BSP International Research Conference on Remittances
"The Macroeconomic Consequences of Remittances: Implications for Monetary and Financial Policies in Asia"
30-31 March 2009
Mandaluyong City, Philippines

Conference Paper No. 1

"Immigration and the Macroeconomy: An International Business Cycle Model"

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Immigration and the Macroeconomy*

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October 23, 2008

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.

JEL classification: F22, F41

Keywords: Labor migration, sunk emigration cost, skill heterogeneity, international real business cycles.

*We thank James Anderson, Susanto Basu, Bora Durdu, Fabio Ghironi, Fabià Gumbau-Brisa, Peter Ireland, Myriam Quispe-Agnoli, Pedro Silos, Paul Willen, and seminar participants at the FRB of Atlanta, the FRB of Boston, the Green Line Macro Meeting at Boston College/Boston University as well as the System Committee on International Economic Analsysis conference at the Federal Reserve Board for very helpful comments. We are grateful to Gita Gopinath and Pedro Silos who kindly provided part of the data. We acknowledge Gustavo Canavire for superb research assistance. All errors are our own. Part of this project was developed while Andrei Zlate was visiting the FRB of Atlanta and the FRB of Boston, whose hospitality he gratefully acknowledges. The views expressed here are those of the authors and not necessarily those of the FRB of Atlanta or the Federal Reserve System.

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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) was the first to document the procyclical pattern of European immigration into the United States, showing that recessions were associated with drastic declines in immigration flows, while relatively larger inflows occurred during the recovery years.[1] 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 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. 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. 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 home on a regular basis. Conservative estimates indicate that the remittances sent by emigrants from developing economies back to their countries of origin reached $240 billion in 2007, which was more than double the amount of 2002.[3] In 2007, the recorded remittances represented more than 20 percent of the GDP of several receiving countries,[4] 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.[5] Figure 2 shows the pattern of remittances from the U.S. to Mexico vis-a-vis the relative performance of these economies adjusted for the real exchange rate. The correlations of these detrended series in Figure

[1] For instance, the number of arrivals into the United declined by 39.1 percent in the depression year of 1908. The same was observed during the depression years of 1876-1879, 1894 and 1922. During these years there were few restrictions on European immigration and most of the arrivals into the U.S. were properly documented (see 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] Due to unrecorded flows through formal and informal channels, the actual numbers are believed to be significantly larger than the reported numbers.

[4] Examples include Moldova (36.2%), Honduras (25.6%), Guyana (24.3%) and Jordan (20.3%), Philippines (13.5%), among many others. Remittances account for roughly 2.5 % of Mexico's GDP (World Bank, 2008).

[5] See Ratha and Xu (2008).

3(b) confirm that periods with faster U.S. economic growth have been associated with larger outflows of remittances to Mexico and vice versa. The evidence highlights the potential insurance role of remittances in smoothing the consumption path of Mexican households' members residing on both sides of the border during the cycle.

Despite this evidence, the workhorse model of international macroeconomics assumes that labor is immobile across countries. Instead, immigration is generally analyzed within formal setups limited to comparisons of long-run positions or to the study of growth dynamics after permanent changes in immigration variables. These models are not suitable for the analysis of immigration dynamics at business cycle frequencies, as they neglect the standard macroeconomic dynamics within a general equilibrium context.

This paper aims to bridge the gap between modern international macroeconomic literature and immigration theory. We use a standard 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 labor migration and remittance flows. Beginning with Sjaastad (1962), economists have regarded migration as an investment decision; thus, we construct a microfounded model of immigration that follows this principle. 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. The sunk cost of emigration varies in nature, as it may include the cost of searching for employment, the cost of adjusting to a new lifestyle (learning a new language, integration into a new community, housing arrangements, etc.), transportation expenditures, working visa procedures, 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. Stricter border enforcement thus reduces the incentive for foreign labor to emigrate. In addition, the return rate affecting the established immigrants 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).

In our model, a temporary economic expansion in the destination economy leads to an increase in the immigrant wage; however, the greater incentive for labor migration is partially offset by the sunk cost. During economic expansions, immigrant labor becomes relatively scarce, as the increase in the stock of immigrant labor does not keep up with the increase in labor demand. Thus, immigrant labor receives relatively higher wages and sends larger remittances to the foreign economy. The opposite occurs during recessions, when immigrant labor becomes relatively more abundant and the immigrant wage declines.[6]

In order to take skill heterogeneity among the native labor into account, we extend the baseline model by introducing 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. Although the macroeconomic dynamics of the extended model remain unchanged at the aggregate level relative to the baseline, immigration has an asymmetric effect on the skilled and unskilled labor, benefiting the former and harming the latter.

We also explore the effects of an alternative immigration policy in which lower border enforcement reduces the sunk costs, while a countercyclical tax imposed on the immigrant wage regulates the quantity of immigrant labor. A countercylical immigration tax increases the procyclicality of the stock of immigrant labor (i.e. more immigrants arrive during booms and fewer arrive during recessions). In particular, it improves the stance of native unskilled workers during recessions, when their employment and wages decline by less due to the lower stock of immigrant labor.

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.

We also extend the baseline model to allow for financial integration between the home and foreign economies through international trade in bonds. In steady state, as predicted by Lucas (1990), financial integration in principle allows capital to migrate towards the economy with a relatively higher rate of return (i.e. in our model, the foreign economy), where the resident labor becomes relatively more productive, receives a higher wage, and has a lower incentive to emigrate. Over the business cycle, following a positive technology shock in the home economy, foreign households have the option to lend offshore as an alternative to investing in emigration. In this last case, remittances serve as a substitute for contingent claims in the presence of imperfect financial integration among countries.

[6] Consistent with this result, empirical evidence in Rodriguez-Zamora (2008) shows that the recent increase in border enforcement resulted in less volatile migration inflows and outflows across the US-Mexico Border.

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 (2004) and Polgreen and Silos (2006), who use skill heterogeneity and capital-skill complementarity with two representative households. Finally, our model results are consistent with the vast empirical evidence showing that the inflows of remittances are associated with a more robust appreciation of the real exchange for the receiving country (Amuedo-Dorantes and Pozo, 2004; López et al., 2007; Lartey et al., 2008) as well as with a decline in labor supply (Hanson, 2005; Acosta, 2006).

The rest of the paper is organized as follows: Section 2 introduces the benchmark model; Section 3 presents the extended models with skill heterogeneity and financial integration; 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 concludes.

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. In our baseline specification, we assume financial autarky. 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 implications of capital-skill complementarity by introducing two types of labor in the home economy (skilled and unskilled) 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:

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

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:

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

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 foreign labor supply L_t^*, 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.[7]

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.[8] It maximizes the inter-temporal utility with respect to total labor L_t^*, emigrant labor $L_{e,t}$ and capital K_{t+1}^*:

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

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 $f_e w_{i,t}Q_t^{-1}$. Finally, r_t^* is the return on foreign capital net of depreciation.

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

[8] 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.

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:

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

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):

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

Finally, capital accumulation is described by:

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

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:

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

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

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 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, expressed in units of the home consumption basket:

$$\Xi_t = w_{i,t} L_{i,t} - \frac{L_{i,t}}{L_t^*} C_t^* Q_t. \tag{34}$$

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

$$CA_t = p_{h,t} Y_{h2,t} - p_{f,t} Q_t Y_{f1,t} - \Xi_t. \tag{35}$$

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.[9]

3 Alternative Model Specifications

3.1 Financial Integration

Following Ghironi and Melitz (2005), we assume that: (1) International asset markets are incomplete, as households in each country issue risk-free bonds denominated in their own currency. (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:

$$\begin{aligned} & w_t L_t + \left(1 + r_t^k\right) K_t + \left(1 + r_t^b\right) B_{h,t} + \left(1 + r_t^{b*}\right) Q_t B_{f,t} + T_t \\ & \geqslant C_t + K_{t+1} + B_{h,t+1} + \frac{\pi}{2} \left(B_{h,t+1}\right)^2 + Q_t B_{f,t+1} + \frac{\pi}{2} Q_t \left(B_{f,t+1}\right)^2, \end{aligned} \tag{36}$$

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 $(1 + r_t^{b*}) Q_t B_{f,t}$ 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

[9] 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 $p_{f,t} Y_{f,t} = \left(1 - \frac{L_{i,t}}{L_t^*}\right) C_t^* + I_t^* + f_e w_{i,t} Q_t^{-1} L_{e,t} - Q_t^{-1} TB_t$.

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:

$$1+\pi B_{h,t+1}=\beta E_t\left[(1+r^b_{t+1})\frac{C_t}{C_{t+1}}\right], \tag{37}$$

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

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

$$\begin{aligned} & w_t^*\left(L_t^*-L_{i,t}\right)+w_{i,t}Q_t^{-1}L_{i,t}+\left(1+r_t^{k*}\right)K_t^*+\left(1+r_t^b\right)Q_t^{-1}B^*_{h,t}+\left(1+r_t^{b*}\right)B^*_{f,t}+T_t^* \\ & \geqslant C_t^*+f_e w_{i,t}Q_t^{-1}L_{e,t}+K^*_{t+1}+Q_t^{-1}B^*_{h,t+1}+\frac{\pi}{2}Q_t^{-1}\left(B^*_{h,t+1}\right)^2+B^*_{f,t+1}+\frac{\pi}{2}\left(B^*_{f,t+1}\right)^2, \end{aligned} \tag{39}$$

and the corresponding Euler equations for bonds are:

$$1+\pi B^*_{h,t+1}=\beta^* E_t\left[\frac{Q_t}{Q_{t+1}}(1+r^b_{t+1})\frac{C_t^*}{C^*_{t+1}}\right], \tag{40}$$

$$1+\pi B^*_{f,t+1}=\beta^* E_t\left[(1+r^{b*}_{t+1})\frac{C_t^*}{C^*_{t+1}}\right]. \tag{41}$$

The market clearing conditions for bonds are:

$$B_{h,t+1}+B^*_{h,t+1}=0, \tag{42}$$

$$B_{f,t+1}+B^*_{f,t+1}=0. \tag{43}$$

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:

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

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).

Thus, financial integration through trade in country-specific bonds adds 6 variables ($B_{h,t}$, $B_{f,t}$, $B^*_{h,t}$,

[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.

$B^*_{f,t}$, r^b_t and r^{b*}_t) and 6 equations (37, 38, 40, 41, 42 and 43) to the baseline model with financial autarky.

3.2 Skill Heterogeneity in Home

Now 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).

Optimization 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:

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

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:

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

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

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

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

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:

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

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

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

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:

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

4 Model Parameterization

We introduce an asymmetric steady state across countries using uneven discount factors, $\beta > \beta^*$.[11] Thus, the relatively larger capital accumulation in Home, where households are more patient, provides an extra wage incentive for immigrant foreign labor.

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; $\omega = 0.85$ reflects the degree of home bias in Home and $\omega^* = 0.75$ shows home bias in Foreign; we set $\omega > \omega^*$ in order to account for the relatively greater trade openness in Mexico relative to the U.S. The inverse of the elasticity of labor supply to labor is $\psi = 0.33$. We also set $\psi^* = 0.66$, following the finding in Hotchkiss and Quispe-Agnoli (2008) that the labor supply elasticity of undocumented immigrants is half the value of the labor supply elasticity of U.S. workers.[12]

We set the quarterly return rate of 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

[11] The calibration $\beta = 0.99$ and $\beta^* = 0.98$ reflects a larger quarterly interest rate in Foreign (where capital is scarce) relative to Home in steady state ($r^* = 0.02$ and $r = 0.01$, respectively).

[12] One caveat is that the labor supply elasticity of immigrant labor originating in Foreign is not necessarily equal to the labor supply elasticity of the foreign labor that resides in Foreign. However, the results are very similar when assuming that the elasticity of labor supply is the same for foreign emigrant and resident workers, as we do in this paper. The alternative results, not reported here, are available upon request.

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).[13]

Baseline Model Calibration For the baseline model with symmetric elasticity of substitution between capital and each type of labor (native and immigrant), 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 needs to match 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) The ratio between the average wages of native and immigrant labor is $\frac{w}{w_i} = 2.1$[14]; (3) Remittances represented the equivalent of 2.5 percent of Mexico's GDP in 2004 (Bank of Mexico, 2004)[15]; (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), $\theta = 1.55$ (the elasticity of substitution between native and immigrant labor[16]), $\zeta = 5.4$ (the relative productivity of native vs. immigrant labor), and $f_e = 4$ (the sunk cost of labor migration). 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 $\theta = 2.5$.

Table 4.1 Baseline model calibration

$\gamma = 0.08$	Share of immigrant labor in total labor income
$\zeta = 5.4$	Relative productivity of native vs. immigrant labor
$\theta = 1.55$	Elasticity of substitution between native and immigrant labor
$f_e = 4$	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

[13] 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 $(1 - \delta_{l,4y})^{16} = 0.35$.

[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] 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).

[16] 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.

adult population without a high school degree; using data from the U.S. Census Bureau, we set the share of unskilled labor at $(1-s) = 0.1$.

We choose values for parameters $\widetilde{\gamma}$, $\widetilde{\theta}$, $\widetilde{\eta}$, $\widetilde{\zeta}$ and $\widetilde{f}_e$ so that the model generates a set of five steady state-ratios that match the empirical evidence from the U.S. and Mexico: (1) The share of Mexico's labor force residing in the U.S. is $\frac{L_i}{L^*} = 0.1$, as discussed above (Hanson, 2006). (2) The ratio between the wages of the native skilled and unskilled labor in the U.S. is $\frac{w_s}{w_u} = 2.2$.[17] (3) 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 $\frac{w_i}{Qw^*} = 2.1$, enough to maintain the incentive for labor migration);[18] (4) Remittances represent the equivalent of 2.5 percent of Mexico's GDP (compared to which the model generates the more conservative estimate of 2.1 percent); (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. To this end, we choose $\widetilde{\gamma} = 0.1$, $\widetilde{\theta} = 1.30$, $\widetilde{\eta} = 1.06$, $\widetilde{\zeta} = 2$ 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]

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.

[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.

Table 4.2 Alternative model calibration

$s = 0.9$	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
$\widetilde{\eta} = 1.06$	Elasticity of substitution, capital vs. skilled labor
$\widetilde{\zeta} = 2.00$	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 further that productivity follows a first-order autoregressive process that persists at the rate of 0.95 per quarter. Figures 4-7 show the responses of key variables of the model (measured as the percent deviation from steady state in each quarter after the initial shock) to transitory changes in productivity, as described next.

Baseline Model with Financial Autarky As shown in Figure 4, following a transitory 1 percent increase in productivity in Home, the increase in the immigrant wage premium encourages the entry of immigrants, which is however dampened by the presence of the sunk cost (i.e. barriers to immigration). Foreign output declines by less in the scenario with the high sunk cost; the result is due to the larger amount of resident labor that is forced to remain in Foreign, which in turn dampens the increase of wages and enhances the accumulation of physical capital in Foreign. Also in the case with the higher sunk cost, immigrant labor becomes relatively more scarce in Home, and the immigrant wage increases by more. Thus, as foreign households attempt to smooth consumption across members residing in both countries, remittances increase notably.

Due to the complementarity between capital and immigrant labor, the higher sunk cost of immigration ($f_e = 6$) dampens investment and output growth in Home relative to the scenario with the relatively low sunk cost ($f_e = 1$).Although small in the baseline model, the effect increases with the complementarity between the two types of labor. The impulse responses in Figure 5 show that a higher complementarity between the immigrant and native labor ($\theta = 0.5$) relative to the baseline calibration ($\theta = 1.55$) 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 the accumulation of capital in Home, which results in a relatively lower increase in home output, native wage and consumption than in the baseline calibration case .

High barriers to immigration and high complementarity between the native and immigrant labor deliver a paradoxical behavior of the real exchange rate and of the terms of trade. Although this scenario generates relatively more scarce home output and relatively more abundant foreign output (as explained above), higher remittances improve the purchasing power of residents in Foreign (that have a home bias towards foreign goods). In turn, this leads to an increase in the relative price of foreign output, so that the real exchange rate Q increases by relatively more (i.e. the real exchange rate of Home depreciates by more).

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 can be used for smoothing households' 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 1 percent increase in home productivity, financial integration allows capital to migrate towards the economy with a relatively high rate of return (the Home economy). As Home borrows from Foreign and accumulates capital, the home trade balance becomes negative. In turn, Home 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 for $f_e = 1$ increase by more) relative to the case with financial autarky (depicted in Figure 4).

Skill Heterogeneity and Policy Experiments The model dynamics with skill heterogeneity and capital-skill complementarity are similar to the ones of the baseline model. In addition, we conduct an informative experiment under the framework with skill heterogeneity, in which we compare the implications of an alternative immigration policy to those from the setup with sunk costs. Namely, we propose a simple counter-cyclical tax on the immigrant wage, payable every period:

$$(1 + \tau_t)w_{i,t} = MPL_{i,t} = w_{u,t}, \tag{58}$$

while setting the sunk cost of immigration at zero. The amount of tax, which is rebated to native households, thus decreases with home output:

$$\tau_t = \overline{\tau} \left(\frac{Y_{h,t}}{\overline{Y_h}} \right)^{\kappa}, \ \kappa < 0. \tag{59}$$

In other words, the tax becomes the only deterrent to immigration, as a substitute for border enforcement in regulating the amount of immigrant labor on the balanced growth path.[20]

In the setup with the counter-cyclical tax on immigrant wage, we set the tax parameter $\overline{\tau} = 1/3$ and the sunk emigration cost $f_e = 0$ (i.e. net of the immigration tax, the immigrant labor takes home only 75 percent of the wage of the native unskilled labor). In the benchmark model with sunk costs, we set $\overline{\tau} = 0$ and the sunk emigration cost $f_e = 1.91$, so that the two calibrations generate the same amount of immigrant labor in steady state. We find that the counter-cyclical tax on the immigrant wage generates an income transfer from the foreign to the home households, and thus improves the welfare of the latter: In steady state, the aggregate consumption in Home increases by 2.49 per cent in the setup with the countercyclical tax on the immigrant wage compared to the benchmark model with sunk costs (where home consumption is defined as the weighted average of the consumption of the skilled and unskilled, $C = sc_s + (1 - s)c_u$).

The business cycle implications of this alternative immigration tax policy are illustrated in Figure 7. Following a 1 percent decrease in home productivity that persists at the rate of 0.95 per quarter, wages of both skilled and unskilled labor decline. Under the alternative policy, the counter-cyclical tax on immigrant labor acts as an extra deterrent to immigrant entry. On impact, absent sunk costs, immigrant entry declines as the forward-looking foreign household re-optimizes the stock of immigrant labor to remain significantly lower during the recession. With the tax in place, the native unskilled labor benefits from the sharp decline in the number of immigrants. As a consequence, the native unskilled wages and the native unskilled labor demand do not fall by as much under the alternative tax policy.[21]

The foreign economy suffers from the counter-cyclical tax on immigration imposed by Home. The lower stock of immigrant labor and the lower immigrant wages (both due to the tax) leads to lower foreign households' overall consumption relative to the policy with sunk emigration costs. However, the larger amount of resident labor encourages capital accumulation, which leads to an output expansion

[20] We use this example for illustrative reasons. Clearly, border enforcement is just an additional factor behind the sunk costs of immigration.

[21] Unskilled, lower-income individuals are usually unfavorably exposed to economic downturns due to liquidity constraints, for instance. We abstract from modelling those motives in here.

in Foreign.

5.2 Theoretical Moments

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

$$\begin{bmatrix} \log A_t \\ \log A_t^* \end{bmatrix} = \begin{bmatrix} \rho_A & \rho_{AA^*} \\ \rho_{A^*A} & \rho_{A^*} \end{bmatrix} \begin{bmatrix} \log A_{t-1} \\ \log A_{t-1}^* \end{bmatrix} + \begin{bmatrix} \xi_t \\ \xi_t^* \end{bmatrix}, \tag{60}$$

Following Heathcote and Perri (2002), we estimate its parameters using the seemingly unrelated regression (SURE) method.[22] To this end, we use the Solow residual as a measure for aggregate productivity 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.[23]

Our estimates for the transition matrix of the productivity process **A** and for the variance-covariance matrix **Σ** are given below (with standard errors in parentheses):

$$\mathbf{A} = \begin{bmatrix} \underset{(0.014)}{0.996} & \underset{(0.015)}{0.003} \\ \underset{(0.040)}{0.049} & \underset{(0.040)}{0.951} \end{bmatrix}, \Sigma = \begin{bmatrix} 0.0050939^2 & 0.00001898 \\ 0.00001898 & 0.0139570^2 \end{bmatrix}. \tag{61}$$

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).

International real business cycle (IRBC) models have difficulty in accounting for at least four empirical patterns that are visible in cross-country data (see Heathcote and Perri, 2002, for details). First, the empirical cross-country correlations for consumption are lower (or similar at most) than for output, whereas the IRBC framework generates consumption correlations that are much higher than the corresponding output correlations. Second, investment in the data tends to be positively

[22] Tipically, international real business cycle models are solved assuming that total factor productivity (TFP) processes are stationarity (See Rabanal et al., 2008). For model comparison we follow these guidelines.
[23] For Mexico, we use the Solow residual data in Aguiar and Gopinath (2007).

correlated across countries, whereas the IRBC models predict a negative correlation. Third, IRBC models generate considerable lower volatilities of the terms of trade and of the real exchange rate than it is observed in the data. Finally, as first highlighted by Backus and Smith (1993), while IRBC models predict a positive correlation (close to 1.00) between the relative consumption and the real exchange rate, the data shows that this correlation is often negative across countries (see Corsetti et al., 2008, for details).[24] In particular, the assumption that the productivity process is stationary leads to negligible wealth effects, so that the results of the model with a single insurance mechanism (one-period, non-contingent bond) mimic those of the model with a complete set of state-contingent securities. That is, the evidence is at odds with some of the basic risk-sharing implications of the IRBC setup.

To test the empirical relevance of our model we thus compute the second moments of the theoretical economy described by the baseline model with international trade in bonds, and contrast them to the corresponding empirical moments (Table 5.1). As expected, the inclusion of labor migration flows and remittances (as an extra insurance mechanism) does not solve any of the puzzles mentioned above. In particular, the cross-country correlation of consumption is considerably larger than that of output, contrary to the data. In fact, the cross-country correlation of consumption increases in the model with labor migration relative to the model with no labor mobility. This result, nonetheless, highlights the insurance role of labor migration and remittances in cross-country consumption smoothing. Furthermore, results show that the trade balance of the baseline model with labor migration is less counter-cyclical in the than in the benchmark model without labor mobility and remittances. Our result is consistent with the finding in Durdu and Sayan (2008) that remittance inflows dampen the current account reversals during economic downturns, reducing household consumption volatility.[25]

[24] For instance, during Mexico's Tequila crisis (1995), the Mexican peso suffered a sizable depreciation. Due to the nominal rigidities, the real exchange rate depreciated as well, while consumption in Mexico droped notably relative to consumption in the U.S. This model, instead, predicts the opposite: Relatively lower consumption in Mexico is associated with a real exchange rate depreciation in the U.S. A productivity improvement in Home relative to Foreign leads to a relative increase in home consumption as well as to a relative decline in foreign output. As the latter becomes relatively scarce, the foreign terms of trade improve (offsetting the relatively low productivity) while the real exchange rate (measured as the ratio of the foreign-to-home price indices) depreciates (i.e. increases).

[25] Supporting evidence for this result can be find in Esteves and Khoudour-Castéras (2008), who focus instead on European Countries with high emigration rates between 1880-1914.

Table 5.1 Theoretical and Empirical Moments of Macroeconomic Variables

	Absolute std. dev.		Relative std. dev.		Correlations with output		Other correlations	
(A) Empirics								
	U.S.	Mex	U.S.	Mex	U.S.	Mex		
Output	1.24	2.32	1.00	1.00	–	–	GDP_h, GDP_f	0.16
Consumption	0.93	2.84	0.75	1.23	0.83	0.92	C, C^*	−0.04
Investment	4.18	9.26	3.36	4.00	0.90	0.90	I, I^*	0.21
NX/GDP	0.33	1.47	0.26	0.63	−0.42	−0.72	$\frac{C}{C^*}, Q$	−0.47
Q	12.53	12.53	10.07	5.41	0.35	−0.56		
(B) Labor migration (baseline), trade in bonds								
	Home	Foreign	Home	Foreign	Home	Foreign		
Output	0.90	2.41	1.00	1.00	–	–	GDP_h, GDP_f	0.27
Consumption	0.42	0.93	0.47	0.83	0.94	0.92	C, C^*	0.51
Investment	2.68	15.91	2.97	5.59	0.92	0.93	I, I^*	−0.24
NX	1.61	1.02	1.79	0.42	−0.13	−0.73	$\frac{C}{C^*}, Q$	0.99
Q	0.64	0.64	0.71	0.27	0.09	0.83		
(C) No labor migration, BKK(94), trade in bonds								
	Home	Foreign	Home	Foreign	Home	Foreign		
Output	0.88	2.78	1.00	1.00	–	–	GDP_h, GDP_f	0.26
Consumption	0.48	0.99	0.55	0.36	0.90	0.90	C, C^*	0.43
Investment	2.96	13.08	3.36	4.70	0.87	0.96	I, I^*	−0.34
NX	0.47	0.47	0.53	0.17	−0.33	−0.63	$\frac{C}{C^*}, Q$	0.93
Q	0.69	0.69	0.78	0.25	0.09	0.83		

In Table 5.2 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 by the real exchange rate, (2) real GDP in the U.S., and (3) real GDP in Mexico. Both 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.[26]

[26] We report the empirical correlations of series in natural logs and HP-filtered. For the trade balance, we HP-filter directly the ratio of net exports/GDP.

Our model succeeds qualitatively in replicating the key cyclical characteristics of labor migration observable from the data. Thus, the baseline theoretical model generates 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, and counter-cyclical with the GDP of the economy where the migrant labor originates. For the immigrant labor income ($w_i L_i$) the correlations with the GDP ratio and with the home GDP are positive.

Our measure of remittances "inherits" one of the risk-sharing anomalies of the IRBC setup. 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 decreases when measured in units of the foreign basket, although it increases when measured in units of the home basket. As a result, the correlation of remittances with the home GDP is positive (as expected), whereas the correlation of remittances measured in units of the foreign basket with foreign GDP is also positive (contrary to the empirical evidence). Also at odds with the the data, the correlation of remittances with the GDP ratio is negative.

Table 5.2 Correlations of labor migration flows and remittances[27]

(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	0.99	0.17	−0.89
Remittances	−0.62	0.63	0.89
Immigrant labor income	0.19	0.94	0.73

[27] GDP for each country is output expressed in units of the corresponding consumption basket, i.e. $GDP_h = p_h y_h$ and $GDP_f = p_f y_f$.

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.[28] 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 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:

$$V_{t'} = E_{t'} \sum_{v=t'}^{\infty} \beta^v U\left(\overline{C}_v, \overline{L}_v\right). \tag{62}$$

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

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

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 extended 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:

$$V_0 = \frac{1}{1-\beta} \left\{ \phi s U\left(\overline{c_s}, \overline{l_s}\right) + (1-\phi)(1-s) U\left(\overline{c_u}, \overline{l_u}\right) \right\} \tag{63}$$

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

$$V_{t'} = E_{t'} \sum_{v=t'}^{\infty} \beta^v \left\{ \phi s_v U\left(c_{s,v}, l_{s,v}\right) + (1-\phi)(1-s_v) U\left(c_{u,v}, l_{u,v}\right) \right\}. \tag{64}$$

The results in Figure 10 show that 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 immigrants, despite the accumulation of human capital.

Using the extended 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 consider the insurance role of workers' remittances as a substitute for contingent claims in smoothing consumption across households' members residing in different countries over the business cycle.

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. Immigration stimulates the accumulation of capital in the destination economy, which in turn increases the productivity of native labor. The baseline model successfully matches the cyclical dynamics of labor migration which we document using U.S. and Mexican data on border apprehensions. International borrowing and lending facilitate capital flows and reduce the incentive of foreign labor to emigrate in steady state. Over the business cycle, however, the flow of capital towards the expanding economy reinforces the cyclical pattern of labor migration.

In an alternative specification, we extend the baseline model to allow for skill heterogeneity among home households in the presence of capital-skill complementarity. The overall welfare 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. At the sectoral level, the inflow of unskilled immigrants harms the welfare of unskilled native workers, but a compensation policy mechanism in the form of a countercyclical tax on the immigrant wage can potentially address this issue.

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:

$$r^* = \frac{1-\beta^*}{\beta^*}, \tag{65}$$

$$\frac{Y_f}{K^*} = \frac{r^* + \delta^*}{\alpha^*}, \tag{66}$$

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

$$Y_f = \left(\frac{Y_f}{K^*}\right) K^* = \left(\frac{r^* + \delta^*}{\alpha^*}\right)^{\frac{\alpha^*}{\alpha^*-1}} L_f^*, \tag{68}$$

$$w^* = (1-\alpha^*)\frac{Y_f}{L_f^*} = (1-\alpha^*)\left(\frac{r^* + \delta^*}{\alpha^*}\right)^{\frac{\alpha^*}{\alpha^*-1}}, \tag{69}$$

$$I^* = \delta^* K^*. \tag{70}$$

The home economy For the home economy, we solve the steady state numerically using a system of eight non-linear equations (71, 72, 76-81) 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:

$$Y_h = K^\alpha \left[\gamma^{\frac{1}{\theta}} (L_i)^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} (\zeta L_n)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}(1-\alpha)}, \tag{71}$$

$$\frac{\partial Y_h}{\partial K} = \alpha \frac{Y_h}{K} = r + \delta. \tag{72}$$

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:

$$Q^{-1} w_i = w^* + d, \tag{73}$$

$$= w^* + \frac{1-\beta^*(1-\delta_l)}{\beta^*(1-\delta_l)} f_e Q^{-1} w_i. \tag{74}$$

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:

$$\Theta \equiv \frac{w_i}{w^* Q} = \left[1 - \frac{1-\beta^*(1-\delta_l)}{\beta^*(1-\delta_l)} f_e\right]^{-1}, \tag{75}$$

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:

$$\underbrace{(1-\alpha)\left(Y_h\right)^{\frac{1-\theta\alpha}{\theta(1-\alpha)}} K^{\frac{\alpha(\theta-1)}{\theta(1-\alpha)}} \left(\frac{\gamma}{L_{i,t}}\right)^{\frac{1}{\theta}}}_{w_i} = \Theta \underbrace{(1-\alpha^*)\left(\frac{r^*+\delta^*}{\alpha^*}\right)^{\frac{\alpha^*}{\alpha^*-1}}}_{w^*} Q. \tag{76}$$

Equation 4: The balanced current account condition implies:

$$p_h Y_{h2} = p_f Q Y_{f1} + L_i w_i - \frac{L_i}{L^*} C^* Q, \tag{77}$$

where w_i is given above, and:

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

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

$$\frac{Y_h - Y_{h2}}{Y_{f1}} = \frac{\omega}{1-\omega}\left(\frac{p_h}{p_f Q}\right)^{-\mu}, \tag{78}$$

$$\frac{Y_f - Y_{f1}}{Y_{h2}} = \frac{\omega^*}{1-\omega^*}\left(\frac{p_f Q}{p_h}\right)^{-\mu^*}. \tag{79}$$

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

$$1 = \omega \left(p_h\right)^{1-\mu} + (1-\omega)(p_f Q)^{1-\mu}, \tag{80}$$

$$1 = \omega^* \left(p_f\right)^{1-\mu^*} + (1-\omega^*)\left(\frac{p_h}{Q}\right)^{1-\mu^*}. \tag{81}$$

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 71, 76 and 77 are replaced by:

$$(Y_h)^{\frac{\theta-1}{\theta}} = \gamma^{\frac{1}{\theta}} (L_i + L_u)^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} \left[\lambda^{\frac{1}{\eta}} K^{\frac{\eta-1}{\eta}} + (1-\lambda)^{\frac{1}{\eta}} (\zeta L_s)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}\frac{\theta-1}{\theta}}, \tag{82}$$

$$\underbrace{\left(\gamma \frac{Y_h}{L_i + L_u}\right)^{\frac{1}{\theta}}}_{w_i} = \underbrace{\Theta(1-\alpha^*)\left(\frac{r^* + \delta^*}{\alpha^*}\right)^{\frac{\alpha^*}{\alpha^*-1}} Q}_{w^*}, \tag{83}$$

$$p_h Y_{h2} = p_f Q Y_{f1} + L_i \underbrace{\left(\gamma \frac{Y_h}{L_i + L_u}\right)^{\frac{1}{\theta}}}_{w_i} - \frac{L_i}{L^*} C^* Q. \tag{84}$$

A.3 Baseline Model of 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:

$$r^b = \frac{2}{\beta + \beta^*} - 1, \tag{85}$$

$$B_h = -B_h^* = \frac{\beta(1 + r^b) - 1}{\pi}. \tag{86}$$

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:

$$r^{b*} = \frac{2}{\beta + \beta^*} - 1 = r^b, \tag{87}$$

$$B_f = -B_f^* = \frac{\beta(1 + r^{b*}) - 1}{\pi}. \tag{88}$$

Finally, the balanced current account condition (77) is replaced by the expression for the balance of international payments (44) in steady state:

$$p_h Y_{h2,t} - p_f Y_{f1} Q - \underbrace{\left(w_i L_i - \frac{L_i}{L^*} C^* Q \right)}_{\text{Remittances}} + r^b B_h + r^{b*} Q B_f = 0. \tag{89}$$

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

A.4 Benchmark Model without Labor Migration

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 $(r_t, w_t, C_t, L_t, Y_{h,t}, Y_t, Y_{h,t}, Y_{h2,t}, I_t, K_t, p_{h,t})$:

$$1 = \beta(1 + r_t) E_t \left(\frac{C_t}{C_{t+1}} \right), \tag{90}$$

$$\frac{w_t}{C_t} = \chi L_t^{\psi}, \tag{91}$$

$$Y_{h,t} = A_t K_{t-1}^{\alpha} L_t^{1-\alpha}, \tag{92}$$

$$Y_{h,t} = Y_{h1,t} + Y_{h2,t}, \tag{93}$$

$$(Y_t)^{\frac{\mu-1}{\mu}} = \omega^{\frac{1}{\mu}} \left(Y_{h,t} - Y_{h2,t}\right)^{\frac{\mu-1}{\mu}} + (1-\omega)^{\frac{1}{\mu}} \left(Y_{f1,t}\right)^{\frac{\mu-1}{\mu}}, \tag{94}$$

$$Y_t = C_t + I_t, \tag{95}$$

$$K_t = I_t + (1-\delta) K_{t-1}, \tag{96}$$

$$Y_{h1,t} = \omega \left(p_{h,t}\right)^{-\mu} Y_t, \tag{97}$$

$$Y_{f1,t} = (1-\omega) \left(p_{f,t} Q_t\right)^{-\mu} Y_t, \tag{98}$$

$$r_t = \alpha \frac{Y_{h,t+1}}{K_t} - \delta \tag{99}$$

$$w_t = (1-\alpha) \frac{Y_{h,t}}{L_t} \tag{100}$$

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:

$$NX_t = \underbrace{Y_{h2,t} p_{h,t}}_{\text{exports}} - \underbrace{Y_{f1,t} p_{f,t} Q_t}_{\text{imports}}. \tag{101}$$

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:

$$1 + \pi B_{h,t+1} = \beta E_t \left[(1 + r_{t+1}^b) \frac{C_t}{C_{t+1}} \right], \tag{102}$$
$$1 + \pi B_{f,t+1} = \beta E_t \left[\frac{Q_{t+1}}{Q_t} (1 + r_{t+1}^{b*}) \frac{C_t}{C_{t+1}} \right], \tag{103}$$
$$1 + \pi B_{h,t+1}^* = \beta^* E_t \left[\frac{Q_t}{Q_{t+1}} (1 + r_{t+1}^b) \frac{C_t^*}{C_{t+1}^*} \right], \tag{104}$$
$$1 + \pi B_{f,t+1}^* = \beta^* E_t \left[(1 + r_{t+1}^{b*}) \frac{C_t^*}{C_{t+1}^*} \right], \tag{105}$$
$$B_{h,t+1} + B_{h,t+1}^* = 0, \tag{106}$$
$$B_{f,t+1} + B_{f,t+1}^* = 0. \tag{107}$$

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

$$p_{h,t} Y_{h2,t} - p_{f,t} Q_t Y_{f1,t} + r_t^b B_{h,t} + r_t^{b*} Q_t B_{f,t} = 0. \tag{108}$$

A.5 Benchmark Model without Labor Migration, Asymmetric Steady State

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

$$r = \frac{1-\beta}{\beta}, r^* = \frac{1-\beta^*}{\beta^*}, \tag{109}$$

$$\alpha\frac{Y_h}{K} - \delta = r \rightarrow \frac{Y_h}{K} = \frac{r+\delta}{\alpha}, \frac{Y_f}{K^*} = \frac{r^*+\delta^*}{\alpha^*}, \tag{110}$$

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

$$Y_h = \left(\frac{Y_h}{K}\right) K = \left(\frac{r+\delta}{\alpha}\right)^{\frac{\alpha}{\alpha-1}} L, Y_f = \left(\frac{r^*+\delta^*}{\alpha^*}\right)^{\frac{\alpha^*}{\alpha^*-1}} L^*, \tag{112}$$

$$I = \delta K, I^* = \delta^* K^*. \tag{113}$$

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

$$p_h = p_f = Q = 1. \tag{114}$$

$$Y_{h1} = Y_{f2} = \omega Y_h. \tag{115}$$

$$Y_{h2} = Y_{f1} = (1-\omega) Y_h, \tag{116}$$

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

$$Y = \left[\omega^{\frac{1}{\mu}} (Y_{h1})^{\frac{\mu-1}{\mu}} + (1-\omega)^{\frac{1}{\mu}} (Y_{f1})^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} = Y_h, \tag{117}$$

$$C = Y - I. \tag{118}$$

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 (109)-(113) still hold. We obtain the steady-state solutions numerically using a system of 5 equations in 5 unknowns

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

$$\frac{Y_{h1}}{Y_f - Y_{f2}} = \frac{\omega}{1-\omega}\left(\frac{p_h}{p_f Q}\right)^{-\mu}, \tag{119}$$

$$\frac{Y_{f2}}{Y_h - Y_{h2}} = \frac{\omega^*}{1-\omega^*}\left(\frac{p_f Q}{p_h}\right)^{-\mu^*}, \tag{120}$$

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

$$1 = \omega^*\,(p_f)^{1-\mu^*} + (1-\omega^*)\left(\frac{p_h}{Q}\right)^{1-\mu^*} \tag{122}$$

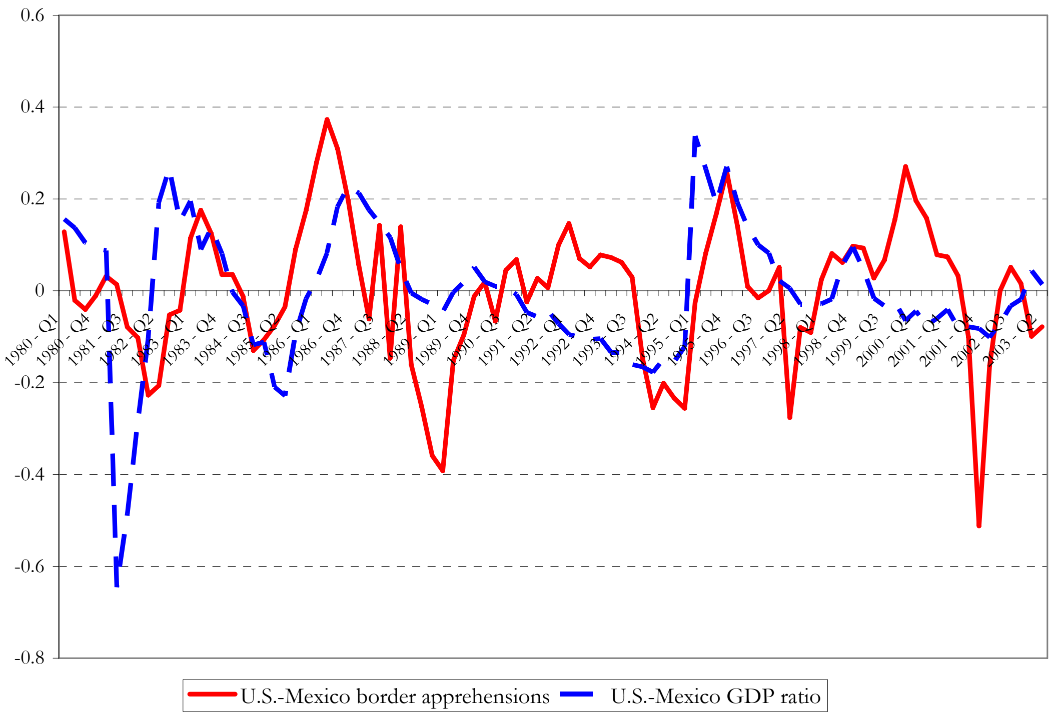
In financial autarky, the balanced trade condition is:

$$Y_{h2} p_h - Y_{f1} p_f Q = 0. \tag{123}$$

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

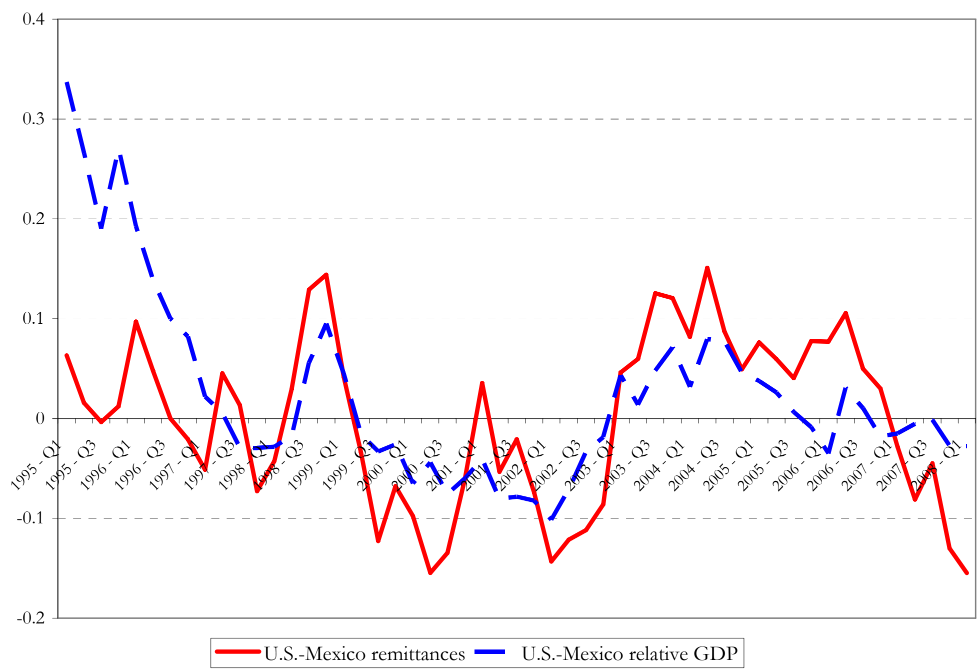
$$p_h Y_{h2} - p_f Q Y_{f1} + r^b B_h + r^{b*} Q B_f = 0. \tag{124}$$

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



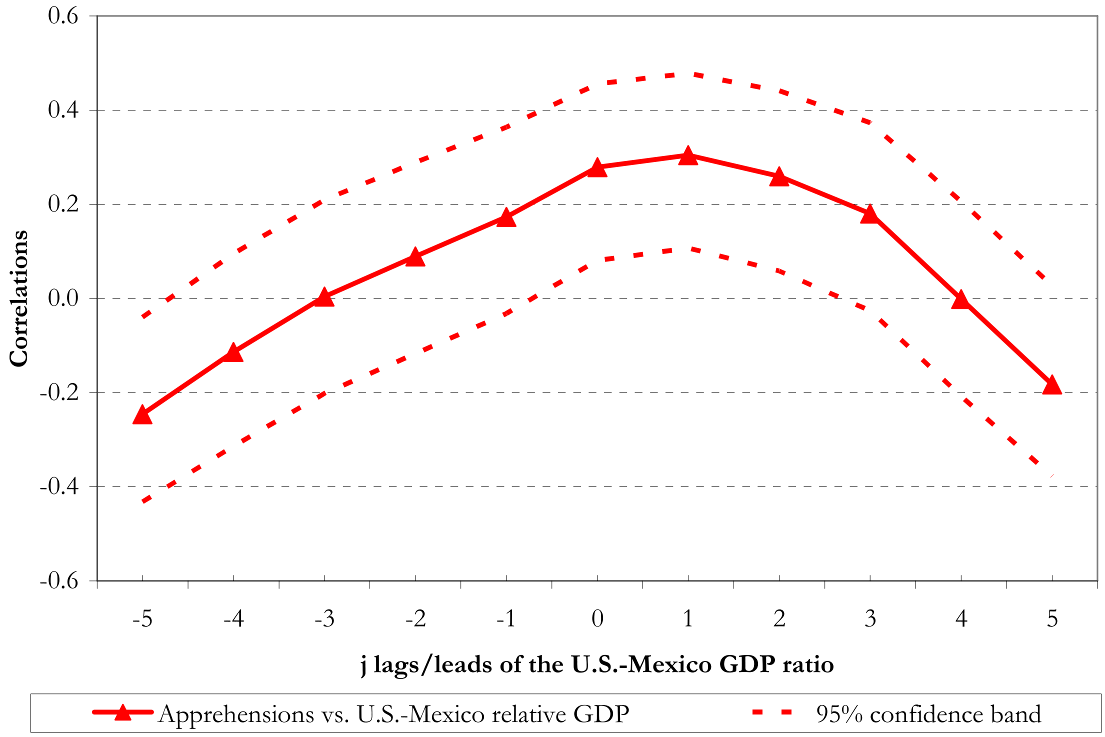
Source: Hanson (2007), *Haver Statistics,* and International Financial Statistics (2008).
Note: We have seasonally-adjusted the series for border apprehensions using the X-12 ARIMA method of the U.S. Census Bureau. The resulting seasonally-adjusted series were logged and HP(1600) filtered. The U.S.-Mexico 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



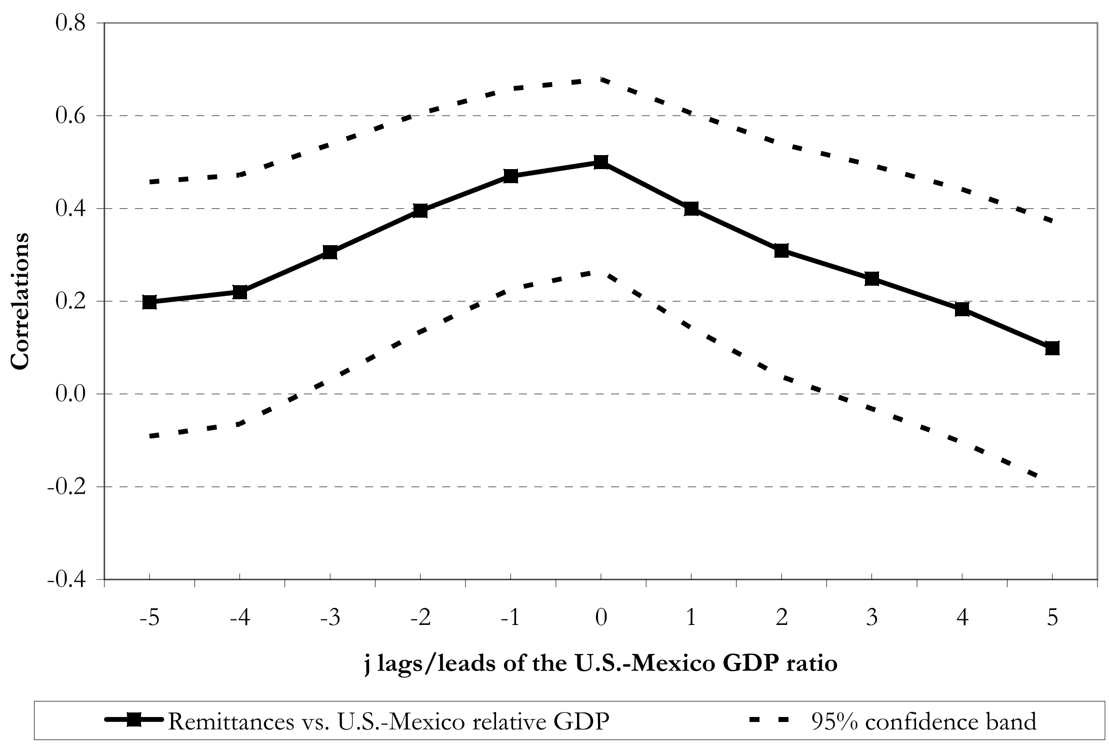
Source: *Haver Statistics* and Banco de México. Remittances are expressed in Mexican pesos at constant prices. Series were seasonally adjusted and detrended with the methods described in Figure 1.

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



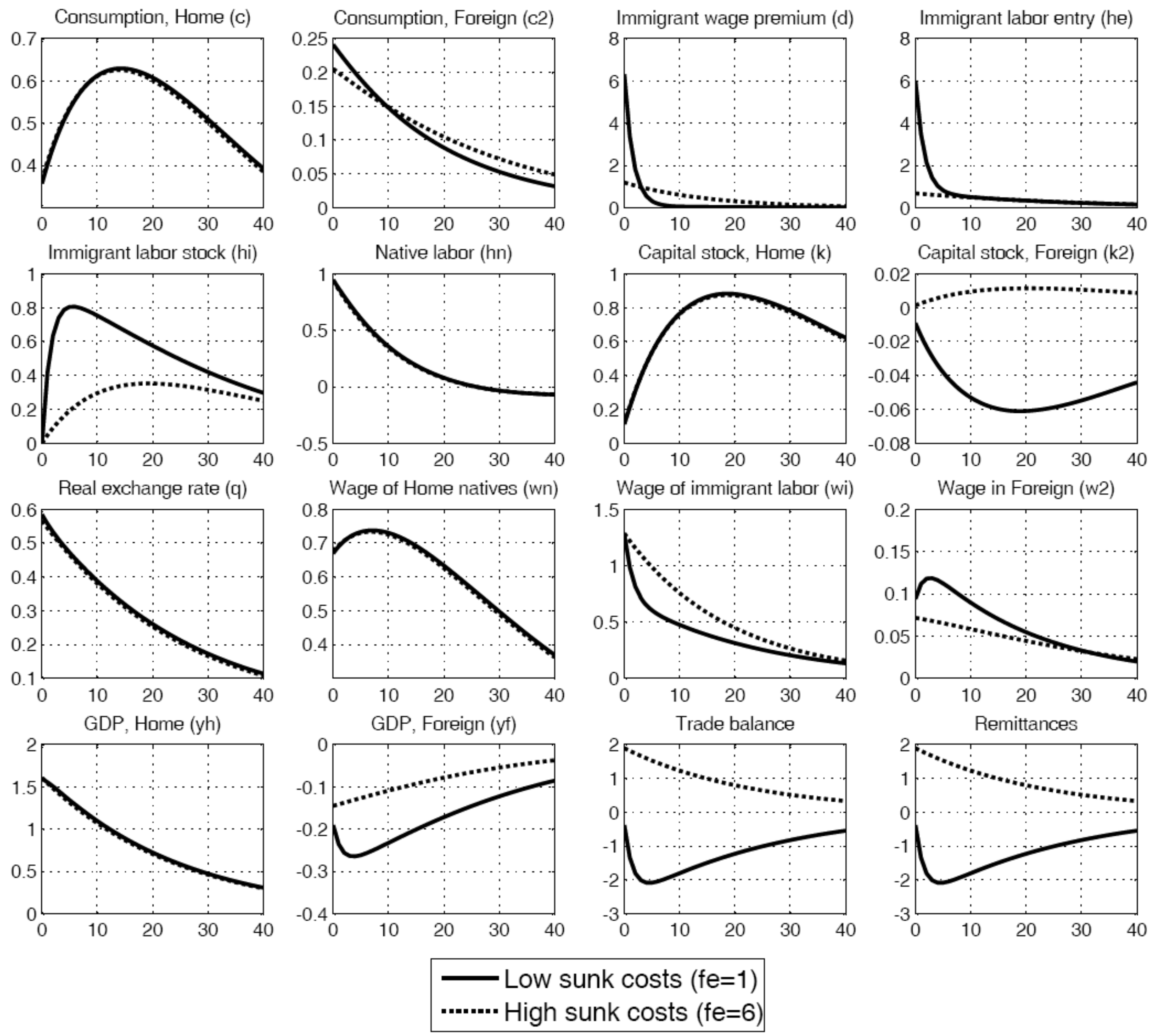
Note: correlations are computed based on the data in Figure 1.

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



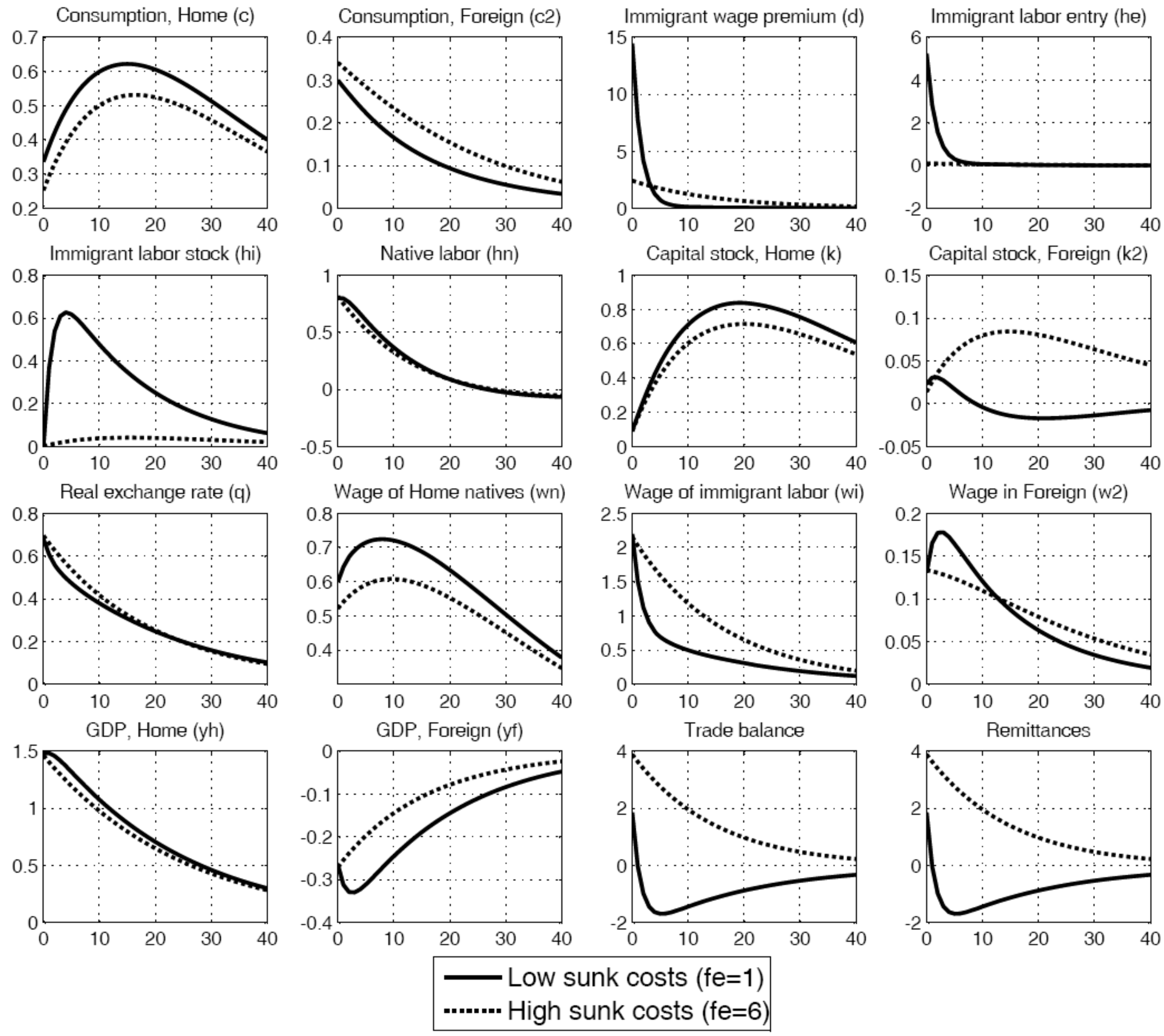
Note: correlations are computed based on the data in Figure 2.

Figure 4. Baseline model with financial autarky



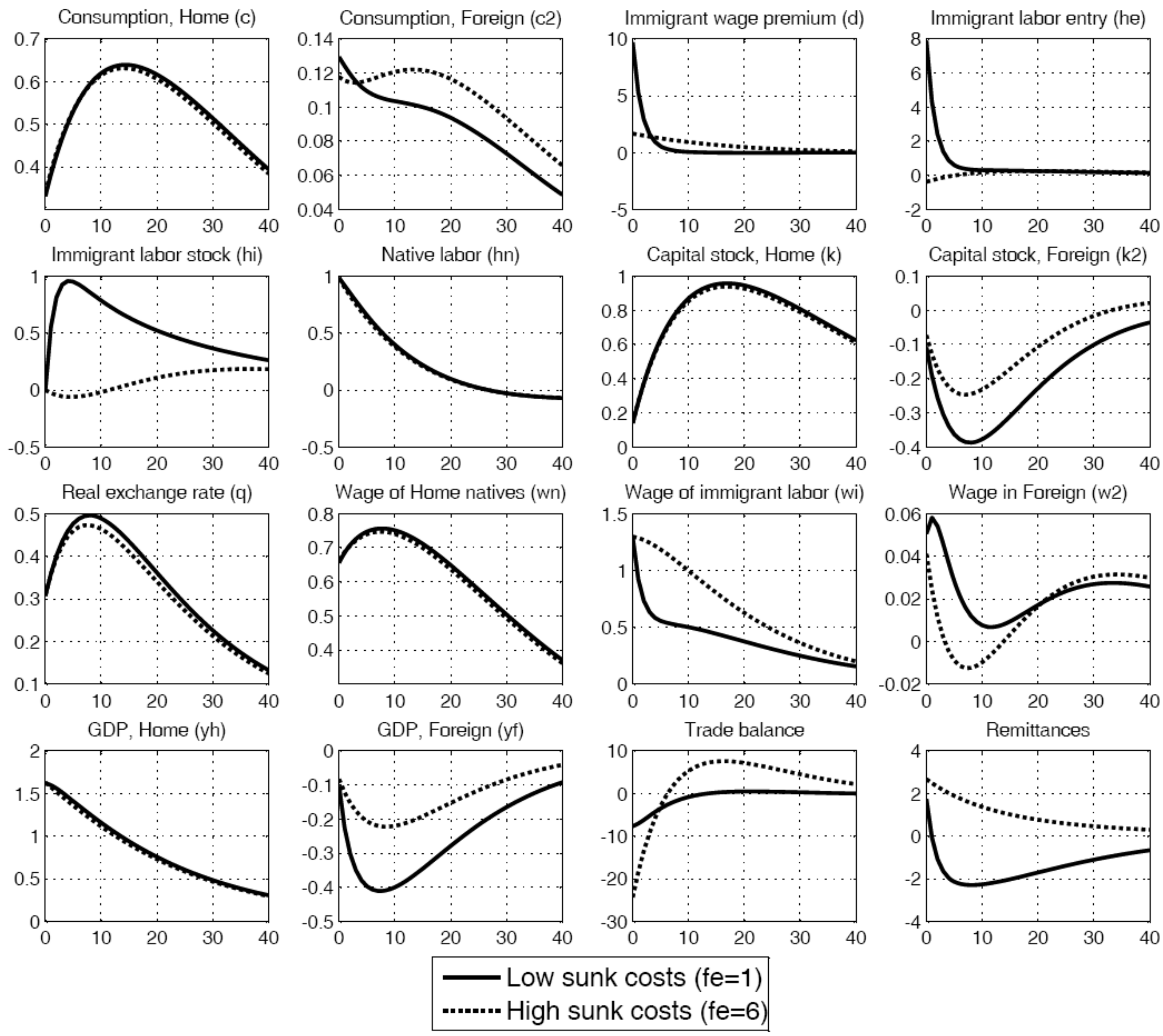
Each panel shows the response (percent deviations from steady state) to a transitory 1 percent increase in home productivity, for the cases with high sunk cost (f_e =6, dashed) and low sunk cost (f_e =1, solid).

Figure 5. Baseline model with financial autarky, low elasticity of substitution between native and immigrant labor



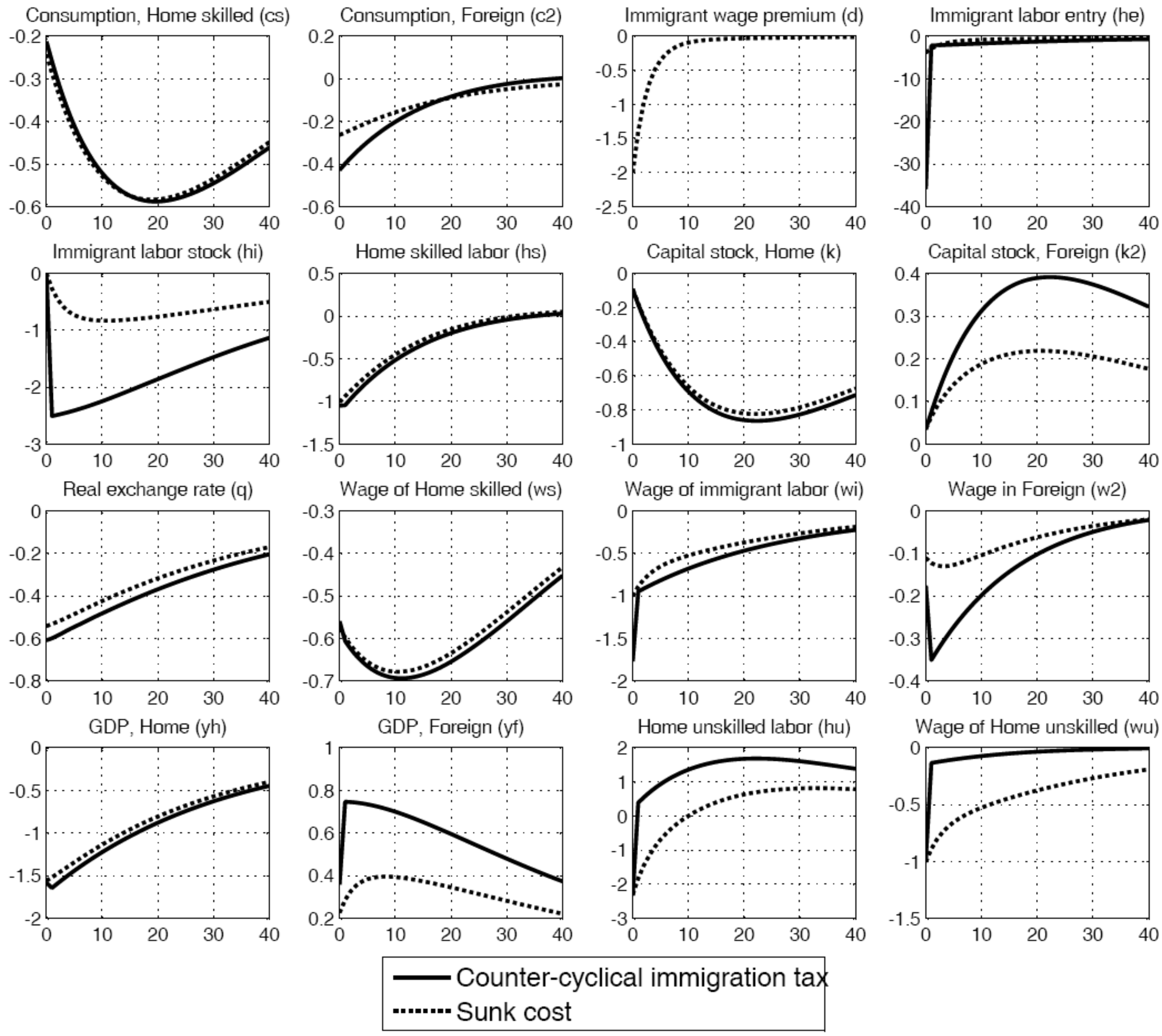
Each panel shows the response (percent deviations from steady state) to a transitory 1 percent increase in home productivity, under high complementarity between the native and immigrant labor ($\theta = 0.5$), for the cases with high sunk cost ($f_e = 6$, dashed) and low sunk cost ($f_e = 1$, solid).

Figure 6. Baseline model with financial integration



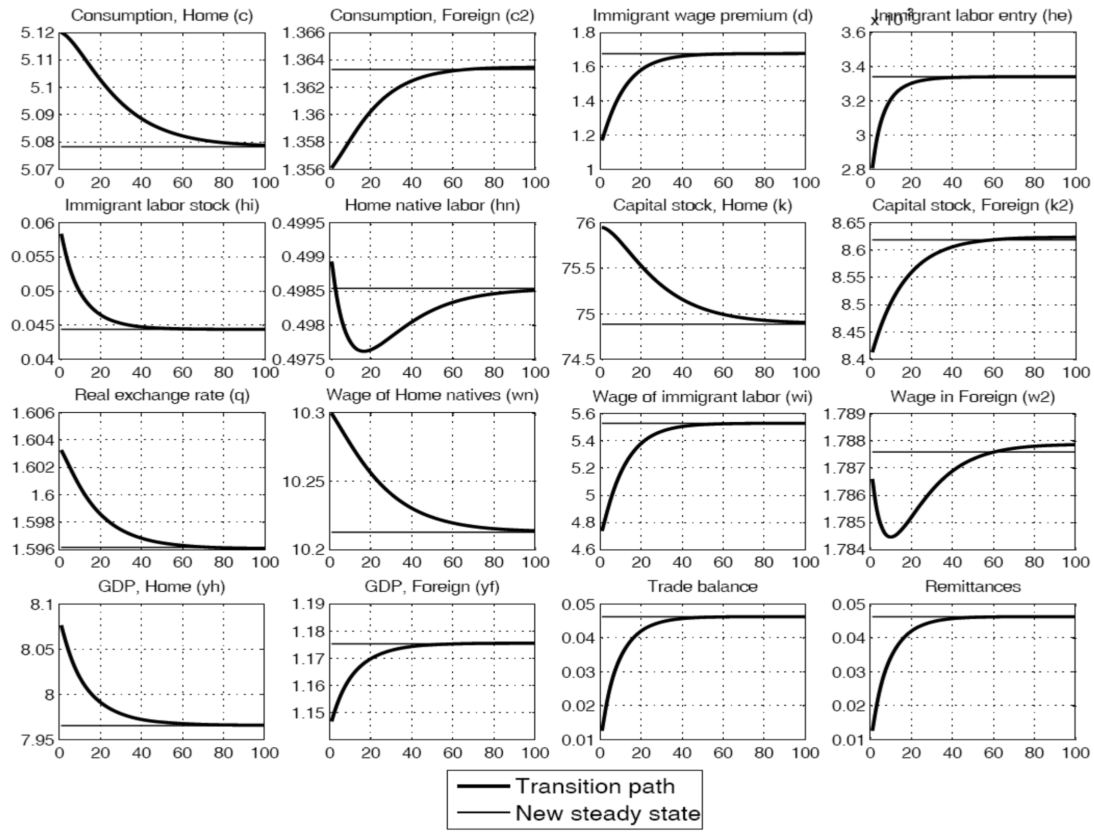
Each panel shows the response (percent deviations from steady state) to a transitory 1 percent increase in home productivity, for the cases with high sunk cost (f_e =6, dashed) and low sunk cost (f_e =1, solid). The model allows for international trade in risk-free bonds (with adjustment cost parameter $\pi = 0.005$).

Figure 7. Alternative model with financial autarky



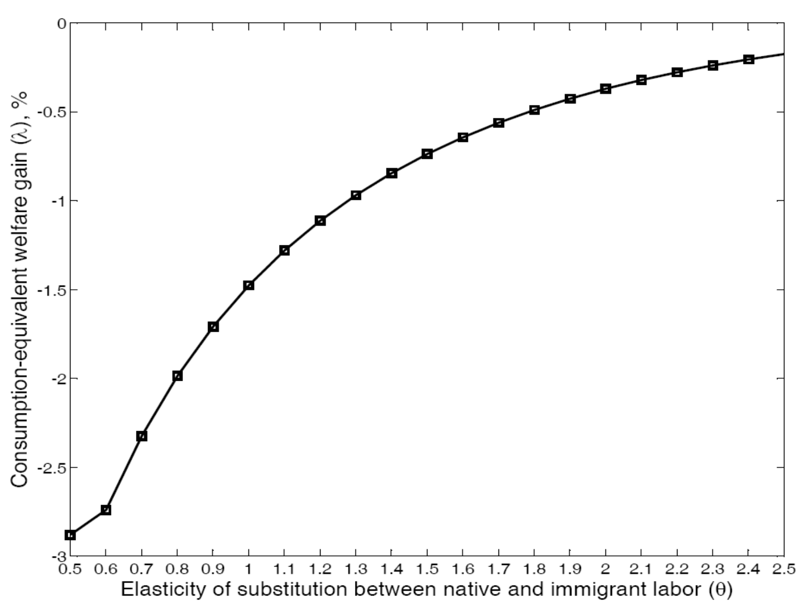
Each panel shows the response (percent deviations from steady state) to a transitory 1 percent <u>decrease</u> in home productivity in the alternative model (i.e. in which we allow for skill heterogeneity among the native labor, and we assume capital-skill complementarity), in the presence of (1) counter-cyclical immigration tax (solid), and (b) sunk emigration cost (dashed).

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



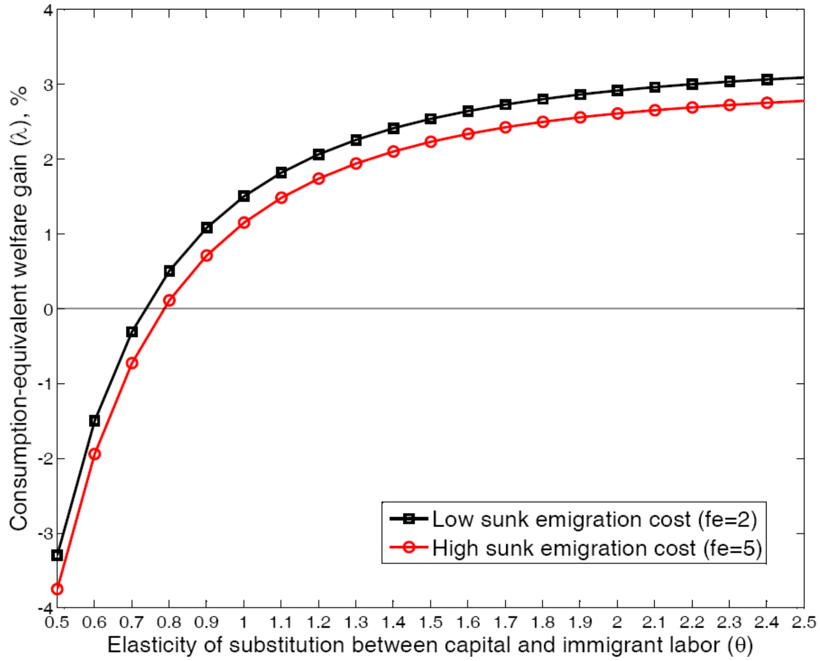
Each panel shows the transition path of the model's variables with a permanent increase in the sunk emigration cost (sudden increase from f_e =4 to f_e =5).

Figure 9. Welfare analysis, baseline model with financial autarky



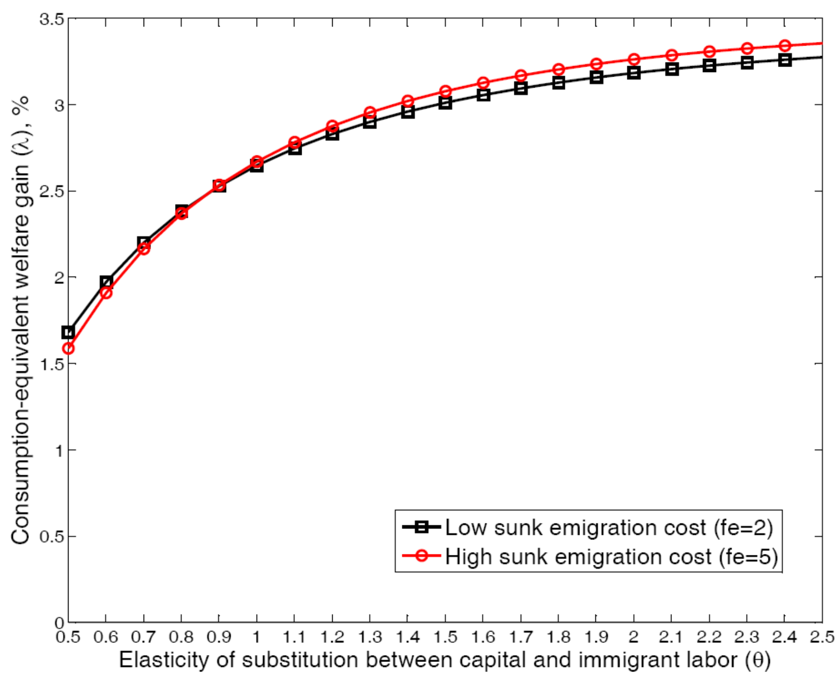
Consumption-equivalent welfare gain/loss with a permanent increase in the sunk emigration cost (sudden increase from f_e =4 to f_e =5).

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.