ETC, due to the increase in low-skilled efficiency, there is a reallocation of welfare from high-skilled to low-skilled so that the welfare gains for the low-skilled is greater.

Moreover, in further analysis, I investigate the short-run effects of the second experiment and show that the predictions of the model with ETC are more in line with the existing empirical findings. Specifically, I compare the short-run wage changes in the model with those of Ottaviano and Peri (2012). The model with ETC predicts that in the short-run, high-skilled wages increase by 0.13% and low-skilled wages decrease by 0.72% relative to the initial steady state. On the contrary, the model without ETC predicts a 0.67% increase in high-skilled wages and 1.29% decrease in low-skilled wages. Comparing these results with the ones reported in Ottaviano and Peri (2012), authors predict a 0.14% increase in high-skilled wages and a 0.3% decrease in low-skilled wages, which suggests that the predictions of the model with ETC are more in line with the existing empirical findings.

Lastly, in both experiments, I conduct tests to explore the conditions under which these findings are robust with respect to changes in the technology frontier parameters. The test results suggest that the main findings are not driven by the variation in the elasticity of substitution. Moreover, the model outcomes are not influenced when the technology frontier is estimated using primary or secondary education as the threshold for being high-skilled. However, despite its caveats, when a college degree is used as the threshold, the positive effects of ETC for high-skilled immigration are reduced because the estimation of the technology frontier creates larger errors, leading to more costly technology adjustment.

Consequently, these results imply that ETC has significant effects on wages and welfare, while its effects on the individual asset and labor decisions are limited. Moreover, especially in the case of high-skilled immigration, if ETC is not taken into account, the long-run analyses of immigration will be incomplete, and even misleading.

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit http://dx.doi.org 10.1017/S1365100520000553.

NOTES

1. On the other hand, studies such as Borjas (2003) and Borjas and Katz (2007) find that the immigration effect on wages is negative and significant.

2. See Dustmann and Glitz (2012), Hanson and Slaughter (2002), Lewis (2003), and Gonzales and Ortega (2011) for further analysis.

3. Another channel that has been proposed in the literature is the changes in the product mix due to trade. Studies focusing on the first channel claim that changes in the supply of high-skilled and low-skilled labor can be absorbed by an increase in the share of the product type that uses the newly available labor type more intensely in its production (Leamer and Levinsohn (1995)). However, studies like Beaudry et al. (2010) find that the effect of a change in the production technology dominates the skill-mix channel.

4. In this regard, the use of an OLG framework has two advantages over the growth models with infinitely-lived agents. First and foremost, an OLG model allows for the intergenerational reallocation of income through the social security system. This is vital in the current setup as immigration changes the demographic structure and the contribution rate to the social security system. As a result of the changes in the contribution rate, the OLG model creates income redistribution between generations, which consequently leads to changes in consumption and welfare. Moreover, in the OLG model, the secondary effects of immigration on welfare due to differences in fertility and skill-inheritance rates can also be analyzed.

5. While the former analyzes the change in the supply of technologies that augment the more abundant type of labor, the latter investigates the change in the firms' demand with respect to those technologies.

6. Immigrants who have arrived before the current period and are already residing in the country.

7. For further examples of the Auerbauch and Kotlikoff model, see Cagetti and De Nardi (2006, 2009), De Nardi et al. (1999), Storesletten (2000), Kitao (2014), Imrohoroglu et al. (1995), Imrohoroglu et al. (2003), and Akin (2011).

8. Children survive to the age of 21 with probability 1.

9. The total number of immigrants already residing in the country is calculated by summing up the number of immigrants for both skill levels who are age 2 and above.

10. With this specification, at the initial steady state, immigrants constitute 12% of the total population, which is close to the population distribution of the US economy.

11. The characterization of the firm's problem in the case without technology choice is omitted as it is the same problem without technology frontier, implying that $\Phi_{H,t}$ and $\Phi_{L,t}$ are constant.

12. For proof see Caselli and Coleman (2006).

13. I assume that there is a single sector in this economy. See Kane (2019) for the analysis of a multi-sector endogenous technology choice models.

14. This setting is important in order to understand how ETC affects the social security system solvency.

15. It should be noted that in this model, all individuals are legal and are entitled to the social security payments.

16. The solution of the stationary equilibrium is discussed in Online Appendix A.

17. Calibration of these parameters can be found in Online Appendix B.

18. Note that the children of immigrants are considered to be natives.

19. The steady state results for all σ values can be found in Table 14 in Online Appendix C.1.1.2.

20. These results are also applicable to other values of σ.

21. The results are very similar for the immigrants, and only a small discrepancy emerges as a result of differences in their productivity.

22. In the initial steady state, both shares are set equal to 1%.

23. Stationary distribution is defined as the distribution where the share of the population with respect to age, skill, and nativity is constant, and the overall population grows at a constant rate denoted by g_{pop}.

24. Relative labor supply, namely $\frac{H}{L}$, becomes constant at the stationary distribution.

25. See Equation (42) in Online Appendix A.

26. Initial wealth is defined in terms of the consumption good.

27. The initial steady state in this experiment is the same as the one in the first experiment where the immigration policy is defined as $\psi(L) = 1\%$ and $\psi(H) = 1\%$.

28. The discussion of the changes in the other variables can be found in Online Appendix D.

29. In Online Appendix D.1.1, I present suggestive evidence that these predictions are in line with the findings of Ottaviano and Peri (2012). Specifically, the model with ETC predicts that in the short-run, high-skilled wages increase by 0.13%, and low-skilled wages decrease by 0.72% relative to the initial steady state. On the contrary, the model without ETC predicts a 0.67% increase in high-skilled wages and 1.29% decrease in low-skilled wages. In Ottaviano and Peri (2012), authors predict a 0.14% increase in high-skilled wages and a 0.3% decrease in low-skilled wages, which suggests that the predictions of the model with ETC are more in line with the existing empirical findings.

30. See Equation (42) in Online Appendix A.

31. In the case of low-skilled immigration, since all low-skilled immigrants are legal in this model, they are entitled to receive social security benefits when they retire. However, in real life, even though immigrants pay social security benefits through fake social security numbers, they are not entitled to receive any benefits. Accordingly, the effect of low-skilled immigrants on the welfare of legal immigrants and natives is likely to be higher.

REFERENCES

Aaronson, D., E. French and I. Sorkin (2013) Firm Dynamics and the Minimum Wage: A Putty-Clay Approach. Working Paper Series WP-2013-26, Federal Reserve Bank of Chicago.

Acemoglu, D. (1998) Why do new technologies complement skills? Directed technical change and wage inequality. *The Quarterly Journal of Economics* 113(4), 1055–1089.

Acemoglu, D. (2002a) Technical change, inequality and the labor market. *Journal of Economic Literature* 40(1), 70–72.

Acemoglu, D. (2002b) Directed technical change. *The Review of Economic Studies* 69(4), 781–809.

Akin, S. (2012) Immigration, fiscal policy, and welfare in an aging population. *The B.E. Journal of Macroeconomics* 12(1), 1–45.

Altonji, J. G. and D. Card (1991) The effects of immigration on the labor market outcomes of less-skilled natives. In: J. M. Abowd and R. B. Freeman (eds.), *Immigration, Trade, and the Labor Market*, Chicago: University of Chicago Press.

Angrist, J. (1995) The economic returns to schooling in the West Bank and Gaza Strip. *American Economic Review* 85, 1065–1087.

Auerbach, A. J. and L. J. Kotlikoff (1987) *Dynamic Fiscal Policy.* Cambridge, MA: Cambridge University Press.

Beaudry, P., M. Doms and E. Lewis (2010) Should the PC be considered a technological revolution? Evidence from U.S. metropolitan areas. *Journal of Political Economy* 118(5), 988–1036.

Borjas, G. J. (1987) Immigrants, minorities, and labor market competition. *Industrial and Labor Relations Review* 40(3), 382–392.

Borjas, G. J. (1994) The economics of immigration. *Journal of Economic Literature* 32(4), 1667–1717.

Borjas, G. J. (2003) The labor demand curve is downward sloping: Reexamining the impact of immigration on the labor market. *The Quarterly Journal of Economics* 118(4), 1335–1374.

Borjas G. J. (2006) Native internal migration and the labor market impact of immigration. *Journal of Human Resources* 41(2), 221–257 32.

Borjas, G. J. (2009) The Analytics of the Wage Effect of Immigration. Harvard University. Mimeo.

Borjas, G. J., J. Grogger and G. H. Hanson (2008) Imperfect Substitution Between Immigrants and Natives: A Reappraisal. NBER Working Paper 13887.

Borjas, G. J. and L. F. Katz (2007) The evolution of the Mexican-Born workforce in the United States. In: G. J. Borjas (ed.), *Mexican Immigration to the United States*, Chicago: University of Chicago Press.

Card, D. (1990) The impact of the Mariel Boatlift on the Miami labor market. *Industrial and Labor Relations Review* 43(2), 245–257.

Card, D. (2001) Immigrant inflows, native outflows, and the local labor market impacts of higher Immigration. *Journal of Labor Economics* 19(1), 22–64.

Card, D. (2009) Immigration and inequality. *American Economic Review* 99(2), 1–21.

Card, D. and E. Lewis (2007) The diffusion of Mexican immigrants during the 1990s: Explanations and impacts. In: G. J. Borjas (ed.), *Mexican Immigration to the United States*, Chicago: University of Chicago Press.

Cagetti, M. and M. De Nardi (2006) Entrepreneurship, frictions, and wealth. *Journal of Political Economy* 114(5), 835–870.

Cagetti, M. and M. De Nardi (2009) Estate taxation, entrepreneurship, and wealth. *American Economic Review* 99(1), 85–111.

Caselli, F. and W. J. Coleman II (2006) The world technology frontier. *American Economic Review* 96(3), 499–522.

Cortes, P. (2008) The effect of Low-skilled immigration on U.S. prices: Evidence from CPI data. *Journal of Political Economy* 116(3), 381–422.

De Nardi, M., S. Imrohoroglu and T. Sargent (1999) Projected U.S. demographics and social security. *Review of Economic Dynamics* 2(3), 575–615.

Dustmann, C. and A. Glitz (2012) How Do Industries and Firms Respond to Changes in Local Labor Supply? University College London. Mimeo.

Doms, M. and E. Lewis (2006) Labor Supply and Personal Computer Adoption. Federal Reserve Bank of San Francisco Working Paper 2006–18.

Friedberg, R. M. (2001) The impact of mass migration on the Israeli labor market. *The Quarterly Journal of Economics* 116(4), 1373–1408.

Friedberg, R. M. and J. Hunt (1995) The impact of immigrants on host country wages, employment and growth. *Journal of Economic Perspectives* 9(2), 23–44.

Gonzales, L. and F. Ortega (2011) How do very open economies absorb large immigration flows? Recent evidence from Spanish regions. *Labour Economics* 18(1), 57–70.

Hanson, G. H. and M. J. Slaughter (2002) Labor-market adjustment in open economies: Evidence from US states. *Journal of International Economics* 57(1), 3–29.

Heer, B. and A. Irmen (2014) Population, pensions and endogenous economic growth. *Journal of Economic Dynamics and Control* 46, 50–72.

Imrohoroglu, A., S. Imrohoroglu and L. Fuster (2003) A welfare analysis of social security in a dynastic framework. *International Economic Review* 44, 1247–1274.

Imrohoroglu, A., S. Imrohoroglu and D. Joines (1995) A life cycle analysis of social security. *Economic Theory* 6(1), 83–114.

Johnson, G. E. (1997) Changes in earnings inequality: The role of demand shifts. *The Journal of Economic Perspectives* 11, 41–54.

Kane, R. (2019) Directed structural change. *Macroeconomic Dynamics* 23(5), 1921–1958.

Katz, L. and K. M. Murphy (1992) Changes in relative wages, 1963-1987: Supply and demand factors. *Quarterly Journal of Economics* 107, 35–78.

Kitao, S. (2014) Sustainable social security: Four options. *Review of Economic Dynamics* 17(4), 756–779.

Krusell, P., L. Ohanian, J. V. Rios-Rull and G. L. Violante (2000) Capital skill complementarity and inequality: A macroeconomic analysis. *Econometrica* 68, 1029–1054.

Leamer, E. and J. Levinsohn (1995) International trade theory: The evidence. In: G. M. Grossman and K. Rogoff (eds.), *Handbook of International Economics*. Amsterdam, Netherlands: Elsevier.

Lewis, E. (2003). Local, Open Economies Within the U.S.: How Do Industries Respond to Immigration? Federal Reserve Bank of Philadelphia Working Paper 04–01.

Lewis, E. (2005) Immigration, Skill Mix, and the Choice of Technique. Federal Reserve Bank of Philadelphia Working Paper 05–08.

Lewis, E. (2011a) Immigration, skill mix, and capital−skill complementarity. *Quarterly Journal of Economics* 126(2), 1029–1069.
McAdam, P. and A. Willman (2018) Unraveling the skill premium. *Macroeconomic Dynamics* 22(1), 33–62.
Ottaviano, G. and G. Peri (2012) Rethinking the effect of immigration on wages. *Journal of the European Economic Association* 10, 152–197.
Paserman, D. (2013) Do high-skill immigrants raise productivity? Evidence from Israeli manufacturing firms, 1990–1999. *IZA Journal of Migration* 2(6), 1–31.
Peri, G. (2012) The effect of immigration on productivity: Evidence from U.S. states. *Review of Economics and Statistics* 94(1), 348–358.
Storesletten, K. (2000) Sustaining Fiscal policy through immigration. *Journal of Political Economy* 108(2), 300–323.