Immigration and the Macroeconomy*

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Abstract

We analyze the dynamics of labor migration and the insurance role of remittances in a two-country, real business cycle framework. Emigration increases with the expected stream of future wage gains, but is dampened by the sunk cost reflecting border enforcement. During booms in the destination economy, the scarcity of established immigrants lessens capital accumulation, labor productivity and the native wage. The welfare gain from the inflow of unskilled labor increases with the complementarity between skilled and unskilled labor, and with the share of the skilled among native labor. The model matches the cyclical dynamics of the unskilled immigration from Mexico.

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1 Introduction

Labor migration is sizable and has a non-negligible economic impact on the economies involved. The number of foreign-born residents is rising worldwide: As much as 12.5 percent of the total U.S. population in 2007 was foreign born, as compared to less than 6 percent in 1980, a pattern which is also visible in several other OECD countries (Grogger and Hanson, 2008). Labor migration also varies over the business cycle. Jerome (1926) documented the procyclical pattern of European immigration into the U.S. during the 19th and early 20th centuries, showing that recessions were associated with drastic declines in immigration flows, while relatively larger inflows occurred during the recovery years.[1] Adding to this evidence, in Figure 1 we plot the number of apprehensions at the U.S.-Mexico border, which the existing literature uses as a proxy for attempted illegal crossings into the U.S.,[2] along with the U.S./Mexico ratio of real GDP measured in purchasing power parity terms (both series logged and HP-detrended). The chart shows that periods in which the U.S. economy outperformed Mexico's were generally accompanied by an increase in border apprehensions. The correlations in Figure 3(a) confirm this pattern.[3] Evidence of procyclical immigration also exists for Canada (Sweetman, 2004), the United Kingdom (Gordon et al., 2007) and Australia (RBA, 2007), among other countries.

Immigrants send remittances to their country of origin on a regular basis. Conservative estimates indicate that the remittances sent by emigrants from developing economies back home reached $240 billion in 2007, which was more than double the amount of 2002.[4] In 2007, the recorded remittances represented more than 10 percent of the GDP of several receiving countries,[5] while globally they represented the equivalent of two-thirds of the amount of foreign direct investment received by developing economies, thus becoming a principal component of their total financial inflows.[6] Just like labor migration, the remittance flows also vary over the business cycle. In Figure 2 we plot the pattern of remittances from the U.S. to Mexico vis-a-vis the relative performance of these economies. The correlations of detrended series in Figure 3(b) confirm that periods with faster U.S. economic growth

[1] For instance, the number of arrivals into the U.S. declined by 39.1 percent in the recession year of 1908. The same was observed during the recessions of 1876-79, 1894 and 1922. During these years, there were fewer restrictions on European immigration and most of the arrivals into the U.S. were properly documented (O'Rourke and Williamson, 1999).

[2] See Hanson (2006) for references. Today's legal immigration involves complicated and long administrative processes which are arguably less related to economic considerations (see Hanson and McIntosh 2007).

[3] Similarly, Hanson and Spilimbergo (1999) find that a 10 percent relative decline in the Mexican real wage has been associated with a 6-8 percent increase in U.S. border apprehensions, with this effect being fully realized within 3 months.

[4] Due to unrecorded flows through formal and informal channels, the actual numbers are believed to be significantly larger than the reported numbers.

[5] Examples include Moldova (36.2%), Honduras (25.6%), Guyana (24.3%) and Jordan (20.3%), Philippines (10%), among many others. Remittances account for roughly 2.5 % of Mexico's GDP (World Bank, 2008).

[6] See Ratha and Xu (2008).

(or lower Mexican growth) have been associated with larger outflows of remittances to Mexico and vice versa. The combined evidence in Figures 1 and 2 highlights the potential insurance role of remittances in smoothing the consumption path of Mexican households whose members reside on both sides of the border.

With this evidence in mind, we examine the business cycle fluctuations of labor migration and remittance flows, as well as their propagation to the rest of the economy. In particular, we study the role of labor migration in explaining the cyclicality of remittance flows over the business cycle. We also study the effect of immigration policy (reflected by the magnitude of immigration barriers) on the volatility of immigration and remittances. To this end, we use a dynamic stochastic general equilibrium (DSGE), two-country, real business cycle model along the lines of Backus, Kehoe and Kydland (1994), in which we allow for endogenous labor migration and remittances. In order to take skill heterogeneity among the native labor into account, we introduce two types of labor in the home economy (skilled and unskilled) while assuming that capital and skilled labor are relative complements as in Krusell et al. (2000), and that the native unskilled and immigrant labor are perfect substitutes as in Borjas et al. (2008). We calibrate the model to match the empirical socio-economic characteristics of labor migration between Mexico and the U.S.

Our methodology bridges the gap between modern international macroeconomic literature and immigration theory. In contrast to our approach, the workhorse model of international macroeconomics assumes that labor is immobile across countries. Instead, labor migration is generally analyzed within formal setups limited to comparisons of long-run positions or to the study of growth dynamics. These models are not suitable for the analysis of immigration dynamics at business cycle frequencies. In our model, the incentive to emigrate depends on the expectation of future earnings at the destination relative to the country of origin, on the perceived sunk costs of emigration, as well as on the return rate of immigrant labor. This return rate has a non-trivial role, as about 70 percent of undocumented Mexican immigrants in the U.S. tend to return to their country within ten years after their arrival (Reyes, 1997). The sunk cost includes the cost of searching for employment, adjustment to a new lifestyle, transportation expenditures, and in the case of undocumented immigration, the need to hire human smugglers (also known as *coyotes)* as well as the physical risk and legal implications of illegally crossing the border.

In line with the empirical evidence, our model generates immigration and remittance flows that are procyclical with the relative economic performance of the two economies. Both of them are procyclical with output in the destination economy, and countercyclical with output in the country of origin. An additional result consistent with the data is that stricter border enforcement reduces the volatility of the stock of immigrant labor while significantly increasing the volatility of the immigrant wage and remittances.[7] In the model, the absence of labor mobility restrictions implies that the immigrant labor efficiently exploits the ups and downs of the business cycle. That is, they arrive in large numbers during economic expansions when are most needed, and promptly return to their country of origin when a bad shock hits the destination economy. Higher border enforcement breaks this logic, as the increase in the stock of immigrant labor does not keep up with the increase in labor demand during expansions. Immigrant labor becomes relatively scarce, receives relatively higher wages and sends larger remittances to the foreign economy. In turn, the scarcity of immigrant labor during booms reduces the incentive to accumulate capital, and reduces the productivity of the destination economy. During recessions, the effect is the opposite. Established immigrants are deterred from returning to their country of origin, bearing in mind that future re-emigration when the destination economy recovers would involve a large sunk cost. Thus, the established immigrant labor remains in the destination economy during recessions, placing additional extra downward pressure on the wage of the native unskilled.

When computing the welfare effects of different enforcement policies, we focus on anticipated deterministic shocks with permanent effects on the balanced growth path, in addition to the stochastic temporary shocks and the associated cyclical considerations. The results indicate that "tightening" the border to constrain the inflow of unskilled labor has a negative impact on welfare in the destination economy, particularly when the complementarity between skilled and unskilled labor is relatively higher, and when the share of the skilled labor in total native labor converges to a relatively higher steady-state level.

This paper is related to existing literature that quantifies the effect of migration in both static (Borjas, 1995; Hamilton and Whalley, 1984; Moses and Letnes, 2004; Walmsley and Winters, 2003) and dynamic frameworks (Djacic, 1987). Our paper is closely related to Klein and Ventura (2007) and Urrutia (1998), who use growth models with endogenous labor movement to assess the welfare effects of removing barriers to labor migration. In the context of DSGE models of international business cycles, our paper is also related to Acosta et al. (2007), Chami et al. (2006) and Durdu and Sayan (2008), who include remittance endowment shocks; to Ghironi and Melitz (2005) and Bilbiie et al. (2006), who introduce an endogenous firm entry mechanism subject to sunk costs; and to Lindquist

[7] Rodriguez-Zamora (2008) shows that the recent increase in border enforcement resulted in less volatile migration inflows and outflows across the US-Mexico border. After growing at double digit rates, remittances drastically fell in the aftermath of the US financial crisis.

(2004) and Polgreen and Silos (2006), who use skill heterogeneity and capital-skill complementarity with two representative households.

The rest of the paper is organized as follows: Section 2 introduces the benchmark model of immigration and remittances; Section 3 presents the alternative model with skill heterogeneity in the destination economy; Section 4 discusses the parameterization; Section 5 describes the model dynamics, providing impulse response and quantitative analysis; Section 6 performs a welfare analysis in the presence of both stochastic and permanent deterministic shocks affecting the sunk immigration costs and the skill composition of the native labor force in the home economy; Section 7 presents the main conclusions.

2 The Model

The model is representative of a standard two-country setup along the lines of Backus, Kehoe, Kydland (1994, henceforth BKK). Our setup differs from that of BKK in that we use for simplicity log-CRRA preferences and abstract from government purchases and time-to-build in capital formation. Each country specializes in the production of a single (intermediate) good. The final good is a composite of domestic and foreign goods, and can be either consumed or invested.

The novel characteristic of our setup is the presence of labor mobility, as we allow for labor to migrate from the foreign economy to the home one. In the baseline model specification, native and immigrant labor form a CES aggregate which enters, along with capital, in a Cobb-Douglas production function in the home economy. In the model with an alternative production specification (which we describe in the next section) we explore the asymmetric implications of unskilled immigration on native labor at the destination, by introducing two types of labor in the home economy (skilled and unskilled) in the presence of capital-skill complementarity as in Krusell et al. (2000), while assuming that the native unskilled and immigrant labor are perfect substitutes following the findings in Borjas et al. (2008).

2.1 The Home Economy

Supply of Native Labor The representative home household supplies $L_{n,t}$ hours of labor, consumes C_t units of the home composite basket, and invests in physical capital K_t. It maximizes the inter-temporal utility:

$$\underset{\{C_t, L_{n,t}, K_{t+1}\}}{max} E_t \left[\sum_{s=t}^{\infty} \beta^{s-t} U(C_s, L_{n,s}) \right], \tag{1}$$

where the period utility function takes the form

$$U(C_t, L_{n,t}) = \ln C_t - \chi \frac{(L_{n,t})^{1+\psi}}{1+\psi},\ \chi > 0 \tag{2}$$

subject to the constraint:

$$w_{n,t} L_{n,t} + (1 + r_t) K_t \geqslant C_t + K_{t+1}. \tag{3}$$

Parameter $1/\psi \geqslant 0$ is the Frisch elasticity of labor supply and the inter-temporal elasticity of substitution in labor supply. Following King et al. (1998), we use separable preferences and log-utility from consumption in order to obtain balanced growth path in steady state, i.e. the income and substitution effects of changes in the real wage on hours worked cancel out and generate constant steady-state labor effort. $w_{n,t}$ is the domestic wage and r_t denotes the return on capital net of depreciation, all expressed in units of the home composite good. The usual first-order conditions with respect to consumption and labor follow:

$$1 = \beta E_t \left[(1 + r_{t+1}) \frac{C_t}{C_{t+1}} \right], \tag{4}$$

$$\frac{w_{n,t}}{C_t} = \chi (L_{n,t})^{\psi}. \tag{5}$$

Production of the Home Intermediate Good

In our baseline model specification, total domestic output is defined by the production of the country specific good, $Y_{h,t}$, which is a Cobb-Douglas function of capital and a CES aggregate of immigrant and native labor:

$$Y_{h,t} = A_t (K_t)^{\alpha} \left[\gamma^{\frac{1}{\theta}} (L_{i,t})^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} (\zeta L_{n,t})^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta(1-\alpha)}{\theta-1}}, \tag{6}$$

where $L_{i,t}$ and $L_{n,t}$ denote immigrant and native labor; γ is the share of immigrant labor income in Home's total labor income; ζ is a parameter that reflects the productivity of native labor relative to that of immigrant labor in steady state; and α is the share of capital in output. Thus, the elasticity of substitution between native labor and capital is the same as that between immigrant labor and capital. The supply of immigrant labor is a decision of the foreign household and will be described later.

Competitive firms maximize profits. Thus, the rental rate of capital (plus depreciation) and the real wages are equal to the marginal products of capital, immigrant and native labor, respectively:

$$\frac{\partial Y_{h,t}}{\partial K_t} = \alpha \frac{Y_{h,t}}{K_t} = r_t + \delta, \tag{7}$$

$$\frac{\partial Y_{h,t}}{\partial L_{i,t}} = (1-\alpha)\gamma^{\frac{1}{\theta}} \left(Y_{h,t}\right)^{\frac{1-\theta\alpha}{\theta(1-\alpha)}} \left(A_t K_t^{\alpha}\right)^{\frac{\theta-1}{\theta(1-\alpha)}} \left(L_{i,t}\right)^{-\frac{1}{\theta}} = w_{i,t}, \tag{8}$$

$$\frac{\partial Y_{h,t}}{\partial L_{n,t}} = (1-\alpha)\left(1-\gamma\right)^{\frac{1}{\theta}} \left(Y_{h,t}\right)^{\frac{1-\theta\alpha}{\theta(1-\alpha)}} \left(A_t K_t^{\alpha}\right)^{\frac{\theta-1}{\theta(1-\alpha)}} \left(\zeta\right)^{\frac{\theta-1}{\theta}} \left(L_{n,t}\right)^{-\frac{1}{\theta}} = w_{n,t}. \tag{9}$$

The country-specific good is used both domestically and offshore:

$$Y_{h,t} = Y_{h1,t} + Y_{h2,t}, \tag{10}$$

where $Y_{h1,t}$ denotes the domestic use of the home-specific good, and $Y_{h2,t}$ denotes the exports of the home intermediate good to the foreign economy. Consumption and investment are composites of the home and foreign-specific goods:

$$Y_t = \left[\omega^{\frac{1}{\mu}} \left(Y_{h1,t}\right)^{\frac{\mu-1}{\mu}} + (1-\omega)^{\frac{1}{\mu}} \left(Y_{f1,t}\right)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}}, \tag{11}$$

where $Y_{f1,t}$ denotes the imports of Home from Foreign. The demand functions for the home and foreign-specific goods are:

$$Y_{h1,t} = \omega \left(p_{h,t}\right)^{-\mu} Y_t, \tag{12}$$

$$Y_{f1,t} = (1-\omega)\left(p_{f,t} Q_t\right)^{-\mu} Y_t, \tag{13}$$

where $p_{h,t}$ is the price of the home-specific good in units of the home composite good, $p_{f,t}$ is the price of the foreign good in units of the foreign composite good, and Q_t is the real exchange rate. At the aggregate level, the resource constraint takes into account not only the consumption and investment of the native population (i.e. $C_t + I_t$), but also the consumption of the immigrant labor established in Home:

$$Y_t = C_t + I_t + \frac{L_{i,t}}{\overline{L^*}} C_t^* Q_t. \tag{14}$$

We define the consumption of the immigrant labor residing in Home as the amount of foreign consumption C_t^* that is proportional with the share of immigrant labor $L_{i,t}$ in the steady state foreign labor supply $\overline{L^*}$, expressed in units of the home consumption basket. (The optimization problem of the foreign household with respect to labor supply and emigration will be described shortly.) Finally, the rule of motion for the capital stock is:

$$K_{t+1} = (1 - \delta) K_t + I_t. \tag{15}$$

2.2 The Foreign Economy

We model labor migration from Foreign to Home. To this end, we introduce cross-country labor mobility with sunk immigration costs: Foreign households have the option to work in the home economy, where wages are higher. However, labor migration from Foreign to Home requires a sunk cost per unit of emigrant labor, a cost which in equilibrium equals the present discounted value of the difference between the future stream of wages obtained as an immigrant in the home economy and the stream of wages obtained in the country of origin.

Location of Labor The foreign household supplies L_t^* units of labor every period. They can either emigrate and work in Home, $L_{i,t}$, or work domestically in Foreign, $L_{f,t}^*$:

$$L_t^* = L_{i,t} + L_{f,t}^*. \tag{16}$$

As will be discussed later, we calibrate the sunk migration cost so that the stock of emigrant labor is always lower than the total labor supply in Foreign in any period t, i.e. $0 < L_{i,t} < L_t^*$. The calibration ensures that the immigrant wage in Home is significantly higher than the wage in the country of origin, so that the incentive to emigrate from Foreign to Home exists every period. We also assume that macroeconomic shocks are small enough for this condition to hold every period. For simplicity, we do not allow for labor to flow from Home to Foreign.

Every period foreign workers have the option to emigrate to Home. The time-to-build assumption in place implies that new immigrants start working one period after arriving at the destination. They continue working in the home economy in all subsequent periods, until an exogenous return-inducing shock, which hits them with probability δ_l every period, forces them to return to the country of origin (i.e. the foreign economy). This shock occurs at the end of every time period, and may be linked to issues such as the likelihood of deportation, the impossibility of finding employment in the home economy, or the lack of adaptation to the new country of residence, etc.[8]

[8] This endogenous entry-exogenous exit formulation closely follows the model guidelines in Ghironi and Melitz (2005).

Thus, the rule of motion for the stock of immigrant labor in Home is:

$$L_{i,t} = (1 - \delta_l)(L_{i,t-1} + L_{e,t-1}), \tag{17}$$

where $L_{e,t}$ is the amount of new foreign labor that emigrates to Home every period (i.e. a flow variable), and $L_{i,t}$ is the amount of immigrant labor that is located and works in Home every period (i.e. a stock variable).

Household's Problem The representative foreign household has preferences over real consumption and labor effort.[9] It maximizes the inter-temporal utility with respect to total labor L_t^*, emigrant labor $L_{e,t}$ and capital K_{t+1}^*:

$$\underset{\{C_t^*, L_t^*, L_{e,t}, K_{t+1}^*\}}{max} E_t \left[\sum_{s=t}^{\infty} (\beta^*)^{s-t} U(C_s^*, L_s^*) \right]. \tag{18}$$

Utility takes the same form as in (2), and the budget constraint is:

$$w_t^* \left(L_t^* - L_{i,t} \right) + w_{i,t} Q_t^{-1} L_{i,t} + (1 + r_t^*) K_t^* \geqslant C_t^* + f_e w_{i,t} Q_t^{-1} L_{e,t} + K_{t+1}^*, \tag{19}$$

where w_t^* is the wage in the foreign economy and $w_t^* \left(L_t^* - L_{i,t} \right)$ denotes the total income from hours worked in Foreign. We define $w_{i,t}$ as the immigrant wage earned in Home, so that the immigrants' total labor income expressed in units of the foreign composite good is $w_{i,t} Q_t^{-1} L_{i,t}$. Emigration requires a sunk cost of f_e units of immigrant labor, equal to $f_e w_{i,t} Q_t^{-1}$ units of the foreign consumption basket. Finally, r_t^* is the return on foreign capital net of depreciation.

It is useful to re-write the constraint as:

$$w_t^* L_t^* + d_t L_{i,t} + (1 + r_t^*) K_t^* \geqslant C_t^* + f_e w_{i,t} Q_t^{-1} L_{e,t} + K_{t+1}^*, \tag{20}$$

where d_t is the difference between the immigrant wage in Home and the wage in the country of origin at time t, expressed in units of the foreign consumption basket:

$$d_t = w_{i,t} Q_t^{-1} - w_t^*. \tag{21}$$

[9] For simplicity, we do not allow for the possibility in which immigrants are integrated into the societies were they reside. Here immigrants and natives remain as separate entities when maximizing utility. We believe that our assumption is reasonable given our emphasis in business cycle implications. In addition, the fact that return migration is sizable (as explained in the introduction) and immigrants' cultural integration is limited, provides support to our premise.

Potential emigrants face a trade-off between the sunk migration cost, $f_e w_{i,t} Q_t^{-1}$, and the present discounted value of the difference between the streams of future wages at the destination, $w_{i,t} Q_t^{-1}$, and in the country of origin, w_t^*, expressed in units of the foreign composite good. Using the new budget constraint and the law of motion for the stock of immigrant labor, $L_{i,t} = (1 - \delta_l)(L_{i,t-1} + L_{e,t-1})$, the optimization with respect to new emigrant labor $L_{e,t}$ every period implies:

$$f_e w_{i,t} Q_t^{-1} = \sum_{s=t+1}^{\infty} \left[\beta^*(1-\delta_l)\right]^{s-t} E_t \left[\left(\frac{C_t^*}{C_s^*} \right) d_s \right], \tag{22}$$

which shows that, in equilibrium, the sunk emigration cost equals the present discounted gain from emigration, measured as the difference between the future expected wages at the destination and in the country of origin, expressed in units of the foreign composite good.

Production of the Foreign Intermediate Good Foreign production is a Cobb-Douglas function of non-emigrant labor, $L_{f,t}^*$, and capital, K_t^*. Following BKK, the resulting foreign-specific intermediate good, $Y_{f,t}$, can be either used domestically, $Y_{f2,t}$, or exported to the Home economy, $Y_{f1,t}$:

$$Y_{f,t} = A_t^* \left(K_t^*\right)^{\alpha^*} \left(L_{f,t}^*\right)^{1-\alpha^*}, \tag{23}$$

$$Y_{f,t} = Y_{f1,t} + Y_{f2,t}. \tag{24}$$

The foreign composite good, Y_t^*, incorporates amounts of both the foreign-specific intermediate good, $Y_{f2,t}$, and the home-specific imported good, $Y_{h2,t}$:

$$Y_t^* = \left[{\omega^*}^{\frac{1}{\mu}} \left(Y_{f2,t}\right)^{\frac{\mu-1}{\mu}} + (1-\omega^*)^{\frac{1}{\mu}} \left(Y_{h2,t}\right)^{\frac{\mu-1}{\mu}} \right]^{\frac{\mu}{\mu-1}}. \tag{25}$$

This final good composite can be consumed by the foreign resident labor (i.e. as opposed to the foreign emigrant labor), can be invested in physical capital, and can be used for investment in new emigration (i.e. to cover the sunk costs required to send new emigrant labor abroad):

$$Y_t^* = \left(1 - \frac{L_{i,t}}{\overline{L^*}}\right) C_t^* + I_t^* + f_e w_{i,t} Q_t^{-1} L_{e,t} \tag{26}$$

Finally, capital accumulation is described by:

$$K_{t+1}^* = \left(1 - \delta^*\right) K_t^* + I_t^*. \tag{27}$$

Optimality Conditions Households' optimization problem delivers a typical Euler equation and pins down the total labor effort:

$$1 = \beta E_t \left[(1 + r_{t+1}^*) \frac{C_t^*}{C_{t+1}^*} \right], \tag{28}$$

$$\frac{w_t^*}{C_t^*} = \chi^* (L_t^*)^{\psi}, \tag{29}$$

The demand functions for the home and foreign-specific goods are:

$$Y_{f2,t} = \omega^* \left(p_{f,t} \right)^{-\mu} Y_t^*, \tag{30}$$

$$Y_{h2,t} = (1 - \omega^*) \left(\frac{p_{h,t}}{Q_t} \right)^{-\mu} Y_t^*, \tag{31}$$

where $p_{f,t}$ and $\frac{p_{h,t}}{Q_t}$, respectively, are the price of the foreign-specific and home-specific good, both expressed in units of the foreign consumption basket.

In turn, the net return on capital and local wages are respectively determined by the marginal product of capital and labor:

$$r_t^* = \alpha^* \frac{Y_{f,t}}{K_t^*} - \delta^*, \tag{32}$$

$$w_t^* = (1 - \alpha^*) \frac{Y_{f,t}}{L_{f,t}^*}. \tag{33}$$

2.3 Financial Integration

We introduce financial integration by assuming that: (1) International asset markets are incomplete, and households in each country issue risk-free bonds denominated in their own currency, as in Ghironi and Melitz (2005); (2) Each type of bond provides a real return denominated in units of that country's consumption basket. (3) In order to avoid the non-stationarity of net foreign assets we introduce quadratic costs of adjustment for bond holdings, a tool which allows us to pin down the steady state and also to ensure stationarity.

The infinitely-lived representative agent maximizes the inter-temporal utility subject to the constraint:

$$\begin{aligned} & w_t L_t + \left(1 + r_t^k\right) K_t + \left(1 + r_t^b\right) B_{h,t} + \left(1 + r_t^{b*}\right) Q_t B_{f,t} + T_t \\ & \geqslant C_t + K_{t+1} + B_{h,t+1} + \frac{\pi}{2} \left(B_{h,t+1}\right)^2 + Q_t B_{f,t+1} + \frac{\pi}{2} Q_t \left(B_{f,t+1}\right)^2, \end{aligned} \tag{34}$$

where r_t^k is the rental rate of capital in Home; r_t^b and r_t^{b*} are the rates of return of the home and foreign bonds; $(1+r_t^b)B_{h,t}$ and $(1+r_t^{b*})Q_tB_{f,t}$ are the principal and interest income from holdings of the home and foreign bonds; $\frac{\pi}{2}\left(B_{h,t+1}\right)^2$ and $\frac{\pi}{2}Q_t\left(B_{f,t+1}\right)^2$ are the cost of adjusting holdings of the home and foreign bonds, respectively; T_t is is the fee rebate.[10] We add the two Euler equations for bonds to the baseline model:

$$1+\pi B_{h,t+1}=\beta(1+r_{t+1}^b)E_t\left[\frac{C_t}{C_{t+1}}\right], \tag{35}$$

$$1+\pi B_{f,t+1}=\beta(1+r_{t+1}^{b*})E_t\left[\frac{Q_{t+1}}{Q_t}\frac{C_t}{C_{t+1}}\right]. \tag{36}$$

With trade in bonds, the budget constraint of the foreign household becomes:

$$\begin{aligned} & w_t^*\left(L_t^*-L_{i,t}\right)+w_{i,t}Q_t^{-1}L_{i,t}+\left(1+r_t^{k*}\right)K_t^*+\left(1+r_t^b\right)Q_t^{-1}B_{h,t}^*+\left(1+r_t^{b*}\right)B_{f,t}^*+T_t^* \\ & \geqslant C_t^*+f_ew_{i,t}Q_t^{-1}L_{e,t}+K_{t+1}^*+Q_t^{-1}B_{h,t+1}^*+\frac{\pi}{2}Q_t^{-1}\left(B_{h,t+1}^*\right)^2+B_{f,t+1}^*+\frac{\pi}{2}\left(B_{f,t+1}^*\right)^2, \end{aligned} \tag{37}$$

and the corresponding Euler equations for bonds are:

$$1+\pi B_{h,t+1}^*=\beta^*(1+r_{t+1}^b)E_t\left[\frac{Q_t}{Q_{t+1}}\frac{C_t^*}{C_{t+1}^*}\right], \tag{38}$$

$$1+\pi B_{f,t+1}^*=\beta^*(1+r_{t+1}^{b*})E_t\left[\frac{C_t^*}{C_{t+1}^*}\right]. \tag{39}$$

The market clearing conditions for bonds are:

$$B_{h,t+1}+B_{h,t+1}^*=0, \tag{40}$$

$$B_{f,t+1}+B_{f,t+1}^*=0. \tag{41}$$

Thus, financial integration through trade in country-specific bonds adds 6 variables ($B_{h,t}$, $B_{f,t}$, $B_{h,t}^*$, $B_{f,t}^*$, r_t^b and r_t^{b*}) and 6 equations (35, 36, 38, 39, 40 and 41) to the baseline model with financial autarky.

2.4 Trade Balance and Remittances

From a theoretical standpoint, we define workers' remittances, Ξ_t, as the difference between (a) the immigrant labor income and (b) the immigrant labor's share in foreign consumption, measured as

[10] π is positive to avoid non-stationarity of the stock of liabilities, but is set close to zero (0.0025) to avoid altering the high-frequency dynamics of the model. In addition, following Bodenstein (2008), later we will pick a sufficiently high value for the trade elasticity of substitution, μ, to avoid the possibility of multiple equilibria.

the amount of foreign consumption that is proportional with the share of immigrant labor in the steady-state foreign labor supply, expressed in units of the home consumption basket:

$$\Xi_t = w_{i,t} L_{i,t} - \frac{L_{i,t}}{\overline{L^*}} C_t^* Q_t. \tag{42}$$

Thus, the current account balance, measured in units of the home composite good, is:

$$CA_t = p_{h,t} Y_{h2,t} - p_{f,t} Q_t Y_{f1,t} - \Xi_t. \tag{43}$$

Under financial autarky, the balanced current account condition, $CA_t = 0$, implies that the trade balance, $TB_t = p_{h,t} Y_{h2,t} - p_{f,t} Q_t Y_{f1,t}$, must equal the amount of remittances, Ξ_t. Here remittances act as a substitute for contingent claims in smoothing income flows in the absence of financial integration.[11]

Under financial integration, we replace the balanced current account condition ($TB_t - \Xi_t = 0$) from the model with financial autarky with the expression for the balance of international payments:

$$(p_{h,t} Y_{h2,t} - p_{f,t} Q_t Y_{f1,t}) + (r_t^b B_{h,t} + r_t^{b*} Q_t B_{f,t}) - \Xi_t = (B_{h,t+1} - B_{h,t}) + Q_t (B_{f,t+1} - B_{f,t}) \tag{44}$$

which shows that the current account balance (i.e. the trade balance plus financial investment income minus remittances) must equal the negative of the financial account balance (i.e. the change in bond holdings).

3 Alternative Model Specification

We allow for skill heterogeneity in Home by introducing two types of native labor: skilled and unskilled. We also assume that the foreign labor is relatively unskilled and can migrate to Home, where it becomes a perfect substitute for the native unskilled labor, as in Borjas et al. (2008). Capital and native skilled labor are relative complements, whereas capital and unskilled labor (i.e. immigrant and native) are relative substitutes, as in Krusell et al. (2000).

[11] It is useful to show that, using the resource constraint $Y_t = p_{h,t} Y_{h1,t} + p_{f,t} Q_t Y_{f1,t} = C_t + I_t + \frac{L_{i,t}}{L_t^*} C_t^* Q_t$, we can re-write the home GDP expressed in units of the home-specific good as $p_{h,t} Y_{h,t} = C_t + I_t + \frac{L_{i,t}}{L_t^*} C_t^* Q_t + TB_t$. Similarly, using that $Y_t^* = p_{h,t} Q_t^{-1} Y_{h2,t} + p_{f,t} Y_{f2,t} = \left(1 - \frac{L_{i,t}}{L_t^*}\right) C_t^* + I_t^* + f_e w_{i,t} Q_t^{-1} L_{e,t}$, we can write the foreign GDP expressed in units of the foreign-specific good as $p_{f,t} Y_{f,t} = \left(1 - \frac{L_{i,t}}{L_t^*}\right) C_t^* + I_t^* + f_e w_{i,t} Q_t^{-1} L_{e,t} - Q_t^{-1} TB_t$.

Native Labor Supply with Two Representative Households While the description of the foreign economy remains identical, the home economy now includes a continuum of two types of infinitely-lived households that supply units of skilled and unskilled labor, as in Lindquist (2004) and Polgreen and Silos (2006). Every period t, each of the two representative households consumes $c_{j,t}$ units the home consumption basket and supplies $l_{j,t}$ units of labor, where subscript $j \in \{s, u\}$ denotes skilled and unskilled labor, respectively. Thus, the planner maximizes the weighted sum of utilities for the two representative households:

$$\underset{\{c_{s,t},l_{s,t},c_{u,t},l_{u,t},K_{t+1}\}}{max} \sum_{t=0}^{\infty} \beta^{s-t} \left\{ \phi s U\left(c_{s,t}, l_{s,t}\right) + (1-\phi)(1-s) U\left(c_{u,t}, l_{u,t}\right) \right\}, \tag{45}$$

where utility takes the log-CRRA form as in (2), and the constraint is:

$$w_{s,t} L_{s,t} + w_{u,t} L_{u,t} + (1+r_t) K_t \geqslant C_{s,t} + C_{u,t} + K_{t+1}, \tag{46}$$

where s denotes the fraction of skilled households and $1-s$ is the fraction of unskilled households in the total population; ϕ and $1-\phi$ are the weights of the utility of skilled and unskilled households, respectively, in the objective function of the planner. $L_{s,t} = s l_{s,t}$ and $L_{u,t} = (1-s) l_{u,t}$ are the aggregate amounts of skilled and unskilled labor which firms hire at the equilibrium wages $w_{s,t}$ and $w_{u,t}$, respectively. $C_{s,t} = s c_{s,t}$ and $C_{u,t} = (1-s) c_{u,t}$ are the aggregate consumptions of the skilled and unskilled households.

The maximization problem for the two representative agents generates the usual first-order conditions:

$$\frac{\phi}{c_{s,t}} = \frac{1-\phi}{c_{u,t}} = \zeta_t, \tag{47}$$

$$1 = \beta E_t \left[(1+r^*_{t+1}) \frac{\zeta_{t+1}}{\zeta_t} \right], \tag{48}$$

$$\frac{w_{s,t}}{c_{s,t}} = \frac{\chi_s}{s} \left(l_{s,t}\right)^{\psi_s}, \tag{49}$$

$$\frac{w_{u,t}}{c_{u,t}} = \frac{\chi_u}{(1-s)} \left(l_{u,t}\right)^{\psi_u}. \tag{50}$$

where $\chi_j,\ \psi_j,\ j \epsilon \{s, u\}$ represent weights in the utility function and the inverse of the Frisch elasticity of skilled and unskilled labor supply.

Production of the Home Intermediate Good In the alternative specification, production function is a nested CES aggregate:

$$Y_{h,t} = A_t \left\{ \gamma^{\frac{1}{\theta}} \left(\Upsilon_{1,t}\right)^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} \left(\Upsilon_{2,t}\right)^{\frac{\theta-1}{\theta}} \right\}^{\frac{\theta}{\theta-1}}, \tag{51}$$

of the following components:

$$\Upsilon_{1,t} = L_{i,t} + L_{u,t}, \tag{52}$$

$$\Upsilon_{2,t} = \left[\lambda^{\frac{1}{\eta}} \left(K_t\right)^{\frac{\eta-1}{\eta}} + (1-\lambda)^{\frac{1}{\eta}} \left(\zeta L_{s,t}\right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{53}$$

where $\Upsilon_{1,t}$ is a function in which the unskilled immigrant and native labor enter as perfect substitutes; $\Upsilon_{2,t}$ is a CES function of capital and skilled native labor; γ is the fraction of unskilled labor in output; $\lambda/(1-\gamma)$ is the share of capital in output. Finally, $\theta > 0$ governs the elasticity of substitution between skilled and unskilled labor, which is the same as the elasticity of substitution between capital and unskilled labor; $\eta > 0$ is the elasticity of substitution between capital and skilled labor. Following Krusell et al. (2000), we restrict $\theta > \eta$ under the assumption of capital-skill complementarity.

The profit maximization problem of firms generates the following optimality conditions:

$$\frac{\partial Y_{h,t}}{\partial K_t} = \xi_1 \left(A_t\right)^{\frac{\theta-1}{\theta}} \left(Y_{h,t}\right)^{\frac{1}{\theta}} \left(\Upsilon_{2,t}\right)^{\frac{\theta-\eta}{\eta\theta}} \left(K_t\right)^{-\frac{1}{\eta}} = r_t + \delta, \tag{54}$$

$$\frac{\partial Y_{h,t}}{\partial L_{i,t}} = \frac{\partial Y_{h,t}}{\partial L_{u,t}} = \left(A_t\right)^{\frac{\theta-1}{\theta}} \left(\gamma \frac{Y_{h,t}}{L_{i,t} + L_{u,t}} \right)^{\frac{1}{\theta}} = w_{u,t}, \tag{55}$$

$$\frac{\partial Y_{h,t}}{\partial L_{s,t}} = \xi_2 \left(A_t\right)^{\frac{\theta-1}{\theta}} \left(Y_{h,t}\right)^{\frac{1}{\theta}} \left(\Upsilon_{2,t}\right)^{\frac{\theta-\eta}{\eta\theta}} \left(\zeta\right)^{\frac{\eta-1}{\eta}} \left(L_{s,t}\right)^{-\frac{1}{\eta}} = w_{s,t}, \tag{56}$$

where $\xi_1 = (1-\gamma)^{\frac{1}{\theta}} \lambda^{\frac{1}{\eta}}$ and $\xi_2 = (1-\gamma)^{\frac{1}{\theta}} (1-\lambda)^{\frac{1}{\eta}}$.

The rest of the economy is described by the equations of the baseline specification model outlined in the previous section. The only exception is the resource constraint in the home economy, which becomes:

$$Y_t = C_{s,t} + C_{u,t} + I_t + \frac{L_{i,t}}{\overline{L^*}} C_t^* Q_t \tag{57}$$

4 Model Parameterization

We use the standard quarterly calibration from BKK: $\mu = 1.5$ is the elasticity of substitution between the home and foreign-specific goods in the composite basket of both countries; $\alpha = 0.33$ is the share of capital in output; $\delta = 0.025$ is the depreciation rate of the capital stock; $\omega = \omega^* = 0.85$ reflects the degree of home bias in each economy; $\psi = \psi^* = 0.33$ is the inverse of the elasticity of labor supply. In addition, we set the quarterly return rate for the established immigrant labor $\delta_l = 0.07$, which reflects the findings in Reyes (1997) that approximately 50 percent of the undocumented Mexican immigrants return to their country of origin within two years after their arrival in the U.S. (which corresponds to a quarterly exit rate of 0.0635), and that 65 percent of them return within four years after their arrival (i.e. quarterly exit rate of 0.0830).[12]

Baseline Model Calibration For the baseline model with symmetric elasticity of substitution between capital and each type of labor (native and immigrant) and international trade in bonds, the calibration parameters are described in Table 4.1. We are left with four parameters to calibrate: γ, θ, ζ and f_e. To this end, we choose four empirical moments that the model should match within reasonable limits in steady state: (1) The share of Mexico's labor force residing in the U.S. is 10 percent (Hanson, 2006); (2) Remittances represented the equivalent of 2.5 percent of Mexico's GDP in 2004 (Bank of Mexico, 2004)[13]; (3) The ratio between the average wages of U.S. native and Mexican immigrant labor is 2.1[14]; (4) The U.S.-Mexico ratio of GDP per capita expressed in terms of purchasing power parity is approximately 3.3, according to IMF's World Economic Outlook data. To this end, we set $\gamma = 0.08$ (the share of immigrant labor in total labor income), $\zeta = 6.2$ (the relative productivity of native vs. immigrant labor), $\theta = 1.30$ (the elasticity of substitution between native and immigrant labor[15]), and $f_e = 4.7$ (the sunk cost of labor migration).[16] Given the key role of the degree of complementarity between native and immigrant labor, we perform robustness checks with low and high substitutability between immigrant and native workers, $\theta = 0.5$ and $\theta = 2.5$.

[12] Using the information that 35 percent of the undocumented Mexican immigrants are still in the U.S. four years after their arrival, we compute the quarterly exit rate as $(1 - \delta_{l,4y})^{16} = 0.35$.

[13] The model generates a more conservative estimate (1 percent) compared to the 2.5 percent recorded in 2004 (Bank of Mexico, 2004), as remittances to Mexico more than doubled between 1997 and 2004 (Hernández-Coss, 2005).

[14] For the immigrant wage we use the average hourly wages for immigrant Mexican males in the U.S. (28 to 32 years of age, with 9 to 11 years of schooling completed) provided by Hanson (2006); we also compute the weighted average hourly wage of the U.S. native labor using data from the U.S. Census Bureau (2007).

[15] We take the estimate of the elasticity of substitution between skilled and unskilled labor (1.26) under the symmetric model setup in Krusell et al. (2000) as a benchmark for the value of θ in our baseline model.

[16] Relative to these targets, the baseline model with trade in bonds generates: (1) the steady state share of immigrant labor in Foreign's total is $\frac{L_i}{L^*} = 0.1$; (2) the ratio between the native and immigrant labor is $\frac{w_n}{w_i} = 1.63$; (3) remittances represent the equivalent of 1.5 percent of the foreign GDP; (4) the GDP ratio between Home and Foreign is 2.3.

Table 4.1 Baseline model calibration

$\gamma = 0.08$	Share of immigrant labor in total labor income
$\zeta = 6.2$	Relative productivity of native vs. immigrant labor
$\theta = 1.3$	Elasticity of substitution between native and immigrant labor
$f_e = 4.7$	Sunk cost of labor migration

Alternative Model Calibration For the alternative model with two types of native labor in Home (skilled and unskilled), in which native unskilled and immigrant labor are perfect substitutes, the calibration is summarized in Table 4.2. We define the pool of native unskilled labor to include the adult population without a high school degree; using data from the U.S. Census Bureau, we set the share of unskilled labor at $(1 - s) = 0.08$.

We choose values for parameters $\widetilde{\gamma}$, $\widetilde{\theta}$, $\widetilde{\eta}$, $\widetilde{\zeta}$ and $\widetilde{f}_e$ so that the alternative model with trade in bonds comes reasonably close to replicating a set of five empirical moments from the U.S. and Mexico in steady state: (1) The share of Mexico's labor force residing in the U.S. is $\frac{L_i}{L^*} = 0.1$ (Hanson, 2006). (2) Remittances represent the equivalent of 2.5 percent of Mexico's GDP (compared to which the model generates the more conservative estimate of 1.5 percent); (3) The ratio between the wages of the native skilled and unskilled labor in the U.S. is 2.2 (and $\frac{w_s}{w_u} = 2.2$ in the model).[17] (4) Controlling for age and educational attainment, the ratio between the hourly wage of Mexican immigrants in the U.S. and the corresponding wage in Mexico expressed in terms of purchasing power parity is 3.64 (compared to which the model generates $\frac{w_i}{Qw^*} = 1.9$, enough to maintain the labor migration incentive);[18] (5) The U.S.-Mexico share of GDP per capita expressed in purchasing power parity terms is approximately 3.3, according to IMF's World Economic Outlook data (vs. 3.5 in the model). To this end, we choose $\widetilde{\gamma} = 0.1$, $\widetilde{\theta} = 1.30$, $\widetilde{\eta} = 1.07$, $\widetilde{\zeta} = 3.1$ and $\widetilde{f}_e = 5.4$. As already discussed, we base the assumption that $\widetilde{\theta} > \widetilde{\eta}$ on the findings of Krusell et al. (2000) that skilled labor and capital are relative complements, whereas skilled and unskilled labor are relative substitutes.[19]

[17] We take the weighted average of hourly earnings for the U.S. skilled labor (i.e. high school degree or more), as well as for the U.S. unskilled labor (i.e. without a high school degree) using data provided by the U.S. Census Bureau (2006, 2007). We divide the sample into four groups: (a) no high school degree; (b) completed high school; (c) some college or associate's degree; and (d) bachelor's degree or higher. Then we take the average of the respective earnings weighted by their share in the total population.

[18] We build this ratio using wage data provided in Hanson (2006) for (1) the hourly wage of the recent Mexican immigrants in the U.S., and (2) the hourly wage of those of similar age and educational attainement that reside in Mexico (i.e. males between 28-32 years of age with 9 to 11 years of schooling), adjusted for purchasing power parity. The wage ratios for other age and educational attainment groups are similar (see Hanson, 2006).

[19] We take the estimates for the elasticity of substitution between skilled and unskilled labor (1.67) and that for capital and skilled labor (0.67) from the specification with capital-skill complementarity in Krusell et al. (2000) as benchmarks for the values of $\widetilde{\theta}$ and $\widetilde{\eta}$ in our alternative model with skill heterogeneity.

Finally, we set the weight on the utility of representative skilled household $\phi = 0.688$, so that the consumption ratio for the home representative skilled and unskilled households matches the corresponding wage ratio, $\frac{c_s}{c_u} = \frac{w_s}{w_u} = 2.2$. We base our assumption on the findings of Krueger and Perri (2007) and Attanasio and Davis (1996) that differences in the consumption of population groups with different levels of educational attainment (e.g. skilled and unskilled) closely reflect the income differences between the respective groups.

Table 4.2 Alternative model calibration

$s = 0.92$	Share of Home skilled in total households
$\widetilde{\gamma} = 0.1$	Share of native + immigrant unskilled in GDP
$\widetilde{\lambda} = \alpha/(1-\widetilde{\gamma})$	Share of capital in GDP
$\widetilde{\theta} = 1.30$	Elasticity of substitution, capital vs. unskilled labor
$\widetilde{\eta} = 1.07$	Elasticity of substitution, capital vs. skilled labor
$\widetilde{\zeta} = 3.1$	Relative productivity of native vs. immigrant labor
$\widetilde{f_e} = 5.4$	Sunk cost of labor migration
$\phi = 0.688$	Weight on the utility of skilled labor

5 Model Results

5.1 Impulse Response Analysis

To illustrate the workings of the model, we consider the response paths of key variables (percent deviations from steady state) to unanticipated productivity innovations in the home economy for both the baseline and the alternative model (Figures 4-7). We assume that productivity follows a first-order autoregressive process that persists at the rate of 0.95 per quarter. We report the responses of the key variables, measured as the percent deviation from steady state in each quarter after the initial shock, to transitory changes in productivity.

Baseline Model with Financial Autarky As shown in Figure 4, following a transitory one percent increase in productivity in Home, the increase in the immigrant wage premium (d) encourages the entry of new immigrants (L_e), entry which is however dampened by the sunk emigration cost. The immigrant wage premium and immigrant entry persist above their steady-state levels after the initial shock, so that the stock of established immigrant labor (L_i) adjusts gradually over time. The stock of immigrant labor increases by more in the economy with the relatively low sunk immigration cost ($f_e = 2.0$, dotted line). In contrast, immigrant labor becomes relatively more scarce during booms in Home in the scenario with the higher sunk cost ($f_e = 4.7$, continuos line), thus causing the immigrant wage to increase by more. Therefore, as foreign households attempt to smooth consumption across members residing in both countries, remittances increase by more in the model with the higher sunk immigration cost. The results indicate that a more restrictive immigration policy and higher immigration barriers enhance the volatility of the immigrant wage and remittances.

In the foreign economy, output declines by less in the scenario with the higher sunk cost of immigration. The result is due to the larger amount of resident labor that is forced to remain in Foreign, which in turn dampens the wage increase and enhances the accumulation of physical capital in Foreign.

Baseline Model with High Complementarity Due to the complementarity between capital and immigrant labor, the higher sunk cost of immigration dampens investment and output growth in Home relative to the scenario with the relatively low sunk cost. Although small in the baseline calibration, the effect increases with the complementarity between the native and immigrant labor. The impulse responses in Figure 5 show that a higher complementarity between the two types of labor ($\theta = 0.5$) relative to the baseline calibration ($\theta = 1.5$) makes the barriers to immigration more harmful for the home economy. The higher complementarity dampens the increase in the demand for native labor and also capital accumulation in Home, which causes a relatively lower increase in home output, native wage and consumption than in the baseline calibration case.[20]

Baseline Model with Financial Integration The response paths are similar for the baseline model with international trade in bonds (Figure 6). In this case, one-period risk-free bonds constitute an additional instrument - other than remittances - that foreign households can use to smooth their inter-temporal consumption path. That is, from a risk sharing perspective, foreign households have the option to lend offshore as an alternative to investing in emigration. Following a transitory one percent increase in home productivity, financial integration allows capital to migrate towards the economy with a relatively high rate of return (Home), whose trade balance becomes negative. In turn, Home

[20] The case of high immigration barriers and high complementarity between the native and immigrant labor delivers a paradoxical behavior of the real exchange rate and of the terms of trade. Although the scenario with high barriers to immigration generates a relatively more scarce home output and more abundant foreign output (becase a larger share of foreign labor remains in the country of origin, as explained above) relative to the scenario with low immigration costs, higher remittances improve the purchasing power of residents in Foreign, that have a home bias towards the foreign good. In turn, this leads to an increase in the relative price of foreign output, so that the real exchange rate Q increases by more (i.e. the real exchange rate of Home depreciates by more) than in the case with low sunk cost.

becomes relatively more capital intensive, which improves the productivity of labor and encourages more immigration over the business cycle (i.e. the entry and the stock of immigrant labor increase by more for $f_e = 2.0$, dotted line) relative to the case with financial autarky (depicted in Figure 4).

Alternative Model with Financial Integration The alternative model with financial integration generates results that suggest a similar link between immigration flows and remittances. Following a one percent transitory increase in home productivity, the adjustment in the stock of established immigrant labor is faster and larger in the economy with the lower immigration cost. In turn, the greater flexibility of the supply of immigrant labor during booms leads to a lower increase in the immigrant wage and the amount of remittances.

In the presence of skill heterogeneity in Home, the results highlight the asymmetric effect of unskilled immigration on the native labor. During booms, the relatively quick adjustment in the stock of immigrant labor in the scenario with a lower immigration cost dampens the increase in the native unskilled wage, as the native unskilled and immigrant unskilled labor are perfect substitutes. Conversely, during recessions in Home, the sharper decline in the stock of immigrant labor allows for a smaller decline in the wage of native unskilled labor. Thus, a more flexible immigration policy reduces the volatility of wages for the native labor types that are close substitutes with immigrant labor.

5.2 Theoretical Moments

In order to test the empirical relevance of our model, we compute the second moments of migration flows and remittances generated by the baseline and alternative models with trade in bonds, and contrast them to the corresponding empirical moments. We show that both models succeed qualitatively in replicating the key cyclical characteristics of labor migration and remittances which we document using data for the U.S. and Mexico.

As in the standard international real business cycles literature, we assume that productivity follows an autoregressive bivariate process:

$$\begin{bmatrix} \log A_t \\ \log A_t^* \end{bmatrix} = \begin{bmatrix} \rho_A & \rho_{AA^*} \\ \rho_{A^*A} & \rho_{A^*} \end{bmatrix} \begin{bmatrix} \log A_{t-1} \\ \log A_{t-1}^* \end{bmatrix} + \begin{bmatrix} \xi_t \\ \xi_t^* \end{bmatrix}, \tag{58}$$

Following Heathcote and Perri (2002), we estimate its parameters using the seemingly unrelated regression (SURE) method.[21] To this end, we use the Solow residual as a measure for aggregate productivity

[21] Tipically, international real business cycle models are solved assuming that total factor productivity (TFP) processes

in the U.S. and Mexico, computed from quarterly data on GDP, the capital stock and employment (measured as the number of workers) for the interval between 1987:1 and 2003:2.[22]

Our estimates for the transition matrix of the productivity process $\mathbf{A}$ and for the variance-covariance matrix $\mathbf{\Sigma}$ are given below (with standard errors in parentheses):

$$\mathbf{A} = \begin{bmatrix} \underset{(0.014)}{0.996} & \underset{(0.015)}{0.003} \\ \underset{(0.040)}{0.049} & \underset{(0.040)}{0.951} \end{bmatrix}, \Sigma = \begin{bmatrix} 0.0050939^2 & 0.00001898 \\ 0.00001898 & 0.0139570^2 \end{bmatrix}. \tag{59}$$

We find that (1) productivity in Mexico shows a lower persistence than in the U.S.; (2) the spillover estimates are not statistically different from zero (although the point estimate of the U.S.-to-Mexico spillover is positive and notably larger than that for the Mexico-to-U.S. one); thus, we set them to be zero in the model calibration; (3) the productivity process is notably more volatile in Mexico than in the U.S.; (4) the correlation between the productivity innovations in the U.S. and Mexico (0.27) is only slightly higher than the one provided by Backus, Kehoe, and Kydland (1992) for the U.S. and Europe (0.26), but lower than the one they find for the U.S. and Canada (0.43).

In Table 5.1 (Panel A) we report the empirical correlations of border apprehensions (which we use as a proxy for the entry of immigrants) and remittances with (1) the ratio of real GDP in the U.S. and Mexico adjusted for the real exchange rate, (2) real GDP in the U.S., and (3) real GDP in Mexico. In the data, immigrant entry and remittances are pro-cyclical with the U.S.-Mexico GDP ratio, pro-cyclical with the U.S. GDP, and counter-cyclical with Mexico's GDP.

Both the baseline and alternative models replicate qualitatively the cyclicality of migration flows and remittances observable from the data (Table 5.1, Panels B and C). The models generate labor migration flows (L_e) that are pro-cyclical with the GDP ratio between the two economies, pro-cyclical with the GDP of the destination economy (Home), and counter-cyclical with the GDP of the economy where the immigrant labor originates (Foreign). The models also replicate the cyclical behavior of the "altruistic" remittance flows from the U.S. to Mexico. In both models, the remittance flows are procyclical with the GDP ratio between Home and Foreign, pro-cyclical with the GDP of the economy where the immigrant labor earns its income (Home), and counter-cyclical with the GDP of the economy that receives remittances (Foreign).[23]

are stationarity (See Rabanal et al., 2008). For model comparison we follow these guidelines.

[22] For Mexico, we use the Solow residual data in Aguiar and Gopinath (2007).

[23] Our measure of remittances "inherits" one of the risk-sharing anomalies of the IRBC framework. Namely, following a productivity increase in Home, the real exchange rate depreciates. Due to the increase in the foreign price index, the immigrant labor income and remittances decrease when measured in units of the foreign consumption basket, although

Table 5.1 Correlations of labor migration flows and remittances[24]

(A) Empirical moments			
	$\frac{GDP_{US}}{Q*GDP_{Mex}}$	GDP_{US}	GDP_{Mex}
Immigrant entry	0.28	0.28	−0.16
Remittances	0.50	0.49	−0.35
(B) Baseline model with bonds			
	$\frac{GDP_h}{Q*GDP_f}$	GDP_h	GDP_f
Immigrant entry	0.98	0.22	−0.87
Remittances	0.39	0.88	−0.05
(C) Alternative model with bonds			
	$\frac{GDP_h}{Q*GDP_f}$	GDP_h	GDP_f
Immigrant entry	0.98	0.03	−0.96
Remittances	0.54	0.87	−0.19

International real business cycle (IRBC) models have difficulty in accounting for a set of empirical patterns visible in cross-country data (Heathcote and Perri, 2002), and our model of immigration and remittances is no exception. In particular, the empirical cross-country correlations for consumption are lower than for output, whereas the IRBC framework generates consumption correlations that are notably higher than the corresponding output correlations (Table 5.2). In fact, adding labor migration flows and remittances as an extra insurance mechanism enhances the correlation of consumption in the baseline and alternative models with labor migration relative to the model with no labor mobility. This result highlights the insurance role of labor migration and remittances in generating cross-country consumption smoothing.

they increase when measured in units of the home basket. As a result, the correlation of remittances measured in units of the home basket (as in Table 5.1) with the foreign GDP is negative (as in the data), whereas the correlation of remittances measured in units of the foreign basket with foreign GDP is positive (contrary to the data).

[24] We report the empirical correlations of series in natural logs and HP-filtered. For each economy, the theoretical GDP is measured in units of the consumption basket, $GDP_h = p_h y_h$ and $GDP_f = p_f y_f$. Theoretical remittances are measured in units of the home consumption basket.

Table 5.2 Theoretical and Empirical Moments of Macroeconomic Variables

	Data	No migration	Labor migration	
Correlations:	(U.S.-Mexico)	(BKK94)	Baseline	Alternative
GDP_h, GDP_f	0.16	0.28	0.27	0.26
C, C^*	-0.04	0.43	0.47	0.61

6 Welfare Implications

6.1 Tightening the Border

In this section we analyze the welfare effects of a sudden and permanent increase in the sunk immigration cost in the baseline setup (from $f_e = 4$ to $f_e = 5$) that could be related to an increase in border enforcement. The transition paths to a new steady state in Figure 8 show that the declining availability of immigrant labor makes capital less productive and therefore dampens investment, which leads to a decline in the capital stock. Due to the higher entry barriers, firms initially substitute the immigrant for native labor. Despite the lack of increase in native wages, the inter-temporal optimization determines native households to commit more hours in the present, when wages and the return on capital (interest rate) are significantly higher, than in the future. However, as the rate of capital depletion decreases, the incentive for inter-temporal substitution weakens and labor supply increases again, however without exceeding the original steady state.

While the impulse response analysis previously done illustrated the workings of the model, the quantitative welfare analysis needs to take into account that permanent changes in border enforcement have not only cyclical but also permanent effects on the balanced-growth path. We solve the model using a second-order approximation to the policy function around the steady state and consider both temporary stochastic, and permanent deterministic shocks which are perfectly anticipated by economic agents.[25] We study the welfare effect of the permanent increase in the sunk cost over a wide range of values for the elasticity of substitution between immigrant and native labor in the baseline model, i.e. $\theta \in [0.5, 2.5]$.

We define welfare (V_t) as the present discounted value of the stream of expected utility. Thus, we compare the welfare of home households in the initial steady-state (V_0) with their welfare as of the period t' when the increase in the sunk cost of immigration takes place. The welfare level as of

[25] We add the future values of the deterministic balanced growth path to the list of state variables (see Juillard, 2006, for details).

the period t' takes into account the discounted stream of utilities that the representative household achieves at all periods during the transition path to the new steady state after the permanent increase in the sunk cost of emigration:

$$V_{t'} = E_{t'} \sum_{v=t'}^{\infty} \beta^v U \left(\overline{C}_v, \overline{L}_v \right). \tag{60}$$

Next we define the constants $\overline{C_0}$ and $\overline{C_1}$ to denote the permanent streams of aggregate consumption that would generate the welfare values V_0 and $V_{t'}$: $V_0 = \frac{1}{1-\beta} \ln(\overline{C_0}), V_{t'} = \frac{1}{1-\beta} \ln(\overline{C_1})$, and compute the consumption-equivalent welfare gain ($\lambda > 0$) or loss ($\lambda < 0$) that corresponds to the permanent increase of the barriers to immigration: $\lambda = \left(\frac{\overline{C_1}}{\overline{C_0}} - 1 \right) \times 100$. The results in Figure 9 show that the home economy experiences a consumption-equivalent welfare loss for the entire range of values $\theta \in [0.5, 2.5]$ of the elasticity of substitution between immigrant and native labor. In particular, the loss increases with the degree of complementarity between capital and immigrant labor.

6.2 Alternative Model: Gradual Increase in the Share of Native Skilled

This section explores the impact of immigration barriers on welfare in the presence of a gradual and permanent increase in the share of skilled native labor in Home. In the alternative model with two types of native labor (skilled and unskilled), we introduce a deterministic growth path in the share of skilled native labor in the total population, allowing it to increase from 0.90 to 0.97 over 20 years. In our model parameterization this number accounts for the share of natives without a high school diploma.

We assume that households take into account with perfect certainty the expected growth path of the share of skilled labor when solving their inter-temporal optimization problem, and compute the consumption-equivalent welfare gain (or loss) associated with the increasing share of skilled labor relative to the initial steady state. To this end, we compare the home welfare in the initial steady state:

$$V_0 = \frac{1}{1-\beta} \left\{ \phi s U \left(\overline{c_s}, \overline{l_s} \right) + (1-\phi)(1-s) U \left(\overline{c_u}, \overline{l_u} \right) \right\} \tag{61}$$

with home welfare as of period t' when households learn about the growth path of the share of skilled labor:

$$V_{t'} = E_{t'} \sum_{v=t'}^{\infty} \beta^v \left\{ \phi s_v U \left(c_{s,v}, l_{s,v} \right) + (1-\phi)(1-s_v) U \left(c_{u,v}, l_{u,v} \right) \right\}. \tag{62}$$

The results in Figure 10 show that an economy is likely to experience a welfare loss from maintaining immigration barriers for the unskilled when its share of skilled native labor increases over time. The welfare loss increases with the magnitude of barriers to immigration and with the degree of complementarity between capital and immigrant labor. Although the immigrant and native unskilled labor are perfect substitutes, the welfare loss suffered by the home unskilled households is offset by the larger accumulation of capital which enhances the productivity of the home skilled labor in the presence of immigration. In particular, for very low values of θ (for which it is particularly difficult to substitute away from unskilled labor), we obtain the paradoxical result that the economy becomes worse off as it limits the inflow of unskilled immigrants, despite the accumulation of human capital.

Using the alternative model with two types of native labor (skilled and unskilled), we repeat the welfare analysis with the share of skilled native labor increasing deterministically from a lower initial level (i.e. from 0.60 to 0.67 over 20 years). As shown in Figure 11, in contrast to the previous exercise, we find that the welfare gain increases with border enforcement. When a larger fraction of the native labor becomes exposed to competition from the immigrant labor, the welfare loss of the home unskilled offsets the welfare gains of the home skilled labor that benefits from the greater accumulation of capital. This leads to an overall welfare loss for the home economy.

To sum up, the results indicate that stricter border enforcement reduces welfare for economies in which unskilled labor is becoming relatively scarce, particularly when it is hard to substitute unskilled for skilled labor. In contrast, economies with relatively abundant amounts of unskilled labor experience welfare losses from lowering the barriers to immigration, particularly when it is easy to substitute unskilled for skilled labor.

7 Conclusion

This paper attempts to bridge the gap between modern international macroeconomics and immigration theory. In contrast to the former, we allow for labor mobility across countries; in contrast to the latter, we consider the business cycle dynamics and account for the transmission of aggregate stochastic shocks across countries in the presence of labor migration. In this context, we study the role of labor migration in explaining the behavior of remittances across the economies involved. Thus, we consider the insurance role of remittances as a substitute for contingent claims in smoothing the consumption of households in the country of origin. We also examine the effect of immigration policy on the volatility of labor migration and remittance flows.

In the baseline model, we introduce labor migration flows within a parsimonious standard two-country model of international real business cycles. The incentive to emigrate depends on the difference between the expected future earnings at the destination and in the country of origin, as well as on the perceived sunk costs of labor migration which reflects the immigration policy at the destination. In an alternative specification, we extend the baseline model to allow for skill heterogeneity among the native labor in the destination economy in the presence of capital-skill complementarity.

The impulse responses and theoretical moments show that both model specifications match qualitatively the cyclical dynamics of labor migration and remittances that we document using data for the U.S. and Mexico. Restricting immigration dampens the adjustment in the stock of established immigrant labor during both expansions and recessions in the destination economy, and thus enhances the volatility of immigrant labor income and remittances. The welfare analysis also shows that the overall gain from unskilled immigration for the destination economy increases with the degree of complementarity between the skilled and unskilled labor, as well as with the share of the skilled in total native labor.

International real business cycle models have difficulty in reconciling their risk sharing implications with the empirical evidence. Recent contributions properly address these concerns while extending the standard setup (see for example, Boz et al, 2008 Corsetti et al, 2008, Rabanal et al, 2008, among others). Accounting for these contributions can improve the match between our model's implications and the data. Finally, although we acknowledge the importance of the cross-country migration of skilled labor, we do not model it in this paper. Future research should explore these issues.

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A Appendix

A.1 Baseline Model of Labor Migration with Financial Autarky, Steady State

The foreign economy In steady state, $A^* = 1$. With the classic Cobb-Douglas production function $Y_f = (K^*)^{\alpha^*} \left(L_f^*\right)^{1-\alpha^*}$, it is straightforward to solve for the steady state in the foreign economy:

$$r^* = \frac{1-\beta^*}{\beta^*}, \tag{63}$$

$$\frac{Y_f}{K^*} = \frac{r^* + \delta^*}{\alpha^*}, \tag{64}$$

$$K^* = \left(\frac{Y_f}{K^*}\right)^{\frac{1}{\alpha^*-1}} L_f^*, \tag{65}$$

$$Y_f = \left(\frac{Y_f}{K^*}\right) K^* = \left(\frac{r^* + \delta^*}{\alpha^*}\right)^{\frac{\alpha^*}{\alpha^*-1}} L_f^*, \tag{66}$$

$$w^* = (1-\alpha^*)\frac{Y_f}{L_f^*} = (1-\alpha^*)\left(\frac{r^* + \delta^*}{\alpha^*}\right)^{\frac{\alpha^*}{\alpha^*-1}}, \tag{67}$$

$$I^* = \delta^* K^*. \tag{68}$$

The home economy For the home economy, we solve the steady state numerically using a system of eight non-linear equations (69, 70, 74-79) in eight unknowns (Y_h, K, L_i, Y_{h2}, Y_{f1}, p_h, p_f, Q), as described below.

Equations 1-2: With $A = 1$, output and the marginal product of capital are:

$$Y_h = K^\alpha \left[\gamma^{\frac{1}{\theta}} \left(L_i\right)^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} \left(\zeta L_n\right)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}(1-\alpha)}, \tag{69}$$

$$\frac{\partial Y_h}{\partial K} = \alpha \frac{Y_h}{K} = r + \delta. \tag{70}$$

Equation 3: Using the steady-state expression for the present discounted value of the future gains from immigration, $f_e Q^{-1} w_i = \frac{\beta^*(1-\delta_l)}{1-\beta^*(1-\delta_l)} d$, we obtain:

$$Q^{-1} w_i = w^* + d, \tag{71}$$

$$= w^* + \frac{1-\beta^*(1-\delta_l)}{\beta^*(1-\delta_l)} f_e Q^{-1} w_i. \tag{72}$$

Thus, the steady state ratio of the immigrant wage and the wage in in the country of origin expressed in units of the same consumption basket is:

$$\Theta \equiv \frac{w_i}{w^* Q} = \left[1 - \frac{1-\beta^*(1-\delta_l)}{\beta^*(1-\delta_l)} f_e\right]^{-1}, \tag{73}$$

where $\Theta = 1$ when $f_e = 0$, i.e. with zero sunk cost of labor migration, the wage ratio is equal to unit.

Next, we insert $w_i = \frac{\partial Y_h}{\partial L_i}$ and $w^* = \frac{\partial Y_f}{\partial L^*}$ into the previous equation to obtain:

$$\underbrace{(1-\alpha)\,(Y_h)^{\frac{1-\theta\alpha}{\theta(1-\alpha)}}\, K^{\frac{\alpha(\theta-1)}{\theta(1-\alpha)}} \left(\frac{\gamma}{L_{i,t}}\right)^{\frac{1}{\theta}}}_{w_i} = \Theta \underbrace{(1-\alpha^*)\left(\frac{r^*+\delta^*}{\alpha^*}\right)^{\frac{\alpha^*}{\alpha^*-1}} Q}_{w^*}. \tag{74}$$

Equation 4: The balanced current account condition implies:

$$p_h Y_{h2} = p_f Q Y_{f1} + L_i w_i - \frac{L_i}{L^*} C^* Q, \tag{75}$$

where w_i is given above, and:

$$\begin{aligned}
Y^* &= \left[\omega^{*\frac{1}{\mu}}\,(Y_f - Y_{f1})^{\frac{\mu-1}{\mu}} + (1-\omega^*)^{\frac{1}{\mu}}\,(Y_{h1})^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}}, \\
Y_f &= \left(\frac{r^*+\delta^*}{\alpha^*}\right)^{\frac{\alpha^*}{\alpha^*-1}} (L^* - L_i)\,, \\
L_e &= \frac{\delta_l}{1-\delta_l} L_i.
\end{aligned}$$

Equations 5-6: We write the demand ratios for the two intermediate goods in each economy as:

$$\frac{Y_h - Y_{h2}}{Y_{f1}} = \frac{\omega}{1-\omega}\left(\frac{p_h}{p_f Q}\right)^{-\mu}, \tag{76}$$

$$\frac{Y_f - Y_{f1}}{Y_{h2}} = \frac{\omega^*}{1-\omega^*}\left(\frac{p_f Q}{p_h}\right)^{-\mu^*}. \tag{77}$$

Equations 7-8: The price indexes for the composite good of each country are:

$$1 = \omega\,(p_h)^{1-\mu} + (1-\omega)(p_f Q)^{1-\mu}, \tag{78}$$

$$1 = \omega^*\,(p_f)^{1-\mu^*} + (1-\omega^*)\left(\frac{p_h}{Q}\right)^{1-\mu^*}. \tag{79}$$

A.2 Alternative Model of Labor Migration with Financial Autarky, Steady State

The presence of skill heterogeneity among native labor (skilled and unskilled) in Home requires several modifications in the calculation of steady state relative to the baseline model. In the system of eight equations in eight unknowns described above, L_n becomes L_s (i.e. native skilled labor). One must also distinguish between individual vs. aggregate labor supply (i.e. l_j vs. L_j) and consumption (i.e. c_j vs. C_j) for the representative skilled and unskilled households (where $j \in \{s, u\}$). Thus, equations 69, 70, 74 and 75 are replaced by:

$$(Y_h)^{\frac{\theta-1}{\theta}} = \gamma^{\frac{1}{\theta}} (L_i + L_u)^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} \left[\lambda^{\frac{1}{\eta}} K^{\frac{\eta-1}{\eta}} + (1-\lambda)^{\frac{1}{\eta}} (\zeta L_s)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}\frac{\theta-1}{\theta}}, \tag{80}$$

$$r + \delta = \xi_1 (Y_h)^{\frac{1}{\theta}} \left[\lambda^{\frac{1}{\eta}} K^{\frac{\eta-1}{\eta}} + (1-\lambda)^{\frac{1}{\eta}} (\zeta L_s)^{\frac{\eta-1}{\eta}} \right]^{\frac{\theta-\eta}{(\eta-1)\theta}} K^{-\frac{1}{\eta}}, \tag{81}$$

$$\underbrace{\left(\gamma \frac{Y_h}{L_i + L_u}\right)^{\frac{1}{\theta}}}_{w_i} = \underbrace{\Theta(1-\alpha^*) \left(\frac{r^* + \delta^*}{\alpha^*}\right)^{\frac{\alpha^*}{\alpha^*-1}}}_{w^*} Q, \tag{82}$$

$$p_h Y_{h2} = p_f Q Y_{f1} + L_i \underbrace{\left(\gamma \frac{Y_h}{L_i + L_u}\right)^{\frac{1}{\theta}}}_{w_i} - \frac{L_i}{L^*} C^* Q. \tag{83}$$

A.3 Labor Migration with International Trade in Bonds, Steady State

The presence of quadratic costs of adjustment for bond holdings allows us to pin down their steady-state levels. From $1 + \pi B_h = \beta(1 + r^b)$, $1 + \pi B_h^* = \beta^*(1 + r^b)$ and $B_h + B_h^* = 0$, it follows that:

$$r^b = \frac{2}{\beta + \beta^*} - 1, \tag{84}$$

$$B_h = -B_h^* = \frac{\beta(1 + r^b) - 1}{\pi}. \tag{85}$$

Similarly, using that $1 + \pi B_f = \beta(1 + r^{b*})$, $1 + \pi B_f^* = \beta^*(1 + r^{b*})$ and $B_f + B_f^* = 0$, it follows that:

$$r^{b*} = \frac{2}{\beta + \beta^*} - 1 = r^b, \tag{86}$$

$$B_f = -B_f^* = \frac{\beta(1 + r^{b*}) - 1}{\pi}. \tag{87}$$

Finally, the balanced current account condition (75) is replaced by the expression for the balance of international payments (44) in steady state:

$$p_h Y_{h2,t} - p_f Y_{f1} Q - \underbrace{\left(w_i L_i - \frac{L_i}{L^*} C^* Q \right)}_{\text{Remittances}} + r^b B_h + r^{b*} Q B_f = 0. \tag{88}$$

The steady state solutions for the remaining variables are as in Appendix A.1 and A.2.

A.4 Benchmark Model without Labor Migration (BKK94)

In the model without labor migration, each country specializes in the production of a single good, labeled $Y_{h,t}$ for home and $Y_{f,t}$ for foreign, as in Backus, Kehoe, Kydland (1994). We use log-CRRA preferences and abstract from government purchases and time-to-build in capital formation.

The model with financial autarky The home economy is characterized by 11 equations in 11 variables $(r_t, w_t, C_t, L_t, Y_{h,t}, Y_t, Y_{h,t}, Y_{h2,t}, I_t, K_t, p_{h,t})$:

$$1 = \beta(1 + r_t) E_t \left(\frac{C_t}{C_{t+1}} \right), \tag{89}$$

$$\frac{w_t}{C_t} = \chi L_t^{\psi}, \tag{90}$$

$$Y_{h,t} = A_t K_{t-1}^{\alpha} L_t^{1-\alpha}, \tag{91}$$

$$Y_{h,t} = Y_{h1,t} + Y_{h2,t}, \tag{92}$$

$$(Y_t)^{\frac{\mu-1}{\mu}} = \omega^{\frac{1}{\mu}} \left(Y_{h,t} - Y_{h2,t} \right)^{\frac{\mu-1}{\mu}} + (1-\omega)^{\frac{1}{\mu}} \left(Y_{f1,t} \right)^{\frac{\mu-1}{\mu}}, \tag{93}$$

$$Y_t = C_t + I_t, \tag{94}$$

$$K_t = I_t + (1-\delta) K_{t-1}, \tag{95}$$

$$Y_{h1,t} = \omega \left(p_{h,t} \right)^{-\mu} Y_t, \tag{96}$$

$$Y_{f1,t} = (1-\omega) \left(p_{f,t} Q_t \right)^{-\mu} Y_t, \tag{97}$$

$$r_t = \alpha \frac{Y_{h,t+1}}{K_t} - \delta \tag{98}$$

$$w_t = (1-\alpha) \frac{Y_{h,t}}{L_t} \tag{99}$$

All equations for the foreign economy are similar. Note that the price of the home intermediate good expressed in units of the foreign consumption basket is $Q_t^{-1} p_{h,t}$; therefore, the demand functions for the home and foreign-specific good in the foreign economy are: $Y_{f2,t} = \omega^* \left(p_{f,t} \right)^{-\mu} Y_t^*$ and $Y_{h2,t} = (1-\omega^*) \left(Q_t^{-1} p_{h,t} \right)^{-\mu} Y_t^*$, respectively.

Technology follows the process:

$$\log A_t = \rho \log A_{t-1} + e_t,$$
$$\log A_t^* = \rho \log A_{t-1}^* + e_t^*$$

The real exchange rate Q_t is pinned down by the trade balance, measured in units of the home composite good:

$$NX_t = \underbrace{Y_{h2,t}p_{h,t}}_{\text{exports}} - \underbrace{Y_{f1,t}p_{f,t}Q_t}_{\text{imports}}. \tag{100}$$

Under financial autarky and without remittances, $NX_t = 0$.

Financial integration, trade in risk-free bonds International trade in risk-free bonds (with quadratic cost of adjustment of bond holdings) adds 6 extra variables (i.e. the rates of return of the home and foreign bonds, r_t^b and r_t^{b*}; holdings of the home and foreign bonds by home households, $B_{h,t}$ and $B_{f,t}$; holdings of the home and foreign bonds by foreign households, $B_{h,t}^*$ and $B_{f,t}^*$) and 6 new equations to the model with financial autarky:

$$1 + \pi B_{h,t+1} = \beta(1 + r_{t+1}^b)E_t\left[\frac{C_t}{C_{t+1}}\right], \tag{101}$$
$$1 + \pi B_{f,t+1} = \beta(1 + r_{t+1}^{b*})E_t\left[\frac{Q_{t+1}}{Q_t}\frac{C_t}{C_{t+1}}\right], \tag{102}$$
$$1 + \pi B_{h,t+1}^* = \beta^*(1 + r_{t+1}^b)E_t\left[\frac{Q_t}{Q_{t+1}}\frac{C_t^*}{C_{t+1}^*}\right], \tag{103}$$
$$1 + \pi B_{f,t+1}^* = \beta^*(1 + r_{t+1}^{b*})E_t\left[\frac{C_t^*}{C_{t+1}^*}\right], \tag{104}$$
$$B_{h,t+1} + B_{h,t+1}^* = 0, \tag{105}$$
$$B_{f,t+1} + B_{f,t+1}^* = 0. \tag{106}$$

The expression for the balance of international payments replaces the balanced trade condition from the model with financial autarky:

$$p_{h,t}Y_{h2,t} - p_{f,t}Q_tY_{f1,t} + r_t^bB_{h,t} + r_t^{b*}Q_tB_{f,t} = 0. \tag{107}$$

A.5 Benchmark Model without Labor Migration (BKK94), Steady State

In steady state, $A = A^* = 1$. In each country,

$$r = \frac{1-\beta}{\beta}, r^* = \frac{1-\beta^*}{\beta^*}, \tag{108}$$

$$\alpha\frac{Y_h}{K} - \delta = r \to \frac{Y_h}{K} = \frac{r+\delta}{\alpha}, \frac{Y_f}{K^*} = \frac{r^*+\delta^*}{\alpha^*}, \tag{109}$$

$$Y_h = K^\alpha L^{1-\alpha} \to K = \left(\frac{Y_h}{K}\right)^{\frac{1}{\alpha-1}} L, K^* = \left(\frac{Y_f}{K^*}\right)^{\frac{1}{\alpha^*-1}} L^*, \tag{110}$$

$$Y_h = \left(\frac{Y_h}{K}\right) K = \left(\frac{r+\delta}{\alpha}\right)^{\frac{\alpha}{\alpha-1}} L, Y_f = \left(\frac{r^*+\delta^*}{\alpha^*}\right)^{\frac{\alpha^*}{\alpha^*-1}} L^*, \tag{111}$$

$$I = \delta K, I^* = \delta^* K^*. \tag{112}$$

The symmetric case The solution with symmetric calibration parameters for the two economies is described by:

$$p_h = p_f = Q = 1. \tag{113}$$

$$Y_{h1} = Y_{f2} = \omega Y_h. \tag{114}$$

$$Y_{h2} = Y_{f1} = (1-\omega)Y_h, \tag{115}$$

where $(1-\omega)$ represents the share imports in GDP. Using that $Y_{h1} = \omega Y_h$ and $Y_{h2} = (1-\omega)Y_h$,

$$Y = \left[\omega^{\frac{1}{\mu}} (Y_{h1})^{\frac{\mu-1}{\mu}} + (1-\omega)^{\frac{1}{\mu}} (Y_{f1})^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} = Y_h, \tag{116}$$

$$C = Y - I. \tag{117}$$

Asymmetric steady state This section describes the steady-state solution for cross-country asymmetries of the type $\alpha \neq \alpha^*, \beta \neq \beta^*, \mu \neq \mu^*$ and $\omega \neq \omega^*$.The equations (108)-(112) still hold. We obtain the steady-state solutions numerically using a system of 5 equations in 5 unknowns

$(Y_{h1}, Y_{f2}, p_h, p_f, Q)$:

$$\frac{Y_{h1}}{Y_f - Y_{f2}} = \frac{\omega}{1-\omega}\left(\frac{p_h}{p_f Q}\right)^{-\mu}, \tag{118}$$

$$\frac{Y_{f2}}{Y_h - Y_{h2}} = \frac{\omega^*}{1-\omega^*}\left(\frac{p_f Q}{p_h}\right)^{-\mu^*}, \tag{119}$$

$$1 = \omega\,(p_h)^{1-\mu} + (1-\omega)(p_f Q)^{1-\mu}, \tag{120}$$

$$1 = \omega^*\,(p_f)^{1-\mu^*} + (1-\omega^*)\left(\frac{p_h}{Q}\right)^{1-\mu^*} \tag{121}$$

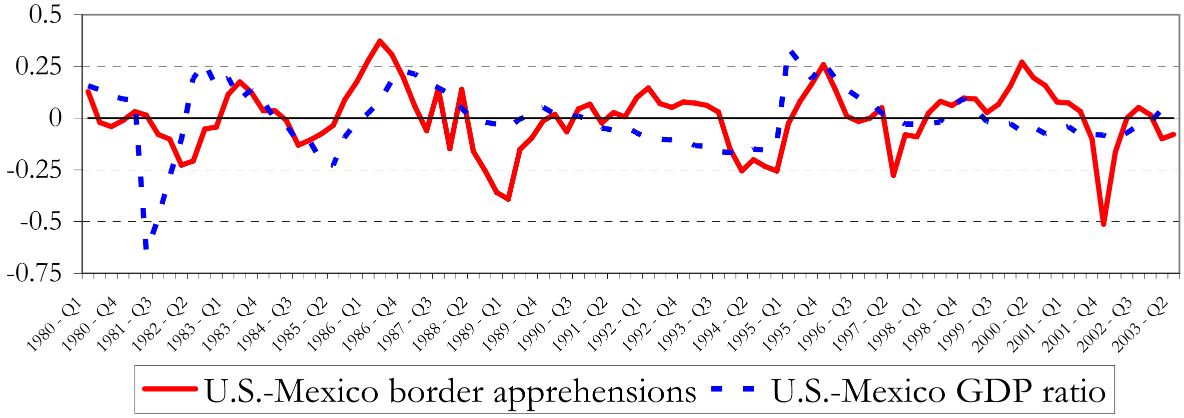
In financial autarky, the balanced trade condition is:

$$Y_{h2} p_h - Y_{f1} p_f Q = 0. \tag{122}$$

With financial integration, balanced trade is replaced by the expression for the balance of international payments:

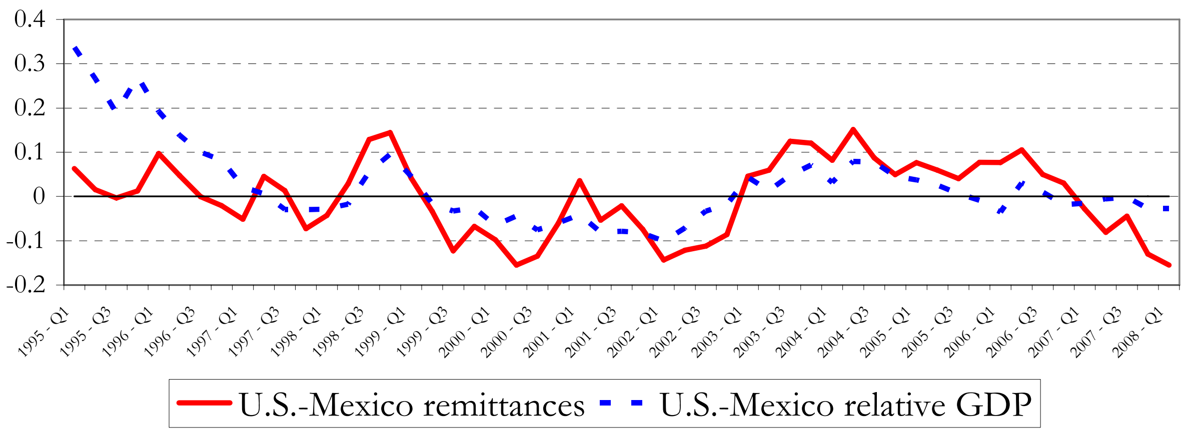
$$p_h Y_{h2} - p_f Q Y_{f1} + r^b B_h + r^{b*} Q B_f = 0. \tag{123}$$

Figure 1. U.S.-Mexico border apprehensions and the U.S.-Mexico GDP ratio



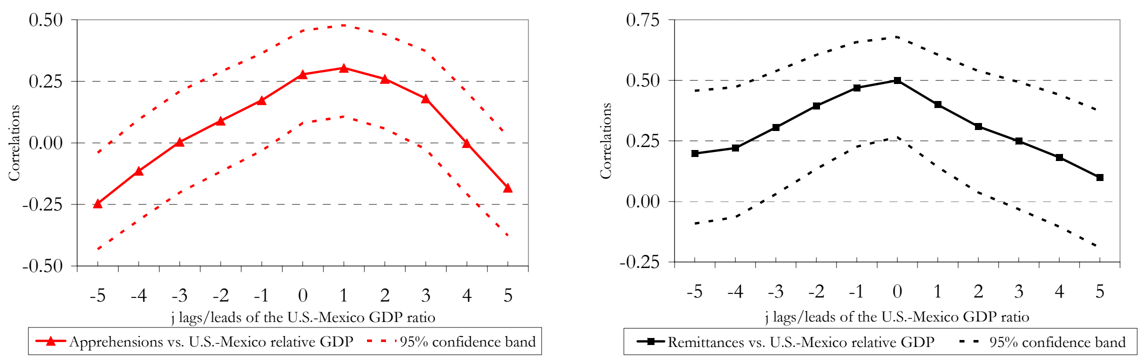
Source: Hanson (2007), *Haver Statistics*, and International Financial Statistics (2008).
Note: We have seasonally-adjusted the series for border apprehensions using the X-12 ARIMA method of the U.S. Census Bureau. The resulting seasonally-adjusted series were logged and HP(1600) filtered. The U.S.-Mexico GDP ratio is computed as the ratio between (1) the U.S. real GDP and (2) the real Mexican GDP multiplied by the bilateral real exchange rate.

Figure 2. U.S.-Mexico remittances and the U.S.-Mexico GDP ratio



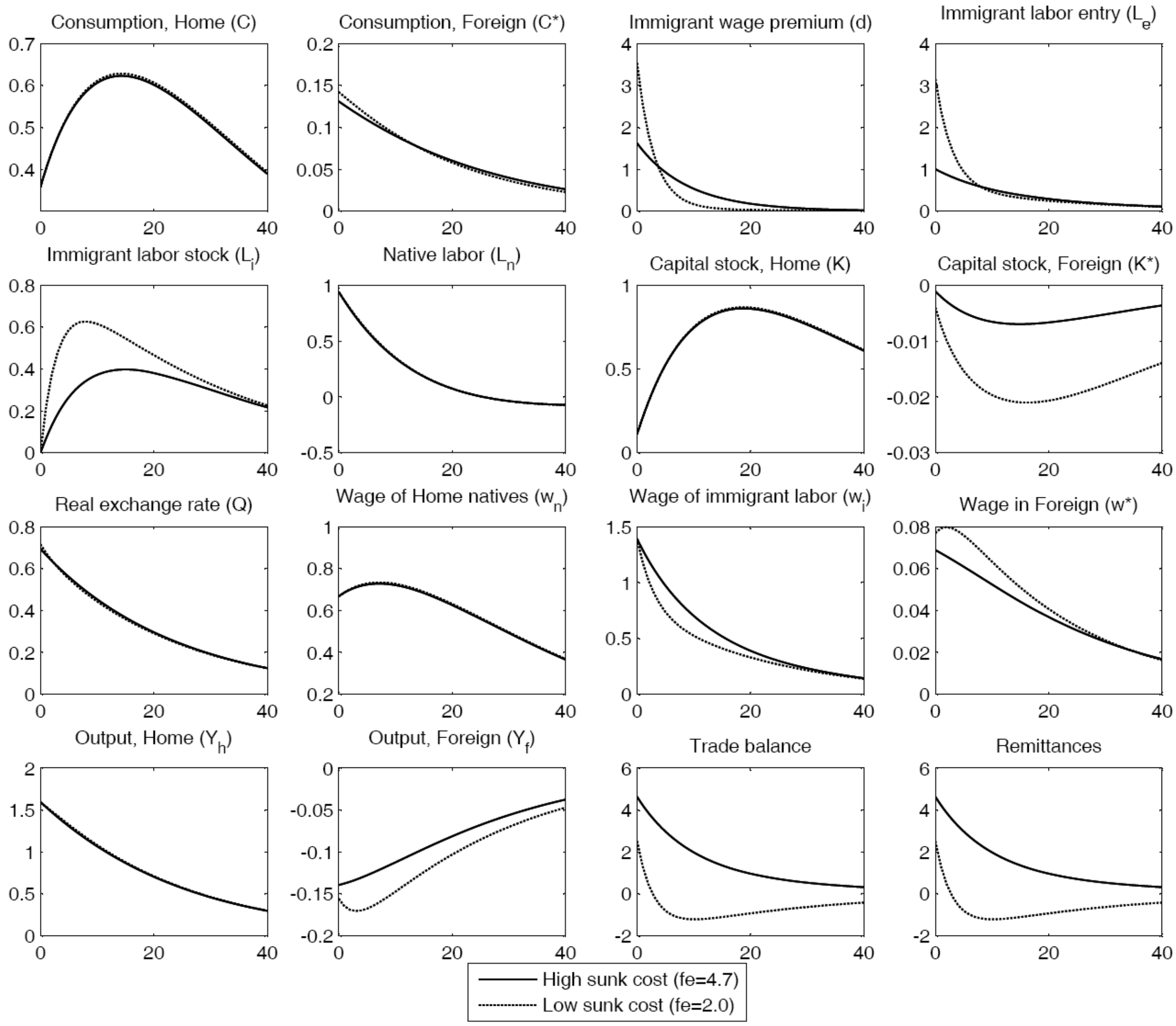
Source: *Haver Statistics* and Banco de México. Remittances are expressed in Mexican pesos at constant prices. Series were seasonally adjusted and detrended with the methods described in Figure 1.

Figure 3. Correlations of U.S.-Mexico border apprehensions (left) and U.S.-Mexico remittances (right) with the *j* lags and leads of the U.S.-Mexico GDP ratio



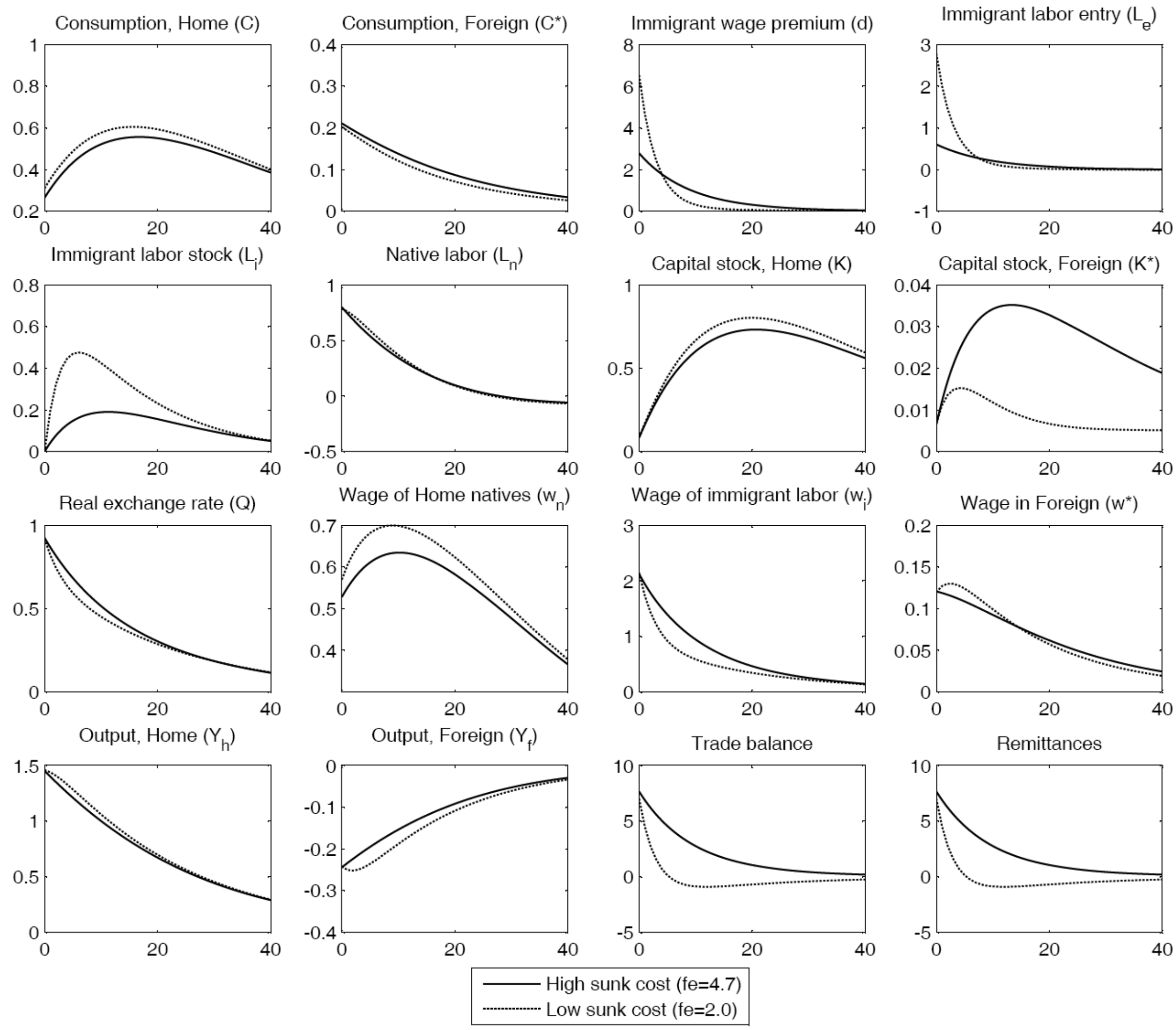
Note: correlations are computed based on the data in Figures 1 and 2, respectively.

Figure 4. Baseline model with financial autarky



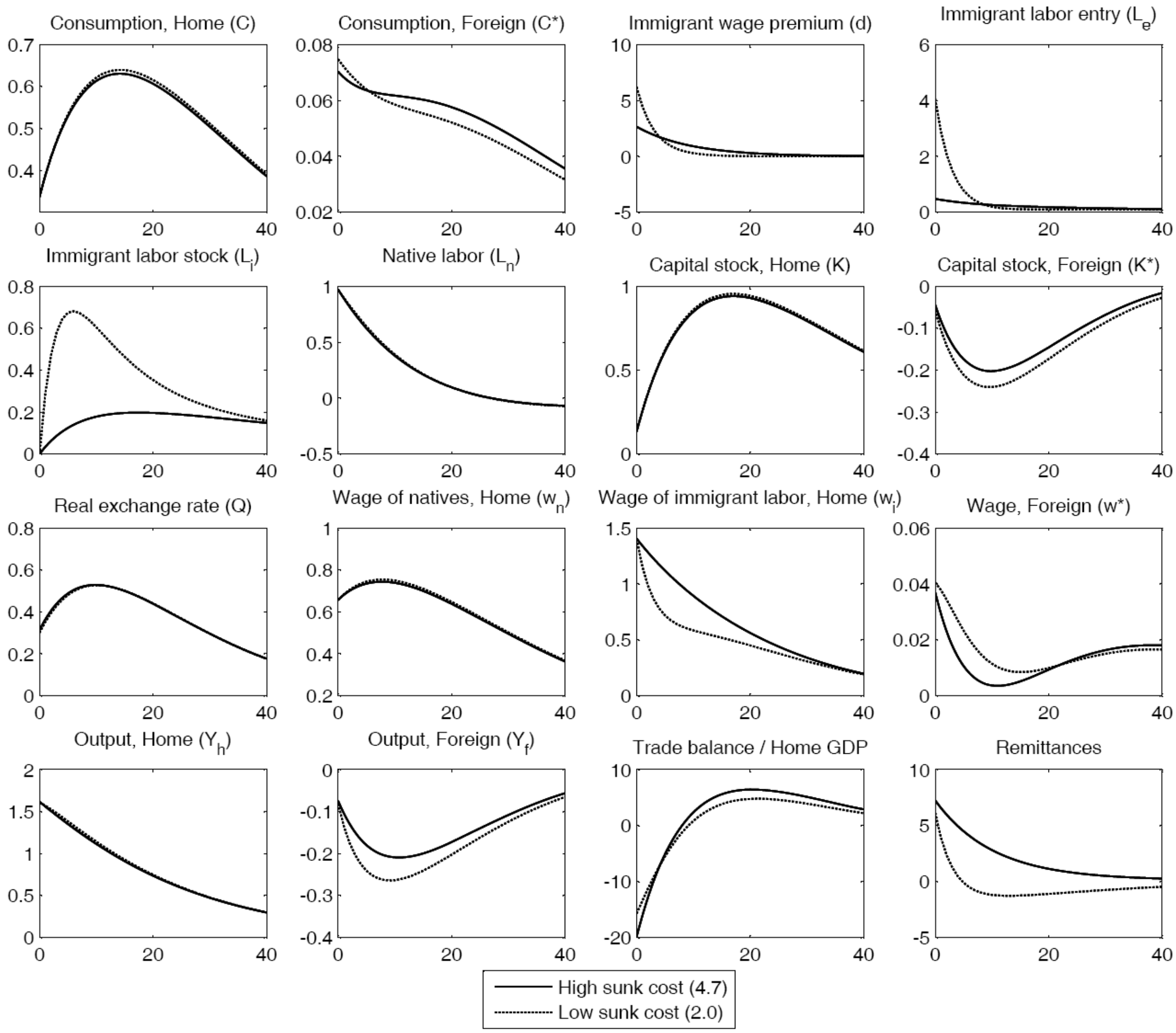
Each panel shows the response (percent deviations from steady state) to a transitory 1 percent increase in home productivity, for the cases with high sunk cost (solid line) and low sunk cost (dashed line).

Figure 5. Baseline model with financial autarky, high complementarity between native and immigrant labor



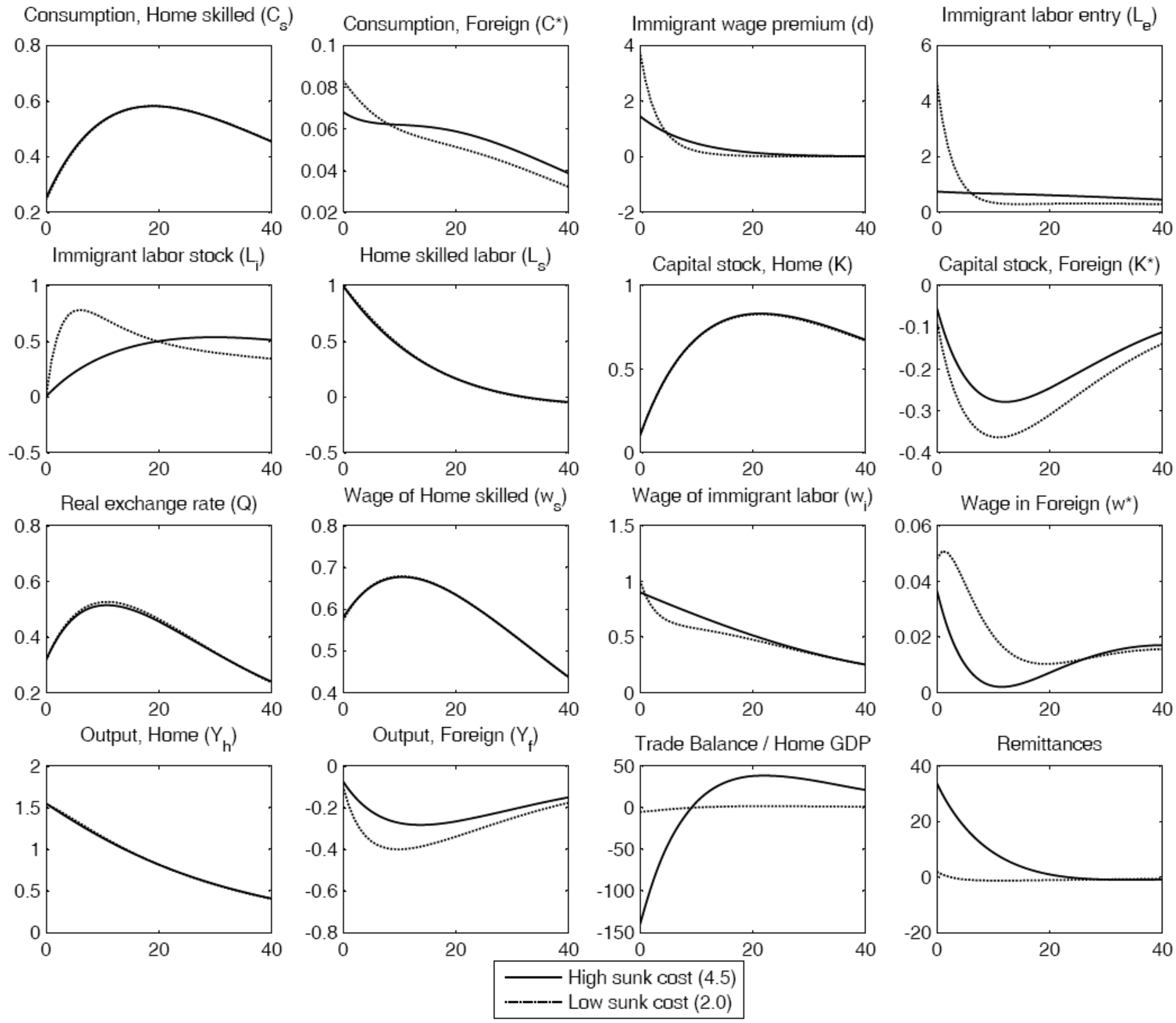
Each panel shows the response (percent deviations from steady state) to a transitory 1 percent increase in home productivity, under high complementarity ($\theta = 0.5$) between the native and immigrant labor, for the cases with high sunk cost (solid line) and low sunk cost (dashed line).

Figure 6. Baseline model with financial integration



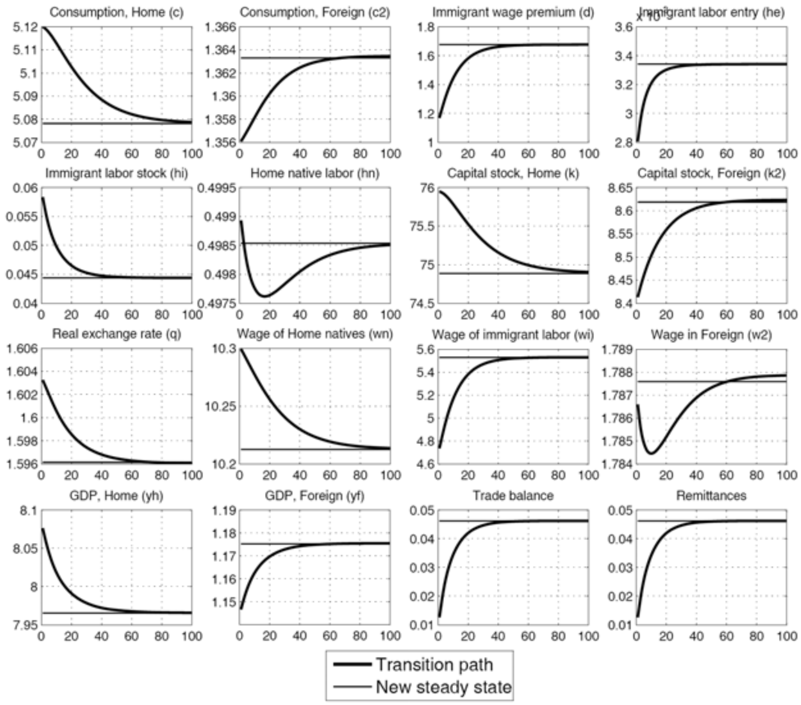
Each panel shows the response (percent deviations from steady state) to a transitory 1 percent increase in home productivity, for the cases with high sunk cost (solid line) and low sunk cost (dashed line). The model allows for international trade in risk-free bonds (with adjustment cost parameter $\pi = 0.0025$).

Figure 7. Alternative model with financial integration



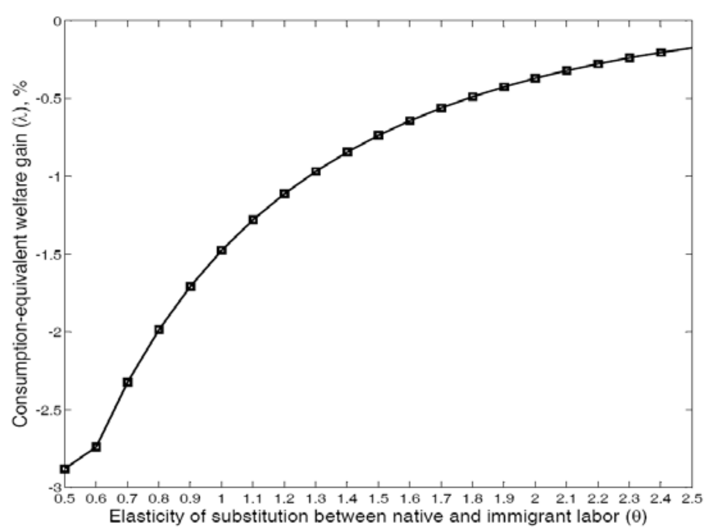
Each panel shows the response (percent deviations from steady state) to a transitory 1 percent increase in home productivity in the alternative model (i.e. with skill heterogeneity among the native labor and capital-skill complementarity), for the cases with high sunk cost (solid line) and low sunk cost (dashed line). The model allows for international trade in risk-free bonds (with adjustment cost parameter $\pi = 0.0025$).

Figure 8. Baseline model with financial autarky: permanent increase in border enforcement



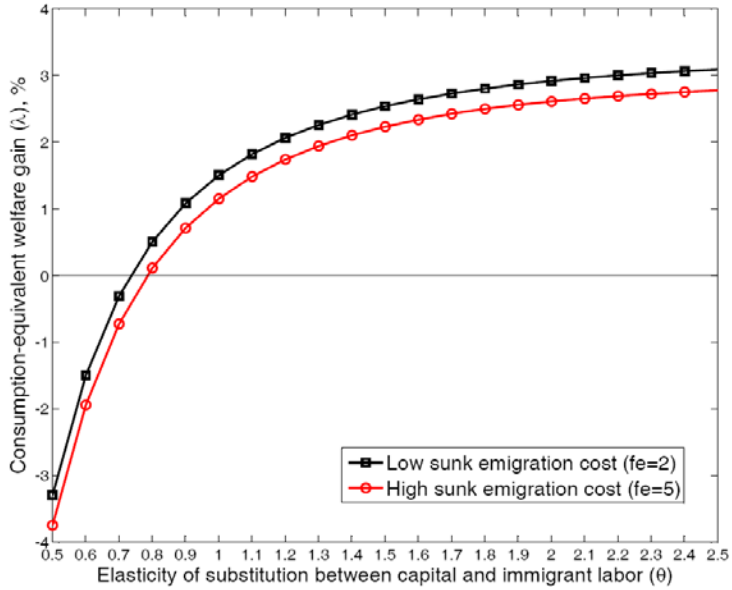
Each panel shows the transition path of the model's variables with a permanent increase in the sunk emigration cost (sudden increase from f_e =4 to f_e =5).

Figure 9. Welfare analysis, baseline model with financial autarky



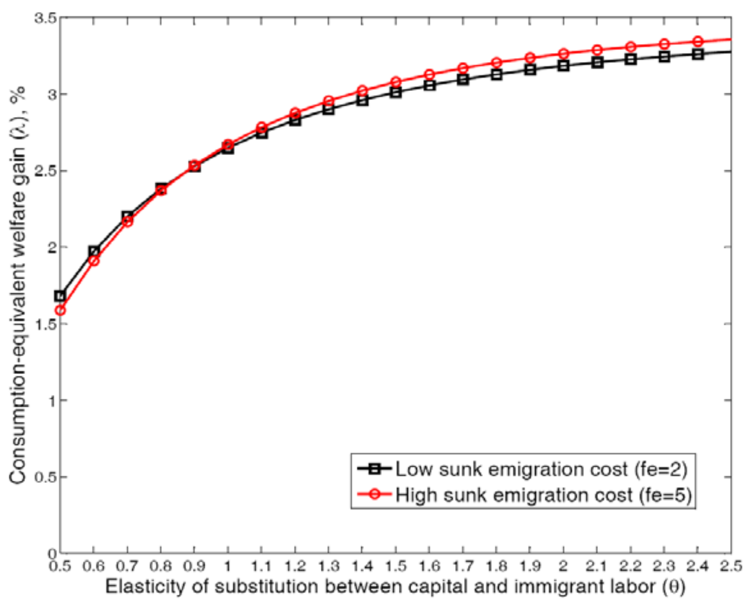
Consumption-equivalent welfare gain/loss with a permanent increase in the sunk emigration cost (sudden increase from f_e =4 to f_e =5).

Figure 10. Welfare analysis, alternative model with financial autarky: implications of a rising share of skilled labor (1)



Consumption-equivalent welfare gain/loss from a rising share of native skilled labor (<u>from 0.9 to 0.97 over 20 years</u>), in the presence of the sunk emigration cost.

Figure 11. Welfare analysis, alternative model with financial autarky: implications of a rising share of skilled labor (2)



Consumption-equivalent welfare gain/from a rising share of native skilled labor (<u>from 0.6 to 0.67 over 20 years</u>), in the presence of the sunk emigration cost.