Online Appendix

"Immigration, Endogenous Skill Bias of Technological Change, and Welfare Analysis" by

Gonca Senel

A Technical Appendix

A.1 Value Function Representation of Individual's Problem

$$V(a_{t+i-1}, i, j, s) = \max\{\frac{(c_t^{\gamma}(i,j,s)(1-l_t(i,j,s))^{(1-\gamma)})^{1-\eta}}{1-\eta} + \beta\lambda_{i,i+1}V(a_{t+i}, i+1, j, s)\} \quad (20)$$

subject to the following constraints:

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

if 1≤i≤45, $b_{t+i-1}(i,j,s) = 0$

if i>45, $l_{t+i-1}(i,j,s) = 0$.

A.2 Solution of the Individual's Problem

$$\max \frac{(c_t^{\gamma}(1,j,s)(1-l_t(1,j,s))^{(1-\gamma)})^{1-\eta}}{1-\eta} + \sum_{i=2}^{T}\beta^{i-1}(\prod_{q=1}^{i-1}\lambda_{q,q+1})\frac{(c_{t+i-1}^{\gamma}(i,j,s)(1-l_{t+i-1}(i,j,s))^{(1-\gamma)})^{1-\eta}}{1-\eta}, \quad (21)$$

subject to the following constraints:

for every i

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

if 1≤i≤45, $b_{t+i-1}(i,j,s) = 0$

if i>45, $l_{t+i-1}(i,j,s) = 0$.

Solution:

1. for $1 \leq i \leq 45$

$$\beta^t\gamma(1-\eta)c_t^{(1-\eta)\gamma-1}(1-l_t)^{(1-\gamma)(1-\eta)} = \Omega_t \quad (22)$$

$$\beta^t(1-\gamma)(1-\eta)c_t^{(1-\eta)\gamma}(1-l_t)^{(1-\gamma)(1-\eta)-1} = \lambda_t(1-\tau_w-\tau_b)w_t(s)e(i,j,s) \quad (23)$$

$$(1+(1-\tau_r)r_{t+1})\Omega_{t+1} = \Omega_t \quad (24)$$

2. for $i \geq 46$

$$l_t(i,j,s) = 0 \tag{25}$$

$$\beta^t \gamma(1-\eta) c_t^{(1-\eta)\gamma-1} = \Omega_t \tag{26}$$

- if $i \leq 79$

$$(1 + (1-\tau_r) r_{t+1}) \Omega_{t+1} = \Omega_t \tag{27}$$

- if $t = 80$

$$b_t(i,j,s) + (1 + (1-\tau_r) r_t) a_t(i,j,s) + tr_t(i,j,s) = c_t(i,j,s) \tag{28}$$

Accordingly, the solution is:

1. for $1 \leq i \leq 45$

$$\frac{(1-\gamma)}{\gamma} \frac{c_t}{(1-l_t)} = (1-\tau_w-\tau_b) w_t(s) e(i,j,s) \tag{29}$$

$$\lambda_t \beta (1 + (1-\tau_r) r_{t+1}) c_{t+1}^{(1-\eta)\gamma-1} (1-l_{t+1})^{(1-\gamma)(1-\eta)} = c_t^{(1-\eta)\gamma-1} (1-l_t)^{(1-\gamma)(1-\eta)} \tag{30}$$

2. for $i \geq 46$

$$l_t(i,j,s) = 0 \tag{31}$$

$$\beta^t \gamma(1-\eta) c_t^{(1-\eta)\gamma-1} = \Omega_t \tag{32}$$

- if $i \leq 79$

$$\lambda_t (1 + (1-\tau_r) r_{t+1}) \beta c_{t+1}^{(1-\eta)\gamma-1} = c_t^{(1-\eta)\gamma-1} \tag{33}$$

- if $i = 80$

$$b_t(i,j,s) + (1 + (1-\tau_r) r_t) a_t(i,j,s) + \chi_t(i,j,s) = c_t(i,j,s) \tag{34}$$

A.3 Solution of the Firm's Problem

$$\max_{\Phi_{H,t}\Phi_{L,t}K_t,L_t,H_t} \{K_t^\alpha [A_t^{\frac{\sigma-1}{\sigma}} (\Phi_H H_t)^{\frac{\sigma-1}{\sigma}} + A_t^{\frac{\sigma-1}{\sigma}} (\Phi_L L_t)^{\frac{\sigma-1}{\sigma}}]^{(\frac{\sigma}{\sigma-1})(1-\alpha)} - (r_t+\delta) K_t - w_t(l) L_t - w_t(h) H_t\} \tag{35}$$

subject to

$$\Phi_{H,t}^\omega + \kappa \Phi_{L,t}^\omega \leq B \tag{36}$$

1. FOC wrt K_t:

$$\alpha A_t^{1-\alpha} K_t^{\alpha-1} [(\Phi_{H,t} H_t)^{\frac{\sigma-1}{\sigma}} + (\Phi_{L,t} L_t)^{\frac{\sigma-1}{\sigma}}]^{(\frac{\sigma}{\sigma-1})(1-\alpha)} - \delta = r_t \tag{37}$$

2. FOC wrt L_t:

$$A_t^{1-\alpha}K_t^{\alpha}(1-\alpha)\Phi_{L,t}^{\frac{\sigma-1}{\sigma}}L_t^{\frac{-1}{\sigma}}[(\Phi_{H,t}H_t)^{\frac{\sigma-1}{\sigma}}+(\Phi_{L,t}L_t)^{\frac{\sigma-1}{\sigma}}]^{(\frac{1-\alpha\sigma}{\sigma-1})}=w_t(l) \tag{38}$$

3. FOC wrt H_t:

$$A_t^{1-\alpha}K_t^{\alpha}(1-\alpha)\Phi_{H,t}^{\frac{\sigma-1}{\sigma}}H_t^{\frac{-1}{\sigma}}[(\Phi_{H,t}H_t)^{\frac{\sigma-1}{\sigma}}+(\Phi_{L,t}L_t)^{\frac{\sigma-1}{\sigma}}]^{(\frac{1-\alpha\sigma}{\sigma-1})}=w_t(h) \tag{39}$$

4. FOC wrt $\Phi_{H,t}$:

$$A_t^{1-\alpha}K_t^{\alpha}(1-\alpha)\Phi_{H,t}^{\frac{-1}{\sigma}}H_t^{\frac{\sigma-1}{\sigma}}[(\Phi_{H,t}H_t)^{\frac{\sigma-1}{\sigma}}+(\Phi_{L,t}L_t)^{\frac{\sigma-1}{\sigma}}]^{(\frac{1-\alpha\sigma}{\sigma-1})}=\Omega_t\omega\Phi_{H,t}^{\omega-1} \tag{40}$$

5. FOC wrt $\Phi_{L,t}$:

$$A_t^{1-\alpha}K_t^{\alpha}(1-\alpha)\Phi_{L,t}^{\frac{-1}{\sigma}}L_t^{\frac{\sigma-1}{\sigma}}[(\Phi_{H,t}H_t)^{\frac{\sigma-1}{\sigma}}+(\Phi_{L,t}L_t)^{\frac{\sigma-1}{\sigma}}]^{(\frac{1-\alpha\sigma}{\sigma-1})}=\kappa\Omega_t\omega\Phi_{L,t}^{\omega-1} \tag{41}$$

The second and third expressions give the following relationship:

$$\frac{\Phi_H}{\Phi_L}=[(\frac{H_t}{L_t})^{\frac{1}{\sigma}}\frac{w_t(h)}{w_t(l)}]^{\sigma/(\sigma-1)} \tag{42}$$

The last two expressions give the following relationship:

$$\frac{\Phi_H}{\Phi_L}=(\kappa(\frac{H_t}{L_t})^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma\omega-\sigma+1}} \tag{43}$$

$$\Phi_H=\Phi_L(\kappa(\frac{H_t}{L_t})^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma\omega-\sigma+1}} \tag{44}$$

If I plug this expression into the technology constraint:

$$(\Phi_L(\kappa(\frac{H_t}{L_t})^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma\omega-\sigma+1}})^{\omega}+\kappa\Phi_L^{\omega}=B \tag{45}$$

$$\Phi_L^{\omega}[(\kappa(\frac{H_t}{L_t})^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma\omega}{\sigma\omega-\sigma+1}}+\kappa]=B \tag{46}$$

$$\Phi_L=(\frac{B}{[(\kappa(\frac{H_t}{L_t})^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma\omega}{\sigma\omega-\sigma+1}}+\kappa]})^{\frac{1}{\omega}} \tag{47}$$

$$\Phi_H=(B-\kappa\Phi_L^{\omega})^{\frac{1}{\omega}} \tag{48}$$

A.4 Stationary Version of the Solutions

On the balanced growth path, the economy grows at a constant rate, denoted by $(1+g)(1+g_{pop})$, where g is the exogenous growth rate of the Hicks-neutral technology A_t, and g_{pop} is the population growth rate.

In order to make the model stationary, I detrend the model. Aggregates grow at the rate of $(1+g)(1+\eta)-1$, and the individual choice variables a_t and c_t grow at the rate of $(1+g)$. In addition, tr_t and b_t variables also grow at the rate of $(1+g)$. Therefore, I divide aggregate variables K_t, Y_t with (A_tN_t) and variables tr_t, b_t, a_t, c_t by (A_t). In addition, while r_t is constant in the stationary equilibrium, w_t is growing at the rate (1+g).

Stationary aggregate variables are defined as:

$\tilde{k_t} \equiv \frac{K_t}{A_t N_t}$, $\tilde{T_t} \equiv \frac{T_t}{A_t N_t}$, $\tilde{G_t} \equiv \frac{G_t}{A_t N_t}$

$\tilde{C_t} \equiv \frac{C_t}{A_t N_t}$, $\tilde{Y_t} \equiv \frac{Y_t}{A_t N_t}$, $\tilde{Beq_t} \equiv \frac{Beq_t}{A_t N_t}$

Stationary individual variables are defined as:

$\tilde{c_t} \equiv \frac{c_t}{A_t}$, $\tilde{a_t} \equiv \frac{a_t}{A_t}$, $\tilde{b_t} \equiv \frac{b_t}{A_t}$ $\tilde{w_t} \equiv \frac{w_t}{A_t}$, $\tilde{tr_t} \equiv \frac{tr_t}{A_t}$

A.4.1 Stationary Version of Individual's Problem

In order to make the model stationary, we divide both sides by $A_t^{\gamma(1-\eta)}$

$$\tilde{V}(\tilde{a}_{t+i-1}, i, j, s) = \max\{\frac{(\tilde{c}_t^{\gamma}(i,j,s)(1-l_t(i,j,s))^{(1-\gamma)})^{1-\eta}}{1-\eta} + \beta\lambda_{i,i+1}(1+g)^{\gamma(1-\eta)}\tilde{V}(\tilde{a}_{t+i}, i+1, j, s)\} \quad (49)$$

subject to the following constraints:

$\tilde{b}_{t+i-1}(i,j,s)+(1-\tau_w-\tau_b)\tilde{w}_t(s)e(i,j,s)l_{t+i-1}(i,j,s)+(1+(1-\tau_r)r_t)\tilde{a}_{t+i-1}(i,j,s)+\tilde{tr}_{t+i-1} = \tilde{c}_{t+i-1}(i,j,s)+(1+g)\tilde{a}_{t+i}(i,j,s)$

if 1≤i≤45, $\tilde{b}_{t+i-1}(i,j,s) = 0$

if i>45, $l_{t+i-1}(i,j,s) = 0$.

In this stationary model, the solution is:

1. for $1 \leq i \leq 45$

$$\frac{(1-\gamma)}{\gamma}\frac{\tilde{c_t}}{(1-l_t)} = (1-\tau_w-\tau_b)\tilde{w}_t(s)e(i,j,s) \quad (50)$$

$$\lambda_t\beta(1+(1-\tau_r)r_{t+1})\tilde{c_{t+1}}^{(1-\eta)\gamma-1}(1+g)^{(1-\eta)\gamma-1}(1-l_{t+1})^{(1-\gamma)(1-\eta)} = \tilde{c_t}^{(1-\eta)\gamma-1}(1-l_t)^{(1-\gamma)(1-\eta)} \quad (51)$$

$$\lambda_t\beta(1+(1-\tau_r)r_{t+1})\tilde{c_{t+1}}^{(1-\eta)\gamma-1}(1+g)^{(1-\eta)\gamma-1}(1-l_{t+1})^{(1-\gamma)(1-\eta)} \quad (52)$$

$$= \tilde{c_t}^{(1-\eta)\gamma-1}[\frac{\tilde{c_t}}{(1-\tau_w-\tau_b)\tilde{w}_t(s)e(i,j,s)}]^{(1-\gamma)(1-\eta)} \quad (53)$$

$$\lambda_t\beta(1+(1-\tau_r)r_{t+1})\tilde{c_{t+1}}^{(1-\eta)\gamma-1}(1+g)^{(1-\eta)\gamma-1}(1-l_{t+1})^{(1-\gamma)(1-\eta)} \quad (54)$$

$$= \tilde{c_t}^{(-\eta)}[\frac{1-\gamma}{\gamma}\frac{1}{(1-\tau_w-\tau_b)\tilde{w}_t(s)e(i,j,s)}]^{(1-\gamma)(1-\eta)} \quad (55)$$

2. for $i \geq 46$

$$l_t(i,j,s) = 0 \tag{56}$$

- if $i \leq 79$

$$\lambda_t(1+(1-\tau_r)r_{t+1})\beta \tilde{c_{t+1}}^{(1-\eta)\gamma-1}(1+g)^{(1-\eta)\gamma-1} = \tilde{c_t}^{(1-\eta)\gamma-1} \tag{57}$$

- if $i = 80$

$$\tilde{b_t}(i,j,s) + (1+(1-\tau_r)r_t)\tilde{a_t}(i,j,s) + \tilde{tr_t}(i,j,s) = \tilde{c_t}(i,j,s) \tag{58}$$

A.4.2 Stationary Version of Firm's Problem

- FOC wrt K_t:

$$\alpha(\tilde{k_t})^{\alpha-1}[(\Phi_{H,t}\frac{H_t}{N_t})^{\frac{\sigma-1}{\sigma}} + (\Phi_{L,t}\frac{L_t}{N_t})^{\frac{\sigma-1}{\sigma}}]^{(\frac{\sigma}{\sigma-1})(1-\alpha)} - \delta = r_t \tag{59}$$

- FOC wrt L_t:

$$(\tilde{k_t})^{\alpha}(1-\alpha)\Phi_{L,t}^{\frac{\sigma-1}{\sigma}}(\frac{L_t}{N_t})^{\frac{-1}{\sigma}}[(\Phi_{H,t}\frac{H_t}{N_t})^{\frac{\sigma-1}{\sigma}} + (\Phi_{L,t}\frac{L_t}{N_t})^{\frac{\sigma-1}{\sigma}}]^{(\frac{1-\alpha\sigma}{\sigma-1})} \tag{60}$$

$$= \tilde{w_t}(l) \tag{61}$$

- FOC wrt H_t:

$$(\tilde{k_t})^{\alpha}(1-\alpha)\Phi_{H,t}^{\frac{\sigma-1}{\sigma}}(\frac{H_t}{N_t})^{\frac{-1}{\sigma}}[(\Phi_{H,t}\frac{H_t}{N_t})^{\frac{\sigma-1}{\sigma}} + (\Phi_{L,t}\frac{L_t}{N_t})^{\frac{\sigma-1}{\sigma}}]^{(\frac{1-\alpha\sigma}{\sigma-1})} \tag{62}$$

$$= \tilde{w_t}(h) \tag{63}$$

A.4.3 Stationary Version of Government's Problem

$$\tilde{T_t} = \tau_w \tilde{w_{l,t}}\frac{L_t}{A_tN_t} + \tau_w w\tilde{h}, t\frac{H_t}{A_tN_t} + \frac{\tau_r r_t K_t}{A_tN_t} \tag{64}$$

$$\tilde{Tr_t} = \sum_{i,j,s}\tilde{tr}(i,j,s)\tilde{P_t}(i,j,s) \tag{65}$$

$$\tilde{T_t} + \tilde{Beq_t} = \tilde{G_t} + \tilde{Tr_t} \tag{66}$$

$$\tilde{G_t} = \overline{y}\tilde{Y_t} \tag{67}$$

A.4.4 Stationary Version of Balanced Social Security

$$\sum_{i\in 4,5,j,s}\zeta(1-\tau_w-\tau_b)\tilde{w_t}(s)e(i,j,s)\tilde{P_t}(i,j,s) = \sum_{i\in 2,3,j,s}\tau_b\tilde{w_t}(s)e(i,j,l)l_t(i,j,s)\tilde{P_t}(i,j,s) \tag{68}$$

B Calibration Procedures of Model Parameters

B.1 Calibration of Parameters for Individuals' Preferences

The coefficient of relative risk aversion, denoted by η, is set equal to 2. The share of consumption in the utility function, denoted by γ, is set equal to 0.32 so that resulting average labor supply is approximately 0.3. The time discount factor, denoted by β, is set equal to 0.99.

B.2 Calibration of Production Function Parameters

The firm's production function is given as:

$$Y_t = K_t^{\alpha}[A_t^{\frac{\sigma-1}{\sigma}}(\Phi_H H_t)^{\frac{\sigma-1}{\sigma}} + A_t^{\frac{\sigma-1}{\sigma}}(\Phi_L L_t)^{\frac{\sigma-1}{\sigma}}]^{(\frac{\sigma}{\sigma-1})(1-\alpha)}. \tag{69}$$

where σ is the elasticity of substitution between high-skilled and low-skilled labor, and α is the income share of capital. In this specification, I follow the convention in the literature for α and set it equal to 0.33. For σ, there are different values suggested in the literature which range between 1.5 and 2.5.[32] It should be noted that the value of σ is important in configuration of the technology frontier parameters, and therefore, for σ, I consider values between 1.1 and 2.1 in calibration of the technology frontier.[33]

Furthermore, the growth rate of the Hicks-neutral technology A_t is set equal to 0.016, and the depreciation rate of capital, denoted by δ, is set equal to 0.055, following De Nardi et al. (1999).

B.3 Calibration of Technology Frontier Parameters

In Equation 69, Φ_H and Φ_L represent the efficiency of high-skilled and low-skilled labor, respectively. These efficiency levels are optimally chosen by the firm from a set of efficiency pairs represented by the following technology frontier:

$$\Phi_{H,t}^{\omega} + \kappa\Phi_{L,t}^{\omega} \leq B.$$

In this characterization, ω and κ govern the trade-off between the efficiency of high-skilled and low-skilled labor while B determines the height of the technology frontier.

For each given value of σ, I estimate the parameters κ, ω, and B for the U.S. economy using the method proposed by Caselli and Coleman (2006). There are three steps in this method: 1) creating the data for skill intensities, 2) estimating the technology frontier, and 3) constructing the country-specific technology frontier.

B.3.1 Creating the Data for Skill Intensities

The first step is to solve the firm's profit maximization problem to obtain the optimal relative efficiency of high-skilled and low-skilled labor, denoted by $\frac{\Phi_H}{\Phi_L}$. In this equation, $\frac{\Phi_H}{\Phi_L}$ is defined as a function of relative supply of high-skilled and low-skilled labor and wages:[34]

$$\frac{\Phi_H}{\Phi_L} = [(\frac{H_t}{L_t})^{\frac{1}{\sigma}}\frac{w_t(h)}{w_t(l)}]^{\sigma/(\sigma-1)} \tag{70}$$

The second equation is the output function defined as in Caselli and Coleman (2006):

$$Y_t = K_t^{\alpha}[(\Phi_H H_t)^{\frac{\sigma-1}{\sigma}} + (\Phi_L L_t)^{\frac{\sigma-1}{\sigma}}]^{(\frac{\sigma}{\sigma-1})(1-\alpha)}. \tag{71}$$

In order to calculate the relative efficiency $\frac{\Phi_H^q}{\Phi_L^q}$ for each country q, Caselli and Coleman (2006) provide the data for Y_t^q, K_t^q, L_t^q, H_t^q, $\frac{w_t^q(H)}{w_t^q(L)}$, for 52 countries in 1988.[35] Given the available data and parameter values for σ and α, there are two equations (Equation 70 and Equation 71) and two unknowns $\{\Phi_{H,t}, \Phi_{L,t}\}$ and since the production function is monotonic with respect to both variables, there is a unique solution for the pair $\left\{\Phi_{H,t}^q, \Phi_{L,t}^q\right\}$ for each country q.[36] Using the calculated skill intensity pairs $\left\{\Phi_{H,t}^q, \Phi_{L,t}^q\right\}$, I obtain the relative skill intensity of the production function $\frac{\Phi_H^q}{\Phi_L^q}$ that will be used in the following step.

B.3.2 Estimating the Technology Frontier

One of the first order conditions of the firm's problem presented in Equation 43 in Online Appendix A.3 reveals the following relationship between relative skill intensity and relative labor supply:

$$\frac{\Phi_H^q}{\Phi_L^q} = (\kappa(\frac{H_t^q}{L_t^q})^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma\omega-\sigma+1}} \tag{72}$$

Linearizing this equation by taking the logarithm would generate the following relationship:

$$log(\frac{\Phi_H^q}{\Phi_L^q}) = \frac{\sigma}{\sigma\omega-\sigma+1}(\frac{\sigma-1}{\sigma})log(\frac{H_t^q}{L_t^q}) + \frac{\sigma}{\sigma\omega-\sigma+1}log(\kappa^q). \tag{73}$$

Equation 73 summarizes the relationship between the relative skill supply and relative skill intensity. The first term of this equation shows that the coefficient of the variable $(log(\frac{H_t^q}{L_t^q}))$ is a function of σ and ω. Moreover, in this equation, the second term is a function of σ, ω, and κ. Given σ, and calculated values for country-specific variables $\frac{\Phi_H^q}{\Phi_L^q}$ and $\frac{H^q}{L^q}$, I estimate Equation 73 so that the estimation output becomes:[37]

$$log(\frac{\Phi_H^q}{\Phi_L^q}) = \hat{\beta}\ log(\frac{H_t^q}{L_t^q}) + \epsilon_q \tag{74}$$

In Table 4, I report the technology frontier estimation results of Equation 74 for the U.S. economy. The results depend on the characterization of the $\frac{H_t}{L_t}$ with respect to different educational thresholds. When a larger threshold is used, the coefficients get smaller implying a weaker relationship between relative high-skilled labor supply and skill intensity of the technology frontier.

Table 4: Comparison of regression coefficients and error terms

	Regression estimates for the technology frontier of the U.S.					
	Primary education threshold		Secondary education threshold		Higher education threshold	
σ	$\hat{\beta}$	ϵ_{USA}	$\hat{\beta}$	ϵ_{USA}	$\hat{\beta}$	ϵ_{USA}
1.1	9.316	2.233	7.456	5.597	5.619	5.540
1.3	3.064	0.880	2.331	2.205	1.608	2.182
1.5	1.813	0.609	1.306	1.527	0.805	1.511
1.7	1.277	0.493	0.867	1.236	0.461	1.223
1.9	0.980	0.429	0.623	1.074	0.270	1.063
2.1	0.790	0.388	0.468	0.971	0.149	0.961

Notes: This table shows the technology frontier parameters ω, κ, and B as well as the optimality condition for a given σ level. Each panel reports the results for a different specification of high-skilled labor. In the first panel, all workers who finished primary education are considered as high-skilled. In the second panel, workers who receive at least a secondary education or above are included in the high-skilled labor group. In the last panel, workers who receive college education are considered as high-skilled.

In next step, given σ, I first obtain ω from the coefficient of the $(\frac{H_t^q}{L_t^q})$, denoted by $\hat{\beta}$, by solving the following equation:

$$\hat{\beta} = \frac{\sigma - 1}{\sigma\omega - \sigma + 1} \tag{75}$$

which gives the following result with respect to ω:

$$\hat{\omega} = \frac{(\sigma - 1)(1 + \hat{\beta})}{\sigma\hat{\beta}} \tag{76}$$

In the equation above, as long as $\sigma > 1$, the resulting $\hat{\omega}$ is positive, implying that there is a trade-off between the efficiency levels of high-skilled and low-skilled labor. Moreover, considering the partial derivative of ω with respect to σ, $\frac{\partial\omega}{\partial\sigma} = \frac{\hat{\beta}(1+\hat{\beta})}{\sigma^2\hat{\beta}^2}$ is positive when $\beta > 0$, implying that when the substitutability of high-skilled labor increases, substitutability of high-skilled intensive technologies on the technology frontier also goes up.

Using the estimated value of $\hat{\omega}$, as a next step to estimate the technology frontier for country q, I calculate country-specific $\hat{\kappa}^q$ from the residual of the regression by solving the following equation:

$$\epsilon_q = \frac{\sigma}{\sigma\hat{\omega} - \sigma + 1} log(\kappa^q) \tag{77}$$

which gives the following result with respect to country-specific κ^q:

$$\hat{\kappa}^q = e^{\frac{\epsilon_q(\sigma\hat{\omega} - \sigma + 1)}{\sigma}} \tag{78}$$

B.3.3 Constructing the Country-Specific Technology Frontier

In the last step, I use the estimated value for $\hat{\omega}$ and the estimated country-specific values for $\hat{\kappa}^q$ as well as the efficiencies of the high-skilled and low-skilled labor, namely $\Phi_{H,t}^q$ and $\Phi_{L,t}^q$, in the following equation in order to calculate B for country q:

$$\Phi_{H,t}^{q\ \omega} + \kappa^q \Phi_{L,t}^{q\ \omega} = B^q.$$

Note that in my analysis, I use the technology frontier for the U.S. where κ and B are U.S.-specific while ω is common for all countries:

$$\Phi_{H,t}^{US\ \omega} + \kappa^{US} \Phi_{L,t}^{US\ \omega} = B^{US}.$$

In order to ensure that there is an interior solution for $\Phi_{H,t}$ and $\Phi_{L,t}$, the estimated value of ω should be greater than $\sigma - 1$ so that all firms choose the same levels of nonzero skill intensities on the technology frontier. Otherwise, there would be a corner solution, and firms would choose to maximize the skill intensity of only one type of labor. I calculate the technology frontier for the given set of values of σ and check whether the above restriction holds.

Furthermore, regarding the estimation procedure described above, the supply of high-skilled and low-skilled labor as well as their wages depend on the definition of being high-skilled.[38] In Caselli and Coleman (2006), high-skilled workers are defined with respect to three education thresholds. In the first specification, primary education is enough to be considered as high-skilled. In the second specification, all high-skilled workers have at least secondary education. In the final specification, the college degree is the threshold above which the workers are considered as high-skilled. Since the technology frontiers are calculated cross-country, when the third specification is used, there is less variation in the high-skilled labor. I consider all three specifications to calculate the technology frontier. The results for the technology frontier under different values of σ and under different definitions of high-skilled labor can be found in Table 5.

Table 5: Comparison of the U.S. technology frontier with alternative skill thresholds

	Technology frontier for the U.S.											
	Primary education threshold				Secondary education threshold				Higher education threshold			
σ	ω	κ	B	$\omega > \sigma - 1$	ω	κ	B	$\omega > \sigma - 1$	ω	κ	B	$\omega > \sigma - 1$
1.1	0.101	1.022	1.583	Yes	0.103	1.071	1.654	Yes	0.107	1.094	1.668	Yes
1.3	0.306	1.069	4.044	Yes	0.330	1.244	5.009	Yes	0.374	1.368	5.982	Yes
1.5	0.517	1.118	10.601	Yes	0.589	1.476	17.816	Yes	0.747	1.869	35.547	Yes
1.7	0.734	1.172	28.547	Yes	0.887	1.798	77.216	Yes	1.304	2.978	508.720	Yes
1.9	0.957	1.230	79.061	Yes	1.234	2.264	428.384	Yes	2.225	6.440	$4.2e+04$	Yes
2.1	1.187	1.293	225.462	Yes	1.644	2.969	3252.806	Yes	4.043	29.485	$2.5e+08$	Yes

Notes: This table shows the U.S. technology frontier parameters ω, κ, and B as well as the optimality condition for a given σ level. Each panel reports the estimation results for a different specification of high-skilled labor. In the first panel, all workers who finished primary education are considered as high-skilled. In the second panel, workers who receive at least a secondary education or above are included in the high-skilled labor group. In the last panel, workers who receive college education are considered as high-skilled.

For a set of commonly used values for σ within the range of 1.1 and 2.1, Table 5 shows the technology frontier for the U.S. in terms of ω, κ and B where each panel demonstrates the technology frontier for a different specification of high-skilled labor. In the first panel, all workers who finished primary education are considered as high-skilled. In the second panel, workers who receive at least a secondary education or above are included in the high-skilled labor group. In the last panel, workers who receive college education are considered as high-skilled. Furthermore, in the last column of each panel, I report whether the $\omega > \sigma - 1$ condition is satisfied so that there is an interior solution.

The estimation results show that, as expected, if σ increases, ω also increases. Furthermore, in our estimations, as σ increases, κ also goes up implying that it is costlier to switch to low-skilled-intensive production technologies.[39] At each panel, $\Phi_{H,t}$ and $\Phi_{L,t}$ are constant. Therefore, increase in ω and κ due to an increase in σ results in an increase in B.

Comparing the results with respect to the threshold above which a worker would be considered as high-skilled (primary, secondary, or higher education), it is found that ω, κ, and B increase as the high-skilled labor threshold goes up.[40] Furthermore, when the high-skilled workers are grouped with respect to the college degree threshold, since there are not many people with college degrees in the sample other than the U.S., the variation with respect to high-skilled workers is less, and the relationship between relative supply of high-skilled workers and efficiency is lower.

Lastly, instead of using Equation 78, κ^q can also be calculated using Equation 72 given the value of σ and estimated value of ω as well as the relative skill intensity $\frac{\Phi_H^q}{\Phi_L^q}$ and relative high-skilled labor supply $\frac{H_t^q}{L_t^q}$. Technology frontier parameters estimated using this methodology are reported in Table 6. The results are very similar to the ones reported in Table 5.

Table 6: Comparison of the U.S. technology frontier with alternative with alternative κ and B definition

	Technology frontier of the U.S.											
	Primary education threshold				Secondary education threshold				Higher education threshold			
σ	ω	κ	B	$\omega > \sigma - 1$	ω	κ	B	$\omega > \sigma - 1$	ω	κ	B	$\omega > \sigma - 1$
1.1	0.101	1.069	1.585	0.103	1.146	1.675	Yes	0.107	1.094	1.669	Yes	
1.3	0.306	1.224	4.053	0.330	1.547	5.201	Yes	0.374	1.370	5.988	Yes	
1.5	0.517	1.407	10.639	0.589	2.180	18.967	Yes	0.747	1.875	35.623	Yes	
1.7	0.734	1.623	28.685	0.887	3.235	84.249	Yes	1.304	2.995	510.636	Yes	
1.9	0.957	1.880	79.539	1.234	5.124	478.616	Yes	2.225	6.500	$4.2e+04$	Yes	
2.1	1.187	2.187	227.077	1.644	8.816	3716.188	Yes	4.043	29.987	$2.5e+08$	Yes	

Notes: This table shows the technology frontier parameters ω, κ, and B as well as the optimality condition for a given σ level. Each panel reports the results for a different specification of high-skilled labor. In the first panel, all workers who finished primary education are considered as high-skilled. In the second panel, workers who receive at least a secondary education or above are included in the high-skilled labor group. In the last panel, workers who receive college education are considered as high-skilled.

B.3.4 Discussion of Technology Frontier

In this section, I discuss the main features of endogenous technology choice models and argue that the technology frontier used in Caselli and Coleman (2006) includes the two main components of the microfounded endogenous technology choice models characterized in Acemoglu (2002). First, there is a trade-off between high-skill-augmenting versus low-skill-augmenting technologies. Second, if the relative supply of a specific type of labor (either high-skilled or low-skilled) increases, firms choose technologies that use this type of labor more efficiently. These two points are summarized in Equation 79 and Equation 80.

Specifically, Equation 79 is derived from the first order conditions of the firm's problem:[41]

$$\frac{\Phi_{H,t}}{\Phi_{L,t}} = [\kappa(\frac{H_t}{L_t})^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma\omega-\sigma+1}}. \tag{79}$$

This equation shows that as long as $\omega > \sigma - 1$ and $\sigma > 1$, an increase in the relative supply of high-skilled labor leads to an increase in the efficiency of high-skilled labor relative to low-skilled, and vice versa.

Furthermore, Equation 80 characterizes the technology frontier from which firms choose the optimal level of $\Phi_{H,t}$ and $\Phi_{L,t}$:

$$\Phi^{\omega}_{H,t} + \kappa\Phi^{\omega}_{L,t} \leq B, \tag{80}$$

In this specification, the technology frontier parameters κ, ω, and B are exogenously given and determine the efficiency levels. Moreover, since the choice of $\Phi_{H,t}$ and $\Phi_{L,t}$ is constrained by the height of the frontier, namely B, there is a trade-off between increasing the efficiency level of high-skilled versus low-skilled labor. It can be argued that the specification above does not say anything about the microfoundations of the technology frontier and is demand-driven: as one factor of production becomes more abundant, firms demand a technology that would increase the efficiency of it.

On this aspect, I compare the features of the threshold I use in this paper with the model used in Acemoglu (2002) where the microfoundations of the technology frontier are constructed. In this case, technologies that determine N_H and N_L (corresponding to Φ_H and Φ_L in my model, respectively) are produced by inventors (technology monopolists) where the relative productivities, namely $\frac{N_H}{N_L}$, are determined by a frontier of innovation possibilities:

$$(\frac{\dot{N}_L}{N_L}) = \Gamma(\frac{\dot{N}_H}{N_H}) \tag{81}$$

where Γ is a strictly decreasing, differentiable, and concave function. On this threshold, similar to our specification, there is a trade-off between a higher rate of high-skilled-labor-augmenting technological change and a higher rate of low-skilled-labor-augmenting technological change.

Furthermore, solving this model, the balance growth path solution of the relative technologies becomes:[42]

$$(\frac{N_H}{N_L})^* = (\frac{\eta_H}{\eta_L})^{\sigma}\gamma^{\epsilon}(\frac{H}{L})^{(\sigma-1)} \tag{82}$$

In this equation, similar to Equation 79, the relative high-skilled labor supply, namely $\frac{H}{L}$, determines the optimal technology supply of the monopolists. Specifically, as long as $\sigma > 1$–so that high-skilled and low-skilled labor are substitutes–an increase in the supply of high-skilled labor increases the relative productivity of high-skilled labor.

Accordingly, the endogenous technology frontier proposed by Caselli and Coleman (2006) contains the essential ingredients of the microfounded models of endogenous technology choice which are a trade-off between technologies augmenting different types of labor (Equation 80) and the positive relationship between the increase in the skill supply and the efficiency of high-skilled labor (Equation 79). Since it is easier to estimate a static frontier, I use the frontier proposed by Caselli and Coleman (2006).[43]

B.4 Calibration of Efficiency Units

In addition to the endogenous skill-specific productivity choice of firms, I assume that there are exogenous productivity differences between high-skilled natives and high-skilled immigrants as well as low-skilled natives and low-skilled immigrants.

In order to calculate the nativity-specific productivity differences within the same skill group, the aggregate high-skilled labor (H) and low-skilled labor (L) are represented by two distinct Armington aggregators that classify each skill type with respect to immigrants and natives.

With this specification in mind, high-skilled labor is defined as $H = [\Phi_{M,H} H_{M,t}^{\phi_1} + (1 - \Phi_{M,H}) H_{N,t}^{\phi_1}]^{\frac{1}{\phi_1}}$ where $H_{M,t}$ and $H_{N,t}$ represent the labor supply of high-skilled immigrants and high-skilled natives at time t, respectively. $\Phi_{M,H}$ is the time-invariant efficiency parameter that captures the relative productivity of immigrants. I assume that high-skilled immigrants and natives are perfect substitutes ($\phi_1 = 1$) so that the supply of high-skilled labor can be written as $H = [\Phi_{M,H} H_{M,t} + (1 - \Phi_{M,H}) H_{N,t}]$. Assuming that $w_{H,M}$ and $w_{H,N}$ equal the marginal product of immigrants and natives, respectively, the relative efficiency of high-skilled immigrants and natives is defined by the following regression:

$$ln\left(\frac{w_{H,M,t}}{w_{H,N,t}}\right) = ln\left(\frac{\Phi_{M,H}}{1 - \Phi_{M,H}}\right) + f(age, t) + \epsilon \tag{83}$$

Using American Community Survey (ACS) data between years 2000 and 2007, I calculate the relative wages of high-skilled immigrants and high-skilled natives and run the regression specified in Equation 83 while controlling for the age and year effects.[44] In this regression, the constant term of the regression specifies the logarithm of the productivity of high-skilled immigrants relative to that of high-skilled natives.

Table 7: Regression results for high-skilled workers

$ln\left(\frac{\widehat{\Phi_{M,H}}}{1-\Phi_{M,H}}\right)$	$\left(\frac{\widehat{\Phi_{M,H}}}{1-\Phi_{M,H}}\right)$	$\widehat{\Phi_{M,H}}$
0.072	1.074	0.518

Notes: This table shows the estimated constant term of the regression equation (Equation 83). The first column reports the estimation output while the second column reports the efficiency of high-skilled immigrants relative to high-skilled natives. The third column shows the estimated high-skilled immigrant productivity.

Table 7 reports the estimated constant term of the regression equation (Equation 83). The first column reports the estimation output while the second column reports the efficiency of high-skilled immigrants relative to high-skilled natives. The third column shows that the estimated high-skilled immigrant productivity, namely $\widehat{\Phi_{M,H}}$, is equal to 0.518, whereas estimated high-skilled native productivity is equal to 0.482. This implies that high-skilled immigrants are slightly more productive than their native counterparts.

Similar to the previous analysis, low-skilled labor is defined as $L = [\Phi_{M,L} L_{M,t}^{\phi_2} + (1 - \Phi_{M,L}^{\phi_2}) L_{N,t}]^{\frac{1}{\phi_2}}$ where $L_{M,t}$ and $L_{N,t}$ represent the supply of low-skilled immigrants and natives, respectively. $\Phi_{M,L}$ is the time-invariant efficiency parameter that captures the productivity of low-skilled immigrants relative to their native counterparts. Similar to the case of high-skilled workers, I assume that low-skilled immigrants and natives are perfect substitutes ($\phi_2 = 1$) so that the supply of low-skilled labor is given as $L = [\Phi_{M,L} L_{M,t} + (1 - \Phi_{M,L}) L_{N,t}]$. Assuming that $w_{L,M}$ and $w_{L,N}$ equal the marginal product of immigrants and natives, respectively, the relative efficiency of low-skilled immigrants and natives is defined by the following regression:

$$ln\left(\frac{w_{L,M,t}}{w_{L,N,t}}\right) = ln\left(\frac{\Phi_{M,L}}{1-\Phi_{M,L}}\right) + f(age,t) + \epsilon \tag{84}$$

As before, using ACS data between years 2000 and 2007, I calculate the relative wages of low-skilled immigrants and low-skilled natives, and run the regression specified in Equation 84 while controlling for age and year effects. In this regression, the constant term of the regression specifies the logarithm of the productivity of low-skilled immigrants relative to that of low-skilled natives.

Table 8: Regression results for low-skilled workers

$ln\left(\widehat{\frac{\Phi_{M,L}}{1-\Phi_{M,L}}}\right)$	$\left(\widehat{\frac{\Phi_{M,L}}{1-\Phi_{M,L}}}\right)$	$\widehat{\Phi_{M,L}}$
-0.069	0.934	0.483

Notes: This table shows the estimated constant term of the regression equation (Equation 84). The first column reports the estimation output while the second column reports the efficiency of low-skilled immigrants relative to high-skilled natives. The third column shows the estimated low-skilled immigrant productivity.

Table 8 reports the estimated constant term of the regression. The third column shows that the estimated low-skilled immigrant productivity, namely $\widehat{\Phi_{M,L}}$, is equal to 0.483 whereas estimated low-skilled native productivity is equal to 0.517. This implies that low-skilled immigrants are slightly less productive than their native counterparts.

Table 9: Relative efficiency

	Natives	Immigrants
Low-skilled	1.034	0.966
High-skilled	0.964	1.036

Notes: This table shows the relative efficiency of workers with respect to their nativity and skill. The first row shows the efficiency levels for low-skilled natives and immigrants while the second row shows the efficiencies for the high-skilled natives and high-skilled immigrants.

Table 9 summarizes the relative efficiency estimation results. The first row shows the efficiency levels for low-skilled natives and immigrants while the second row shows the efficiencies for the high-skilled natives and high-skilled immigrants. The average of each row is equal to 1 so that the efficiency is normalized within each skill group.[45] Results imply that low-skilled natives have higher productivity as compared to their native counterparts while for high-skilled workers, the relationship is reversed.

Beside nativity (j) and skill-level (s), the efficiency of workers also varies with respect to age (i). The age-dependent efficiency units are obtained from Heer and Irmen (2014), which uses the data provided by Hansen (1993). The data is interpolated in between years and normalized to 1.[46]

B.4.1 Construction of Hourly Wages to Calculate Relative Efficiencies

I use the 1 percent sample of the ACS between years 2000 and 2007. I generate two data series for the working-age population and the total population. Details are described below.

Working-Age Population

- Eliminate people who are not civilians (those with gq equal to 0, 3, or 4).
- Eliminate people younger than 17 and older than 65.
- Eliminate people who have not worked in the last year. I define these people as the ones who have worked 0 weeks in the previous year (those who have wkswork2=0 for years 1960 and 1970 and wkswork1=0 for datasets including years 1980-2006).
- Eliminate people with invalid salary reported (those with incwage= or incwage=999999).
- Eliminate people who have experience < 1 and > 40 ((experience)=(age)-(time first worked). Latter Variable (time first worked) is 16 for workers with no HS degree, 19 for HS graduates, 21 for people with some college education, and 23 for college graduates.
- Eliminate people who are self-employed (classwkrd<20 or classwkrd>28).

Total Population

- Eliminate people who are not civilians (those with gq equal to 0, 3, or 4).
- Eliminate people younger than 17 and older than 65.

Individual Variables

Hours Worked and Employment: In order to calculate the total hours of worked for each group that is of interest (nativity and skill level), for each person in the group I multiply hours worked with the personal weight (perwt) and add over all members of the group.
Average Hourly Wage: In order to calculate the average hourly wage for each group that is of interest (nativity, skill level, etc.), for each person in the group I weight the his/her hourly wages by the hours worked by the individual.
Education: In the analysis I define two education (skill) levels. A person is defined as low-skilled if s/he has less than a bachelor's degree (educd<= 100) and high-skilled if s/he has a bachelor's degree or more (educd> 100).
Immigration Status: Immigrants are defined as the people who are not citizens or who are naturalized citizens. I use the variable *citizen* in order to determine immigration status. A person is an immigrant if $citizen = 2, 3, 4, 5$.
Hours Worked in a Week: I use the exact number of hours worked, represented by the variable uhrswork.
Hours Worked in a Year: Hours worked in a year is calculated by multiplying the hours worked in a week by the weeks worked in a year.
Yearly Wages: In order to calculate the yearly wages in constant 2000 U.S. dollars ,I multiply incwage by the price deflator. Deflators that have been used are the following:

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Deflator	1	0.973	0.957	0.936	0.912	0.882	0.854	0.830	0.800	0.803	0.790

Top Codes for Yearly Wages: Following Peri (2012), I multiply the top codes for yearly wages in 1960, 1970, and 1980 by 1.5.

Hourly Wages: Each individual hourly wage is constructed by dividing the yearly wage by the hours worked in a year.

B.5 Calibration of Conditional Survival Probability

I calculate conditional survival probabilities from the life table for the total population taken from the National Vital Statistics Reports, United States Life Tables, 2006.[47] I assume that the survival probabilities are the same for immigrants and natives.

B.6 Calibration of Total Fertility Rates for Native- and Foreign-Born Women in the U.S.

In the model, I assume that the fertility rates are nativity- and skill-specific and are exogenously given. Total fertility rate is defined as the average number of children a woman will have in her lifetime. Given an age group i, fertility rate in that specific age group is equal to $\frac{X^i}{Y^i}$, where X^i represents the total number of births of the women in age group i, and Y^i is the total number of women in age group i.[48] In this paper, given the fertility rate $\frac{X^i}{Y^i}$ for each five-year age group, the total fertility rate is calculated as follows:

$$TFR = 5 \sum_i \frac{X^i}{Y^i} \tag{85}$$

Equation 85 implies that in order to calculate the total fertility rate in the U.S., data on the number of births within each age group (X^i) as well as the total number of women at each group (Y^i) is needed.

Furthermore, given fertility $X^i_{j,s}$ and female population $Y^i_{j,s}$ for a specific age group (i), skill level (s) and nativity (j), the skill and nativity specific fertility rate is calculated as follows:

$$TFR_{j,s} = 5 \sum_i \frac{X^i_{j,s}}{Y^i_{j,s}} \tag{86}$$

There are two methods that can be used in order to calculate $TFR_{j,s}$. The first method, described in detail in Bohn and Lopez-Velasco (2017), utilizes three different sources of data in order to get an estimate of the skill and nativity-specific TFR. Actual number of births is obtained from the National Center for Health Statistics. Data on female population characteristics is taken from Current Population Survey (CPS). The data that is needed to calculate the ratio of foreign and native fertilities is collected from ACS. In this method, since the actual number of births is used, it is more accurate than the previous method. However, due to merging different datasets, some inconsistencies may still arise.

The alternative method utilizes the fertility and population data extracted from the ACS. In this case, all data is obtained from the ACS which prevents inconsistencies. However, immigrants are underrepresented in this survey, and this may lead to higher fertility rates for the immigrants.

In this paper, fertility rates that I use are based on the first (primary) method.

B.6.1 Total Fertility Rates - Primary Method

In order to calculate the skill- and nativity-specific total fertility rates, I use NCHS' Vital Statistics Natality Birth Data, Community Population Survey, and the ACS for years 2002, 2004, 2006, and 2008, and after calculating total fertility rates for each given year, I average them in order to get the total fertility rates used in the analysis. I define an individual as low-skilled if s/he has a high school degree or less, whereas high-skilled individuals are defined as individuals who hold a college degree or more. I use the immigration specification defined by the Census Bureau, as the foreign-born persons living in the U.S. who were not U.S. citizens at birth.[49] Furthermore, in order to calculate the total fertility rates, I use five-year age groups between years 15 and 49.

Using the data described above, nativity- (j) and skill- (s) specific total fertility rates, namely TFR_s^N and TFR_s^M, are calculated following these steps summarized below:

- Calculate the skill-specific fertility rates without differentiating with respect to nativity:

$$TFR_s = 5 \sum_i^n \frac{X_{i,s}}{Y_{i,s}} \tag{87}$$

  Given the total number of five-year age groups, denoted by n, $X_{i,s}$ is the number of children with respect to the skill level (s) of the mother within the age group i. This is provided by the NCHS' Vital Statistics Natality Birth Data.[50] Moreover, $Y_{i,s}$ is the total female population with respect to age group i and skill level s. This data can be obtained from CPS.

- In this method, direct calculation of TFR_s^j is not possible as there is not reliable information on the nativity of the mother in the NCHS dataset. Instead, I redefine TFR_s^j as a function of TFR_s. First, we rewrite TFR_s:

$$TFR_s = 5 \sum_i^n \frac{X_{i,s}}{Y_{i,s}} = 5 \sum_i^n \frac{(X_{i,s}^N + X_{i,s}^M)}{(Y_{i,s}^N + Y_{i,s}^M)} \tag{88}$$

  writing the equations for TFR_s^M and TFR_s^N as:

$$TFR_s^M = 5 \sum_i^n \frac{X_{i,s}^M}{Y_{i,s}^M} \tag{89}$$

$$TFR_s^N = 5 \sum_i^n \frac{X_{i,s}^N}{Y_{i,s}^N} \tag{90}$$

  We can define TFR_s^M and TFR_s^N with respect to TFR_s as:

$$TFR_s^N = TFR_s - 5 \sum_i^n m_{i,s}(1 - \omega_{i,s}^N) \tag{91}$$

$$TFR_s^M = TFR_s + 5 \sum_i^n m_{i,s}\omega_{i,s}^N \tag{92}$$

  where

$$\omega_{i,s}^N = \frac{Y_{i,s}^N}{(Y_{i,s}^N + Y_{i,s}^F)} \tag{93}$$

$$m_{i,s} = (\frac{X^F_{i,s}}{Y^F_{i,s}} - \frac{X^N_{i,s}}{Y^N_{i,s}}) \tag{94}$$

- First, I construct TFR_s defined in Equation 87 using the birth data from NCHS' Vital Statistics and population data from CPS.
- Next, I calculate $\omega^N_{i,s}$ which is the share of native women in the female population at each age group i, using the CPS data.
- Furthermore, $m_{i,s}$, which is the fertility differential between natives and immigrants at each age group i is calculated using the ACS data on fertility.
- In the last step, I estimate TFR^N_s and TFR^M_s using Equation 91 and Equation 92 for each skill level $s \in \{L, H\}$.

Table 10: Fertility rates

	Natives	Immigrants
Low-skilled	1.87	2.61
High-skilled	1.72	1.98

Notes: This table shows the fertility rates of workers with respect to their nativity and skill. The first row shows the fertility rates for low-skilled natives and immigrants while the second row shows the fertility rates for the high-skilled natives and high-skilled immigrants.

Table 10 summarizes the skill-specific fertility rates with respect to nativity and skill using the procedure described above. Immigrants have more children in both skill groups. Furthermore, the discrepancy between immigrants and natives is more pronounced for the low-skilled workers.[51]

B.6.2 Total Fertility Rates - Alternative Method

Given Equation 87 for the skill- and nativity-specific total fertility rate, the alternative method uses the ACS data collected by the U.S. Census Bureau between years 2001 and 2010.

In the ACS, the respondents are classified with respect to their age, immigration status, and education, among other characteristics. Furthermore, the survey also collects data on whether a woman has given birth in the past year. As before, I define an individual as low-skilled if s/he has a high school degree or less, whereas high-skilled individuals are defined as individuals who hold a college degree or more. I use the immigration specification defined by the Census Bureau, as foreign-born persons living in the U.S. who were not U.S. citizens at birth. Furthermore, in order to calculate the total fertility rates, I use five-year age groups between years 15 and 49.

However, there are some caveats in using this method. As expected, total fertility rates are higher than those using the other method.

Total fertility rates based on the alternative method are shown below:

Table 11: Fertility rates

	Natives	Immigrants
Low-skilled	1.95	2.70
High-skilled	1.89	2.06

Notes: This table shows the fertility rates of workers with respect to their nativity and skill levels, calculated using the alternative method. The first row shows the fertility rates for low-skilled natives and immigrants while the second row shows the fertility rates for high-skilled natives and high-skilled immigrants.

As mentioned, there are some caveats in using this method. First, ACS does not include all births in a given year. Second, in some instances, due to underrepresentation of the foreign-born population in the survey, the denominator may be lower, and the total fertility rates tend to be overstated for the immigrants, which can be seen in Table 11.

B.7 Calibration of Parameters for Government and Social Security System

In the model, government taxes labor and capital income at rates $\tau_r = 0.36$ and $\tau_w = 0.28$, respectively. The values are computed as the average values of the effective U.S. tax rates for the period 1995-2007 reported by Trabant and Uhlig (2010), which follows the same methodology used in Mendoza, Razin, and Tesar (1994). The replacement rate ζ is set equal to 0.5, and the average ratio of government consumption in GDP, denoted by $\bar{y}$, is set equal to 0.195, following Heer and Irmen (2014).[52] In this model, government transfers, Tr, and the contribution rate, τ_b, adjust to sustain a balanced budget for the government and social security system, respectively.

B.8 Calibration of Intergenerational Transition Matrix

Intergenerational mobility matrices are used in order to determine the changes in the skill distribution of children compared to that of their parents.

In order to characterize the transition matrix with respect to a parent's skill type as well as his/her nativity, I use the General Social Survey (GSS), which collects data on the educational level of the respondent as well as his/her parents since 1977. Furthermore, the GSS dataset also includes information on whether the respondent's parents were born in the U.S., which makes it possible to construct individual transition matrices for the immigrants and the natives.

Similar to the methodology of Bohn and Lopez-Velasco (2017), I consider individuals who were born on or after 1945 and whose age at the time of the interview was between 25 and 55 years old.[53] The dataset that specifies the birthplace of the respondent's parents starts from 1977. In my analysis, in order to calculate the transition matrices, I use the dataset that is available between years 1977 and 2016.

An individual is classified as an immigrant's child if at least one of the parents was born outside of the U.S. Equivalently, in order to be classified as a native's child, both parents should be born in the U.S.[54] In the GSS, the educational level of respondents is grouped as: less than high school, high school, junior college, college, and graduate school. I define an individual as "low-skilled" if s/he has a high school degree or less, whereas "high-skilled" individuals are defined as individuals who hold a college degree or more. If the education data is available for both parents, I use the maximum degree that is obtained; otherwise, I use the educational level of the parent whose data is available. Under these restrictions, the total number of observations is 20,939 for the children of natives and 1,709 for the children of immigrants. Among the children of natives, 11,576 are female and 9,363 are male. Among the children of immigrants, 956 are female and 753 are male.

The transition matrices Π_m and Π_n that are used in the paper are estimated from the GSS in order to characterize the skill transition of the population from one generation to the next with regard to nativity. Each element $\pi(j, s, s')$ illustrates the share of the children with education level of s' that are born to parents with educational level s, where j represents the nativity of the parent. In order to estimate the transition matrices for immigrants' and natives' children separately, I first group the sample with respect to nativity of the parents and calculate the number of parents with skill level s. Next, for each nativity and skill group, I calculate the share of children with skill level s'. In the construction of these matrices, I do not make any distinction with respect to gender and calculate the transition matrices by pooling the observations for men and women.

Table 12: Intergenerational Mobility Matrices

$$\Pi_n = \begin{bmatrix} \pi(n,l,l) & \pi(n,l,h) \\ \pi(n,h,l) & \pi(n,h,h) \end{bmatrix} = \begin{bmatrix} 0.806 & 0.194 \\ 0.411 & 0.589 \end{bmatrix}$$

$$\Pi_m = \begin{bmatrix} \pi(m,l,l) & \pi(m,l,h) \\ \pi(m,h,l) & \pi(m,h,h) \end{bmatrix} = \begin{bmatrix} 0.740 & 0.260 \\ 0.350 & 0.650 \end{bmatrix}$$

Table 12 reports the transition matrix for natives and immigrants. At each matrix, columns indicate the skill level of the child while the rows indicate the skill level of the parent. Specifically, the first column shows the probability of a child being low-skilled and the second column shows the probability of a child being high-skilled. Moreover, the first row corresponds to a low-skilled parent and second row corresponds to a high-skilled parent. Comparing immigrants and natives, transition matrices show that immigrants have higher probability of having a high-skilled child irrespective of the skill level of the parent. Accordingly, upward mobility is more common among immigrants as compared to natives.

B.8.1 Transition Matrix Under Alternative Age Range

In the main analysis, the age range is limited to 25-55 years of age. Children who were born before 1945 are excluded. If we include them in the sample, extend the age range to 21-65, and calculate the transition matrices, we get the matrices shown below. As before, immigrants have a higher probability of having high-skilled children. However, the difference between immigrants and natives is less discernible.

$$\Pi_M = \begin{bmatrix} \pi_M(L,L) & \pi_M(L,H) \\ \pi_M(H,L) & \pi_M(H,H) \end{bmatrix} = \begin{bmatrix} 0.782 & 0.218 \\ 0.423 & 0.577 \end{bmatrix}$$

$$\Pi_N = \begin{bmatrix} \pi_N(L,L) & \pi_N(L,H) \\ \pi_N(H,L) & \pi_N(H,H) \end{bmatrix} = \begin{bmatrix} 0.824 & 0.176 \\ 0.449 & 0.551 \end{bmatrix}$$

B.8.2 Transition Matrix Under Different Gender Groupings

In the main analysis, observations with respect to females and males are pooled in order to characterize the transition matrices. In this section, I group the observations with respect to gender and calculate the transition matrices with respect to gender as well as nativity. The results show that as compared to high-skilled males, high-skilled females are more likely to have high-skilled children regardless of their nativity. However, considering low-skilled females, they have a lower probability of having high-skilled children as compared to their male counterparts. Lastly, high-skilled immigrants are more likely to have high-skilled children, irrespective of the gender.

$$\Pi_M^{male} = \begin{bmatrix} \pi_M(L,L) & \pi_M(L,H) \\ \pi_M(H,L) & \pi_M(H,H) \end{bmatrix} = \begin{bmatrix} 0.735 & 0.265 \\ 0.392 & 0.608 \end{bmatrix}$$

$$\Pi_N^{male} = \begin{bmatrix} \pi_N(L,L) & \pi_N(L,H) \\ \pi_N(H,L) & \pi_N(H,H) \end{bmatrix} = \begin{bmatrix} 0.795 & 0.205 \\ 0.416 & 0.584 \end{bmatrix}$$

$$\Pi_M^{female} = \begin{bmatrix} \pi_M(L,L) & \pi_M(L,H) \\ \pi_M(H,L) & \pi_M(H,H) \end{bmatrix} = \begin{bmatrix} 0.744 & 0.256 \\ 0.316 & 0.684 \end{bmatrix}$$

$$\Pi_N^{female} = \begin{bmatrix} \pi_N(L,L) & \pi_N(L,H) \\ \pi_N(H,L) & \pi_N(H,H) \end{bmatrix} = \begin{bmatrix} 0.814 & 0.186 \\ 0.406 & 0.594 \end{bmatrix}$$

B.8.3 Transition Matrix for Immigrants Under Alternative Definition of Second-Generation Immigrants

In the main analysis, second-generation immigrants are defined as individuals with at least one parent who was born outside of the U.S. In this section, immigrants are restricted to the individuals both of whose parents were born outside the U.S. In this case, the sample size becomes 657 for the immigrants, and the resulting transition matrix is given below.

$$\Pi_M = \begin{bmatrix} \pi_M(L,L) & \pi_M(L,H) \\ \pi_M(H,L) & \pi_M(H,H) \end{bmatrix} = \begin{bmatrix} 0.711 & 0.289 \\ 0.383 & 0.617 \end{bmatrix}$$

In this case, the probability of having a high-skilled child is higher for low-skilled immigrants as compared to the previous characterization. However, in comparison with the natives' transition matrix, the probability of having a high-skilled child is still higher, both for the high-skilled and low-skilled parents.

C Experiment I: Increase in High-Skilled Labor

C.1 Steady-State Analysis

C.1.1 Economy Aggregates of the Model with Alternative High-Skilled Definition

C.1.1.1 High-Skilled Defined as Those with Higher Education

Table 13: 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	$\sigma = 1.1$	$\sigma = 1.5$	$\sigma = 1.9$	$\sigma = 1.1$	$\sigma = 1.5$	$\sigma = 1.9$	$\sigma = 1.1$	$\sigma = 1.5$	$\sigma = 1.9$
K_{ss}	96.420	96.879	96.852	111.329	112.711	113.189	113.193	113.687	113.653
H_{ss}	0.081	0.081	0.081	0.122	0.123	0.124	0.124	0.124	0.124
L_{ss}	0.139	0.139	0.139	0.123	0.122	0.121	0.120	0.120	0.120
Tr_{ss}	3.543	3.559	3.559	4.025	4.075	4.092	4.092	4.110	4.109
Beq_{ss}	0.953	0.958	0.957	0.928	0.940	0.943	0.944	0.948	0.947
$\tau_{b,ss}$	0.101	0.101	0.101	0.064	0.064	0.064	0.064	0.064	0.064
$w_{H,ss}$	182.516	183.201	183.141	145.020	154.572	159.938	164.559	165.053	164.992
$w_{L,ss}$	88.695	89.217	89.197	115.016	108.906	104.790	100.307	100.962	100.943
r_{ss}	0.083	0.083	0.083	0.086	0.086	0.086	0.086	0.086	0.086
$\Phi_{H,ss}$	0.410	52.783	90.590	0.410	52.783	90.590	1.560	63.882	96.583
$\Phi_{L,ss}$	0.033	18.006	36.209	0.033	18.006	36.209	0.005	13.736	33.065
Y_{ss}	40.383	40.576	40.565	47.589	48.179	48.384	48.385	48.596	48.582
C_{ss}	19.091	19.182	19.176	23.329	23.619	23.719	23.720	23.823	23.816
K_{ss}/Y_{ss}	2.388	2.388	2.388	2.339	2.339	2.339	2.339	2.339	2.339
$K_{ss}/(w_{H,ss}H_{ss} + w_{L,ss}L_{ss})$	3.564	3.564	3.564	3.492	3.492	3.492	3.492	3.492	3.492

Notes: This table shows the steady-state outcomes of the models with and without ETC for given σ values of 1.1, 1.5, and 1.9. The first three columns report the initial steady-state values. Columns 4-6 report the final steady-state values when the skill intensity levels are constant and equal to initial steady-state levels, and lastly, columns 7-9 report the final steady-state values when 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 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, and $K_{ss}/(w_{H,ss}H_{ss} + w_{L,ss}L_{ss})$ is the steady-state level of the capital-labor income ratio.

C.1.1.2 High-Skilled Defined as Those with Secondary Education

Table 14: 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	$\sigma = 1.1$	$\sigma = 1.5$	$\sigma = 1.9$	$\sigma = 1.1$	$\sigma = 1.5$	$\sigma = 1.9$	$\sigma = 1.1$	$\sigma = 1.5$	$\sigma = 1.9$
K_{ss}	90.403	91.716	93.520	103.004	105.296	107.897	105.412	106.850	108.969
H_{ss}	0.081	0.081	0.081	0.122	0.123	0.123	0.124	0.124	0.124
L_{ss}	0.140	0.140	0.140	0.124	0.122	0.122	0.120	0.120	0.120
Tr_{ss}	3.322	3.370	3.436	3.724	3.807	3.901	3.811	3.863	3.940
Beq_{ss}	0.894	0.907	0.924	0.859	0.878	0.899	0.879	0.891	0.908
$\tau_{b,ss}$	0.101	0.101	0.101	0.064	0.064	0.064	0.064	0.064	0.064
$w_{H,ss}$	164.491	166.516	169.872	129.227	139.288	147.354	154.021	155.639	158.816
$w_{L,ss}$	86.720	88.176	89.866	111.225	106.716	104.856	92.658	94.391	96.178
r_{ss}	0.083	0.083	0.083	0.086	0.086	0.086	0.086	0.086	0.086
$\Phi_{H,ss}$	0.241	43.923	80.057	0.241	43.923	80.057	1.543	60.675	93.413
$\Phi_{L,ss}$	0.052	19.679	38.550	0.052	19.679	38.550	0.004	12.686	31.249
Y_{ss}	37.864	38.414	39.169	44.030	45.010	46.122	45.059	45.674	46.580
C_{ss}	17.900	18.160	18.517	21.585	22.065	22.610	22.089	22.390	22.835
K_{ss}/Y_{ss}	2.388	2.388	2.388	2.339	2.339	2.339	2.339	2.339	2.339
$K_{ss}/(w_{H,ss}H_{ss} + w_{L,ss}L_{ss})$	3.564	3.564	3.564	3.492	3.492	3.492	3.492	3.492	3.492

Notes: This table shows the steady-state outcomes of the models with and without ETC for given σ values of 1.1, 1.5, and 1.9. The first three columns report the initial steady-state values. Columns 4-6 report the final steady-state values when the skill intensity levels are constant and equal to initial steady-state levels, and lastly, columns 7-9 report the final steady-state values when 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 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, and $K_{ss}/(w_{H,ss}H_{ss} + w_{L,ss}L_{ss})$ is the steady-state level of the capital-labor income ratio.

C.2 Transition Analysis

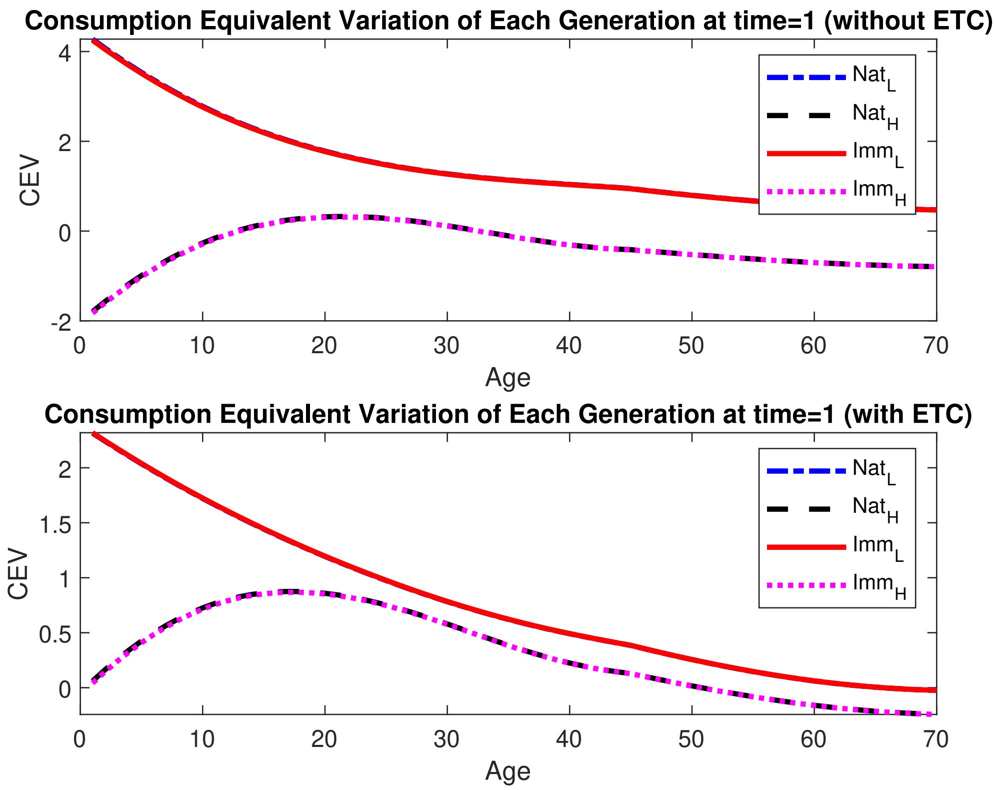
C.2.1 Welfare Analysis: High-Skilled Immigration Policy and Population Preferences

In this section, I show the welfare effects of immigration on the cohorts that are alive when the immigration policy is first implemented at time 1. I use the consumption equivalent variation in order to quantify the changes in the remaining lifetime utility of each cohort with respect to their nativity and skill. In Figure 16, the results show that the effect of high-skilled immigration on each cohort varies with respect to age and skill.[55] First, in the model without ETC, all low-skilled cohorts have a higher utility as they benefit from the increase in low-skilled wages and decrease in pension contribution rate (τ_b). Moreover, this effect is stronger for the younger cohorts as they will still be alive when low-skilled wages continue to rise. For the high-skilled, the decrease in the pension contribution rate (τ_b) benefits only a small group of younger cohorts while the decrease in high-skilled wages affects the whole high-skilled working age population. Considering the model with ETC, there are more high-skilled workers who are better off after the policy change. In this case, the decline in high-skilled wages is smaller, and together with the decline in τ_b, younger high-skilled cohorts benefit more from the policy change, while older high-skilled cohorts are still negatively affected by the policy.

Lastly, Table 15 illustrates the share of the population who would vote in favor of high-skilled immigration. The results including only natives are shown in Table 16.

In both of the models with and without ETC, high-skilled immigration policy change would be accepted due to a large share of low-skilled workers. However, in the model with ETC, despite the decline in their wages, high-skilled workers would also vote in favor of the policy change as they benefit from the decrease in pension contribution rates.

Figure 16: Consumption equivalent variation of each generation at time=1



Notes: This figure shows the consumption equivalent variation (CEV) of cohorts who are alive at time 1 with respect to their 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.

Table 15: Distribution of votes with respect to labor market participation

(a) Without ETC

	Low-skilled	High-skilled
Working age	0.487	0.126
Retired	0.153	0.000
Total	0.640	0.126

(b) With ETC

	Low-skilled	High-skilled
Working age	0.487	0.274
Retired	0.140	0.029
Total	0.627	0.302

Notes: This table illustrates the distribution of positive votes for high-skilled immigration policy change with respect to labor force participation and skill level. The left table reports the distribution in the model without ETC, and the right table reports the distribution in the model with ETC.

Table 16: Distribution of votes with respect to labor market participation (Only Natives)

(a) Without ETC

	Low-skilled	High-skilled
Working age	0.487	0.102
Retired	0.137	0.000
Total	0.573	0.102

(b) With ETC

	Low-skilled	High-skilled
Working age	0.435	0.222
Retired	0.125	0.023
Total	0.561	0.246

Notes: This table illustrates the distribution of positive votes for high-skilled immigration policy change with respect to labor force participation and skill level. The left table reports the distribution in the model without ETC, and the right table reports the distribution in the model with ETC.

C.2.2 Consumption Equivalent Variation - Households

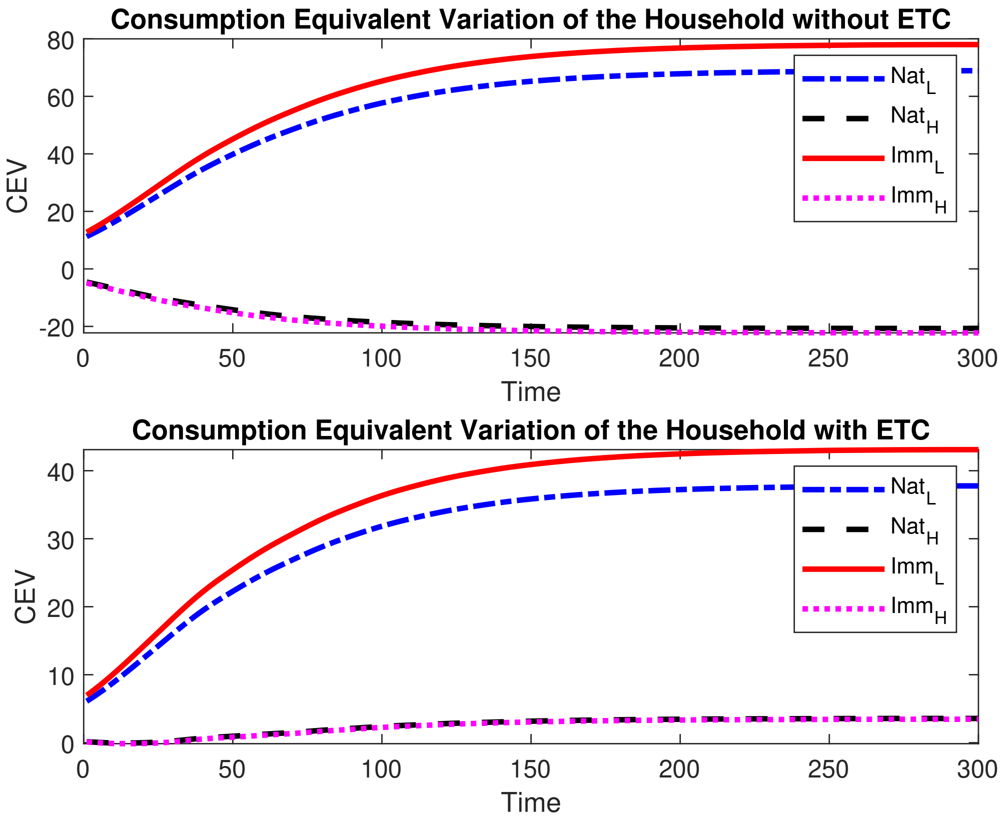
In this section, I present the welfare effects of immigration policy on the households proxied by the OECD equivalence scale. This measure allows us to include children and adult partners in the analysis and obtain an approximation for the changes in the household welfare. The OECD equivalence scale is defined such that each additional adult costs 0.7 of the first adult and each child costs 0.5 of the first adult. Using these weights and the consumption equivalent variation (CEV) as the individual adult welfare measure, we obtain the following equation for the consumption equivalent variation of the household ($CEV_{household}$) :

$$CEV_{t,household}(j,s) = 1.7CEV_t(j,s) + 0.5CEV_t(j,s)\varphi(j,s) \tag{95}$$

where $CEV_t(j,s)$ is the consumption equivalent variation of an individual who was born at time t and $\varphi(j,s)$ is the nativity- and skill-specific fertility rate of the individual, where $j \in \{m,n\}$ and $s \in \{h,l\}$.

Figure 17 shows the household welfare effects of high-skilled immigration policy change. Comparing low-skilled natives and immigrants, because low-skilled immigrants have more children as compared to their native counterparts, the effect of immigration on the low-skilled immigrant household consumption is higher. On the contrary, regarding the high-skilled natives and immigrants, the welfare effects of immigration policy change are similar as their fertility rates are close to each other.

Figure 17: Consumption equivalent variation of the households on the transition path



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.

C.3 Robustness Checks

The increase in welfare of high-skilled workers is dependent on the interaction between the decrease in high-skilled wages and the decrease in the pension system contribution rate (τ_b). Moreover, the sensitivity of high-skilled wages depends on the change in the skill intensity of the production technology, and therefore, the parameters of the technology frontier play an important role on determining the welfare effects of high-skilled immigration. Specifically, if the parameters are such that the ETC effect is strong, the decline in high-skilled wages is less, and together with the decline in the contribution rate (τ_b), the overall effect of the immigration policy on high-skilled workers is positive.

In this section, I explore different estimation scenarios for the technology frontier and analyze the effects of high-skilled immigration in each scenario.[56] In these scenarios, efficiency pairs Φ_H and Φ_L are optimally chosen by the firm from a set of efficiency pairs represented by the following technology frontier:

$$\Phi^{\omega}_{H,t} + \kappa\Phi^{\omega}_{L,t} \leq B,$$

Parameters ω and κ govern the trade-off between high-skilled- and low-skilled-intensive technologies where larger values of ω and κ imply a larger trade-off, which leads to a smaller technology adjustment after the change in the immigration policy. In order to obtain the values of ω and κ, I estimate the following equation using country-level cross-section data, where $\hat{\beta}$ depicts the relationship between relative skill intensity (log) and relative high-skilled labor supply (log):

$$log(\frac{\Phi_H^q}{\Phi_L^q}) = \hat{\beta}\ log(\frac{H_t^q}{L_t^q}) + \epsilon_q \tag{96}$$

Using $\hat{\beta}$, the estimated value for ω can be calculated for an exogenously given σ:

$$\hat{\omega} = \frac{(\sigma - 1)(1 + \hat{\beta})}{\sigma \hat{\beta}} \tag{97}$$

Moreover, using the estimated value for $\hat{\omega}$ (Equation 97) and the residual term ϵ_q (Equation 96), for each country q, country-specific $\hat{\kappa}^q$ can be calculated as below:

$$\hat{\kappa}^q = e^{\frac{\epsilon_q(\sigma\hat{\omega} - \sigma + 1)}{\sigma}} \tag{98}$$

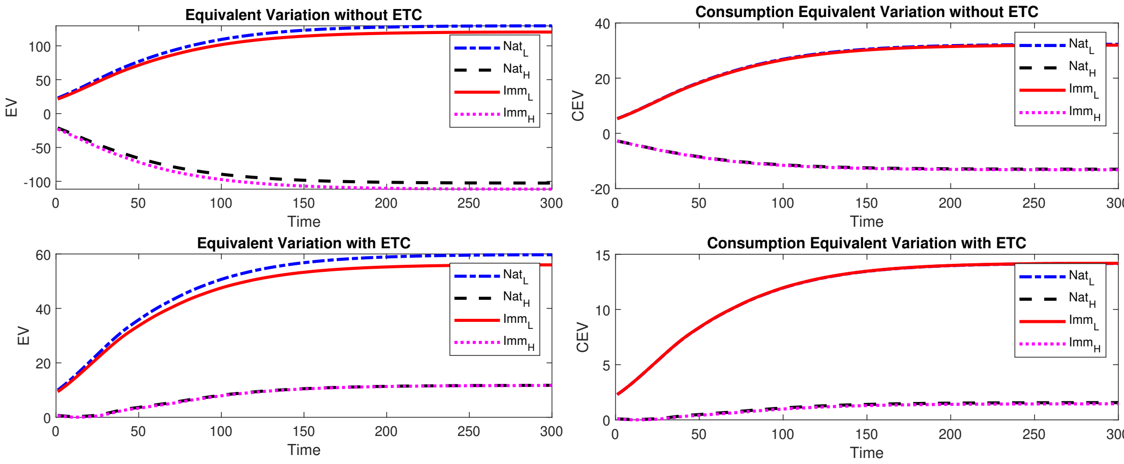
Equation 97 and Equation 98 illustrate that when $\hat{\beta}$ increases, $\hat{\omega}$ decreases together with $\hat{\kappa}^q$, leading to a less costly technology adjustment. Moreover, when the explanatory power of the model increases, the error term ϵ_q gets smaller, which has a negative effect on $\hat{\kappa}^q$, resulting in a smaller cost of technology adjustment.

Based on this analysis, in this model, there are two factors that affect the estimation results of the technology frontier shown in Equation 96. First, the regression coefficient $\hat{\beta}$, which is used to estimate the technology frontier, depends on the initial assumption of σ. Second, the relative supply of high-skilled workers ($\frac{H_t^q}{L_t^q}$) in the regression equation depends on the characterization of high-skilled workers. Specifically, the education level used as the threshold for high-skilled workers determines their relative supply. In the previous analysis, I use $\sigma = 1.5$ and assume that completion of secondary education qualifies a worker as high-skilled. In the following analysis, I relax these assumptions and report the results with respect to different σ values and different high-skilled worker characterizations.

C.3.1 Robustness Checks with Respect to σ

Figure 18 and Figure 19 illustrate the EV and CEV on the transition path when σ is equal to 1.1 and 1.9, respectively. As σ increases, the substitutability of high-skilled workers decreases. Therefore, in the model without ETC, the welfare losses of high-skilled workers is less when σ is higher. Moreover, in the model with ETC, for each σ value, decline in high-skilled wages is lower than the decline in the contribution rate so that the total welfare effect on high-skilled workers is positive. Regarding low-skilled workers, as in the previous cases, the overall welfare effect is always positive. Consequently, the welfare effects of high-skilled immigration is robust with respect to σ.

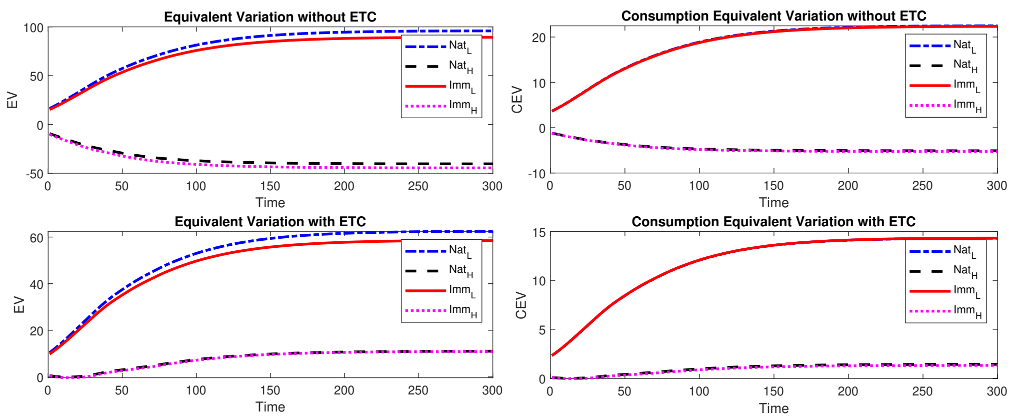
Figure 18: EV and CEV on the transition path when $\sigma = 1.1$



(a) EV (b) CEV

Notes: This figure shows the equivalent variation (EV) and consumption equivalent variation (CEV) on the transition path with respect to nativity and skill when the technology frontier is estimated using $\sigma = 1.1$. EV is measured in terms of the level of the consumption good. CEV is measured in terms of the percentage of the consumption good. The upper panel shows the model without ETC while the lower panel shows the model with ETC. Nat_L shows the EV and CEV of low-skilled natives and is represented by a blue dashed-line, Nat_H shows the EV and CEV of high-skilled natives and is represented by a black dashed-line whereas Imm_L shows the EV and CEV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the EV and CEV of high-skilled immigrants and is represented by a magenta dashed-line.

Figure 19: EV and CEV on the transition path when $\sigma = 1.9$



(a) EV (b) CEV

Notes: This figure shows the equivalent variation (EV) and consumption equivalent variation (CEV) on the transition path with respect to nativity and skill when the technology frontier is estimated using $\sigma = 1.9$. EV is measured in terms of the level of the consumption good. CEV is measured in terms of the percentage of the consumption good. The upper panel shows the model without ETC while the lower panel shows the model with ETC. Nat_L shows the EV and CEV of low-skilled natives and is represented by a blue dashed-line, Nat_H shows the EV and CEV of high-skilled natives and is represented by a black dashed-line whereas Imm_L shows the EV and CEV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the EV and CEV of high-skilled immigrants and is represented by a magenta dashed-line.

C.3.1.1 Robustness Checks with Respect to the Characterization of $\frac{H_t^q}{L_t^q}$

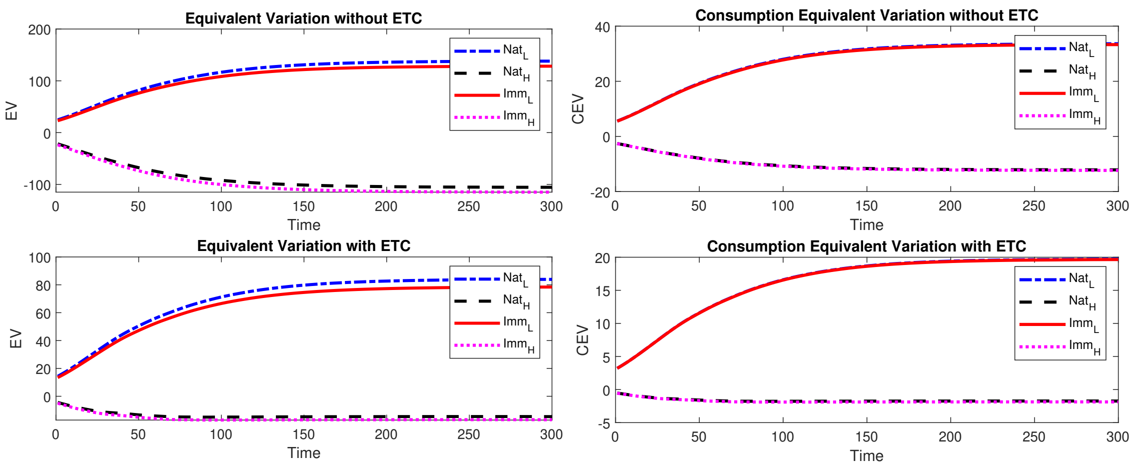
In Online Appendix B.3, in order to calculate the relative supply of high-skilled labor, denoted by $\frac{H_t^q}{L_t^q}$, I assumed that workers who receive at least a secondary education or above constitute the high-skilled labor group. Since the estimation is based on the panel data, including developing countries with lower levels of education, secondary education creates larger variation in the sample, resulting in smaller errors.

In this section, I relax this assumption and explore the welfare changes by estimating a new technology frontier under the assumption that only the workers who receive college education are considered as high-skilled. The caveat of this assumption is that since the sample mainly includes developing countries, there is insignificant variation in the relative high-skilled labor supply, and the explanatory power of the model decreases significantly, which leads to lower $\hat{\beta}$ coefficient and higher error term ϵ_q, creating higher ω and $\hat{\kappa}^q$, implying a more costly technology adjustment. The estimation results can be found in the last four columns of Table 5. In this case, due to larger errors, the estimated values for κ and ω are higher, implying a more costly adjustment to switch to the high-skilled-intensive production technologies. Therefore, the skill intensity of high-skilled workers (ϕ_H) increase less after immigration. Figure 20, Figure 21, and Figure 22 illustrate the EV and CEV on the transition path when σ is equal to 1.1, 1.5, and 1.9, respectively. In this scenario, the increase in high-skilled labor supply affects high-skilled wages more negatively, and the positive effect of the decline in τ_b is insufficient to keep the consumption at the initial steady-state levels. Therefore, both in the models with and without ETC, the welfare effect of high-skilled immigration is negative for high-skilled workers, even if it is less negative in the model with ETC. This implies that the analysis is not robust with respect to usage of college education.

In their analysis, Caselli and Coleman (2002) recommend using primary education, in which case, due to larger variation, the β coefficient goes up and ϵ_q goes down, leading to lower ω and κ levels (see Table 5, first panel in Online Appendix B.3). Therefore, positive welfare effects of high-skilled immigration on the high-skilled workers also hold for the primary education threshold.

Consequently, the results are robust with respect to different σ levels and usage of lower education (primary and secondary) thresholds. However, if we use the college degree as the threshold, the effect of high-skilled immigration on the welfare of the high-skilled workers becomes negative.

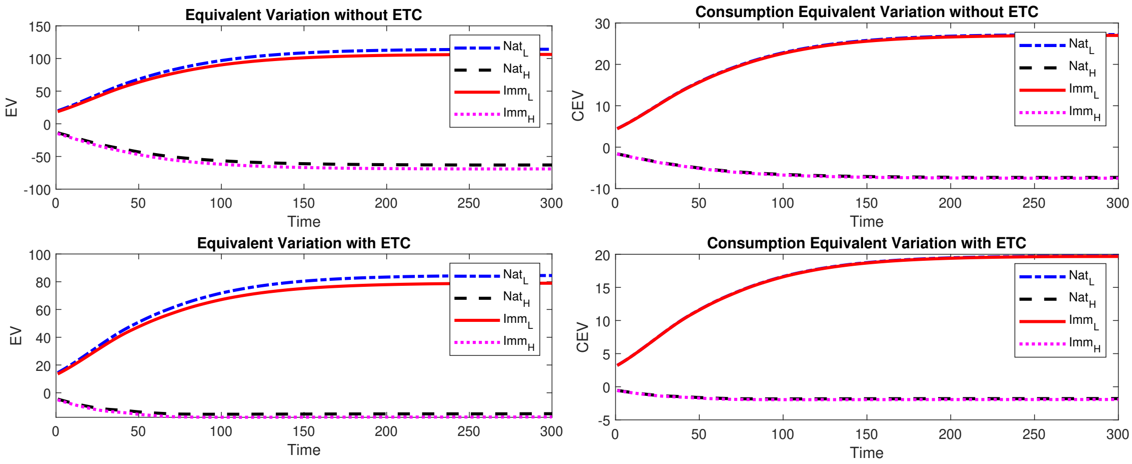
Figure 20: EV and CEV on the transition path when $\sigma = 1.1$



(a) EV (b) CEV

Notes: This figure shows the equivalent variation (EV) and consumption equivalent variation (CEV) on the transition path with respect to nativity and skill when the technology frontier is estimated using $\sigma = 1.1$. EV is measured in terms of the level of the consumption good. CEV is measured in terms of the percentage of the consumption good. The upper panel shows the model without ETC while the lower panel shows the model with ETC. Nat_L shows the EV and CEV of low-skilled natives and is represented by a blue dashed-line, Nat_H shows the EV and CEV of high-skilled natives and is represented by a black dashed-line whereas Imm_L shows the EV and CEV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the EV and CEV of high-skilled immigrants and is represented by a magenta dashed-line.

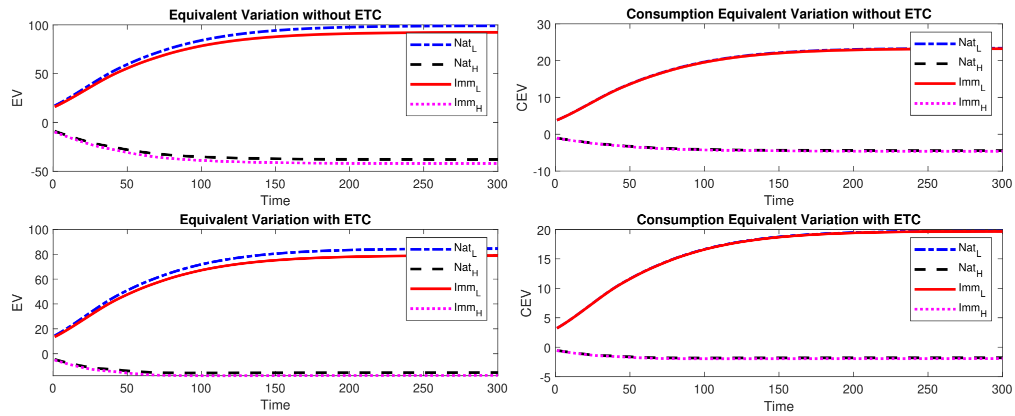
Figure 21: EV and CEV on the transition path when $\sigma = 1.5$



(a) EV (b) CEV

Notes: This figure shows the equivalent variation (EV) and consumption equivalent variation (CEV) on the transition path with respect to nativity and skill when the technology frontier is estimated using $\sigma = 1.5$. EV is measured in terms of the level of the consumption good. CEV is measured in terms of the percentage of the consumption good. The upper panel shows the model without ETC while the lower panel shows the model with ETC. Nat_L shows the EV and CEV of low-skilled natives and is represented by a blue dashed-line, Nat_H shows the EV and CEV of high-skilled natives and is represented by a black dashed-line whereas Imm_L shows the EV and CEV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the EV and CEV of high-skilled immigrants and is represented by a magenta dashed-line.

Figure 22: EV and CEV on the transition path when $\sigma = 1.9$



(a) EV (b) CEV

Notes: This figure shows the equivalent variation (EV) and consumption equivalent variation (CEV) on the transition path with respect to nativity and skill when the technology frontier is estimated using $\sigma = 1.9$. EV is measured in terms of the level of the consumption good. CEV is measured in terms of the percentage of the consumption good. The upper panel shows the model without ETC while the lower panel shows the model with ETC. Nat_L shows the EV and CEV of low-skilled natives and is represented by a blue dashed-line, Nat_H shows the EV and CEV of high-skilled natives and is represented by a black dashed-line whereas Imm_L shows the EV and CEV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the EV and CEV of high-skilled immigrants and is represented by a magenta dashed-line.

D Experiment II: Increase in Low-Skilled Labor

In this section, I analyze the effects of the increase in low-skilled immigration with an experiment. In this experiment, starting from the same initial steady state,[57] the share of new low-skilled immigrants as a percentage of existing immigrants is doubled from 1 percent to 2 percent while the percentage of new high-skilled immigrants is kept at the initial steady-state levels so that the new immigration policy becomes: $\psi(H) = 1\%$ and $\psi(L) = 2\%$.

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

D.1 Steady-State Analysis

This section explores the effect of low-skilled immigration on the final steady state of the economy. Furthermore, in order to assess the effect of ETC, I compare the model without ETC with the one where firms are allowed to choose their production technology (with ETC).

Firstly, immigration increases the share of the working-age population and reduces the contribution rate τ_b. Thus, more resources become available for individuals to save so that capital and output increases. However, as compared to the first experiment with high-skilled immigration discussed in Online Appendix C, in this experiment with low-skilled immigration, the increase in output is lower due to the lower productivity of low-skilled workers. Furthermore, even though the model with ETC predicts higher output and capital in both experiments, the effect of ETC is less significant in the second experiment with low-skilled immigration. Specifically, since the economy in the initial steady state is already low-skilled abundant, the increase in low-skilled labor in the second experiment does not create significant productivity gains as the firms change their technologies to accommodate new low-skilled labor due to diminishing marginal returns on the technology frontier.

Regarding wage effects of immigration policy, in the model without ETC, increase in low-skilled labor reduces the wages for the low-skilled (3.33 percent) and increases the wages for the high-skilled (1.22 percent). On the other hand, the model with ETC predicts that the decline in low-skilled wages is much lower (1.85 percent) while high-skilled wages experience an insignificant decline (0.18 percent), implying that the effect of ETC in the case of low-skilled immigration is less pronounced.

D.1.1 Comparison of Wage Changes with Ottaviano and Peri (2012)

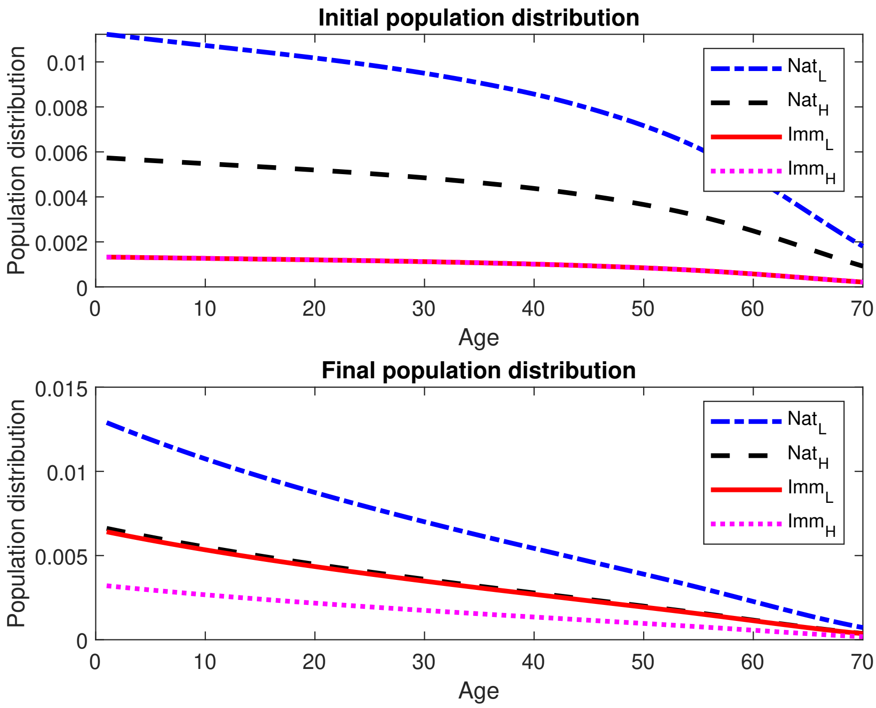
In this section, in order to show that in the short run, the results of the model with ETC are more in line with the results of the empirical literature, I compare my findings with those of Ottaviano and Peri (2012).[58] Ottaviano and Peri (2012) report a 13 percent increase in low-skilled immigration and a 10 percent increase in high-skilled immigration between the years 1990 and 2006. In order to replicate these percentage values, I consider the population distribution on the transition path and observe the period at which the change in the high-skilled and low-skilled working-age population relative to the initial steady state is the closest to the value in Ottaviano and Peri (2012).[59] This corresponds to period 19 in the model where there is a 13 percent increase in low-skilled immigration and a 9 percent increase in high-skilled immigration.[60] In this period, the model without ETC predicts a 0.67 percent increase in high-skilled wages and a 1.29 percent decrease in low-skilled wages relative to the initial steady state. On the contrary, in the model with ETC, high-skilled wages increase by 0.13 percent, and low-skilled wages decrease by 0.72 percent. Next, I compare these results with the simulated values using the method described in Ottaviano and Peri (2012) and find that Ottaviano and Peri (2012) predict a 0.14 percent increase in high-skilled wages and a 0.3

percent decrease in low-skilled wages. This implies that the predictions of the model with ETC are more in line with the results of Ottaviano and Peri (2012).[61]

D.1.2 Population Dynamics

Figure 23 illustrates the initial and final distribution of the total population with respect to nativity and skill. In Figure 23, 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. Similar to the results in Online Appendix C, in the final steady state, the median age of the population including the child population decreases from 37 to 29. Moreover the median age of the working-age population decreases from 27 (47 in real age) to 20 (40 in real age), implying an increase in the working-age population relative to the retirees.[62]

Figure 23: Population distribution



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 the share of 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.

Table 17 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 percent to 32 percent of the total population. Furthermore, the share of working-age population increases from 75 percent to 84 percent, and as the share of the workers paying for the social security system increases, the contribution rate falls. In addition, the share of immigrants in the working-age population increases from 5 percent to 19 percent for low-skilled workers and to 10 percent for high-skilled. Furthermore, in the final steady state, even though the share of working-age low-skilled natives is 6 percent lower than the initial steady state, the percentage of high-skilled natives has declined only by 3 percent as immigrants have more children, and their probability of having a high-skilled child is higher.

Table 17: Population distribution with respect to labor market participation

(a) Initial distribution

	Low-skilled	High-skilled
Natives		
Working age	0.435	0.222
Retired	0.137	0.070
Immigrants		
Working age	0.051	0.051
Retired	0.016	0.016

(b) Final distribution

	Low-skilled	High-skilled
Natives		
Working age	0.373	0.191
Retired	0.070	0.036
Immigrants		
Working age	0.186	0.093
Retired	0.035	0.017

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.

D.1.3 Economy Aggregates

In Table 18, the first four columns show the results at the initial steady state with respect to different values for σ. The following four columns show final steady-state results with the new immigration policy (with a higher share of low-skilled immigrants) without allowing for ETC. In the last four columns, 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 for the columns 1-6 whereas in columns 7-9, firms choose a production technology such that the more abundant low-skilled labor is used more efficiently at the expense of less efficient high-skilled labor. Therefore, in columns 7-9, Φ_L is higher and Φ_H is lower than the previous columns.

In the analysis below, for convenience, I compare Column 2, Column 5, and Column 8 where $\sigma = 1.5$.[63] In the case of low-skilled immigration, the policy change has different short-term and long-term effects. Starting with the model without ETC, in Column 5, when the supply of low-skilled workers goes up, in the short run, the population experiences an increase in L and a relative decrease in H. As the population evolves, in the long run, the share of the high-skilled working-age population starts to go up as the children of immigrants enter the economy as high-skilled. Therefore, due to the initial decrease in the supply of high-skilled labor, high-skilled wages go up. However, as high-skilled children enter the economy, in the long run, high-skilled wages start to fall, the overall effect being positive. For the low-skilled, in the short run, the wages go down due to the increase in supply. In the long run, as high-skilled labor starts to increase, low-skilled wages go up slightly, the overall effect being negative.

As we compare the model without ETC (Column 5) with the one where firms are allowed to choose their optimal technologies (Column 8), the decline in low-skilled wages is lower in magnitude in the case with ETC. The underlying reason is that the increase in the efficiency of low-skilled workers increases the firm's demand, which increases low-skilled wages, creating a counterbalancing effect, consequently mitigating the negative supply effect.

Furthermore, considering high-skilled workers, in the case without ETC, high-skilled wages go up due to decrease in the relative supply of the high-skilled. However, in the case with ETC, high-skilled wages do not increase but rather experience an insignificant decline (0.18 percent). The underlying reason is that in the short run, as the relative supply of high-skilled workers goes down, firms choose to reduce the efficiency of the high-skilled worker. This mitigates the increase in high-skilled wages that was due to the decrease in supply of high-skilled workers. On the other hand, in the long run, as the supply of high-skilled workers starts to increase as a result of the inflow of high-skilled children, high-skilled wages start to decline. Nonetheless, this effect is mitigated as it starts to become more profitable for firms to use high-skilled workers more efficiently. In this case, Φ_H starts to increase so that the total effect on high-skilled wages is insignificant, experiencing a slight decline.

Considering aggregate capital, in the final steady state, for both of the models with and without ETC (Columns 8 and 5, respectively), the economy creates more capital. As the share of the working-age population increases due to immigration, the contribution rate τ_b goes down so that a larger share of the income can be saved.

Moreover, in both of the models (with and without ETC), the initial steady-state economy is low-skilled abundant. This is mainly because the technology frontier is concave, and diminishing marginal returns to technology are present in the case of low-skilled immigration. Therefore, in the model with ETC, the increase in the efficiency of low-skilled workers due to an increase in supply induces limited efficiency gains and has insignificant wage effects. In this case, the differences in aggregate capital is minimal in the models with and without ETC.[64]

Comparing these results with the effects of high-skilled immigration policy change summarized in Table 14 in Section 4.1.2 in the paper, it can be seen that increase in high-skilled immigrants has a more significant effect on the output, capital, and wages due to higher productivity of high-skilled workers. Furthermore, in the case of high-skilled immigration, the model with ETC predicts a much higher effect as the firms choose more efficient technologies for their high-skilled workers. This implies that if ETC is ignored, the effect of immigration will be undermined for both types of labor, but more so in the case with high-skilled immigration.

Table 18: Steady states of the models with and without ETC

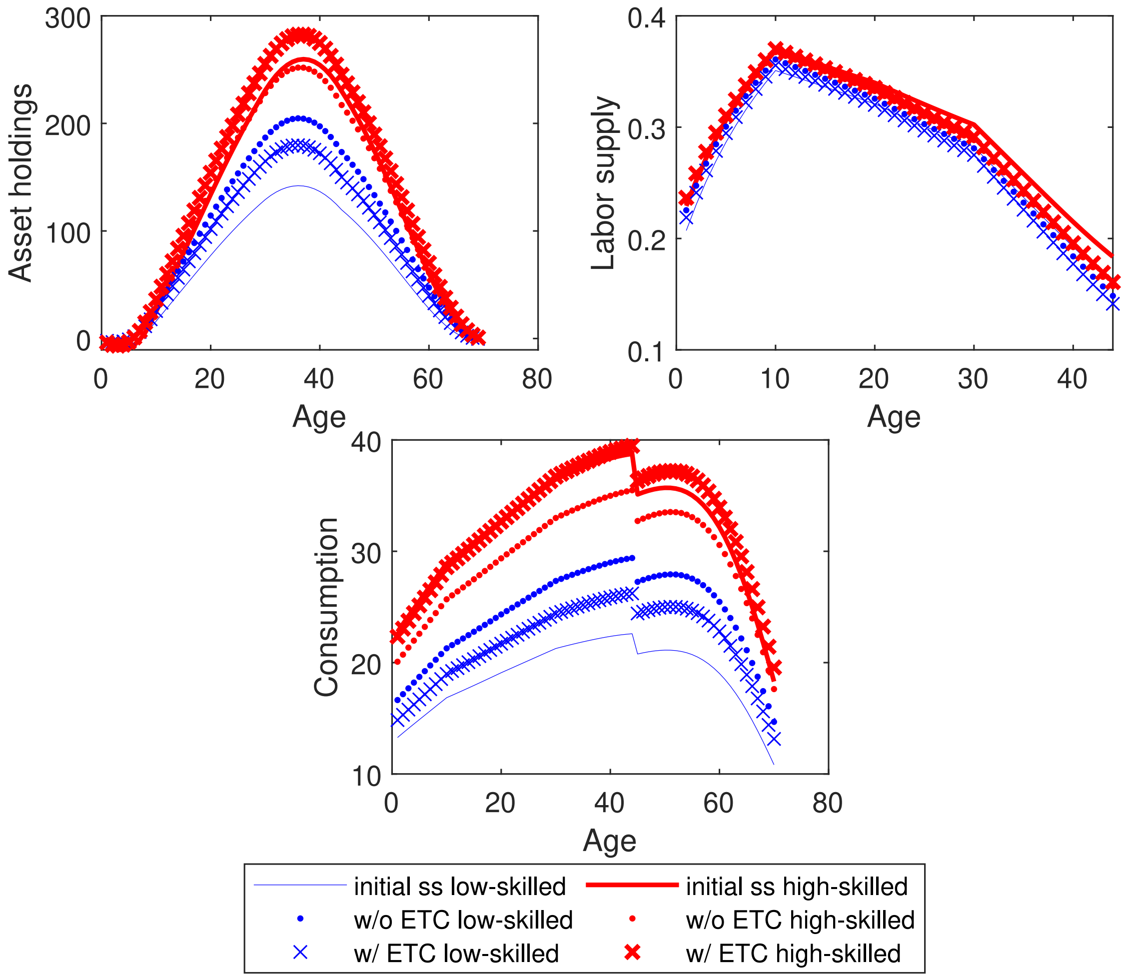
	Steady states								
	Initial steady state			Final steady state (without ETC)			Final steady state (with ETC)		
Variable	$\sigma = 1.1$	$\sigma = 1.5$	$\sigma = 1.9$	$\sigma = 1.1$	$\sigma = 1.5$	$\sigma = 1.9$	$\sigma = 1.1$	$\sigma = 1.5$	$\sigma = 1.9$
K_{ss}	90.403	91.716	93.520	94.937	96.366	98.284	95.057	96.445	98.339
H_{ss}	0.081	0.081	0.081	0.084	0.084	0.084	0.084	0.084	0.084
L_{ss}	0.140	0.140	0.140	0.157	0.157	0.157	0.157	0.157	0.157
Tr_{ss}	3.322	3.370	3.436	3.432	3.484	3.553	3.437	3.487	3.555
Beq_{ss}	0.894	0.907	0.924	0.791	0.803	0.819	0.792	0.804	0.820
$\tau_{b,ss}$	0.101	0.101	0.101	0.064	0.064	0.064	0.064	0.064	0.064
$w_{H,ss}$	164.491	166.516	169.872	167.687	168.555	171.205	164.149	166.210	169.554
$w_{L,ss}$	86.720	88.176	89.866	83.160	85.236	87.284	85.132	86.542	88.203
r_{ss}	0.083	0.083	0.083	0.086	0.086	0.086	0.086	0.086	0.086
$\Phi_{H,ss}$	0.241	43.923	80.057	0.241	43.923	80.057	0.185	41.946	78.315
$\Phi_{L,ss}$	0.052	19.679	38.550	0.052	19.679	38.550	0.069	20.661	39.458
Y_{ss}	37.864	38.414	39.169	40.581	41.192	42.012	40.633	41.226	42.036
C_{ss}	17.900	18.160	18.517	19.894	20.193	20.595	19.919	20.210	20.607
K_{ss}/Y_{ss}	2.388	2.388	2.388	2.339	2.339	2.339	2.339	2.339	2.339
$K_{ss}/(w_{H,ss}H_{ss} + w_{L,ss}L_{ss})$	3.564	3.564	3.564	3.492	3.492	3.492	3.492	3.492	3.492

Notes: This table shows the steady-state outcomes of the models with and without ETC for given σ values of 1.1, 1.5, and 1.9. The first three columns report the initial steady-state values. Columns 4-6 report the final steady-state values when the skill intensity levels are constant and equal to initial steady-state levels, and lastly, columns 7-9 report the final steady-state values when 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 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, and $K_{ss}/(w_{H,ss}H_{ss} + w_{L,ss}L_{ss})$ is the steady-state level of the capital-labor income ratio.

D.1.4 Individuals' Choices at the Steady States

In this section, I examine the effects of low-skilled immigration on the asset holdings, labor choice, and consumption decisions of individuals. The results shown in Figure 24 indicate that as compared to the initial steady state, individuals save and consume more as a result of the decrease in the social security contribution rate, τ_b. Comparing the models with and without ETC, since the production technology is low-skilled intensive in the initial steady state, wage changes due to the increase in low-skilled immigration do not depend on the technology choice of the firms, and therefore the difference between models is small and insignificant.

Figure 24: Asset-holding, labor supply, and consumption profiles with respect to age



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.

D.2 Transition Analysis

In this section, I show the transition path for the economy for 300 years, each period corresponding to one year. At time 1, the share of low-skilled immigrants is increased to 2 percent of the existing immigrants while keeping the high-skilled immigrant share at 1 percent. The change in the immigration policy has distinct effects in the short run and in the long run. In the short run, as more low-skilled workers enter the economy, the supply of low-skilled workers relative to the high-skilled goes up. However, in the long run, as the immigrants' high-skilled children enter into the economy, high-skilled labor supply increases and converges to a point that is slightly above the initial levels. Regarding the technology choice of firms, in the model without ETC, Φ_H and Φ_L are constant on the transition path. However, in the model with ETC, in the short run, due to the increase in L relative to H, Φ_L increases gradually while Φ_H decreases as firms choose to increase the efficiency of the low-skilled at the expense of reducing the efficiency of high-skilled workers. Yet, in the long run, as the children of immigrants enter the economy, the high-skilled labor supply starts to go up, leading to an increase in Φ_H and a decrease in Φ_L. Combining the short-run and long-run effects of ETC, in the final steady state, Φ_H is lower and Φ_L is higher than their initial steady-state values.

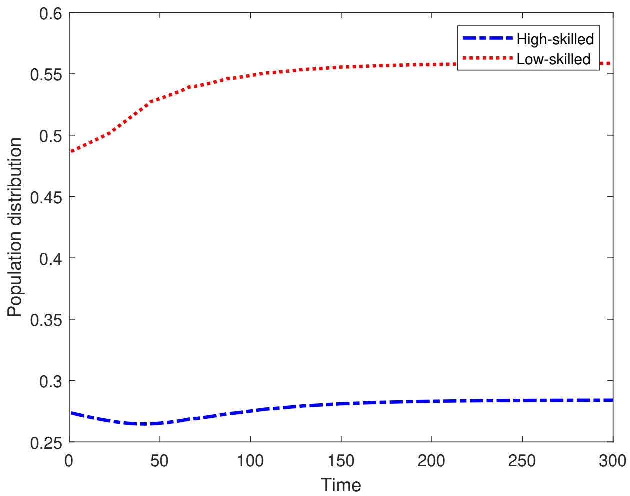
In the following sections, I investigate the effect of the change in the immigration policy on the population dynamics, aggregate labor, firms' efficiency choices, prices, economy aggregates, government and pension budgets as well as long-run capital ratios. Lastly, I conclude this section with the welfare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

D.2.1 Population Dynamics

Figure 25 shows the law of motion for the high-skilled and low-skilled working-age population. In the short term, the share of low-skilled workers goes up while the share of high-skilled workers decreases. However, in the long run, the share of high-skilled working-age population starts to go up and converges to a point slightly above the initial steady state. This is due to the fact that immigrants have higher fertility rates, and their probability of having high-skilled children is also higher, creating additional inflow of high-skilled workers into the economy.

It should also be noted that at the initial steady state, the majority of the working-age population was low-skilled. Therefore, as a result of the change in the immigration policy, the low-skilled working-age population increases from 49 percent to 57 percent, which has a smaller impact on the efficiency choice of firms as well as on wages.

Figure 25: Share of high- and low-skilled workers on the transition path

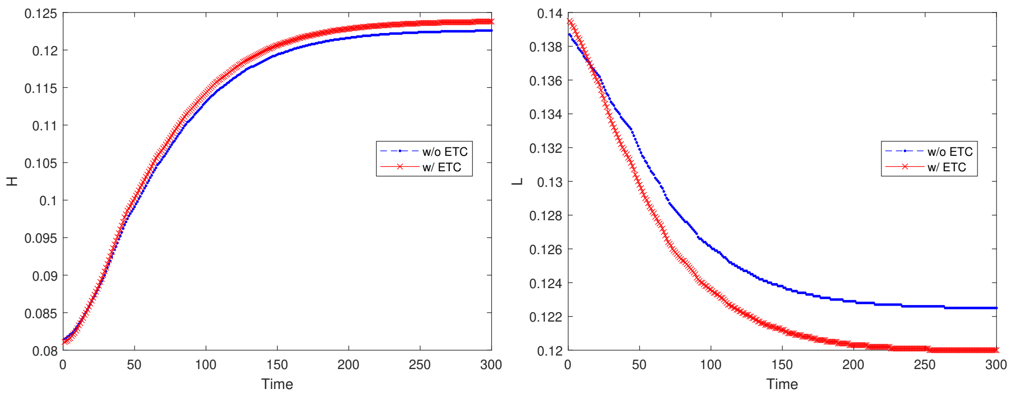


Notes: This figure shows the share of high-skilled and low-skilled workers on the transition path. The red dotted line illustrates the share of low-skilled workers, while the blue dashed line illustrates the share of high-skilled workers.

D.2.2 Aggregate Labor

The evolution of the high-skilled and low-skilled working-age population and the individuals' labor supply decisions determine total supply of labor, namely H and L, in the economy. As can be seen in Figure 26, after the change in the immigration policy, in the final steady state both low-skilled and high-skilled labor supply goes up slightly. In the short run, aggregate high-skilled labor goes down as a result of the decrease in relative supply. However, as the high-skilled children of immigrants enter the economy, aggregate high-skilled labor starts to increase, converging at a level above its initial steady state. Furthermore, when the ETC is introduced into the model, low-skilled workers supply slightly more labor, and the high-skilled reduce their labor share although the difference remains small. The underlying reason is that, in the model with ETC, due to the increase in low-skilled worker efficiency, demand for low-skilled workers goes up while it goes down for the high-skilled. The change in demand reflects on the wages and eventually on the labor supply decisions.

Figure 26: Aggregate labor on the transition path



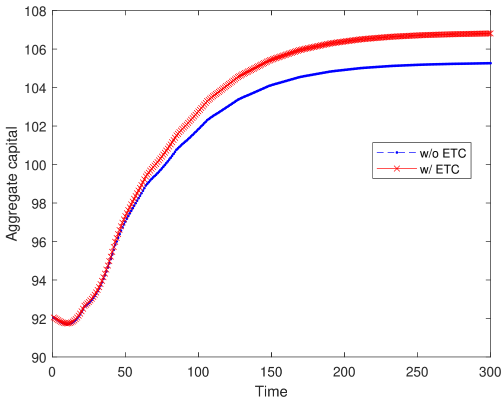
(a) High-skilled labor (b) Low-skilled labor

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.

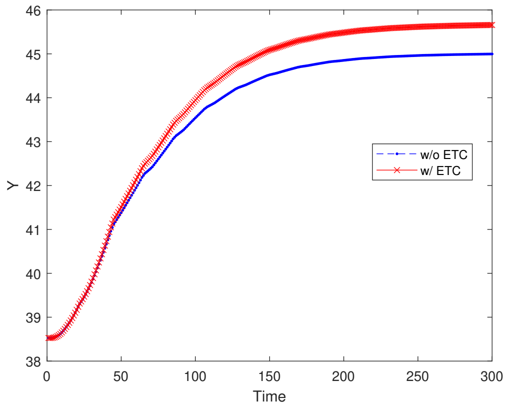
D.2.3 Economy Aggregates

The initial effect of immigration on the aggregate capital is negative because immigrants enter the workforce without any initial capital. However, in the long run, the share of working-age population goes up, leading to a decrease in τ_b. Since individuals pay less for the social security system, more resources become available for them to consume and save, and in the new steady state, both aggregate capital and aggregate consumption go up. Comparing the results with and without endogenous technology choice, there is not a significant difference in the economic aggregates between these models since the wage difference is small, and individuals make almost identical consumption and saving decisions.

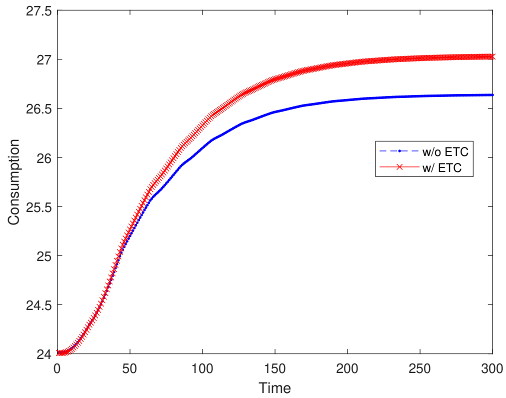
Figure 27: Economy aggregates on the transition path



(a) Aggregate capital



(b) Aggregate output



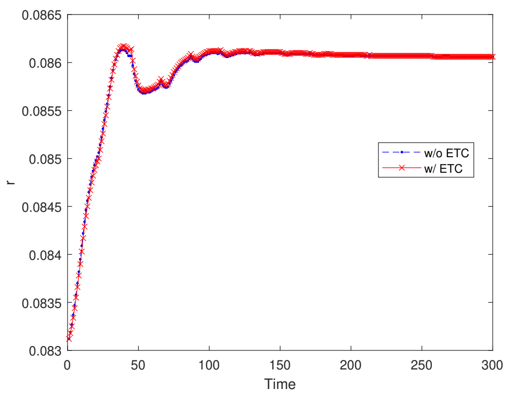
(c) Aggregate consumption

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.

D.2.4 Interest Rates

In the final steady state, even though aggregate capital increases, due to the increase in the demand for capital, interest rates are higher. Furthermore, interest rates are the same in the models with and without ETC.

Figure 28: Interest rates

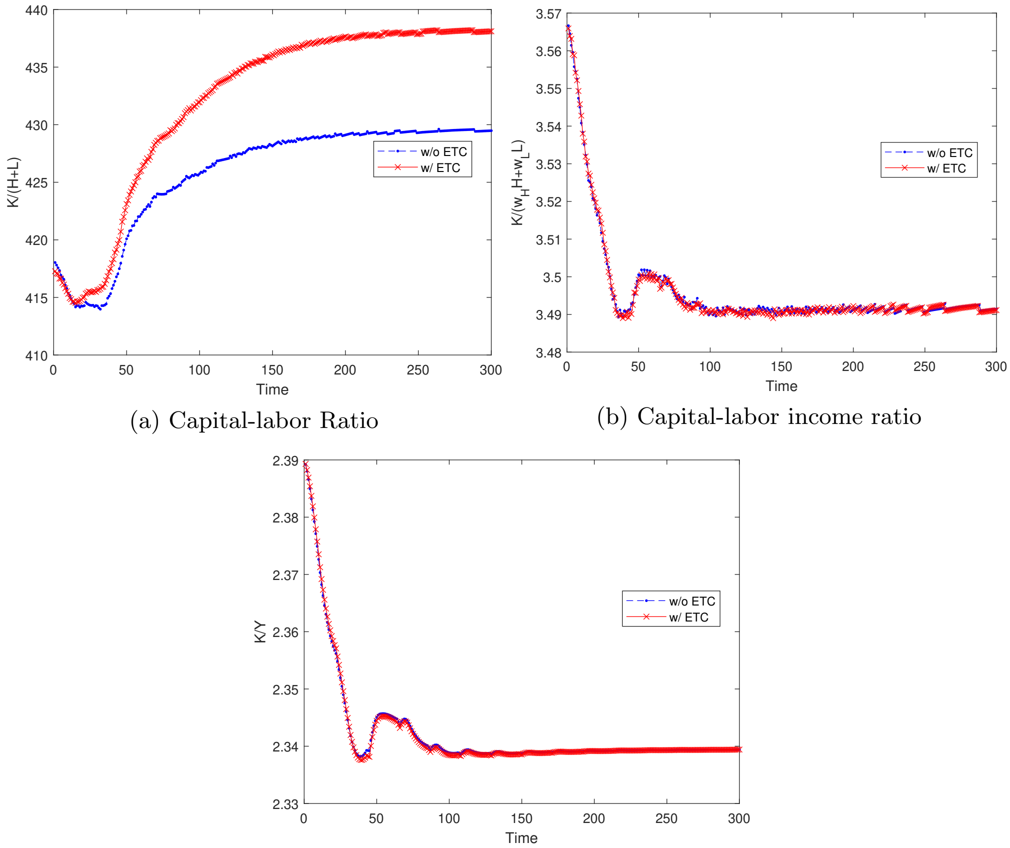


Notes: This figure shows the interest rates on the transition path. The blue dash-dotted line shows the results in the model without ETC, and the red cross line shows the results in the model with ETC.

D.2.5 Capital Ratios

In the final steady state, capital-to-labor ratio goes down since low-skilled wages do not change significantly and low-skilled workers save less. Furthermore, capital-to-labor income and capital-to-output ratios decline at the same rate in scenarios with and without ETC.

Figure 29: Capital ratios on the transition path



(a) Capital-labor Ratio

(b) Capital-labor income ratio

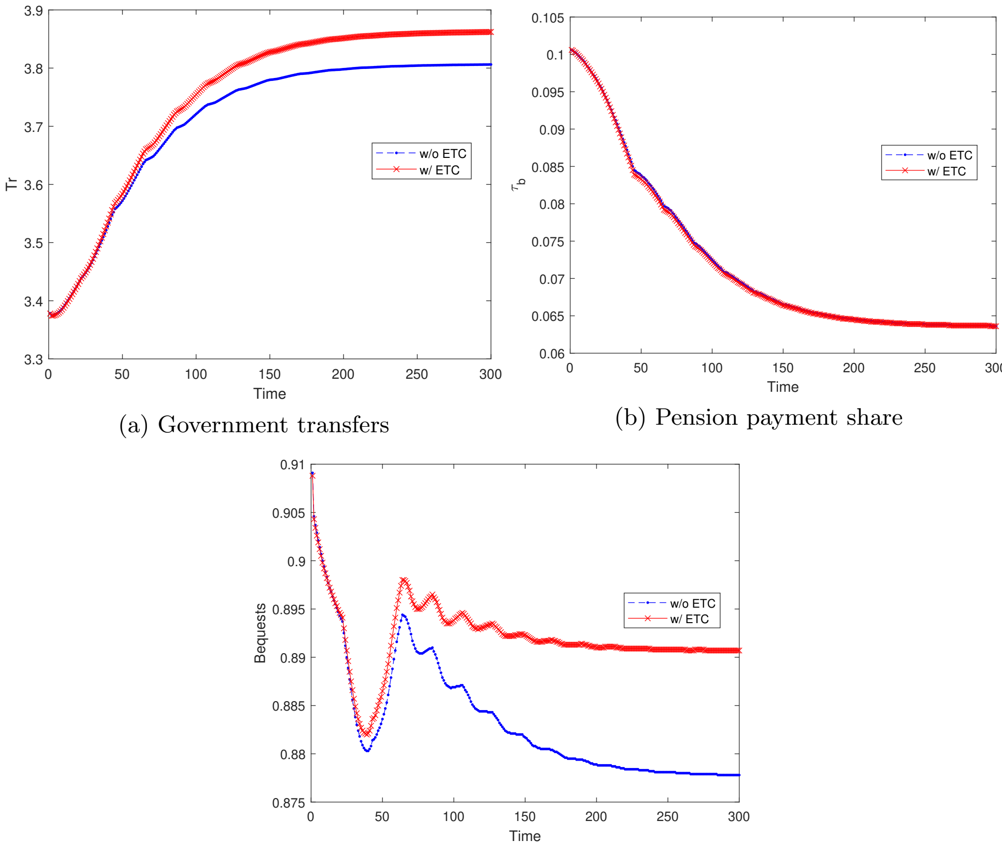
(c) Capital-output ratio

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 the red cross line shows the results in a model with ETC.

D.2.6 Government and Pension System Budget

On the transition path, as low-skilled immigrants enter the economy, total transfers increase, and the increase in transfers is slightly higher in the case with ETC. Moreover, due to the increase in the share of the working-age population, the pension system contribution rate is lower in the final steady state and equal in the models with and without ETC.

Figure 30: Government and pension system budget on the transition path



(a) Government transfers

(b) Pension payment share

(c) Accidental bequests

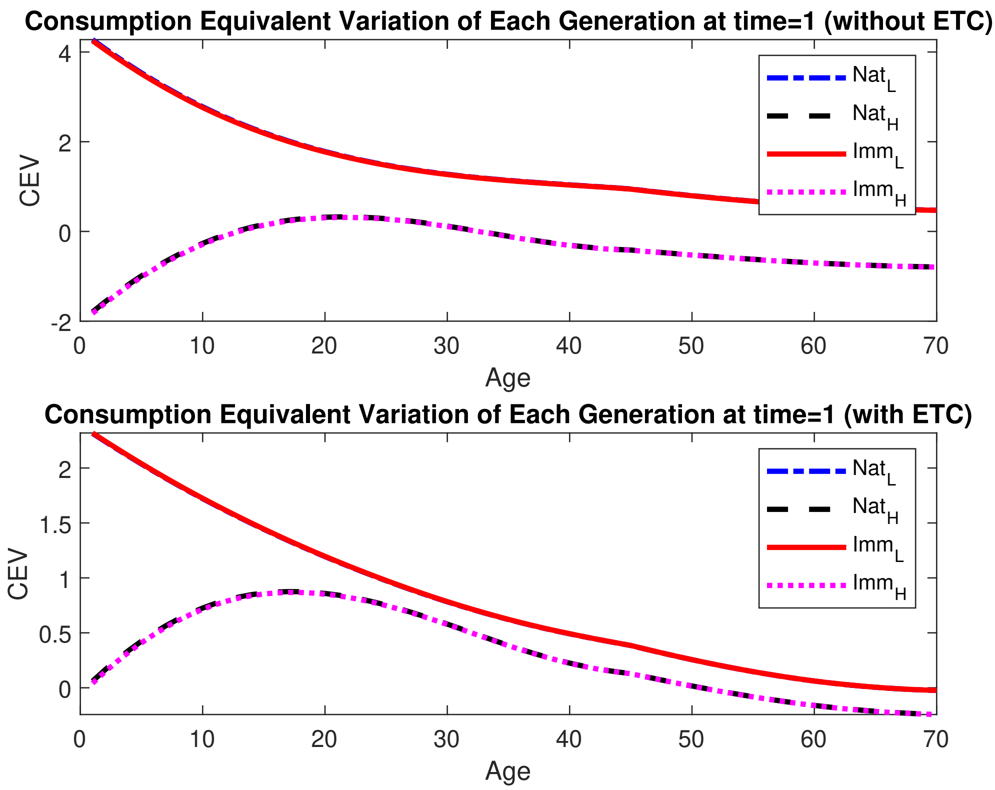
Notes: This figure shows the government and pension system budget on the transition path. Figure (a) shows the government transfers. Figure (b) shows the pension payment share. Figure (c) shows the aggregate accidental bequests. The blue dash-dotted line shows the results in the model without ETC, and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

D.2.7 Welfare Analysis: Low-Skilled Immigration Policy and Population Preferences

In this section, I use the consumption equivalent variation in order to quantify the changes in the remaining lifetime utility of each cohort when the immigration policy is first implemented at time 1. In Figure 31, the results show that the effect of low-skilled immigration on each cohort varies with respect to age and skill.[65] First, in the model without ETC, all high-skilled cohorts have a higher utility as they benefit from the increase in high-skilled wages and the decrease in pension contribution rate (τ_b). Moreover, this effect is stronger for the younger cohorts as they will still be alive when high-skilled wages continue to rise. For the low-skilled, the decrease in the pension contribution rate (τ_b) benefits only a small group of younger cohorts while the decrease in low-skilled wages affects the whole low-skilled working-age population. Considering the model with ETC, there are more low-skilled workers who are better off after the policy change. In this case, the decline in low-skilled wages is smaller, and together with the decline in τ_b, younger low-skilled cohorts benefit more from the policy change, while older low-skilled cohorts are still negatively affected by the policy.

Lastly, Table 19 illustrates the share of the population who would vote in favor of low-skilled immigration. In both of the models with and without ETC, low-skilled immigration policy change would be accepted, only with a slight difference in the model without ETC. However, in the model with ETC, despite the decline in their wages, low-skilled workers would also vote in favor of the policy change as they benefit from the decrease in pension contribution rates. These results do not change even if we only consider natives' votes, which are summarized in Table 20.

Figure 31: Consumption equivalent variation of each generation at time=1



Notes: This figure shows the consumption equivalent variation (CEV) of cohorts who are alive at time 1 with respect to their 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.

Table 19: Distribution of votes with respect to labor market participation

(a) Without ETC

	Low-skilled	High-skilled
Working age	0.487	0.126
Retired	0.153	0.000
Total	0.640	0.126

(b) With ETC

	Low-skilled	High-skilled
Working age	0.487	0.274
Retired	0.140	0.029
Total	0.627	0.302

Notes: This table illustrates the distribution of positive votes for low-skilled immigration policy change with respect to labor force participation, nativity, and skill level. The left table reports the distribution in the model without ETC, and the right table reports the distribution in the model with ETC.

Table 20: Distribution of votes with respect to labor market participation (Only Natives)

(a) Without ETC

	Low-skilled	High-skilled
Working age	0.435	0.102
Retired	0.137	0.000
Total	0.573	0.102

(b) With ETC

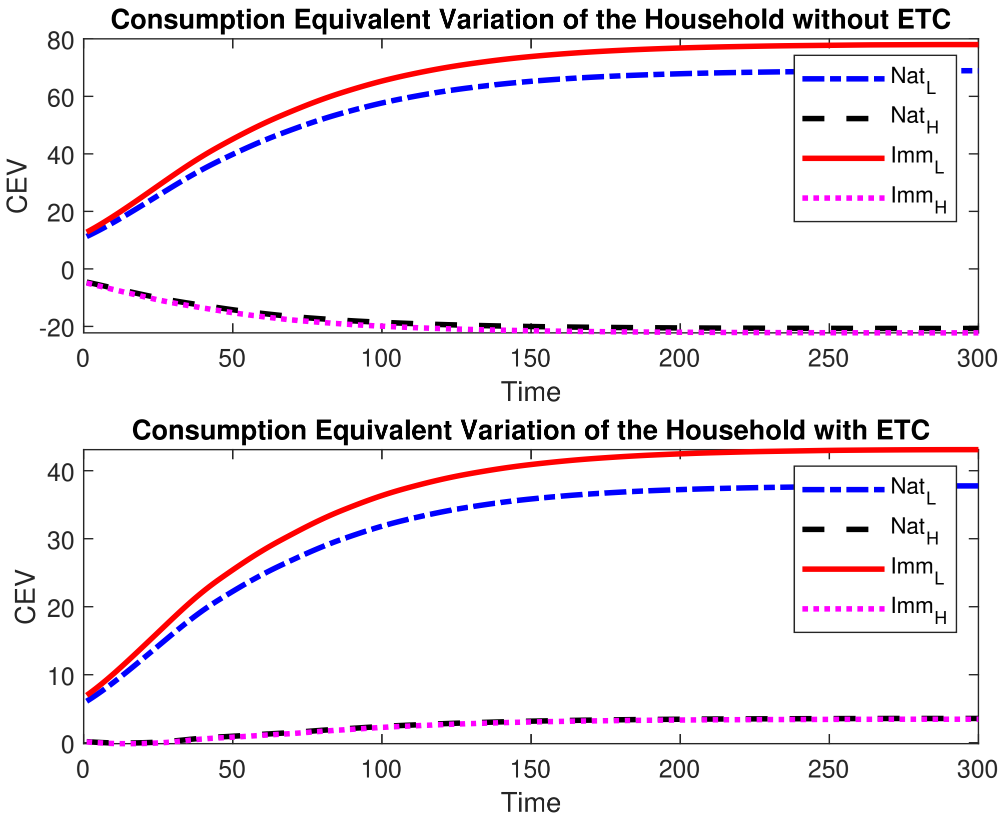
	Low-skilled	High-skilled
Working age	0.435	0.222
Retired	0.125	0.023
Total	0.561	0.246

Notes: This table illustrates the distribution of positive votes for low-skilled immigration policy change with respect to labor force participation, nativity, and skill level. The left table reports the distribution in the model without ETC, and the right table reports the distribution in the model with ETC.

D.2.8 Consumption Equivalent Variation - Households

Figure 32 shows the household welfare effects of low-skilled immigration policy change. Comparing low-skilled natives and immigrants, because low-skilled immigrants have more children as compared to their native counterparts, the effect of immigration on the low-skilled immigrant household consumption is higher, especially in the model with ETC. On the contrary, regarding the high-skilled natives and immigrants, the welfare effects of immigration policy change are higher than the low-skilled counterparts, but similar to each other as their fertility rates are closer.

Figure 32: Consumption equivalent variation of the households on the transition path



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.

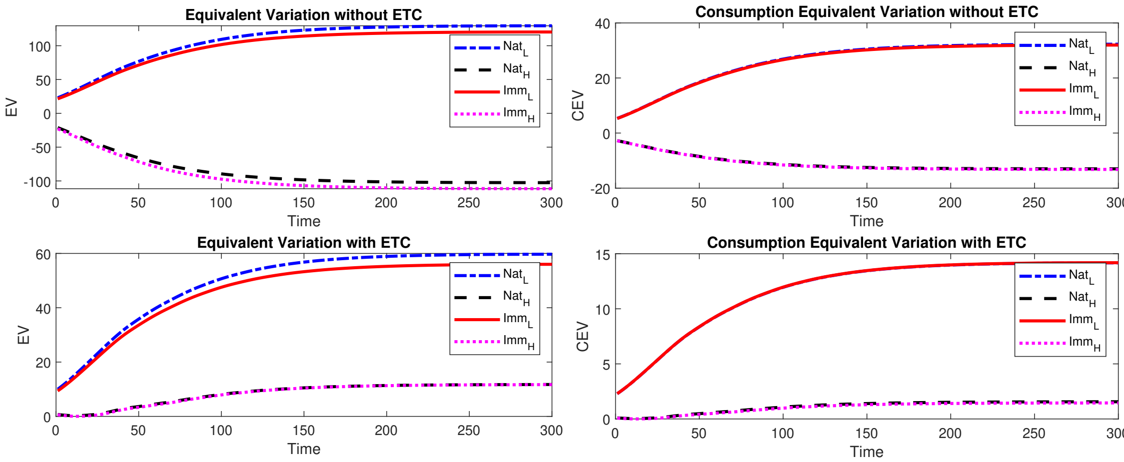
D.3 Robustness Checks

In the following analysis, I relax the assumptions of the initial estimation and report the results with respect to different σ values and different high-skilled worker characterizations.

D.3.1 Robustness Checks with Respect to σ

Figure 33 and Figure 34 illustrate the EV and CEV on the transition path when σ is equal to 1.1 and 1.9, respectively. In this case, the welfare gains of both low-skilled and high-skilled workers are very similar for each given σ.

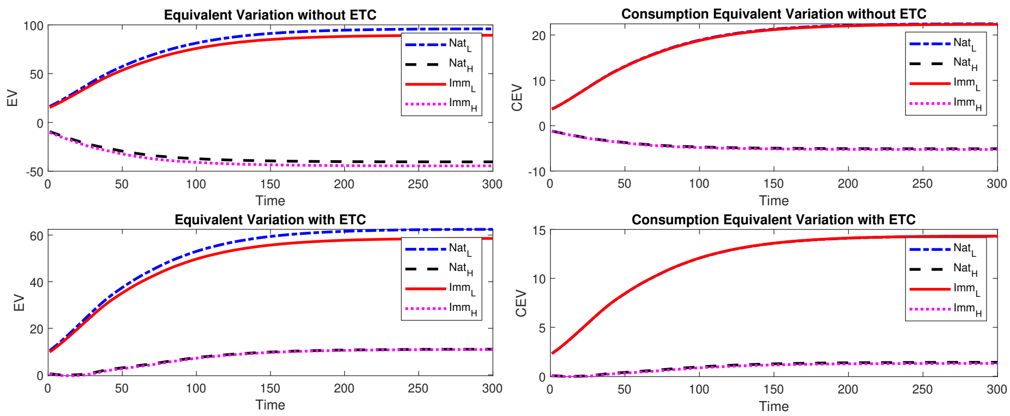
Figure 33: EV and CEV on the transition path when $\sigma = 1.1$



(a) EV (b) CEV

Notes: This figure shows the equivalent variation (EV) and consumption equivalent variation (CEV) on the transition path with respect to nativity and skill when the technology frontier is estimated using $\sigma = 1.1$. EV is measured in terms of the level of the consumption good. CEV is measured in terms of the percentage of the consumption good. The upper panel shows the model without ETC while the lower panel shows the model with ETC. Nat_L shows the EV and CEV of low-skilled natives and is represented by a blue dashed-line, Nat_H shows the EV and CEV of high-skilled natives and is represented by a black dashed-line whereas Imm_L shows the EV and CEV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the EV and CEV of high-skilled immigrants and is represented by a magenta dashed-line.

Figure 34: EV and CEV on the transition path when $\sigma = 1.9$



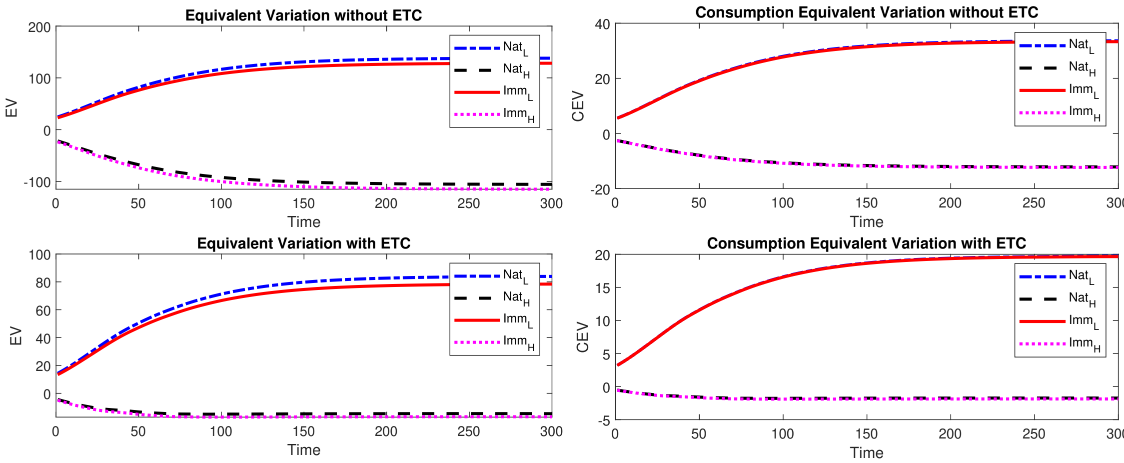
(a) EV (b) CEV

Notes: This figure shows the equivalent variation (EV) and consumption equivalent variation (CEV) on the transition path with respect to nativity and skill when the technology frontier is estimated using $\sigma = 1.9$. EV is measured in terms of the level of the consumption good. CEV is measured in terms of the percentage of the consumption good. The upper panel shows the model without ETC while the lower panel shows the model with ETC. Nat_L shows the EV and CEV of low-skilled natives and is represented by a blue dashed-line, Nat_H shows the EV and CEV of high-skilled natives and is represented by a black dashed-line whereas Imm_L shows the EV and CEV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the EV and CEV of high-skilled immigrants and is represented by a magenta dashed-line.

D.3.2 Robustness Checks with Respect to the Characterization of $\frac{H_t^q}{L_t^q}$

In this section, I explore the welfare changes of low-skilled immigration using the technology frontier estimated under the assumption that only the workers who receive college education are considered as high-skilled. In this case, even though the estimated values for κ and ω are higher, implying a more costly adjustment to switch to skill-intensive production technologies, since the initial population is low-skilled-abundant, the production technology is already low-skilled intensive. Therefore, increase in the cost of technological adjustment does not affect wage changes significantly, and in models with and without ETC, the welfare effect is positive for both high- and low-skilled workers. Consequently, the results are robust with respect to different σ levels and usage of different education thresholds.

Figure 35: EV and CEV on the transition path when $\sigma = 1.1$

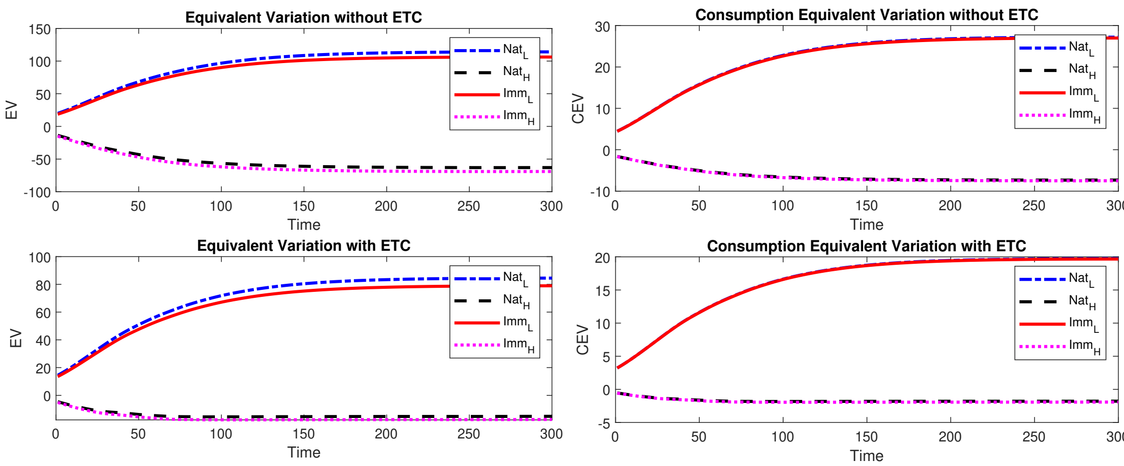


(a) EV

(b) CEV

Notes: This figure shows the equivalent variation (EV) and consumption equivalent variation (CEV) on the transition path with respect to nativity and skill when the technology frontier is estimated using $\sigma = 1.1$. EV is measured in terms of the level of the consumption good. CEV is measured in terms of the percentage of the consumption good. The upper panel shows the model without ETC while the lower panel shows the model with ETC. Nat_L shows the EV and CEV of low-skilled natives and is represented by a blue dashed-line, Nat_H shows the EV and CEV of high-skilled natives and is represented by a black dashed-line whereas Imm_L shows the EV and CEV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the EV and CEV of high-skilled immigrants and is represented by a magenta dashed-line.

Figure 36: EV and CEV on the transition path when $\sigma = 1.5$

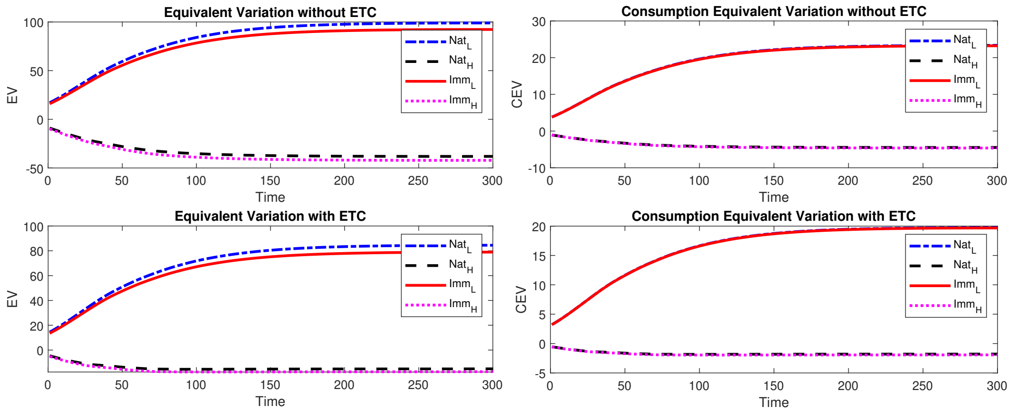


(a) EV

(b) CEV

Notes: This figure shows the equivalent variation (EV) and consumption equivalent variation (CEV) on the transition path with respect to nativity and skill when the technology frontier is estimated using $\sigma = 1.5$. EV is measured in terms of the level of the consumption good. CEV is measured in terms of the percentage of the consumption good. The upper panel shows the model without ETC while the lower panel shows the model with ETC. Nat_L shows the EV and CEV of low-skilled natives and is represented by a blue dashed-line, Nat_H shows the EV and CEV of high-skilled natives and is represented by a black dashed-line whereas Imm_L shows the EV and CEV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the EV and CEV of high-skilled immigrants and is represented by a magenta dashed-line.

Figure 37: EV and CEV on the transition path when $\sigma = 1.9$



(a) EV (b) CEV

Notes: This figure shows the equivalent variation (EV) and consumption equivalent variation (CEV) on the transition path with respect to nativity and skill when the technology frontier is estimated using $\sigma = 1.9$. EV is measured in terms of the level of the consumption good. CEV is measured in terms of the percentage of the consumption good. The upper panel shows the model without ETC while the lower panel shows the model with ETC. Nat_L shows the EV and CEV of low-skilled natives and is represented by a blue dashed-line, Nat_H shows the EV and CEV of high-skilled natives and is represented by a black dashed-line whereas Imm_L shows the EV and CEV of low-skilled immigrants and is represented by a red solid line. Lastly, Imm_H shows the EV and CEV of high-skilled immigrants and is represented by a magenta dashed-line.