FEDERAL RESERVE BANK *of* ATLANTA | WORKING PAPER SERIES

Immigration, Remittances, and Business Cycles

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Working Paper 2008-25b
February 2012

Abstract: Using data on border enforcement and macroeconomic indicators from the United States and Mexico, we estimate a two-country business cycle model of labor migration and remittances. The model matches the cyclical dynamics of unskilled migration and documents the insurance role of remittances in consumption smoothing. Over the cycle, immigration increases with the expected stream of future wage gains, but it is dampened by a sunk emigration cost. Migration barriers slow the adjustment of the stock of immigrant labor, enhancing the volatility of unskilled wages and remittances. Changes in border enforcement have asymmetric welfare implications for the skilled and unskilled households.

JEL classification: F22, F41

Key words: Labor migration, sunk emigration cost, skill heterogeneity, international business cycles, Bayesian estimation

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This paper is a significantly revised version of "Immigration and the Macroeconomy." The authors acknowledge Gustavo Canavire and Menbere Shiferaw for superb research assistance. They thank Esteban Rossi-Hansberg, an anonymous referee, discussants Mario Crucini, Bora Durdu and Antonio Spilimbergo, as well as James Anderson, Susanto Basu, Fabio Ghironi, Matteo Iacoviello, Peter Ireland, Nobuhiro Kiyotaki, Giovanni Peri, Myriam Quispe-Agnoli, B. Ravikumar, Alessandro Rebucci, Pedro Silos, Nicole Simpson, Stephenie Young, and conference and seminar participants who provided helpful comments at the 2012 meeting of the American Economic Association, the Bank of Japan, the Bank of Spain, the Central Bank of the Philippines, the Atlanta Fed, the Boston Fed, the Federal Reserve Board, the Federal Reserve SCIEA 2008, Georgia Tech, the Inter-American Development Bank, the 2010 conference of the Latin American and Caribbean Economic Association, the National Bureau of Economic Research's Summer Institute 2009 (International Finance and Macroeconomics Program), North East Universities Development Consortium 2009, the Paris School of Economics, the 2010 conference of the Society of Government Economists, the Universidad de San Andrés, the University of Delaware, and the Econometric Society World Congress 2010. Part of this project was developed while Andrei Zlate was visiting the Federal Reserve Banks of Atlanta and, whose hospitality he gratefully acknowledges. The views expressed here are the authors' and not necessarily those of the Federal Reserve Bank of Atlanta or the Federal Reserve System. Any remaining errors are the authors' responsibility.

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1. Introduction

Labor migration is sizeable and has a significant economic impact on the economies involved. The number of foreign-born residents is rising worldwide: Foreign-born residents made up as much as 13% of the total U.S. population in 2007, compared to less than 6% in 1980, a pattern visible in several other OECD countries as well (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 U.S. recessions were associated with drastic declines in immigration flows, while relatively larger inflows occurred during recovery years.[1] Adding to this evidence, in Fig. 1 (top) we plot the number of apprehensions at the U.S.-Mexico border (which the existing literature uses as a proxy for attempted illegal crossings of unskilled labor into the U.S.) along with the GDP ratio between the U.S. and Mexico measured in purchasing power parity terms. The chart shows that periods in which the U.S. economy outperformed that of Mexico generally were accompanied by an increase in the number of border apprehensions.[2]

Immigrant workers send remittances to developing countries on a regular basis. Conservative estimates put the amount of workers' remittances to the developing world at $336 billion in 2008. These inflows were equivalent to more than 10% of the GDP of several receiving countries,[3] while globally they were equivalent to 48% of the total private net capital flows to developing economies (including FDI, portfolio equity and private debt). Just like labor migration, the remittance flows also vary during the course of the business cycle. Fig. 1 (bottom) plots the pattern of remittances from the U.S. to Mexico vis-a-vis the relative

[1] For instance, the number of arrivals into the U.S. declined by almost 40 percent in the aftermath of the financial panic episode of 1907. Notable declines also were observed during the U.S. recessions of 1876-79, 1894 and 1922. At that time, there were fewer restrictions on the legal immigration from Europe, and most of the arrivals were properly documented (O'Rourke and Williamson, 1999). Therefore, the recorded flows of immigrant labor in the U.S. were closely related to the economic considerations modeled in this paper.

[2] Similarly, Hanson and Spilimbergo (1999) find that a 10% relative decline in the Mexican real wage has been associated with a 6% to 8% increase in U.S. border apprehensions. Borger (2009) finds similar results using annual survey-based micro estimates of migration flows.

[3] See World Bank (2010). For Mexico, the world's 11th largest economy in PPP, the figure was 2.4%.

performance of these economies. Larger outflows of remittances to Mexico occur during periods with faster U.S. economic growth (or lower Mexican growth). The results are even stronger when remittances are compared with the relative wage across the two economies, measured as the ratio between the real wage of unskilled workers in the U.S. (who lack a high school degree) and workers in export assembly plants (maquiladoras) in Mexico. To sum up, the combined evidence in Fig. 1 highlights the potential insurance role of labor migration and remittances to diversify away country-specific risk and smooth the consumption path for Mexican households whose members reside on both sides of the border.

[LOCATE FIGURE 1 ABOUT HERE]

With this evidence in mind, this paper examines the business cycle fluctuations of labor migration and remittance flows as well as their propagation to the rest of the economy.[4] It also studies the effect of immigration policy (reflected by the magnitude of migration barriers) on the volatility of migration flows and remittances, as well as the insurance role of migration and remittances in smoothing consumption. To this end, we build a two-country dynamic stochastic general equilibrium (DSGE) model along the lines of Backus et al. (1994), which allows for endogenous labor migration and remittances. To account for skill heterogeneity among the native labor, the model features two types of labor (skilled and unskilled) in each country, under the assumption that capital and skilled labor are relative complements as in Krusell et al. (2000). The model is estimated using Bayesian techniques with data on border enforcement and macroeconomic indicators from the U.S. and Mexico.

Our methodology bridges an existing gap between international macroeconomics 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 frameworks limited to comparisons of long-run positions or to the study of growth dynamics. Those models are not suitable for the analysis of

[4] Additional materials, model results and the data sources are available in a technical appendix available online at the authors' websites.

immigration dynamics at business cycle frequencies, which is the main focus of this paper. In our model, the unskilled labor can emigrate subject to a sunk cost; the incentive to emigrate depends on the expectation of future earnings at the destination relative to the country of origin, on the perceived sunk cost of emigration, and on the return probability of immigrant labor. The probability of return plays a significant role, with approximately 70% of undocumented Mexican immigrants in the U.S. returning home within ten years (Reyes, 1997). The sunk cost reflects the intensity of border enforcement, and also includes the cost of searching for employment, adjustment to a new lifestyle and transportation expenditures. In the case of undocumented immigration, it includes the cost of hiring human smugglers (coyotes) as well as the physical risk and legal implications of illegally crossing the border.

In line with the empirical evidence, the model generates immigration and remittance flows that are procyclical with the relative economic performance of the two economies. The skill premium in the destination economy is procyclical and positively correlated with the inflows of migrant unskilled labor, which dampen the unskilled wage during expansions. An additional result is that stricter border enforcement reduces the volatility of the stock of immigrant labor (consistent with the evidence), and increases the volatility of the immigrant wage and remittances.[5] In the model, the absence of labor mobility restrictions would imply that immigrant labor efficiently exploits the ups and downs of the business cycle. That is, migrant labor would arrive in large numbers during economic expansions when it is most needed, and promptly return to the country of origin when a bad shock hits the destination economy. Higher border enforcement breaks this logic, because the increase in the stock of immigrant labor fails to keep pace with labor demand during expansions. Instead, 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 boom times reduces capital accumulation and dampens labor productivity in the

[5] Rodríguez-Zamora (2008) shows that the recent increase in border enforcement resulted in less volatile migration inflows and outflows across the U.S.-Mexico border.

destination economy. During recessions, the opposite effect occurs: Due to the barriers to labor migration, established immigrants are deterred from returning to their country of origin, placing additional downward pressure on the wage of the native unskilled workers.

In the baseline model, only the skilled households in each economy are financially integrated through international trade in bonds, while the unskilled are in financial autarky.[6] This assumption is consistent with the empirical evidence, and allows us to examine the role of labor migration and remittances as a substitute for cross-border financial flows in consumption smoothing.[7] Consistent with the business cycle features from emerging market economies, the baseline model generates consumption that is more volatile than output, since migration is costly and the unskilled do not trade bonds. The volatility of unskilled consumption decreases for lower values of the sunk emigration cost; this decrease is notably steeper in the baseline case with the unskilled in financial autarky (so labor migration is their only insurance mechanism) than in the alternative case when they trade bonds. The model also generates a countercyclical trade balance at the same time with countercylical migration outflows, since during downturns the foreign skilled households invest in bonds overseas while the unskilled households invest in labor migration.

Lowering the restrictions to unskilled labor migration has asymmetric welfare effects on the skilled and unskilled households in the destination economy. However, the welfare gain from loosening the border (due in part to the faster adjustment of the unskilled labor input over the cycle) outweighs the loss arising as the native unskilled labor becomes more exposed to immigration flows: The skilled households can fully compensate the unskilled and still obtain a net welfare gain. In the country of origin, lowering the migration barriers enhances labor income and facilitates consumption smoothing for the unskilled households. However, the measure also reduces the availability of unskilled labor in production, which is

[6] This assumption is relaxed in an alternative model presented in the appendix online.

[7] Honohan (2008) shows that only 25 percent of the adult population in Mexico uses banking services, and that the lack of access to banking services is positively correlated with poverty.

a complement for skilled labor and capital. Nonetheless, the net benefit after compensating the skilled is also positive, indicating a global Pareto improvement.

This paper is related to existing literature that quantifies the effect of migration in both static frameworks (Borjas, 1995; Hamilton and Whalley, 1984; Iranzo and Peri, 2009; Walmsley and Winters, 2003) and dynamic frameworks (Djacic, 1987; Storesletten, 2000). It is closely related to Klein and Ventura (2009) and Urrutia (1998), who model endogenous labor movements to assess the welfare effects of removing barriers to migration. However, these two papers do not model remittances. Crucially, they are based on a growth setup designed to compare long-run outcomes, thus abstracting from cyclical fluctuations. In the context of DSGE models of international business cycles, this paper is related to Acosta et al. (2009), Chami et al. (2006) and Durdu and Sayan (2010), who include remittance endowment shocks in a small open economy framework. However, they refrain from modeling labor migration. Finally, our paper is also related to Alessandria and Choi (2007) and Ghironi and Melitz (2005), who use sunk costs to model exports and firm entry, respectively, as endogenous firm-level decisions; to Polgreen and Silos (2009), who use skill heterogeneity and capital-skill complementarity with two representative households; and to Yang and Choi (2007), who document the insurance role of remittances in response to negative income shocks in the Philippines.

2. The Model

The model is representative of a standard two-country setup (Home and Foreign) along the lines of Backus et al. (1994). The novel characteristic is the presence of labor mobility and remittances. We introduce two types of labor (skilled and unskilled) in each country, while assuming capital-skill complementarity in production as in Krusell et al. (2000). The unskilled labor can migrate from Foreign to Home, and migrant workers send a fraction of their income as remittances back to the country of origin every period. Following the findings in Borjas et al. (2008), the native unskilled and immigrant unskilled labor are perfect substitutes. International asset markets are incomplete, and the skilled households from each country trade country-specific, risk-free bonds. The foreign unskilled households do not trade bonds, but have migration and remittances as an insurance mechanism that substitutes for bond trading.[8] As standard, there are as many shocks as the data series used in the estimation to avoid stochastic singularity.

2.1. Home Households

The home economy includes a continuum of two types of infinitely lived households of relative sizes s and $1-s$, which supply units of skilled and unskilled labor. Each of the two representative households maximizes lifetime utility as a function of consumption $c_{j,t}$ and labor supply $l_{j,t}$:

$$\underset{\{c_{j,t},l_{j,t},i_{j,t},k_{j,t+1}\}}{max} E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left\{ \varepsilon_{\tau}^{b} \left(\ln c_{j,\tau} - \frac{\chi_j}{1+\psi} l_{j,\tau}^{1+\psi} \right) \right\}, \tag{1}$$

where subscript $j \in \{s,u\}$ denotes the household type (skilled and unskilled); $1/\psi \geq 0$ is the Frisch elasticity of labor supply; χ_j is the weight on the disutility from labor; and ε_t^b represents a preference (demand) shock that affects intertemporal substitution.

The skilled household, which trades bonds internationally, faces the budget constraint:

$$\begin{aligned} & w_{s,t} l_{s,t} + r_{s,t} k_{s,t} + \left(1+r_t^b\right) b_{h,t} + \left(1+r_t^{b*}\right) Q_t b_{f,t} + T_{s,t} \\ & \geqslant c_{s,t} + i_{s,t} + b_{h,t+1} + \frac{\pi}{2} \left(b_{h,t+1}\right)^2 + Q_t b_{f,t+1} + \frac{\pi}{2} Q_t \left(b_{f,t+1}\right)^2, \end{aligned} \tag{2}$$

where $w_{s,t}$ is the wage of skilled labor; $r_{s,t}$ is the gross rental rate of the capital owned by skilled households; $k_{s,t}$ and $i_{s,t}$ are the capital and investment of the skilled households; r_t^b

[8] To highlight the insurance role of migration and remittances as a substitute for bond trading, the baseline model assumes financial autarky for the foreign unskilled households. This assumption is relaxed in an alternative model presented in the appendix online. For symmetry, the unskilled households in Home are also in financial autarky. Since the share of unskilled households in Home is relatively small (8 percent, in line with the U.S. data), the results would be similar under financial integration for the home unskilled.

and r_t^{b*} are the rates of return of home and foreign bonds; $\left(1+r_t^b\right) b_{h,t}$ and $\left(1+r_t^{b*}\right) Q_t b_{f,t}$ are the principal and interest from home and foreign bonds expressed in units of the home composite good; Q_t is the real exchange rate; $\frac{\pi}{2}\left(b_{h,t+1}\right)^2$ and $\frac{\pi}{2}\left(b_{f,t+1}\right)^2$ are the adjustment costs for bond holdings; and $T_{s,t}$ is the adjustment cost rebated to the skilled households.[9]

The unskilled household, which does not trade bonds, is subject to the budget constraint: $w_{u,t} l_{u,t} + r_{u,t} k_{u,t} \geqslant c_{u,t} + i_{u,t}$, where $w_{u,t}$ is the equilibrium wage for unskilled labor; $r_{u,t}$ is the gross rental rate of the capital owned by unskilled households; $k_{u,t}$ and $i_{u,t}$ are capital holdings and investment by the unskilled household.

For each type of household $j \in \{s,u\}$, capital accumulation follows the rule: $k_{j,t+1} = (1-\delta) k_{j,t} + \varepsilon_t^I i_{j,t}$, where ε_t^I is an investment-specific technology shock, and δ is the depreciation rate. The first order conditions for capital and labor are:

$$\frac{1}{\varepsilon_t^I} = \beta E_t \left[\frac{\varsigma_{j,t+1}}{\varsigma_{j,t}}\left(r_{j,t+1} + \frac{1-\delta}{\varepsilon_{t+1}^I}\right)\right] \text{ and } \frac{w_{j,t}}{c_{j,t}} = \chi_j \left(l_{j,t}\right)^{\psi}, \tag{3}$$

where $\varsigma_{j,t} = \frac{\varepsilon_t^b}{c_{j,t}}$ for $j \in \{s,u\}$ are the budget constraint multipliers for each household.

For the skilled households, in addition to (3), the Euler equations for bonds are:

$$1 + \pi b_{h,t+1} = \beta(1+r_{t+1}^b) E_t \left[\frac{\varsigma_{s,t+1}}{\varsigma_{s,t}}\right] \text{ and } 1 + \pi b_{f,t+1} = \beta(1+r_{t+1}^{b*}) E_t \left[\frac{Q_{t+1}}{Q_t}\frac{\varsigma_{s,t+1}}{\varsigma_{s,t}}\right]. \tag{4}$$

Market clearing for bonds implies $s b_{h,t+1} + s^* b_{h,t+1}^* = 0$ and $s b_{f,t+1} + s^* b_{f,t+1}^* = 0$.

The total consumption, labor supply, capital and investment of the skilled households are $C_{s,t} = s c_{s,t}$, $L_{s,t} = s l_{s,t}$, $K_{s,t} = s k_{s,t}$ and $I_{s,t} = s i_{s,t}$. The total consumption, labor supply, capital and investment of the unskilled households are $C_{u,t} = (1-s) c_{u,t}$, $L_{u,t} = (1-s) l_{u,t}$, $K_{u,t} = (1-s) k_{u,t}$ and $I_{u,t} = (1-s) i_{u,t}$. The aggregate capital stock is a CES composite of the capital of skilled and unskilled households: $K_t = \left[(\lambda_k)^{\frac{1}{\eta_k}} \left(K_{s,t}\right)^{\frac{\eta_k-1}{\eta_k}} + (1-\lambda_k)^{\frac{1}{\eta_k}} \left(K_{u,t}\right)^{\frac{\eta_k-1}{\eta_k}}\right]^{\frac{\eta_k}{\eta_k-1}}$. The assumption of imperfect substitution between the capital of skilled and unskilled is discussed under the foreign economy below.

[9] The cost parameter π is necessary to avoid non-stationarity of the stock of liabilities.

2.2. Home Output

Production in Home is a nested CES aggregate:

$$\tilde{Y}_{h,t} = \varepsilon_t^a \left\{ (\gamma)^{\frac{1}{\theta}} \left(\Upsilon_{1,t}\right)^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} \left(\Upsilon_{2,t}\right)^{\frac{\theta-1}{\theta}} \right\}^{\frac{\theta}{\theta-1}}, \tag{5}$$

where $\Upsilon_{1,t} = L_{u,t} + L_{i,t}$ is a function in which native and immigrant unskilled labor enter as perfect substitutes; $\Upsilon_{2,t} = \left[\lambda^{\frac{1}{\eta}} \left(K_t\right)^{\frac{\eta-1}{\eta}} + (1-\lambda)^{\frac{1}{\eta}} \left(\zeta L_{s,t}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$ is a function of capital and skilled native labor; γ is the share of unskilled labor in production; $\lambda(1-\gamma)$ is the share of capital in output; and ζ captures the relative productivity of the skilled compared with unskilled labor. Finally, $\theta > 0$ governs the elasticity of substitution between capital and unskilled labor, which is the same as the elasticity of substitution between skilled and unskilled labor; $\eta > 0$ is the elasticity of substitution between capital and skilled labor. The profit maximization problem of the firm implies:

$$r_{s,t} = p_{h,t} \frac{\partial \tilde{Y}_{h,t}}{\partial K_{s,t}} = p_{h,t} \varphi_1 \left(\varepsilon_t^a\right)^{\frac{\theta-1}{\theta}} \left(\tilde{Y}_{h,t}\right)^{\frac{1}{\theta}} \left(\Upsilon_{2,t}\right)^{\frac{\theta-\eta}{\eta\theta}} \left(K_t\right)^{-\frac{1}{\eta}} \left(\frac{\lambda_k K_t}{K_{s,t}}\right)^{\frac{1}{\eta_k}}, \tag{6}$$

$$r_{u,t} = p_{h,t} \frac{\partial \tilde{Y}_{h,t}}{\partial K_{u,t}} = p_{h,t} \varphi_1 \left(\varepsilon_t^a\right)^{\frac{\theta-1}{\theta}} \left(\tilde{Y}_{h,t}\right)^{\frac{1}{\theta}} \left(\Upsilon_{2,t}\right)^{\frac{\theta-\eta}{\eta\theta}} \left(K_t\right)^{-\frac{1}{\eta}} \left(\frac{(1-\lambda_k) K_t}{K_{u,t}}\right)^{\frac{1}{\eta_k}}, \tag{7}$$

$$w_{s,t} = p_{h,t} \frac{\partial \tilde{Y}_{h,t}}{\partial L_{s,t}} = p_{h,t} \varphi_2 \left(\varepsilon_t^a\right)^{\frac{\theta-1}{\theta}} \left(\tilde{Y}_{h,t}\right)^{\frac{1}{\theta}} \left(\Upsilon_{2,t}\right)^{\frac{\theta-\eta}{\eta\theta}} (\zeta)^{\frac{\eta-1}{\eta}} \left(L_{s,t}\right)^{-\frac{1}{\eta}}, \tag{8}$$

$$w_{u,t} = w_{i,t} = p_{h,t} \frac{\partial \tilde{Y}_{h,t}}{\partial L_{u,t}} = p_{h,t} \left(\varepsilon_t^a\right)^{\frac{\theta-1}{\theta}} \left(\gamma \frac{\tilde{Y}_{h,t}}{\Upsilon_{1,t}}\right)^{\frac{1}{\theta}}. \tag{9}$$

with parameters $\varphi_1 = (1-\gamma)^{\frac{1}{\theta}} \lambda^{\frac{1}{\eta}}$ and $\varphi_2 = (1-\gamma)^{\frac{1}{\theta}} (1-\lambda)^{\frac{1}{\eta}}$.

The home intermediate good is used both domestically and abroad: $\tilde{Y}_{h,t} = Y_{h,t} + Y_{h,t}^*$, where $Y_{h,t}$ denotes the domestic use of the home good, and $Y_{h,t}^*$ denotes exports to Foreign. Consumption and investment are composites of the home and foreign goods: $Y_t = \left[\omega^{\frac{1}{\mu}} \left(Y_{h,t}\right)^{\frac{\mu-1}{\mu}} + (1-\omega)^{\frac{1}{\mu}} \left(Y_{f,t}\right)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}}$, where $Y_{f,t}$ denotes the imports of Home from Foreign. The demand functions for the home and foreign goods are $Y_{h,t} = \omega \left(p_{h,t}\right)^{-\mu} Y_t$ and $Y_{f,t} = (1-\omega)\left(p_{f,t} Q_t\right)^{-\mu} Y_t$, where $p_{h,t}$ and $Q_t p_{f,t}$ are the prices of the home and foreign goods expressed in units of the home consumption basket.

At the aggregate level, the resource constraint: $Y_t = C_{s,t} + C_{u,t} + I_{s,t} + I_{u,t} + C_{i,t}$ takes into account not only the consumption and investment of the native population, but also the consumption of immigrant workers established in Home, $C_{i,t}$. Immigrant consumption depends on the optimization problem of the foreign household and on the mechanism of remittances, which are described below.

2.3. Foreign Households

The foreign economy consists of a continuum of skilled and unskilled households of relative sizes s^* and $1 - s^*$. The skilled household in Foreign, which trades bonds internationally, has preferences over consumption $c^*_{s,t}$ and labor $l^*_{s,t}$ similar to those of the skilled household in Home. It maximizes lifetime utility as in (1) subject to a budget constraint like in (2).

We introduce cross-border mobility for the unskilled household in Foreign, whose members have the option to work in Home for a higher wage than in Foreign, but subject to a sunk emigration cost. Each unskilled household supplies $l^*_{u,t}$ units of labor every period. Some household members ($l_{i,t}$) reside and work abroad (in Home), whereas the rest ($l^*_{u,t} - l_{i,t}$) work in the country of origin (Foreign). The calibration ensures that the unskilled wage is higher abroad than in the country of origin, so that the incentive to emigrate from Foreign to Home exists every period.[10] However, a fraction of the foreign unskilled labor always remains in Foreign ($0 < l_{i,t} < l^*_{u,t}$).[11] The macroeconomic shocks are small enough for these conditions to hold every period.

Each unskilled household sends an amount $l_{e,t}$ of new emigrant labor to Home every period, where the stock of immigrant labor $l_{i,t}$ is built gradually over time. The time-to-build assumption implies that the new immigrants start working one period after arriving at the destination (Home). They continue to work in all subsequent periods until the occurrence

[10] Due to the cross-country wage asymmetry, there is no labor migration from Home to Foreign.

[11] Since home and foreign goods are imperfect substitutes, the demand for the foreign good is always positive, and foreign labor is always required for production in Foreign.

of a return-inducing exogenous shock, which hits with probability δ_l every period, and forces them to return to the country of origin (Foreign). This shock occurs at the end of every time period, and reflects issues such as termination of employment in the destination economy, likelihood of deportation, or voluntary return to the country of origin, etc.[12] Under these assumptions, the rule of motion for the stock of immigrant labor is: $l_{i,t} = (1-\delta_l)(l_{i,t-1}+l_{e,t-1})$.

Thus, the unskilled household in Foreign, which does not trade bonds but invests in migration, maximizes lifetime utility from consumption $c^*_{u,t}$ and labor $l^*_{u,t}$ subject to:

$$w^*_{u,t}\left(l^*_{u,t} - l_{i,t}\right) + w_{i,t}Q_t^{-1}l_{i,t} + r^*_{u,t}k^*_{u,t} \geqslant c^*_{u,t} + f_{e,t}w_{i,t}Q_t^{-1}l_{e,t} + i^*_{u,t}, \tag{10}$$

where $w^*_{u,t}$ is the unskilled wage, and $w^*_{u,t}\left(l^*_{u,t} - l_{i,t}\right)$ denotes the total income from hours worked by the non-emigrant unskilled labor in Foreign. The immigrant wage earned in Home is $w_{i,t} = w_{u,t}$, so that the emigrant labor income expressed in units of the foreign composite good is $w_{i,t}Q_t^{-1}l_{i,t}$. On the spending side, emigration requires a sunk cost of $f_{e,t}$ units of immigrant labor, which is equal to $f_{e,t}w_{i,t}Q_t^{-1}$ units of the foreign composite good. Changes in labor migration policies (i.e. border enforcement) are reflected by shocks ε_t^{fe} to the level of the sunk emigration cost f_e, so that $f_{e,t} = \varepsilon_t^{fe} f_e$. The capital and investment of the unskilled household are $k^*_{u,t}$ and $i^*_{u,t}$; the gross rental rate of capital is $r^*_{u,t}$.

The optimality conditions for the skilled household are similar to those in (3) and (4). For the unskilled household, it is useful to re-write the budget constraint as: $w^*_{u,t}l^*_{u,t} + d_t l_{i,t} + r^*_{u,t}k^*_{u,t} \geqslant c^*_{u,t} + f_{e,t}w_{i,t}Q_t^{-1}l_{e,t} + i^*_{u,t}$, where d_t is the difference between the immigrant wage in Home and the unskilled wage in Foreign expressed in units of the foreign consumption basket: $d_t = w_{i,t}Q_t^{-1} - w^*_{u,t}$. The optimization problem of the unskilled household delivers a typical Euler equation and pins down the total labor effort like in (3). In addition, potential emigrants face a trade-off between the sunk emigration cost, $f_{e,t}w_{i,t}Q_t^{-1}$, and the difference between the stream of expected future wages at the destination, $w_{i,t}Q_t^{-1}$, and in the country

[12] Absent other frictions, since wages in Home are always higher than in Foreign, the endogenous return decision rule is outside the scope of this model. Our endogenous entry-exogenous exit formulation follows the guidelines for firm entry and exit in Ghironi and Melitz (2005).

of origin, $w^*_{u,t}$. Using 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 first order condition with respect to new emigrant labor $l_{e,t}$ implies:

$$f_{e,t} w_{i,t} Q_t^{-1} = \sum_{\tau=t+1}^{\infty} [\beta(1-\delta_l)]^{\tau-t} E_t \left[\left(\frac{\varsigma^*_{u,\tau}}{\varsigma^*_{u,t}} \right) d_\tau \right]. \tag{11}$$

In equilibrium, the sunk emigration cost equals the benefit from emigration, with the latter given by the expected stream of future wage gains, d_t, adjusted for the stochastic discount factor and the probability of return to the country of origin every period.

The consumption, labor supply, capital and investment of the foreign skilled and unskilled households are aggregated like in Home. In addition, the total flow of new emigrant labor is $L_{e,t} = (1-s^*) l_{e,t}$, and the total stock of immigrant labor is $L_{i,t} = (1-s^*) l_{i,t}$. Like in Home, it is assumed that the capital stocks of skilled and unskilled households are imperfect substitutes. This assumption is supported by the empirical evidence, and rules out the possibility of risk sharing through equal rates of return on capital, which would have diluted the insurance role of migration and remittances for unskilled households.[13]

2.4. Foreign Output

As in Home, foreign production is:

$$\tilde{Y}_{f,t} = \varepsilon_t^{a^*} \left\{ (\gamma^*)^{\frac{1}{\theta^*}} \left(\Upsilon^*_{1,t} \right)^{\frac{\theta^*-1}{\theta^*}} + (1-\gamma^*)^{\frac{1}{\theta^*}} \left(\Upsilon^*_{2,t} \right)^{\frac{\theta^*-1}{\theta^*}} \right\}^{\frac{\theta^*}{\theta^*-1}}, \tag{12}$$

in which $\varepsilon_t^{a^*}$ is a neutral technology shock, $\Upsilon^*_{1,t} = L^*_{u,t} - L_{i,t}$ is the amount of unskilled labor that works in Foreign, and $\Upsilon^*_{2,t} = \left[(\lambda^*)^{\frac{1}{\eta^*}} \left(K^*_t \right)^{\frac{\eta^*-1}{\eta^*}} + (1-\lambda^*)^{\frac{1}{\eta^*}} \left(\zeta^* L^*_{s,t} \right)^{\frac{\eta^*-1}{\eta^*}} \right]^{\frac{\eta^*}{\eta^*-1}}$ is a function of capital and skilled foreign labor. The profit maximization problem of the firm generates optimality conditions for factor prices similar to those in (6-9).

[13] This assumption is supported by empirical evidence for Mexico such as in Djankov et al. (2008), who show that households with higher levels of education are more likely to keep their savings as deposits at formal financial institutions. In turn, the uneven involvement of skilled and unskilled households with financial institutions causes their savings to be channeled to different investment projects that are imperfect substitutes in aggregate production, with undesirable consequences for risk diversification. Also see Fernando (2007) for a survey on this topic. Similarly, in the United States, the composition of households' financial asset portfolios varies with their level of education (see Curcuru et al., 2009).

The foreign composite good, Y_t^*, incorporates amounts of the foreign and home-specific goods: $Y_t^* = \left[(\omega^*)^{\frac{1}{\mu^*}} \left(Y_{f,t}^* \right)^{\frac{\mu^*-1}{\mu^*}} + (1-\omega^*)^{\frac{1}{\mu^*}} \left(Y_{h,t}^* \right)^{\frac{\mu^*-1}{\mu^*}} \right]^{\frac{\mu^*}{\mu^*-1}}$. It can be consumed by the non-emigrant foreign labor (which excludes the unskilled emigrants established in Home), invested in physical capital, and used for investment in migration (to cover the sunk cost of sending new emigrant labor abroad): $Y_t^* = C_{s,t}^* + C_{u,t}^* - C_{i,t}Q_t^{-1} + I_{s,t}^* + I_{u,t}^* + f_{e,t}w_{i,t}Q_t^{-1}L_{e,t}$.

2.5. Remittances and Current Account

The household's optimization problem pins down the total unskilled consumption, labor supply, and the flow of new emigrant labor sent abroad every period. Our approach, in which the investment in migration and the migrant labor income are part of a unified budget constraint, allows to model labor migration as an inter-temporal decision of the unskilled household. However, since the household maximizes utility as a single agent, one cannot treat emigrants and non-emigrants as separate entities that choose how much to consume, work and remit independently from each other. The allocation of consumption across household members would remain undetermined without further assumptions.

To determine the allocation of consumption within the household over the cycle, this paper introduces an insurance mechanism of remittances parametrized to fit the data. For each household, immigrant workers residing in Home send remittances to Foreign every period, denoted with $\widetilde{\Xi}_t$ (in units of the foreign composite). Thus, the immigrant labor income is divided entirely between remittances sent to Foreign and immigrant consumption taking place in Home: $w_{i,t}l_{i,t} = Q_t\widetilde{\Xi}_t + c_{i,t}$.[14] To highlight the intensive and extensive margins of remittances at the household level, remittances per unit of migrant labor are defined as: $\xi_t = \widetilde{\Xi}_t / l_{i,t}$. At the aggregate level, total remittances are equal to $\Xi_t = (1-s^*)\widetilde{\Xi}_t$, and total immigrant consumption is $C_{i,t} = (1-s^*)c_{i,t}$.

The risk sharing mechanism of remittances follows Acosta et al. (2009), described in the

[14] For simplicity, immigrant workers cannot use their labor income to invest in the destination economy.

technical appendix online. In summary, the mechanism warrants a steady-state allocation in which members of the foreign unskilled household residing in either Home or Foreign enjoy the same amount of consumption per unit of labor, equal to $\bar{c}_u^*/\bar{l}_u^*$ units of consumption.[15] Thus, the steady-state amount of remittances per unit of immigrant labor is equal to the difference between the immigrant wage and immigrant consumption (expressed in units of the composite good in Home): $\overline{Q\xi} = \overline{w}_i - \overline{Q}\bar{c}_u^*/\bar{l}_u^*$.

The sunk emigration cost is a friction that renders the stock of immigrant labor a state variable unable to adjust immediately to shocks. As a result, the gap between the immigrant and foreign wages varies over the cycle, and migrants and non-migrants obtain either a net surplus or a loss relative to the steady-state allocation of consumption. Thus, remittances represent an altruistic compensation mechanism between immigrant and resident workers:

$$\xi_t = \varrho \left(\frac{w_{i,t}}{w_{u,t}^*} \right)^{\varphi} \bar{\xi}, \text{ with } \varphi > 0. \tag{13}$$

A positive value of φ implies that a relative improvement in the purchasing power of the immigrant wage in terms of the consumption basket in Home (where immigrant consumption takes place) or a relative deterioration of the purchasing power of the foreign wage in terms of the foreign consumption basket trigger an altruistic increase in remittances. The magnitude of φ characterizes the thrust of the altruistic motive.

Under financial integration, the current account balance for Home (the trade balance plus financial investment income minus the outflow of remittances) equals the negative of the financial account balance (the change in bond holdings), with $B_{h,t} = sb_{h,t}$ and $B_{f,t} = sb_{f,t}$:

$$(p_{h,t}Y_{h,t}^* - p_{f,t}Q_tY_{f,t}) + (r_t^b B_{h,t} + r_t^{b*} Q_t B_{f,t}) - Q_t \Xi_t = (B_{h,t+1} - B_{h,t}) + Q_t (B_{f,t+1} - B_{f,t}) . \tag{14}$$

2.6. Shocks

Structural shocks are assumed to follow $AR(1)$ processes with i.i.d. normal error terms, $\log \varepsilon_t^{\hat{\imath}} = \rho^{\hat{\imath}} \log \varepsilon_{t-1} + \eta_t^{\hat{\imath}}$, in which $0 < \rho^{\hat{\imath}} < 0$ and $\eta \sim N(0, \sigma^{\hat{\imath}})$, where $\hat{\imath} = \{a, a^*, b, b^*, I, I^*, f_e\}$.

[15] This assumption is relaxed in the appendix online, with similar results. Upper bars denote steady states.

As in Lubik and Schorfheide (2005), domestic and foreign shocks are independent.

3. Bayesian Estimation

The Bayesian estimation technique uses a general equilibrium approach that addresses the identification problems of reduced form models. It is a system-based analysis that fits the solved DSGE model to a vector of aggregate time series (see Fernandez-Villaverde and Rubio-Ramirez, 2004, or Lubik and Schorfheide, 2005, for details).[16]

3.1. Data

The number of data series used in the estimation cannot exceed the number of structural shocks in the model. Therefore, the estimation uses seven data series for the U.S. and Mexico from 1980:Q1 to 2004:Q3, consisting of real GDP, real consumption and real investment for each economy, as well as the number of U.S. border patrol hours as a proxy for the intensity of border enforcement. An increase in border patrol hours is interpreted as an increase in border enforcement. The series are seasonally-adjusted, converted in natural logs, expressed as deviations around a cubic trend, and first-differenced to obtain growth rates.[17]

We also use data on apprehensions (arrests) at the U.S.-Mexico border and remittances from the U.S. to Mexico in real pesos to evaluate the model, but do not include these series in the structural estimation, for several reasons. First, the apprehensions series is noisy due to the random nature of border arrests, and therefore can serve only as a rough proxy for the flows of emigrant labor. Second, there is an identification problem regarding the effect of border enforcement on apprehensions. In this paper, it is assumed that an increase in border enforcement (reflected by U.S. border patrol hours) leads to an increase in the sunk

[16] See the appendix online for details on the data sources, the Bayesian estimation, the comparison of data and model predictions, the variance decomposition, and the Monte Carlo Markov Chain (MCMC) analysis.

[17] $Z_t = [\Delta \ln GDP_t^h,\ \Delta \ln GDP_t^f, \Delta \ln C_t, \Delta \ln I_t, \Delta \ln C_t^*, \Delta \ln I_t^*, \Delta \ln f_{e,t}]$ is the vector of observed variables, where $GDP_t = p_{h,t}\tilde{Y}_{h,t}$, $GDP_t^* = p_{f,t}\tilde{Y}_{f,t}$. Cubic detrending is preferred over the traditional HP filtering, which can result in spurious cycles in the data (Cogley and Nason, 1995). In the appendix, the model is also estimated with linearly detrended data as in Smets and Wouters (2003), with similar results.

emigration cost, following the findings in Orrenius (2001).[18] However, for the same number of attempted illegal crossings, an increase in border patrol hours may also result in more arrests. Because border enforcement affects the number of both crossings and arrests, and because the actual number of attempted crossings is unknown, one cannot disentangle the effect of enforcement from that of crossings on total apprehensions. Third, remittances are not included in the structural estimation, given the short length of this series (available only since 1995:Q1). Bearing these issues in mind, this paper treats the flow of new emigrant labor ($L_{e,t}$) and total remittances (Ξ_t) as latent variables in the estimated model, and compares their estimated moments to those from the actual data to assess the model fit.[19]

Finally, the elasticity of remittances (φ) to the U.S.-Mexico unskilled wage gap is obtained from a reduced form estimation over 1995:Q1 to 2006:Q3, using real hourly wage data for U.S. unskilled workers (less than high school degree) and Mexico's maquiladora workers.

3.2. Calibration

Some parameters are fixed in the estimation to address identification issues: The pool of native unskilled labor in Home and Foreign is defined to include the labor force with less than a high school degree, as in Borjas et al. (2008). Thus, using data from the U.S. Census Bureau and INEGI, the share of unskilled labor is set at $(1 - s) = 0.08$ in Home and $(1 - s^*) = 0.75$ in Foreign. The quarterly exit rate of immigrant labor is $\delta_l = 0.07$, following Reyes (1997).[20] Other parameters are standard: $\beta = 0.99$, $\delta = 0.025$, $\omega = 0.85$ and $\omega^* = 0.75$, allowing for slightly more trade openness for the smaller foreign economy.[21]

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[18] Orrenius (2001) shows that increases in border patrol hours act as a deterrent for migration flows.

[19] The Kalman filter is used to back out the observed (smoothed) shocks and make inferences about these variables through the reconstruction of the historical series.

[20] Reyes (1997) finds that about 50% of undocumented Mexican immigrants return to Mexico within two years after their arrival in the U.S., and 65% of immigrants return within four years. Using that 50% immigrants are still in the U.S. two years after their arrival, the quarterly exit rate is $\delta_{l,2y} = 0.083$, since $(1 - \delta_{l,2y})^8 = 0.5$. Similarly, the 35% retention rate after four years implies a quarterly return rate of 0.064.

[21] Additional details on the calibration and prior distributions are in the appendix online.

3.3. Prior and Posterior Distributions

The remaining parameters are estimated. The first four columns of Table 1 present the mean and standard deviation of the prior distributions, together with their respective density functions. For γ and γ^* (shares of unskilled in output), θ and θ^* (elasticity of substitution between capital and unskilled), ζ and ζ^* (relative productivity of skilled) and f_e (sunk emigration cost), we choose the prior mean values that together allow the model in steady state to match four stylized facts from the data: (1) The share of Mexico's labor force residing in the U.S. is 10% (Hanson, 2006). (2) Remittances represent the equivalent of 2.4% of Mexico's GDP (World Bank, 2010).[22] (3) The U.S. skill premium (given the skill definition above) is $w_s/w_u = 2.2$, according to U.S. Census data. (4) The Mexican skill premium is $w_s^*/w_u^* = 2.5$, according to data from Hanson (2006). The prior means for η and η^* (elasticity of substitution between capital and skilled) are chosen so that $\eta < \theta$ and $\eta^* < \theta^*$, based on the capital-skill complementary assumption in Krusell et al. (2000). As discussed in the previous section, the reduced form estimation of equation (13) sets the prior for φ (elasticity of remittances with respect to the wage differential).

The last five columns of Table 1 report the posterior mean, mode, and standard deviation obtained from the Hessian, along with the 90% probability interval of the structural parameters. The priors are informative in general. Notably, the posterior means of θ and η are closer to each other (0.91 and 0.94) than in the prior distributions despite the tight prior, slightly weakening the implied capital-skill complementarity. The mean for the sunk migration cost f_e (4.73) is significantly higher than its prior, indicating that the sunk cost per unit of emigrant labor is equivalent to the immigrant labor income obtained over five quarters in the destination economy. The estimated mean values for μ and ψ (2.34 and 1.62) are higher than their priors, indicating a larger degree of substitution between the U.S. and Mexican goods, and a labor supply elasticity that is closer to the microeconomic estimates.

[22] This is a conservative estimate, as remittances may be underreported, particularly for neighbor countries.
[22] For the computation of skill premiums in the U.S. and Mexico, see the appendix online.

Note that border enforcement shocks are persistent and volatile ($\rho_{fe} = 0.99$, $\sigma_{fe} = 0.05$), and also that the neutral and investment-specific technology innovations are less persistent and more volatile in Mexico than in the U.S. [LOCATE TABLE 1 ABOUT HERE]

4. Results

This section examines the model-implied moments for labor migration and remittances, and compares them to those from the data. It also discusses the relationship between unskilled labor migration and the skill premium in the destination economy, as well as the effect of border enforcement on the volatility of migration-related variables and consumption.

4.1. Unconditional Correlations

Table 2 reports the unconditional theoretical moments and compares them to their empirical counterparts.[23] For the data (panel A), it shows the standard deviations and first-order autocorrelations for border apprehensions, remittances, border patrol hours, and the Mexican trade balance normalized by GDP.[24] The series are highly volatile, and changes in border patrol hours are somewhat persistent. The table also reports the correlations of each of the four data series with: (1) the U.S.-Mexico real GDP ratio, (2) the U.S. real GDP and (3) Mexico's real GDP adjusted by the bilateral real exchange rate (thus expressed in real dollars). Apprehensions and remittances are procyclical with the U.S.-Mexico GDP ratio and countercyclical with Mexico's GDP; they are procyclical with the U.S. GDP, although the correlation is small, especially for apprehensions. The correlations for border patrol hours are close to zero, indicating that border enforcement is largely a political decision unaffected

[23] As with the vector of observables, the cubic-detrended data and the model predictions are expressed in growth rates. One exception is the trade balance, which is normalized by GDP and expressed in first differences. Table 2 reports correlations for the detrended series in growth rates, while Fig. 1 and 2 plot the detrended data series in levels (rather than growth rates) to facilitate the visual interpretation.

[24] For apprehensions, enforcement and the trade balance, the sample period is 1980:Q2 to 2004:Q3. For remittances (in real pesos) it is 1995:Q2 to 2006:Q3. Mexico's multilateral trade balance is used instead of the bilateral trade balance with the U.S., since the latter series, which is highly correlated with the multilateral balance (0.97), is available only starting in 1990:Q1.

by economic considerations. Finally, the trade balance is countercyclical with Mexico's GDP.

Panel B of Table 2 reports the theoretical moments. It shows the medians from the simulated distributions of moments, using the samples generated with parameter draws from the posterior distribution. In general, the model delivers volatility and persistence values that are fairly close to those in the data. The model does not match the high volatility of remittances and the persistence of border enforcement, despite the high persistence of enforcement shocks in the estimation. However, the model captures particularly well the comovement of labor migration and remittances with the relative economic performance of the U.S. and Mexico. Namely, the correlations of migration flows (L_e) and total remittances (Ξ) with the Home-Foreign GDP ratio are positive and significant. Labor migration flows are negatively correlated with the foreign GDP, whereas their correlation with the home GDP is not significantly different from zero. This finding is consistent with the data, and may be indicative of the inability of migrant labor to react to shocks in the destination economy due to migration costs. Remittances are positively correlated with home output, and negatively correlated with foreign output. The correlations of border enforcement are close to zero, as in the data. Finally, the model matches well the negative correlation between Mexico's trade balance and GDP. [LOCATE TABLE 2 ABOUT HERE]

The alternative model in which all households are in financial autarky (not only the unskilled) would generate moments for labor migration and remittances that are similar to those from the baseline model. The only difference concerns Mexico's trade balance, which would be pro-cyclical with the Mexican GDP, thus contradicting the empirical evidence of counter-cyclical trade balances in emerging market economies (Aguiar and Gopinath, 2007).

4.2. The Role of Border Enforcement

We also compute counterfactual correlations for low and high border enforcement, using the posterior median of the estimated parameters while altering only the sunk emigration cost (which takes values $f_e = 1$ and $f_e = 6$).[25] Notably, when the sunk cost is lowered to $f_e = 1$, the labor migration flows become more responsive to business cycles. (The correlation of migration flows with the GDP ratio is 0.55 with the low sunk cost vs. 0.35 with the high sunk cost.) In particular, they become more correlated with output in Home. However, with the lower sunk cost, remittances become less correlated with foreign output (-0.14 with the low sunk cost vs. -0.23 with the high sunk cost), since the wage gap between Home and Foreign declines, thus reducing the need for remittances as a compensation mechanism.

The simulation results also indicate that migration barriers affect the volatility of the immigrant wage and total remittances. With the low sunk cost, the standard deviations of these two variables are 1.19 and 1.67, respectively. With the high sunk cost, the standard deviations of the immigrant wage and total remittances rise to 1.49 and 1.91. In summary, as migration barriers restrict the ability of the stock of immigrant labor to adjust over the cycle, its factor payments and the associated remittances become more volatile.

4.3. Unskilled Immigration and the U.S. Skill Premium

The flows of unskilled labor migration have direct implications for the skill premium in the destination economy. To illustrate this relationship, we compare the unconditional correlation between the skill premium and migration flows in the data and the model. The U.S. skill premium is computed using the Current Population Survey (CPS).[26] Since the sample group in that survey rotates every month, the skill premium is noisy at the quarterly frequency. To address this problem, the CPS data used to analyze the cyclical dynamics of the skill premium is annualized, like in Polgreen and Silos (2009).[27]

[25] Table 2 reports the median value of a sample of moments generated with a large set of parameter draws from the posterior distribution. For counterfactual scenarios, moments are computed using just the median parameter values from the posterior distribution. The results should be close, but not necessarily the same.

[26] The skill premium is the ratio of the average hourly wage of workers with 12 or more years of schooling (weighted by population) to the average hourly wage of workers with less than 12 years of schooling.

[27] The data series are annualized, expressed in natural logs, and de-trended using a band-pass filter that removes fluctuations accruing in periods shorter than 4 and longer than 25. The model predictions receive a similar treatment. This approach is appropriate not only for the skill premium, but also for border

Fig. 2 shows the detrended series for apprehensions (solid line) and the U.S. skill premium (dashed line). The correlation between the two series in growth rates is positive (0.37). In addition, the U.S. skill premium is correlated positively with the U.S.-Mexico GDP ratio (0.49), positively with the U.S. GDP (0.12), and negatively with Mexico's GDP (-0.45). One interpretation of this result is that, when the U.S. economy outperforms Mexico's, the arrival of unskilled workers places downward pressure on the unskilled wage, thus increasing the skill premium.

The unconditional correlations implied by the model are consistent with those in the data. In particular, the correlation between the skill premium and unskilled immigrant entry in Home is positive (0.31). In addition, the skill premium is positively correlated with the Home-Foreign output ratio (0.18) and with home output (0.52), as in the data; one exception is the correlation with foreign output, which is also positive (0.33).[28]

[LOCATE FIGURE 2 ABOUT HERE]

4.4. Labor Migration and Consumption Volatility

Labor migration and remittances act as a consumption-smoothing mechanism for the foreign unskilled households. In the estimated baseline model (in which only the skilled trade bonds internationally), the relative volatility of total consumption growth with respect to output is 1.60, slightly higher than the observed value for the sample period (1.23). The result is in line with the empirical findings in Aguiar and Gopinath (2007) that consumption in emerging market economies is about 45 percent more volatile than output.

To explain this model outcome, Fig. 3 plots the volatility of foreign unskilled consumption (solid lines) and foreign total consumption (dashed lines) as a function of the sunk emigration

apprehensions, which present sizable short-term swings due to the random nature of border arrests (Fig. 1).

[28] Figure 2 also suggests a lagged response of the U.S. skill premium to unskilled migration from Mexico to the United States (the correlation of the skill premium with migration lagged by one year is 0.26). The model is successful in replicating this pattern as well (the correlation of the skill premium with migration flows lagged by one year is 0.86), due to the modelling of unskilled labor migration as a flow that gradually adds to the stock of established immigrants, as well as the time-to-build assumption for the stock of immigrant labor (i.e. new immigrants start producing one period after arrival).

cost, for two extreme alternative scenarios: One in which both the skilled and unskilled households trade bonds internationally (circle marks), and the other with both types of households in financial autarky (triangle marks). The standard deviations are computed at the median of the estimated parameters.

Several notable results emerge from Fig. 3: First, the volatility of unskilled consumption declines for lower values of the sunk emigration cost, a result which highlights the consumption-smoothing role of migration and remittances. Second, labor migration is a particularly useful tool to smooth consumption under financial autarky: When the sunk migration cost is reduced, the volatility of unskilled consumption falls more steeply under financial autarky, when migration is the only consumption-smoothing mechanism available to unskilled households. Third, unskilled consumption is notably more volatile than output under financial autarky. The volatility of unskilled consumption would match that of output under financial integration; this result lends support to our baseline model with the unskilled households in financial autarky. [LOCATE FIGURE 3 ABOUT HERE]

5. The Effect of Shocks

To examine the drivers of labor migration and remittances and illustrate their effect on the macroeconomy, this section presents the impulse responses of key model variables, as well as the historical contributions of shocks over the sample period.

5.1. Impulse Responses

This subsection analyzes the impulse responses of model variables to temporary shocks to border enforcement and neutral technology. For technology shocks, it considers a series of counterfactual scenarios (high vs. low sunk cost, financial autarky vs. integration).[29]

[29] The impulse response of the estimated model (median and percentiles) for all shocks are in the appendix.

5.1.1. Positive Shock to Border Enforcement

Fig. 4 reports the median impulse response of the estimated model (along the 10th and 90th percentiles) to a positive shock to the sunk emigration cost (one standard deviation), reflecting an increase in border enforcement. As already discussed, this estimated shock is very persistent. The increase in the sunk emigration cost leads to a decline in the arrivals and the stock of immigrant labor, which in turn generates a gradual decline in the capital stock in Home. This translates into lower home output and aggregate consumption (defined as $C_s + C_u$). However, the wage of established immigrants (which is equal to that of native unskilled labor) benefits from this policy change.

As foreign workers are deterred from emigrating to Home, the resident labor supply in Foreign becomes relatively abundant, and the foreign unskilled wage falls. The cheaper labor input encourages capital accumulation and enhances output in Foreign. However, due to the misallocation of labor across countries, the aggregate consumption of foreign households declines. The flow of remittances per unit of labor increases notably to compensate for the wage difference between Home and Foreign. Total remittances decrease slightly as the immigrant labor stock declines. [LOCATE FIGURE 4 ABOUT HERE]

5.1.2. Positive Technology Shock in Home: Low vs. High Sunk Costs

We consider the two counterfactual scenarios with low and high sunk emigration costs: $f_e = 1$ (solid line) and $f_e = 6$ (dashed line). Fig. 5 shows the effect of an unexpected 1% increase in home productivity for each scenario. The impulse responses are computed using the posterior median of the estimated parameters (with the only exception of f_e), and plotted as percent deviations from steady state. Following the positive shock, the rise in the immigrant wage premium encourages the arrival of new immigrant labor (L_e). The wage premium and immigrant entry persist above their steady-state levels after the initial shock, and thus the stock of established immigrant labor (L_i) increases gradually over time.

Notably, the stock of immigrant labor increases relatively less under the higher sunk cost. In turn, the relative scarcity of immigrant labor causes the immigrant wage in Home (which is the same as the domestic unskilled wage) to increase more. Therefore, as the foreign household attempts to smooth consumption across members residing in both countries, the amount of remittances per immigrant worker increases by more in the model with the higher sunk cost. In Foreign, the unskilled wage increases by less in the scenario with the higher sunk migration cost. The result is due to the larger fraction of unskilled labor that remains in Foreign when emigration is more costly, which in turn enhances capital accumulation and output.

Given the model symmetry, a negative productivity shock leads to an economic recession with opposite results. The slower decline in the stock of immigrant labor resembles a lock-in effect that puts additional downward pressure on the wage and employment of the native unskilled. In summary, a less flexible immigration policy reflected by a larger sunk migration costs enhances the volatility of the native unskilled wage, the immigrant wage and remittances per unit of immigrant labor in response to productivity shocks.

[LOCATE FIGURE 5 ABOUT HERE]

5.1.3. Positive Technology Shock in Home: Financial Autarky vs. Integration

Fig. 6 displays the impulse responses computed at the posterior median parameter estimates for: (1) The benchmark model in which the unskilled households are in financial autarky (solid line); (2) An alternative model in which the unskilled households are financially integrated (dashed line).[30] In the alternative model, the one period, risk-free bond constitutes an additional instrument (other than migration and remittances) that foreign unskilled households use to smooth their inter-temporal consumption path and diversify away from country-specific risk. That is, foreign unskilled households have the option to lend abroad as an alternative to investing in emigration.

[30] The alternative model with financial integration for the unskilled is presented in the appendix online.

Following a transitory, 1% increase in home productivity, bond trading (dashed line) generates a more muted increase in the arrival of new immigrant labor (L_e) relative to the case with financial autarky (solid line). Financial integration allows for capital to flow towards the economy with the higher rate of return (Home), whose trade balance becomes negative on impact. Immediately after the shock, as foreign unskilled households lend to Home, they invest less in emigration. However, as capital accumulation enhances labor productivity and wages in Home, emigration recovers in the medium run. Thus, the immigrant labor entry under financial integration catches up with immigrant entry under financial autarky six quarters after the initial shock.[31] [LOCATE FIGURE 6 ABOUT HERE]

5.2. Historical Decomposition

Fig. 7 shows the historical contributions of shocks to the growth of key variables over the sample period (output in Mexico, border enforcement and labor migration). For the first two variables, the actual growth data (expressed as deviations from trend growth) is displayed. As previously explained, the Kalman smoothing procedure is applied to reconstruct the historical contributions of shocks to the labor migration flows as a latent variable.[32]

The historical evidence indicates that output in Mexico (panel 1) was subject to several negative technology shocks of sizable magnitudes throughout the sample period. The debt crisis of 1982 led to a dramatic reversal in the pattern of economic growth. The subsequent recovery was interrupted in late 1985, following a massive earthquake that hit Mexico City in September. As a result, output growth remained subdued until late 1986. Mexican output displays the sharpest decline in 1995 in the aftermath of the "tequila crisis." As the U.S. economy slowed down in late 2000, the Mexican economy fell into a mild recession in 2001,

[31] The response of migration to other shocks vary under the alternative scenario with full financial integration, shown in the appendix online. The Bayes factor shows a better fit for the baseline specification.

[32] The variance decomposition is presented in the appendix online: Mexican technology shocks explain most of the variation in labor migration and remittances in the short run, while border enforcement explains it at longer horizons. Regarding macroeconomic variables, demand shocks explain fluctuations at very short horizons, whereas technology shocks explain medium-to-long term fluctuations.

and output growth remained below trend until 2003.

Panel 2 depicts the detrended number of U.S. border patrol hours, which is a proxy for border enforcement. The series is characterized by persistent swings: border enforcement recorded a sharp increase in 1989, and another steady increase in the late 1990s. Enforcement was relaxed temporarily in late 2001, but a tightening followed at the end of 2002.

Finally, we estimate the contribution of historical shocks to labor migration flows and use them to make inference on this latent variable (panel 3). When compared with the actual number of apprehensions (Fig. 1), the model captures the increase in apprehensions in the aftermath of the debt crisis of 1982, as well as the Mexico City earthquake in 1985. In 1989, apprehensions declined sharply without an apparent economic reason, reflecting a large increase in border enforcement that acted as a migration deterrent. In particular, the model succeeds in accounting for the sharp increase in apprehensions after the "tequila crisis" episode in 1995. Finally, the model captures the sharp increase in border apprehensions that began in early 2002, the result of both a relaxation in border enforcement and the recession in Mexico. [LOCATE FIGURE 7 ABOUT HERE]

6. Welfare Implications of Labor Mobility Restrictions

Policies that restrict unskilled labor mobility have asymmetric welfare effects on the skilled and unskilled households in Home and Foreign. This section discusses the welfare outcomes for two counterfactual scenarios, with a very low ($f_e = 1$) and a relatively high ($f_e = 6$) level of the sunk cost, and compares them to the estimated model ($f_e = 4.73$). The model is solved using a second-order approximation around the deterministic steady state, following Schmitt-Grohé and Uribe (2004). As standard, the welfare cost (or gain) relative to the benchmark estimated model is measured as the fraction of the expected aggregate consumption stream that one should add (or extract) so that households are indifferent between the benchmark estimated model and each of the two counterfactual scenarios.

In the destination economy (Home), there are two channels through which the welfare effects arise. First, in steady state, higher migration barriers deter capital accumulation, since the unskilled labor is scarce and not perfectly substitutable in production, which in turn decreases the skilled wage. On the contrary, the native unskilled households benefit from reduced immigration. Second, in the presence of transitory shocks, the stock of unskilled labor is slow to adjust during expansions and recessions when migration barriers are high. Thus, we compute the steady-state (static) welfare effects by turning off all aggregate shocks, and alternatively compute the static and dynamic effects together by incorporating the estimated stochastic shocks for each scenario. As shown in Table 3, for Home, lowering the sunk cost to $f_e = 1$ generates a steady-state gain for the skilled households and a loss for the unskilled (4.2% and -32.5% of the consumption stream, respectively). On the net, the skilled households can fully compensate the loss of the unskilled (who represent a small fraction of the population) through direct transfers, and still obtain a net sizable gain (3.2%) after the policy change.[33] When shocks are added to the model, the gain of the skilled and the loss of the unskilled are even larger (5.2% and -43.5%); the skilled can compensate the unskilled and obtain even larger net welfare gains (3.8%).[34] The results suggests that, with high barriers to immigration, the loss arising from the slow adjustment of the unskilled labor input to shocks more than offsets the gain arising from shielding the native unskilled from the inflows of migrant labor.

The opposite result emerges in Foreign. In steady state, lower restrictions to unskilled migration generate welfare losses for the skilled and gains for the unskilled (-11.4% and 9.6%). On the net, the unskilled can fully compensate the skilled and still obtain a welfare gain (2.2%). In the presence of shocks, the welfare losses of the skilled, the gains of the un-

[33] In this case, the net transfer made by each skilled household is $\frac{(1-s)*\Delta c_u}{s}$, where Δc_u is the change in consumption stream that the unskilled must receive to remain indifferent after the policy change.

[34] This net welfare gain emerges under the assumption that unskilled natives and immigrants are perfect substitutes. For less than perfect substitution (see Ottaviano and Peri, 2008), the welfare gains could be even larger.

skilled, and the net gain of the unskilled after transfers are even larger (-12.1%, 10.8%, and 2.9%). While the unskilled labor constitutes the majority in Foreign, the extra welfare gains obtained after taking the dynamic effect of shocks into account point to improved consumption smoothing when migration barriers are eased. Overall, the net gains in both countries indicate that lowering the migration barriers results in a global Pareto improvement. On the contrary, when the sunk cost is raised to $f_e = 6$, the welfare effects for both unskilled and skilled workers are reversed, but the Pareto improvement does not hold. Neither the unskilled in Home nor the skilled in Foreign can compensate for the losses of their domestic counterparts and obtain net gains from the increase in migration barriers.[35]

[LOCATE TABLE 3 ABOUT HERE]

7. Conclusion

The model proposed here attempts to bridge an existing gap between the international macroeconomics literature and immigration theory. In contrast to the former, the model allows for labor mobility across countries. In contrast to the latter, it explains the business cycle dynamics and the transmission of aggregate shocks across countries in the presence of labor migration and remittances. The households' decision to emigrate is endogenous, and involves an inter-temporal trade-off between the sunk emigration cost and the wage benefits from labor migration. The framework allows to examine the macroeconomic effects of border enforcement, as well as the insurance role of migration and remittances as a substitute for cross-border financial flows in diversifying from country-specific risk and smoothing consumption in the country of origin. The model is estimated using data on border enforcement and macroeconomic indicators from the U.S. and Mexico. We evaluate the model using data on apprehensions at the U.S.-Mexico border (as a proxy for migration flows) and

[35] Increasing the sunk emigration cost, with all shocks incorporated, harms the home skilled and helps the home unskilled (-3.0% and 19.0%); if the unskilled were to compensate the skilled, they would obtain a net loss (-31.5%). In Foreign, the change benefits the skilled and harms the unskilled (2.9% and -4.7%); however, the skilled cannot compensate the unskilled and be better off (-2.3%).

workers' remittances to Mexico. The model matches qualitatively the cyclical dynamics of both indicators.

Lowering the barriers to unskilled migration has asymmetric welfare effects on the skilled and unskilled households in the destination economy. However, the results show that the skilled can compensate the unskilled for such losses, and still obtain a net welfare gain. In the country of origin, migration also results in net welfare gains as migration and remittances allow for higher labor income and consumption smoothing. All these findings suggest that immigration policies that are flexible to adjust in response to market signals may be beneficial for both economies.

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Immigration, Remittances and Business Cycles

Tables and Figures

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Table 1: Summary of the prior and posterior distributions of estimated parameters

	Prior distribution				Posterior distribution				
Description	Name	Density	Mean	Std Dev	Sd (Hess)	Mode	Mean	5%	95%
Share of unskilled in output (H)	γ	Gamma	0.06	0.01	0.0100	0.0850	0.0850	0.0681	0.1011
Elast. of subst. K, unskilled, (H)	θ	Beta	0.95	0.015	0.0187	0.9426	0.9386	0.9078	0.9684
Elast. of subst. K, skilled (H)	η	Beta	0.85	0.015	0.0090	0.9083	0.9074	0.8925	0.9225
Product. of native skilled (H)	ζ	Gamma	7	0.75	0.7894	8.3244	8.3660	7.0393	9.6160
Share of unskilled in output (F)	γ^*	Gamma	0.40	0.01	0.0048	0.4017	0.4003	0.3923	0.4082
Elast. of subst. K, unskilled, (F)	θ^*	Beta	0.95	0.015	0.0083	0.9575	0.9602	0.9464	0.9737
Elast. of subst. K, skilled (F)	η^*	Beta	0.73	0.015	0.0089	0.7660	0.7692	0.7547	0.7840
Productivity of native skilled (F)	ζ^*	Gamma	5.2	0.75	0.6066	4.7910	4.9585	3.9488	5.9592
Sunk emigration cost	f_e	Gamma	2.8	0.30	0.2065	4.7928	4.7332	4.4305	5.1093
Inverse elast. of labor supply	ψ	Gamma	1	0.2	0.2060	1.5983	1.6188	1.2804	1.9519
Elast. of substitution, goods	μ	Gamma	1.5	0.3	0.2880	2.4115	2.3436	1.8519	2.8124
Elast. of remittances to wages	φ	Gamma	0.99	0.1	0.0981	0.9801	1.0206	0.8591	1.1827
Neutral tech. shock (H)	ρ_a	Beta	0.75	0.1	0.0249	0.9466	0.9385	0.8982	0.9782
Neutral tech. shock (F)	ρ_{a^*}	Beta	0.75	0.1	0.0338	0.9462	0.9264	0.8741	0.9801
Discount factor shock (H)	ρ_b	Beta	0.5	0.05	0.0296	0.7346	0.7327	0.6884	0.7835
Investment tech. shock (H)	ρ_i	Beta	0.5	0.05	0.0208	0.7698	0.7594	0.7305	0.7902
Discount factor shock (F)	ρ_{b^*}	Beta	0.5	0.05	0.0199	0.7735	0.7628	0.7354	0.7902
Investment tech. shock (F)	ρ_{i^*}	Beta	0.5	0.05	0.0376	0.7119	0.7086	0.6496	0.7733
Border enforcement shock	ρ_{fe}	Beta	0.75	0.1	0.0035	0.9947	0.9927	0.9874	0.9981
Neutral tech. shock (H)	σ_a	Inv gamma	0.01	2*	0.0005	0.0065	0.0066	0.0059	0.0074
Neutral tech. shock (F)	σ_{a^*}	Inv gamma	0.01	2*	0.0013	0.0170	0.0171	0.0150	0.0191
Discount factor shock (H)	σ_b	Inv gamma	0.01	2*	0.0029	0.0356	0.0367	0.0318	0.0413
Investment tech. shock (H)	σ_i	Inv gamma	0.01	2*	0.0023	0.0286	0.0295	0.0258	0.0332
Discount factor shock (F)	σ_{b^*}	Inv gamma	0.01	2*	0.0041	0.0401	0.0420	0.0352	0.0485
Investment tech. shock (F)	σ_{i^*}	Inv gamma	0.01	2*	0.0030	0.0281	0.0296	0.0246	0.0344
Border enforcement shock	σ_{fe}	Inv gamma	0.01	2*	0.0037	0.0508	0.0513	0.0453	0.0571

Notes: For the Inverted gamma function the degrees of freedom are indicated. Results are based on 500,000 simulations of the Metropolis-Hastings algorithm.

Table 2: Unconditional moments, data and model

(a) Data for the United States and Mexico					
Variable (growth)	St. dev.	Autocorr.	Corr with $\frac{GDP_{US}}{Q*GDP_{Mex}}$	Corr with GDP_{US}	Corr with $Q*GDP_{Mex}$
Apprehensions	12.52	-0.07	0.13	0.03	-0.13
Remittances	7.07	-0.08	0.61	0.09	-0.61
Border enforcement	5.18	0.46	0.04	-0.02	-0.04
Trade balance, Mexico	0.30	0.32	0.38	-0.16	-0.39

(b) Estimated benchmark model					
Variable (growth)	St. dev.	Autocorr.	Corr with $\frac{GDP_h}{Q*GDP_f}$	Corr with GDP_h	Corr with $Q*GDP_f$
Migration flows	17.09 (14.84/19.19)	-0.06 ($-0.08/-0.04$)	0.33 (0.23/0.40)	-0.04 ($-0.09/0.00$)	-0.38 ($-0.45/-0.32$)
Remittances	1.81 (1.63/2.00)	0.15 (0.05/0.22)	0.28 (0.16/0.40)	0.20 (0.12/0.27)	-0.15 ($-0.27/-0.01$)
Border enforcement	5.31 (4.71/5.92)	0.01 ($-0.01/0.00$)	0.01 (0.00/0.02)	-0.01 ($-0.01/0.00$)	-0.02 ($-0.02/-0.01$)
Trade balance, Mexico	0.72 (0.63/0.80)	-0.38 ($-0.40/-0.36$)	0.47 (0.40/0.53)	0.34 (0.28/0.42)	-0.23 ($-0.31/-0.14$)

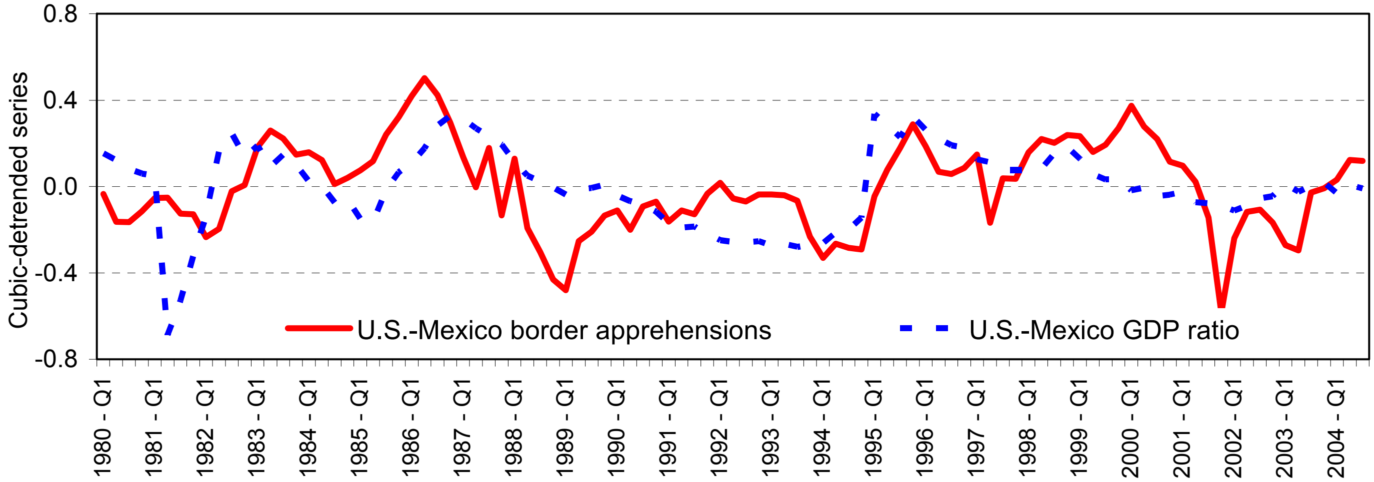
Note: For the data, variables are transformed in $\Delta \ln$ and thus expressed in growth rates. The sample period for border enforcement and apprehensions is 1980:2 to 2004:3. For workers' remittances, the sample period is 1995:2 to 2006:3. For the estimated model, we report the medians from the simulated distribution of moments, using the samples of moments generated with parameters draws from the posterior distribution, for the variables in growth rates. The 5th and 95th percentiles are included in parantheses.

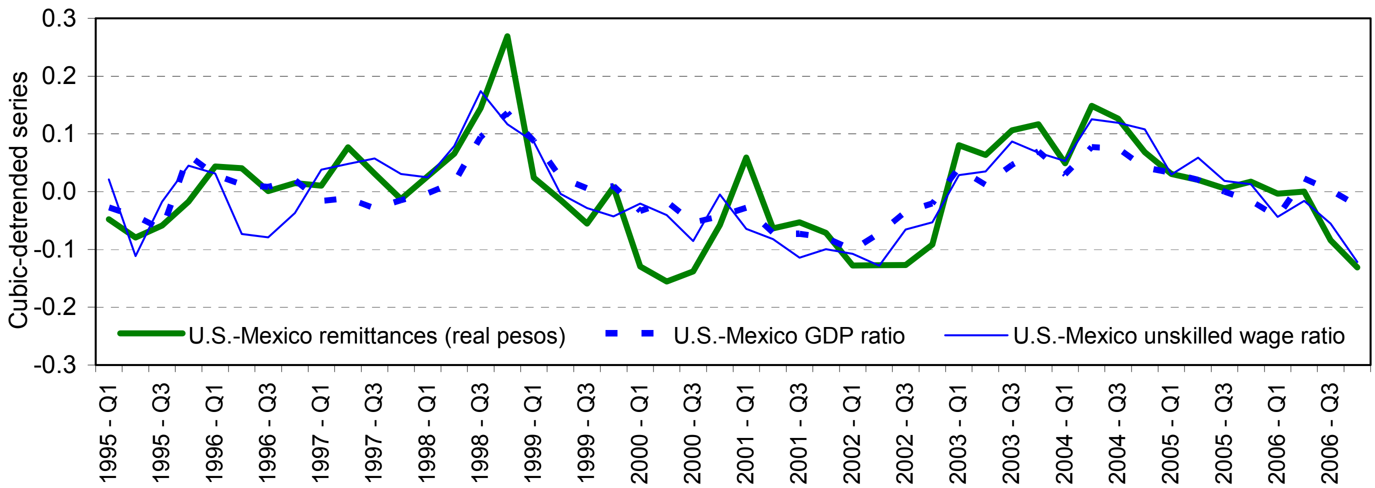
Table 3: Welfare gain/loss from changes in border enforcement

	Home			Foreign		
	Skilled	Unskilled	Net gain/loss	Skilled	Unskilled	Net gain/loss
Sunk cost lowered to $f_e = 1$						
No shocks	$+4.2$	-32.5	$+3.2$ (for skilled)	-11.4	$+9.6$	$+2.2$ (for unskilled)
Shocks	$+5.2$	-43.5	$+3.8$ (for skilled)	-12.1	$+10.8$	$+2.9$ (for unskilled)
Sunk cost raised to $f_e = 6$						
No shocks	-2.0	$+12.6$	-27.4 (for unskilled)	$+3.0$	-3.6	-1.2 (for skilled)
Shocks	-3.0	$+19.0$	-31.5 (for unskilled)	$+2.9$	-4.7	-2.3 (for skilled)

Note: The table shows the welfare gain or loss for the skilled and unskilled households in Home and Foreign, expressed as a percentage of their steady-state stream of expected consumption, when switching from the estimated sunk cost parameter ($f_e = 4.73$) to either a low sunk cost ($f_e = 1$) or a high sunk cost ($f_e = 6$) regime. The "net gain/loss" represents the welfare outcome for the party that initially obtains a benefit, but after it provides compensation to the domestic counter-party that obtains a loss.

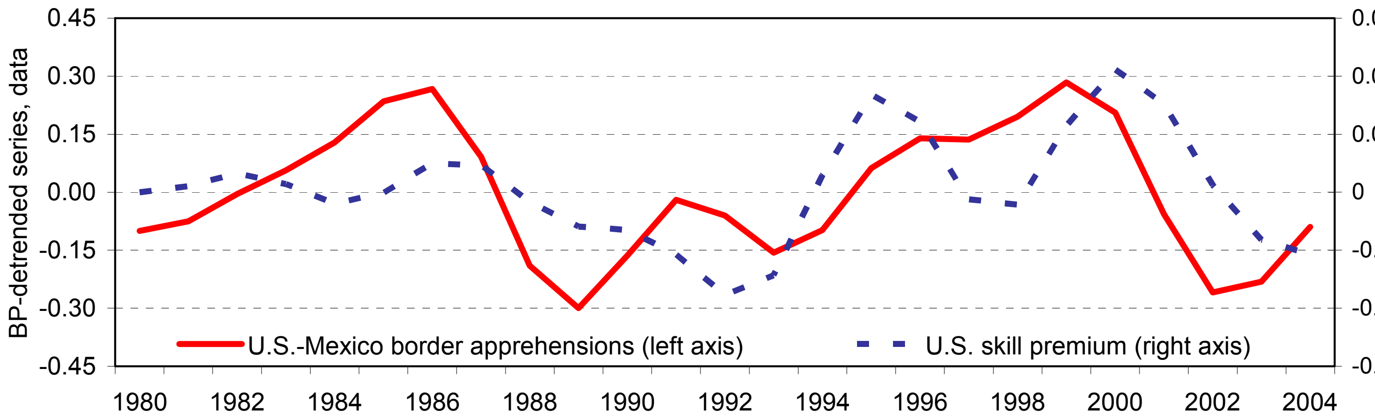
Figure 1. Border apprehensions, remittances and the U.S.-Mexico GDP ratio





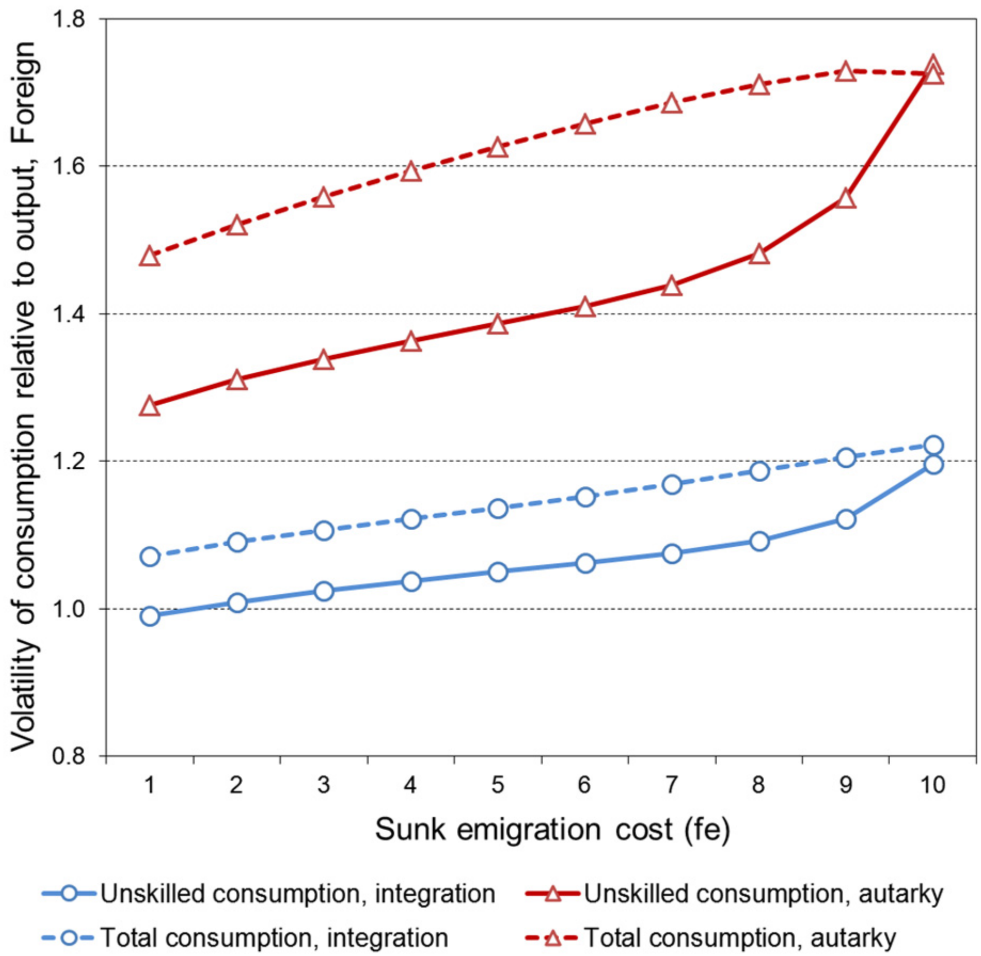
Note: Border apprehensions (seasonally adjusted) and the GDP ratio are expressed in natural logarithms and de-trended with a cubic trend. Remittances (in Mexican pesos at constant prices, seasonally adjusted), the GDP ratio and the wage ratio are expressed in natural logarithms and de-trended with a cubic trend. The U.S.-Mexico GDP ratio is computed as the ratio between (1) the U.S. real GDP and (2) the Mexican real GDP multiplied by the bilateral real exchange rate, with each series seasonally adjusted and GDP re-based to 2000. The U.S.-Mexico wage ratio is computed as the ratio between (1) the U.S. real unskilled wage and (2) the *maquiladora* real wage in Mexico multiplied by the bilateral real exchange rate, with each series seasonally adjusted.

Figure 2. Labor migration and the U.S. skill premium



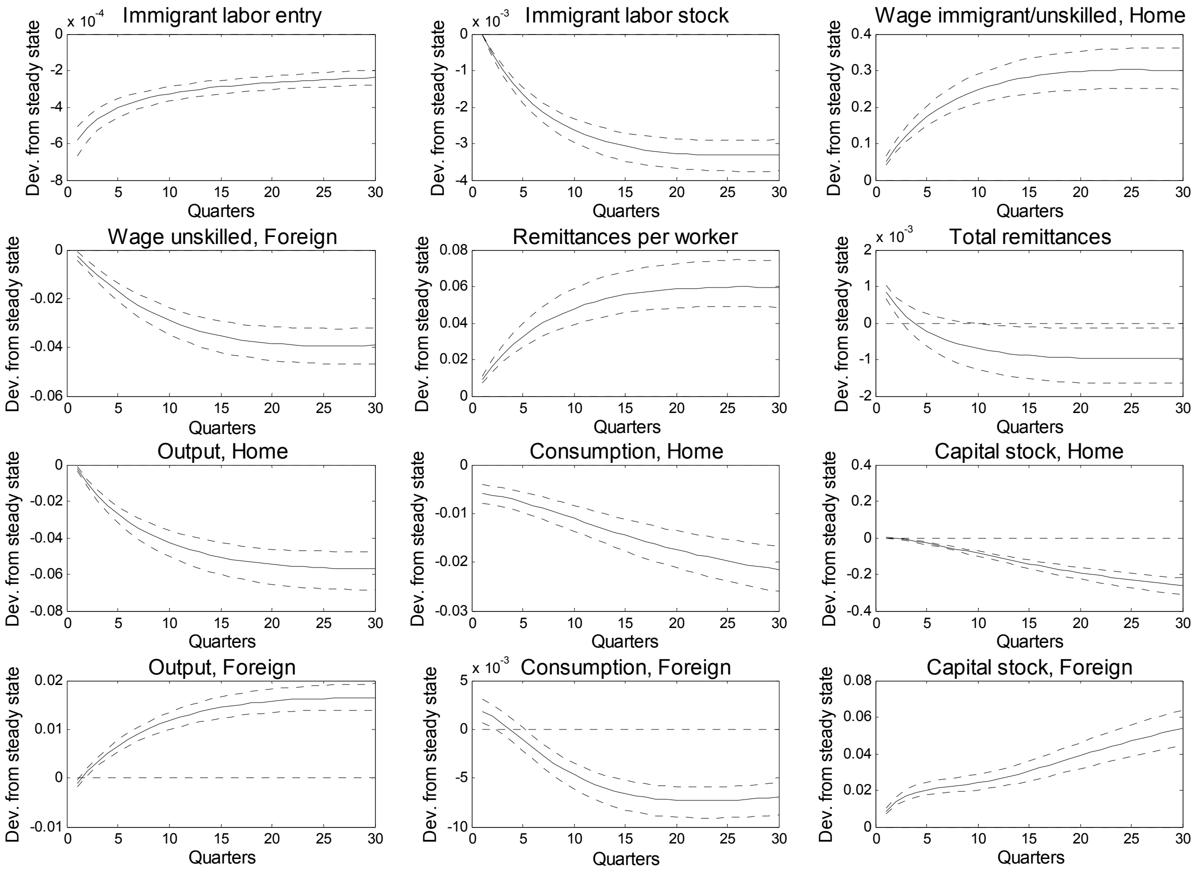
Note: The U.S. skill premium is defined as the skilled-to-unskilled wage ratio, where the skilled include labor with at least a high-school degree. Border apprehensions and the U.S. skill premium are annualized, expressed in natural logarithms and de-trended with a band-pass filter that removes fluctuations accruing in periods shorter than 4 and longer than 25.

Figure 3. Migration barriers, financial frictions, and consumption volatility in Foreign



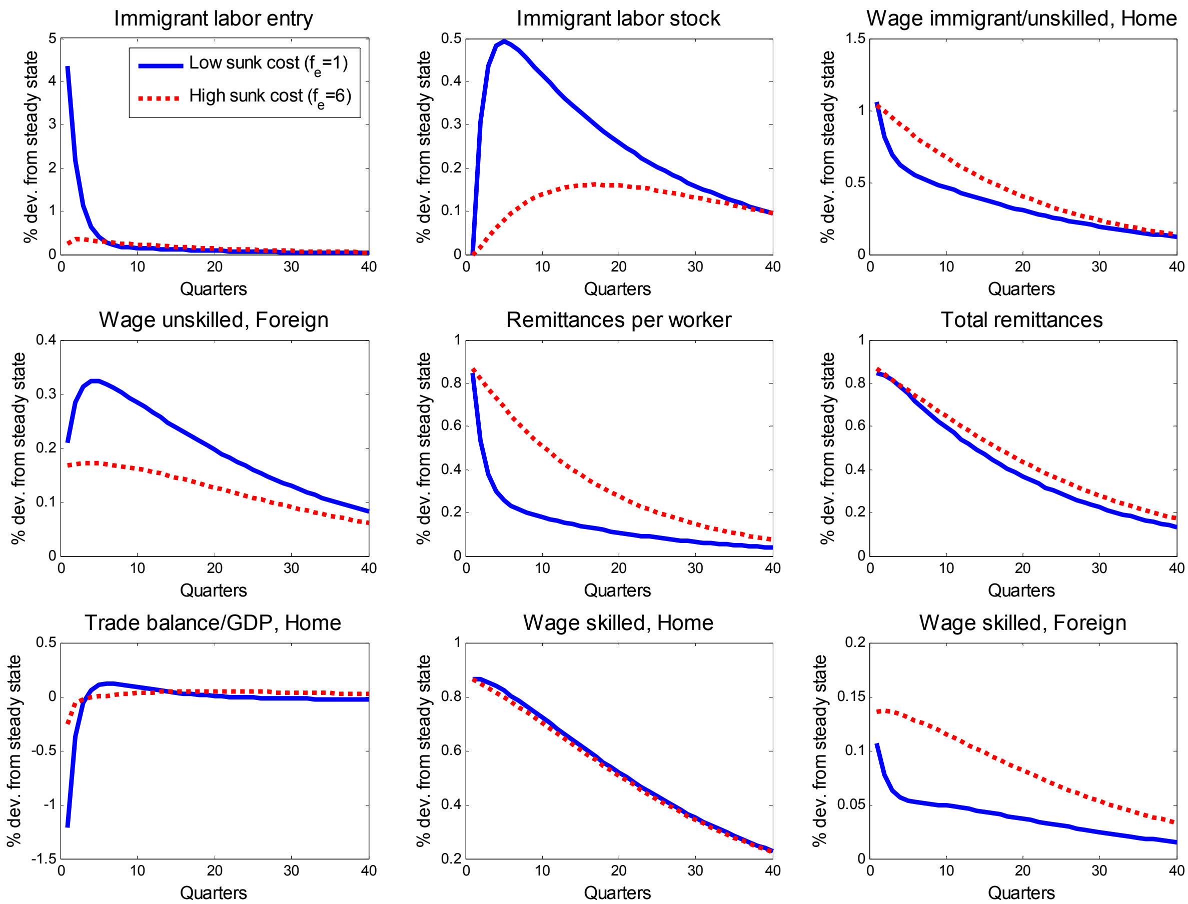
Note: The standard deviations of foreign consumption (unskilled and total) relative to output are computed for the model variables expressed in growth rates. The moments are calculated with the median of the estimated parameters.

Figure 4. Impulse response to an increase in border enforcement



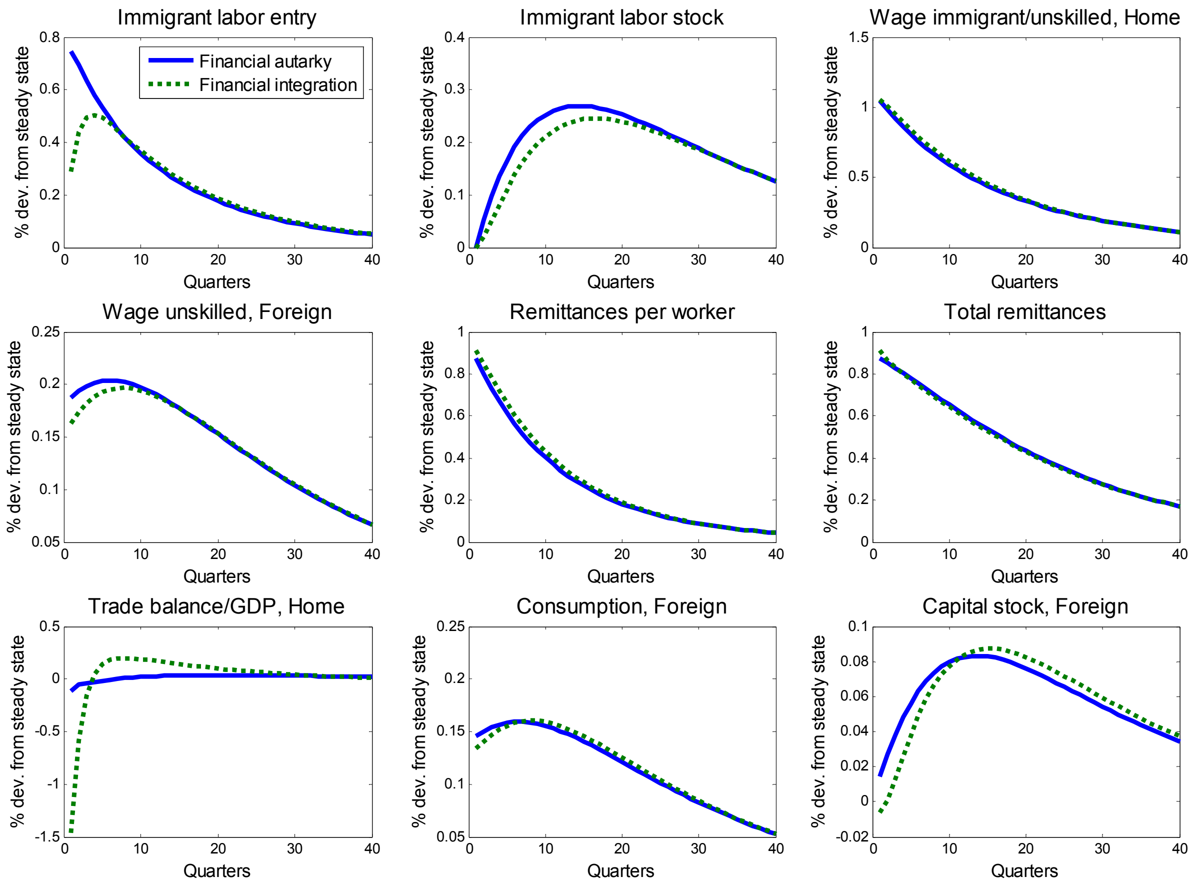
Note: The solid line is the median impulse response to a border enforcement shock (one standard deviation). The dashed lines are the 10 and 90 percent posterior intervals. The impulse responses in this figure are expressed as level deviations from steady-state.

Figure 5. Impulse responses to a positive neutral technology shock in Home, low vs. high sunk emigration cost



Note: Impulse response to a positive neutral technology shock in Home (1% increase in neutral technology) at the median of the estimated parameters with the exception of f_e (which we set as f_e =1 for low border enforcement, and f_e =6 for high border enforcement). For model comparisons, the impulse responses in this figure are expressed as percentage deviations from steady-state.

Figure 6. Impulse responses to a positive neutral technology shock in Home, financial autarky vs. integration



Note: Impulse responses to a positive neutral technology shock in Home (1% increase in neutral technology) at the median of the estimated parameters, expressed as percentage deviations from steady-state.

Figure 7. Historical decomposition