The Costs of Losing Monetary Independence: The Case of Mexico*

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Abstract

This paper develops a two-country monetary model calibrated to data from the U.S. and Mexico to address the question of whether dollarization is welfare improving for the two countries. Our findings suggest that dollarization is not necessarily Pareto superior to monetary independence for Mexico.

1 Introduction

There are two persuasive arguments that are often put forth in support of the idea that many countries would benefit from the adoption of the U.S. dollar as their national currency. One is the standard argument often made in favor of fixed exchange rates, that they promote economic and financial integration and impose some degree of monetary discipline on the participating countries. Countries are disciplined in the sense that it is more difficult for them to unilaterally undertake expansionary monetary policies when the exchange rate has to be kept fixed. With "dollarization" this would necessarily be true since monetary policy would largely be tied to U.S. policy. The other argument is that dollarization would solve the credibility and commitment problem for these countries. The idea is that many countries, particularly in Latin America, have long histories of high inflation and a record of breaking promises to pursue monetary policies that lead to low inflation. Taking monetary policy out of the hands of domestic central banks is one way to address this issue. Thus, one of the conjectured benefits of adopting the U.S. dollar hinges on the prospect that this would eliminate an inflationary bias among the participating countries.

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These benefits have to be balanced against the costs associated with the loss of monetary independence that either dollarization or a currency area necessarily implies. This loss of monetary independence means that the country can no longer use the instruments of monetary policy to adjust to internal or external shocks. The conventional wisdom that emerges from discussions of "optimal currency areas" is that the cost of losing monetary independence will be larger the more asymmetric are the shocks that affect the participating countries.

These considerations suggest two main questions that should be addressed in thinking about the proposal to adopt the U.S. dollar in Mexico. First, is the higher inflation rate in Mexico necessarily the result of the lack of monetary discipline or it can be justified by some principle of optimality in the conduction of monetary policy? Second, is the welfare consequence of losing the ability to react optimally to shocks quantitatively important?

In this paper we address these questions in the context of a simple two-country model where both countries are technologically integrated. The production activity in each country requires two inputs: one is domestically produced and the other is imported. Each country is affected by a productivity shock. Agents own financial assets in the form of bank deposits. These deposits are then used by banks to make loans to firms at the market interest rate, as firms need to finance the purchase of the intermediate inputs. In the model, monetary policy interventions in both countries have liquidity effects, that is, a monetary expansion induces a fall in the domestic nominal interest rate. The fall in the nominal interest rate, then, has an expansionary effect on the real sector of the economy. For monetary policy interventions to have liquidity effects, we have to impose some rigidity in the ability of the households to readjust their portfolio. As in **?**), Fuerst (1992) and Christiano & Eichenbaum (1995), we assume that agents have to wait one period before being able to readjust their stock of deposits.

In this framework we study the optimal and time-consistent monetary policy in country 1 (Mexico) when country 2 (United States) follows a certain exogenous monetary policy. Therefore, we are assuming that the U.S. monetary policy does not react optimally to changes in Mexico. We justify this assumption by the fact that Mexico is small in economic terms, relative to the U.S. economy. The Mexican monetary authority is assumed to maximize the welfare of Mexican consumers using the instruments of monetary policy. There is no commitment technology and the type of policies we analyze are time-consistent. At the end of the paper, however, we will extend the model to consider the case in which the U.S. also conducts monetary policy optimally. As we will see, the assumption that the U.S. does not react to the monetary policy implemented in Mexico, is a good approximation to this more general model. This result derives from the fact that the Mexican economy is small relative to the U.S. economy. A different conclusion would have been reached if Mexico and the U.S. were equally sized and symmetric countries.

We contrast the case in which Mexico conducts monetary policy optimally to the equilibrium that would prevail if Mexico adopts the dollar. By comparing the equilibria of these two economic environments, we answer the two questions proposed above. Regarding the first question—namely, whether the current inflation rate in Mexico can be reconciled with the optimality of the Mexican monetary policy—we show that if the production structure in Mexico is sufficiently dependent from intermediate inputs imported from the U.S., then an inflation rate higher than the one in the U.S. is optimal.

The reasoning behind the higher inflation rate of Mexico in the case of monetary independence is quite straightforward. In this environment, because of frictions in the adjustment of household portfolios, the policy maker has the ability to control the domestic interest rate by changing the liquidity in the economy. The interest rate, in turn, affects the real exchange rate. Specifically, a contractionary policy that increases the nominal interest rate, reduces the demand for foreign imports and induces an appreciation of both the nominal and real exchange rate. With the appreciation of the real exchange rate, foreign imports become cheaper (the country needs to give up less domestic production to pay for the foreign imports) and this allows an increase in production and consumption. Agents anticipate this policy behavior and form expectations of higher future nominal interest rates. These expectations will then be fulfilled by future policies and the equilibrium will be characterized by higher interest rates. In the long-run, a higher nominal interest rate requires a higher rate of inflation (the Fisher effect), and the long-run equilibrium will be characterized by higher inflation. The key assumption that leads to this result is the assumption that imports are production inputs that are complementary to domestic inputs.

When Mexican imports from the U.S. are sufficiently complementary in production, the inflation and interest rates reduction induced by dollarization would generate significant welfare looses for Mexico. However, if the inflation rate in Mexico is not optimal but is high for reasons not explicitly modeled in the paper, like the need to use money to finance government spending, then dollarization could be welfare improving. However, it is still true that, as long as the optimal inflation rate in Mexico is different from the inflation rate in the U.S., dollarization is not the first best solution for the inflation problems of Mexico.

In addition to studying the implications of a common currency for long-term inflation, we also evaluate the welfare costs of loosing the short-term ability to react optimally to asymmetric internal and external shocks. We compute these costs by comparing the welfare level reached by Mexico when it conducts monetary policy optimally, with the welfare level when its monetary policy follows the same process as the U.S. monetary policy, but with a higher long-term growth rate of money. The comparison of these two welfare levels provides an evaluation of the costs of loosing cyclical monetary independence. Our findings are that the costs of losing the ability to react to shocks are much smaller than the potential losses or gains deriving from the reduction of the long term inflation.

The organization of the paper is as follows. Section 2 describes the economic environment and Section 3 analyzes a simplified version of this environment. The analysis conducted in this section will be useful for the understanding of the main economic mechanisms also working in the more general model. Sections 4 and 5 define the equilibrium and analyzes some of the analytical properties of the model in the environment with multiple currencies (monetary independence) and in the environment with a single currency (dollarization). After calibrating the model in Section 6, Section 7 studies the welfare consequences of dollarization. Finally, Section 8 extends the model to the case in which also the U.S. conducts monetary policy optimally and Section 9 concludes.

2 The economic environment

Consider a two-country economy. The first country (Mexico) is populated by a continuum of households of total measure 1 and the second country (the U.S.) is populated by a continuum of households of total measure μ. Thus, μ is the population size of country 2 relative to country 1. In both countries households maximize the life time utility $E_0 \sum_{t=0}^{\infty} \beta^t u(c_t)$, where the period utility is a function of consumption c_t and β is the discount factor.

In each country there is a continuum of firms. For simplicity we assume that each firm employs one household-worker and has access to the following production technology:

$$y_1 = A_1 x_1^{\nu} \qquad\qquad x_1 = \left(x_{11}^{\epsilon} + \phi_1 x_{12}^{\epsilon}\right)^{\frac{1}{\epsilon}} \tag{1}$$

where A_1 is the technology level of country 1, x_{11} is an intermediate input produced by firms in country 1, and x_{12} is an intermediate input produced in country 2 (import). The parameter ϵ affects the degree of complementarity between intermediate inputs: smaller is ϵ and higher is the degree of complementarity (lower the degree of substitutability) between domestic and foreign inputs. Aggregate country-wide shocks take the form of stochastic changes in the level of technology A_1. The same production function, with technology level A_2, is used by firms in country 2. We assume that $\nu < 1$ and $\epsilon < \nu$.

Firms need to finance the purchase of these inputs by borrowing from a financial intermediary. The nominal interest rate on loans in country 1 is R_1 and the interest rate in country 2 is R_2. Denote by e the nominal exchange rate (units of currency of country 1 to purchase one unit of currency of country 2). The real exchange rate is denoted by $\bar{e}$ and is equal to eP_2/P_1, where P_1 is the nominal price in country 1 and P_2 is the nominal price in country 2 (both expressed in their respective currencies). After noting that the price of the final goods must be equal to the price of the intermediate goods produced at home, the loan contracted by a firm in country 1 is equal to $P_1(x_{11} + \bar{e} \cdot x_{12})$ and the loan contracted by a firm in country 2 is $P_2(x_{22} + x_{21}/\bar{e})$. The optimization problem solved by a firm in country 1 is:

$$\max_{x_{11},x_{12}} \left\{ A_1 x_1^{\nu} - (x_{11} + \bar{e} \cdot x_{12})(1 + R_1) \right\} \tag{2}$$

with solution:

$$x_{11} = \left(\frac{\nu A_1}{1+R_1}\right)^{\frac{1}{1-\nu}} \left[1+\phi_1\left(\frac{\phi_1}{\bar{e}}\right)^{\frac{\epsilon}{1-\epsilon}}\right]^{\frac{\nu-\epsilon}{\epsilon(1-\nu)}} \tag{3}$$

$$x_{12} = \left(\frac{\phi_1}{\bar{e}}\right)^{\frac{1}{1-\epsilon}} x_{11} \tag{4}$$

The demands for the domestic and foreign inputs depend positively on the level of technology, and negatively on the domestic interest rate. Moreover, if $\nu > \epsilon$, the real exchange rate has a negative impact on both inputs. Therefore, a policy that induces an appreciation of the real exchange rate for country 1, that is, a fall in $\bar{e}$, has an expansionary effect in this country.

The surplus of a firm in country 1 is denoted by π_1. The surplus is distributed to the households at the end of the period. Given the structure of the model, the form in which this surplus is distributed, whether as wages or profits, is irrelevant.

Households hold financial assets in domestic and foreign banks. Henceforth we will refer to these financial assets as deposits. The stocks of deposits are decided at the end of each period and the households have to wait until the end of the next period before being able to change the stocks of deposits. This is the assumption usually made in the class of "Limited Participation" models. To simplify the analysis, we assume that foreign deposits are always denominated in the currency of the second country (dollars). By making this assumption, we need to keep track only of the net foreign position of country 1. The stock of domestic deposits of a household in country 1 is denoted by d_1 while its net foreign position (foreign deposits if positive or foreign debt if negative) is denoted by b.

Banks make loans only in the currency in which they receive deposits and firms contract loans that are denominated only in domestic currency. In the environment with multiple currencies (pre-dollarization), these assumptions imply that in each country domestic firms borrow only from domestic banks. In the environment with a common currency (dollarization), instead, because banks in the two regions offer loans denominated in the same currency, firms borrow from both domestic and foreign banks. This also implies that the nominal interest rate after dollarization will be equalized in the two regions.

In addition to domestic and foreign deposits, households also own liquid assets used for transactional purposes as they face a cash-in-advance constraint. In country 1, the cash-in-advance constraint is $P_1 c_1 \leq n_1$, where n_1 is the liquid funds retained at the end of the previous period for transaction purposes. The beginning-of-period total financial assets of the household in country 1 are equal to the retained liquidity (in domestic and foreign currency) plus the nominal value of domestic and foreign deposits, that is, $n_1 + d_1 + eb$. In country 2, the beginning-of-period financial assets, denominated in country 2 currency, are $n_2 + d_2$.

2.1 The tools of monetary policy and the objective of the policy maker

In each period households receive a monetary transfer in the form of bank deposits. The monetary transfer in country 1 is denoted by T_1 and is equal to $g_1 M_1$, where M_1 is the pre-transfer nominal stock of domestic liquid assets (money) expressed in per-capita terms and g_1 is its growth rate. The same notation, with different subscript, is used for country 2. Because transfers are in the form of bank deposits and households cannot immediately readjust their portfolios, the monetary authority increases the liquidity available to domestic banks to make loans by increasing these transfers. The increase in liquidity, then, causes a fall in the nominal interest rate (liquidity effect). Therefore, the monetary authority controls the nominal interest rate by changing the growth rate of money.[1]

The monetary authority in the first country (Mexico) chooses the current growth rate of money optimally, in the sense of maximizing the welfare of the domestic households. The monetary authority cannot credibly commit to future policies. Therefore, we consider only policies that are time-consistent. In the class of time-consistent policies, we restrict the analysis to Markov policies, that is, policies that depend only on the current (physical) states of the economy. These policies are denoted by $g_1 = \Psi_1(\mathbf{s})$, where $\mathbf{s}$ is the set of aggregate state variables as specified below.

In the second country (the U.S.), monetary policy is assumed to be exogenously given and is specified as a stochastic process for the growth rate of money. In the event of dollarization, this process for the growth rate of money will be extended to the country adopting the dollar. The case in which the U.S. also conducts monetary policy optimally will be analyzed in section 8.

2.2 Equilibrium conditions

In this section we define the equilibrium conditions that need to be satisfied in all markets of the two economies: the goods markets, the loans markets, the money markets and foreign exchange market.

The equilibrium condition in the goods market in country 1 is:[2]

$$Y_1 = C_1 + X_{11} + X_{21}\mu \tag{5}$$

The gross production (supply) must be equal to the demands of goods for domestic consumption, C_1, and the demand of intermediate inputs from domestic firms, X_{11}, and foreign firms, $X_{21}\mu$.

[1] At the cost of increasing the notational complexity of the model, we could assume that monetary interventions take the form of open market operation conducted by the monetary authority with domestic banks. In Cooley & Quadrini (1999) we take this alternative approach and we show that the transmission mechanism of monetary policy interventions does not change if we make this alternative assumption.

[2] We use capital letters to denote aggregate variables and prices, and lowercase letters to denote individual variables. The only exception is the exchange rate that we denote by e to distinguish it from the expectation operator E.

The equilibrium condition in the loans market of country 1 is:

$$P_1(X_{11} + \bar{e} \cdot X_{12}) = D_1 + T_1 \tag{6}$$

The left-hand-side is the demand for loans from domestic firms and the right-hand-side is the supply of loans from domestic banks. Similar condition holds in the loan market of country 2, that is,

$$P_2(X_{22} + X_{21}/\bar{e}) = B/\mu + D_2 + T_2 \tag{7}$$

Notice that the supply of loans is given by the deposits of foreign residents, B/μ, domestic residents, D_2, and the monetary injection, T_2.

Using the cash-in-advance constraint and equations (5)-(6), we get:

$$P_1Y_1 + P_1\left[\bar{e} \cdot X_{12} - X_{21}\mu - \frac{N_1 - (M_1 - D_1)}{P_1}\right] = M_1 + T_1 \tag{8}$$

which expresses the equality between the volume of transactions executed with the use of domestically denominated liquid funds, and the total quantity of these funds. Notice that the term $N_1 - (M_1 - D_1)$ is the foreign currency owned by the households in country 1. This currency is sold in the exchange rate market at the beginning of the period to purchase consumption goods. We will use the variable $N = N_1 - (M_1 - D_1)$ without subscript to identify the foreign currency held by households in country 1. This variable evolves according to: $N' = B(1 + R_2) - B'$.[3] Using this notation, equation (8) can be rewritten as:

$$P_1Y_1 + P_1\left[\bar{e} \cdot X_{12} - X_{21}\mu - \frac{\bar{e} \cdot N}{P_2}\right] = M_1 + T_1 \tag{9}$$

For country 2, the analog of condition (9) is:

$$P_2Y_2 - \frac{P_2}{\bar{e}\mu}\left[\bar{e} \cdot X_{12} - X_{21}\mu - \frac{\bar{e} \cdot N}{P_2}\right] = M_2 + T_2 \tag{10}$$

Finally, the equilibrium condition in the exchange rate market is:

$$\bar{e} \cdot X_{12} = X_{21}\mu + \frac{\bar{e} \cdot N}{P_2} \tag{11}$$

The exchange rate market takes place at the beginning of the period after the government transfers. The demand for foreign currency (currency of country 2) derives from the purchase of the input produced in country 2 from firms in country 1 (imports of country

[3] Households use all the foreign currency owned at the beginning of the period to buy consumption goods. Therefore, their end-of-period currency position will be given by the repayments received from foreign deposits, that is, $B(1 + R_2)$. Given this position, households decide the new foreign deposits, B'. The difference is the new foreign currency position, that is, $N' = B(1+R_2) - B'$. The next period, this currency will be sold (or purchased if $N' < 0$) in the exchange rate market.

1). The supply derives from the purchase of the input produced in country 1 from firms in country 2 (exports of country 1) and the foreign currency retained by households in country 1. Using the equilibrium condition in the exchange rate market, (9) and (10) become:

$$P_1 Y_1 = M_1 + T_1 \tag{12}$$
$$P_2 Y_2 = M_2 + T_2 \tag{13}$$

Therefore, the total quantity of money in each country is equal to its nominal gross production.

3 Monetary policy equilibrium in a simplified version of the economy

Before characterizing the equilibrium of the dynamic model described above, it is useful to first analyze a simplified version of the economy. This simplified version allows us to illustrate the main tensions faced by the policy maker of country 1 in choosing their optimal policy. These tensions are also at work in the more general model. Illustrating them in this simplified version, however, facilitates the understanding of how these forces work in the more general model.

Consider the deterministic version of the model with $A_1 = \bar{A}_1$ and $A_2 = \bar{A}_2$, where $\bar{A}_1$ and $\bar{A}_2$ are constant. Also assume that there is not international mobility of capital so that $B = 0$ and $N = 0$. Furthermore, to simplify the analysis, assume that there is only one period. Therefore, the model is static and we do not have to deal with the issue of time-consistency.

The absence of financial flows from one country to the other implies that the trade account must be balanced in each period and the country's consumption is always equal to net production. The analytical complexity of the model will be reduced if we assume that the monetary authorities in the two countries control the nominal interest rate rather than the growth rate of money. However, while in country 1 (Mexico) the nominal interest rate maximizes the country's welfare, in the second country (the U.S.) the process for the nominal interest rate is exogenous. In this deterministic version of the model R_2 is just a constant. This change in the target of the monetary authority does not change the equilibrium properties of the model. This is because, given the stocks of deposits in the two countries, there is a unique correspondence between the domestic growth rate of money and the domestic interest rate. Moreover, the domestic interest rate is not affected by the growth rate of money in the other country. As we show in the appendix, the interest rates in the two countries are given by:

$$1 + R_1 = \frac{1 + g_1}{D_1/M_1 + g_1} \tag{14}$$
$$1 + R_1 = \frac{1 + g_2}{D_2/M_2 + g_2} \tag{15}$$

It can be verified that there is a unique and negative correspondence between the domestic growth rate of money and the nominal interest rate and the domestic interest rate does not depend on the foreign growth rate of money and foreign interest rate.

The equilibrium of this simplified economy can be described by the following three equations:

$$C_1 = \left(\frac{\nu \bar{A}_1}{1+R_1}\right)^{\frac{1}{1-\nu}} \left(\frac{1-\nu+R_1}{\nu}\right) \left[1 + \phi_1 \left(\frac{\phi_1}{\bar{e}}\right)^{\frac{\epsilon}{1-\epsilon}}\right]^{\frac{\nu(1-\epsilon)}{\epsilon(1-\nu)}} \tag{16}$$

$$C_2 = \left(\frac{\nu \bar{A}_2}{1+R_2}\right)^{\frac{1}{1-\nu}} \left(\frac{1-\nu+R_2}{\nu}\right) \left[1 + \phi_2 \left(\phi_2 \bar{e}\right)^{\frac{\epsilon}{1-\epsilon}}\right]^{\frac{\nu(1-\epsilon)}{\epsilon(1-\nu)}} \tag{17}$$

$$\left[\frac{\bar{A}_1(1+R_2)}{\bar{A}_2(1+R_1)}\right]^{\frac{1}{1-\nu}} \left(\frac{\phi_1}{\phi_2}\right)^{\frac{1}{1-\epsilon}} = \bar{e}^{\frac{1+\epsilon}{1-\epsilon}} \left[\frac{1+\phi_2(\phi_2\bar{e})^{\frac{\epsilon}{1-\epsilon}}}{1+\phi_1\left(\frac{\phi_1}{\bar{e}}\right)^{\frac{\epsilon}{1-\epsilon}}}\right]^{\frac{\nu-\epsilon}{\epsilon(1-\nu)}} \mu \tag{18}$$

Equation (16) defines the net production and consumption in country 1. Equation (17) defines the net production and consumption in country 2. Equation (18) defines the equilibrium in the exchange rate market (the value of imports must be equal to the value of exports, once evaluated at the same currency). These three equations, derived in the appendix, are functions of only three variables: R_1, R_2 and $\bar{e}$. All the other terms are parameters.

To illustrate the working of this model, figure 1 plots the level of consumption for country 1, as a function of its interest rate, R_1, for given values of the interest rate in country 2, that is, R_2.[4] The figure is constructed using the calibration values that will be discussed later.

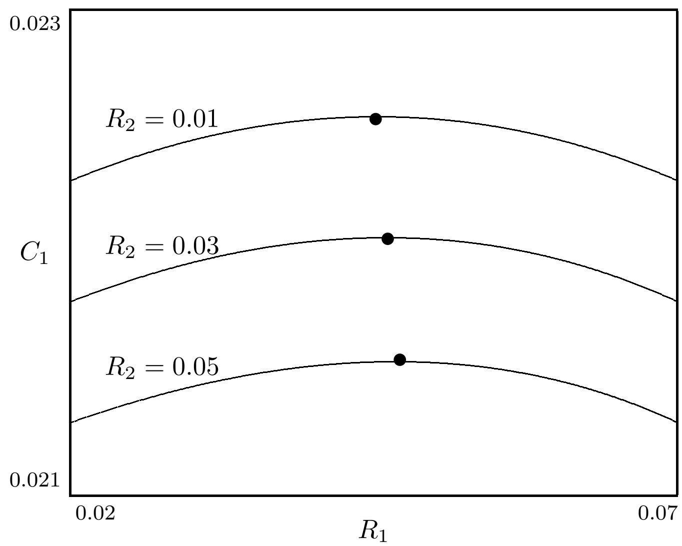
According to the figure, consumption in country 1 is initially increasing in R_1 and then decreasing. Therefore, for each R_2, there exists a value of R_1 that maximizes country 1's consumption. The intuition for this result is as follows. Given the interest rate chosen by country 2, domestic production and consumption depend negatively on the domestic interest rate R_1 and the real exchange rate $\bar{e}$. However, given the external constraint of a balanced trade account, an increase in R_1 also induces a fall in $\bar{e}$ (the country imports less and this induces an appreciation of the exchange rate). Therefore, an increase in R_1 has a direct negative effect and an indirect positive effect on consumption. For low values of R_1 the indirect effect dominates while for high values of R_1 the first effect dominates.

The maximizing value of R_1 constitutes a point in the reaction function of country 1 to the interest rate of country 2. By determining the optimal value of R_1 for each possible value of R_2, we can construct the whole reaction function for country 1. Figure 2 plots this reaction function for different values of ϵ.

The parameter ϵ plays a key role in the determination of the equilibrium interest rate in country 1. As we reduce the value of ϵ, that is we increase the degree of complementarity between domestic and foreign inputs, the reaction function of country 1

[4] After fixing R_1 and R_2, the value of consumption C_1 is given by the solutions of the system formed by equations (16) and (18).

Figure 1: Consumption of country 1 as a function of the domestic interest rate for a given interest rate in country 2.



moves up. This is because when intermediate inputs are not good substitutes, a fall in imports induced by an increase in R_1 generates a large appreciation of the currency which allows the country to import more goods with the same amount of exports, and the monetary authority has a higher incentive to raise the interest rate. Consequently, for smaller values of ϵ, the equilibrium will be characterized by a higher nominal interest rate in country 1. In a world in which the long-term interest rates are determined by a Fisherian rule, the higher interest rates will be associated with higher inflation rates.

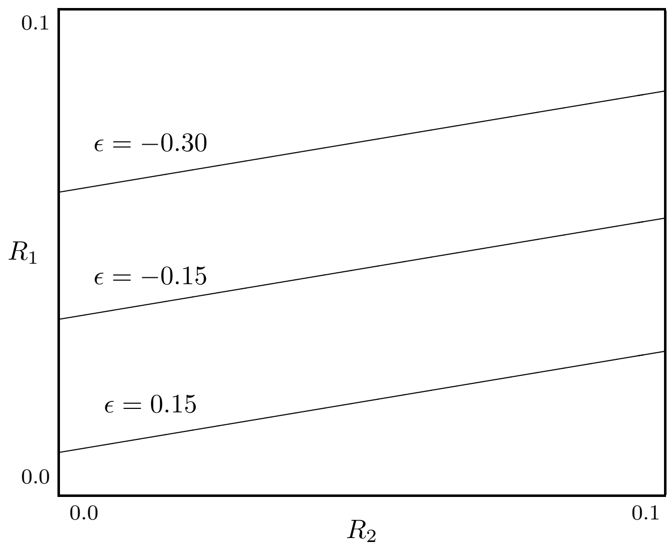
Keeping ϵ constant, the larger is the value of imports as a fraction of production for country 1, the higher the interest rate. This is because production and consumption are more sensitive to the real exchange rate relative to the nominal interest rate.

4 Optimal and time-consistent monetary

The economy analyzed in the previous section is the static version of the general model described in section 2. In this section, however, we will show that the static equilibrium described above is also the per-period equilibrium in the infinite horizon model. To simplify the analysis, we first consider the case in which there is not international mobility of capital, that is, $B = 0$ and $N = 0$. In section 4.4, we will discuss the extension of the results to the case of international mobility of capital. As we will see, the international mobility of capital does not affect the basic results.

The policy maker in country 1 choose g_1 on a period-by-period basis and cannot

Figure 2: Reaction function of country 1 to the interest rate in country 2.



credibly commit to the choice of future growth rates. In country 2, instead, the growth rate of money, g_2, is given by some exogenous stochastic process. As stated above, we restrict the analysis to policies that are Markov stationary, that is, policy rules that are functions of the current aggregate states in both economies. The current states are denoted by $\mathbf{s}$ and they are given by the technology levels in the two countries, A_1 and A_2, the growth rate of money in country 2, and the stock of (per-capita) deposits, D_1 and D_2. A policy rule for country 1 will be denoted by $g_1 = \Psi(\mathbf{s})$.

The procedure we follow to define the time-consistent policies consists of two steps. In the first step we define a recursive equilibrium where the policy maker in country 1 follows arbitrary policy rules Ψ. In the second step we ask what the optimal growth rate of money g_1 would be today for country 1, if the policy maker anticipates that from tomorrow on it will follow the policy rule Ψ. This allows us to derive the optimal g_1 as function of the current states. The optimal policy rule chosen today will be denoted by $g_1 = \psi(\Psi; \mathbf{s})$. If the current policy rule ψ is equal to the policy rule that will be followed starting from tomorrow, that is, $\psi(\Psi; \mathbf{s}) = \Psi(\mathbf{s})$ for all $\mathbf{s}$, then Ψ is the optimal and time consistent policy rule in country 1. We describe these two steps in detail in the next two subsections.

4.1 The household's problem given the policy rules Ψ

In this section we assume that the policy maker in country 1 commits to some policy rule $g_1 = \Psi(\mathbf{s})$. Then, using a recursive formulation, we will describe the household's problems in both countries and define a competitive equilibrium, conditional on this policy rule. In order to use a recursive formulation, we normalize all nominal variables by the pre-transfer stock of money in which these variables are denominated (either M_1 or M_2). The aggregate states of the economy are $\mathbf{s} = (A_1, A_2, g_1, D_1, D_2)$. The individual states for households in country 1 are $\hat{\mathbf{s}}_1 = (n_1, d_1)$, where n_1 are the liquid assets kept for transactional purposes and d_1 are the bank deposits. The problem solved by the households in country 1 is:

$$\Omega_1(\Psi; \mathbf{s}, \hat{\mathbf{s}}_1) = \max_{d_1'} \Big\{ u(c_1) + \beta\, E\, \Omega_1(\Psi; \mathbf{s}', \hat{\mathbf{s}}_1') \Big\} \tag{19}$$

subject to

$$c_1 = \frac{n_1}{P_1} \tag{20}$$

$$n_1' = \frac{(d_1 + g_1)(1 + R_1) + P_1 \pi_1}{(1 + g_1)} - d_1' \tag{21}$$

$$\mathbf{s}' = H(\Psi; \mathbf{s}) \tag{22}$$

$$g_1 = \Psi(\mathbf{s}) \tag{23}$$

In solving this problem, the households take as given the policy rule Ψ and the law of motion for the aggregate states H defined in equation (22). To make clear that this problem is conditional on the particular policy rule Ψ, this function has been included as an extra argument in the household's value function and in the aggregate law of motion. A similar problem is solved by the households in country 2 who also take as given the law of motion for the aggregate states H and the policy rule Ψ in country 1. The value function in country 2 is denoted by $\Omega_2(\Psi; \mathbf{s}, \hat{\mathbf{s}}_2)$.

A solution to this problem is given by the state contingent functions $d_1'(\Psi; \mathbf{s}, \hat{\mathbf{s}}_1)$ in country 1, and $d_2'(\Psi; \mathbf{s}, \hat{\mathbf{s}}_2)$ in country 2. As for the value functions, we make explicit the dependence of these decision rules on the policy function Ψ. We then have the following definition of equilibrium.

Definition 4.1 (Equilibrium given Ψ) *A recursive competitive equilibrium, given the policy rules Ψ is defined as a set of functions for (i) household decisions $d_1'(\Psi; \mathbf{s}, \hat{\mathbf{s}}_1)$, $d_2'(\Psi; \mathbf{s}, \hat{\mathbf{s}}_2)$, and value functions $\Omega_1(\Psi; \mathbf{s}, \hat{\mathbf{s}}_1)$, $\Omega_2(\Psi; \mathbf{s}, \hat{\mathbf{s}}_2)$; (ii) intermediate production inputs $X_{11}(\Psi; \mathbf{s})$, $X_{12}(\Psi; \mathbf{s})$, $X_{22}(\Psi; \mathbf{s})$, $X_{21}(\Psi; \mathbf{s})$; (iii) per-capita aggregate supplies of loans $L_1(\Psi; \mathbf{s})$, $L_2(\Psi; \mathbf{s})$ and aggregate demands of deposits $D_1'(\Psi; \mathbf{s})$, $D_2'(\Psi; \mathbf{s})$; (iv) interest rates $R_1(\Psi; \mathbf{s})$, $R_2(\Psi; \mathbf{s})$, nominal prices $P_1(\Psi; \mathbf{s})$, $P_2(\Psi; \mathbf{s})$ and nominal exchange* *rate $e(\Psi;\mathbf{s})$; (v) law of motion $H(\Psi;\mathbf{s})$. Such that: (i) the households' decisions are optimal solutions to the households' problems; (ii) the intermediate inputs maximizes the firms' profits; (iii) the markets for loans clear; (iv) the exchange rate market clears; (v) the law of motion $H(\Psi;\mathbf{s})$ for the aggregate states is consistent with the individual decisions of households and firms.*

Differentiating the household's objective with respect to d_1' we get:

$$E\left(\frac{u_c(c_1')}{P_1'}\right) = \beta E\left(\frac{(1+R_1')u_c(c_1'')}{P_1''(1+g_1')}\right) \tag{24}$$

where u_c is the derivative of the utility function (marginal utility of consumption). Similar first order conditions with respect to d_2' are obtained for country 2, that is:

$$E\left(\frac{u_c(c_2')}{P_2'}\right) = \beta E\left(\frac{(1+R_2')u_c(c_2'')}{P_2''(1+g_2')}\right) \tag{25}$$

These equations are standard Euler equations in dynamic models with money. The presence of the growth rates of money g_1' and g_2' derives from normalizing all nominal variables by the pre-transfer stock of money in which they are denominated.

4.2 One-shot optimal policy and the policy fixed point

In the previous section we derived the value function $\Omega_1(\Psi;\mathbf{s},\hat{\mathbf{s}}_1)$ for a particular policy rule Ψ used in country 1. We now ask what the optimal growth rate of money is today in country 1, if the policy maker in this country anticipates that from tomorrow on it will follow the policy Ψ.

The objective of the policy maker is the maximization of the welfare of the households in country 1. Therefore, in order to determine the optimal growth rate of money, the policy maker needs to determine how the households' welfare changes in country 1 as the current growth rate of money changes. In other words, it needs to know the function that links the households' welfare to the current growth rate of money. In order to determine this welfare function, consider the following optimization problem faced by households in country 1:

$$\mathbf{V}_1(\Psi;\mathbf{s},\hat{\mathbf{s}}_1,g_1) = \max_{d_1'}\left\{u(c_1)+\beta\, E\,\Omega_1(\Psi;\mathbf{s}',\hat{\mathbf{s}}_1')\right\} \tag{26}$$

subject to

$$c_1 = \frac{n_1}{P_1} \tag{27}$$

$$n_1' = \frac{(d_1+g_1)(1+R_1)+P_1\pi_1}{(1+g_1)} - d_1' \tag{28}$$

$$\mathbf{s}' = \tilde{H}(\Psi;\mathbf{s},g_1) \tag{29}$$

where the function $\Omega_1(\Psi; s', \hat{s}_1')$ is the next period value function conditional on the policy rules Ψ, defined in the previous section. The new function $\mathbf{V}_1(\Psi;\mathbf{s},\hat{\mathbf{s}}_1,g_1)$ is the value function for the representative household in country 1 when the current growth rate of money is g_1, and future rates are determined by the policy rules Ψ.

After solving for this problem and imposing the aggregate consistency condition $\hat{\mathbf{s}}_1 = \mathbf{s}$,[5] we derive the function $\mathbf{V}_1(\Psi;\mathbf{s},g_1)$. This is the welfare level reached by the representative household in country 1, when the current growth rate of money is g_1 and the future rates will be determined according to the rule Ψ. This is the object that is needed to determine the optimal growth rate of money chosen by the policy maker. Because the objective of the policy maker is the maximization of the welfare of households in country 1, the optimal value of g_1 is determined by the solution to the following problem:

$$g_1^{OPT} = \arg\max_{g_1} \mathbf{V}_1(\Psi;\mathbf{s},g_1) = \psi(\Psi;\mathbf{s}) \tag{30}$$

The function $\psi(\Psi;\mathbf{s})$ is the optimal policy rule in the current period when future growth rates of money are determined by the function Ψ. Using this policy rule, we can now define the optimal and time-consistent monetary policy rule.

Definition 4.2 (Time-consistent policy rule) *The optimal and time-consistent policy rule Ψ^{OPT} is the fixed point of the mappings $\psi(\Psi;\mathbf{s})$,* i.e.*,*

$$\Psi^{OPT}(\mathbf{s}) = \psi(\Psi^{OPT};\mathbf{s})$$

The basic idea behind this definition is that, when the agents in both economies (households, firms and monetary authority in country 1) expect that future values of g_1 are determined according to the policy rule Ψ^{OPT}, the optimal values of g_1 today is the one predicted by the same policy rule Ψ^{OPT} that agents assume to determine the future values. This property assures that, in the future, the policy maker in country 1 will continue to use the same policy rule used in the current period, so that it is rational to assume that future values of g_1 will be determined according to this rule.

[5] In writing $\hat{\mathbf{s}} = \mathbf{s}$ we make an abuse of notation as the vector $\hat{\mathbf{s}}$ includes different variables than the vector $\mathbf{s}$. What we mean in writing $\hat{\mathbf{s}}_1 = \mathbf{s}$ is that $d_1 = D_1$, $n_1 = 1 - D_1$.

4.3 Properties of the optimal and time-consistent policy

The key feature of this economy is that, whatever is done in the current period, this is not going to affect the future. The future will be affected by future states and future policies rules, but these states and rules do not depend on the current equilibrium. This is formally stated in the next proposition.

Proposition 4.1 *The time-consistent policy is the equilibrium policy of the static equilibrium derived in section 3.*

The proposition can be proved following the steps used to define a policy equilibrium as described in the previous sections. Assuming that the future policies are given by the rule in the static equilibrium, we ask whether the policy maker in country 1 has the incentive to deviate from this rule in the current period.

In this economy, households can readjust their portfolio of deposits at the end of each period. In choosing the new stock of deposits, agents only care about future policies. The current policy is irrelevant. Therefore, given the policy rules Ψ assumed for the future, agents will choose their next period stock of deposits. Because the current policy does not affect the future states, and therefore policies, the current optimal policy rule is independent of the future rule Ψ. Because agents are rational, they anticipate that the current policy rule will also be followed in the future. Consequently, the current optimal rule is time-consistent.

In section 7, we will use this result to analyze the costs and benefits of dollarization for Mexico.

4.4 Time-consistent policy with international mobility of capital

With international mobility of capital, the foreign position of country 1 changes, that is, $B \neq 0$. The set of state variables, then, also includes the households' position in foreign deposits, B, and the households' position in foreign currency, N. Therefore, the set of state variables are: $\mathbf{s} = (A_1, A_2, g_1, B, N, D_1, D_2)$. The individual states for households in country 1 are $\hat{\mathbf{s}}_1 = (b, n, n_1, d_1)$ and for households in country 2 are $\hat{\mathbf{s}}_1 = (n_1, d_1)$.

The first order conditions for the households' problem with respect to the domestic deposits are still given by 24 and 25 derived in section 4.1. In addition, we also have the first order condition with respect to b' for households in country 1. These are given by:

$$E\left(\frac{u_c(c_1')}{P_1'}\right) = \beta E\left(\frac{(1+R_2')u_c(c_1'')P_2'\bar{e}''}{P_1'P_2''(1+g_2')\bar{e}'}\right) \tag{31}$$

The international mobility of capital introduces a non-stationarity problem in the households decisions. However, it does not change the main properties of the optimal policy. The optimal current policy depends also on B and N but it does not affect future values of B and N. This is because, as observed previously, the growth rate of money chosen by country 1 does not affect the current interest rate in country 2. This implies that the end-of-period position in foreign currency of country 1, $B(1+R_2)$, is not affected by the current policy in country 1. At the same time, because the households are free to reallocate their financial assets at the end of the period, the choice of B' (which in turn affects N'), only depends on the policy expected for the future, not the current one.

In the absence of shocks, the results obtained in the case of international financial autarky extend to the case of capital mobility when countries start with a balanced foreign position. With aggregate shocks, however, to make the system stationary, we have to impose some frictions in the international mobility of capital. One possibility is to assume that the expected return from foreign investments (foreign deposits) decreases when the international position of the country increases. We can justify this assumption with the possibility that the country defaults on the debt. With this further assumption, the performance of the model is similar to the autarky case. Therefore, in reporting the results we will concentrate on the case in which there is not international mobility of capital, that is, $B = 0$.

5 Dollarization

The adoption of a common currency, as in the case of dollarization, is only the visible and perhaps the least important aspect of a more complex process of capital market integration and liberalization. The process leading to a common currency is associated with increasing financial integration of the countries adopting the single currency. This process of financial integration is not only a consequence of legal liberalization, but also the result of market reactions (the elimination of the exchange rate risk, for example, facilitates foreign financial investments).

In the model, the process of financial integration following the adoption of the dollar is captured by the fact that firms start borrowing also from foreign banks. In the pre-dollarization environment, banks had relationships only with domestic firms because they were lending only in the currency in which their deposits were denominated, and firms were borrowing only in domestic currency. After dollarization, however, the difference between domestic and foreign currency disappears. This implies that for firms is indifferent to borrow from domestic and foreign banks and the interest rate will be equalized.

With dollarization it is natural to assume that the U.S. retains full discretion in choosing monetary policy. In our framework, this implies that the process of money growth assumed for the U.S. will also be the growth rate of money in Mexico. The assumption that this process does not change after dollarization can be justified by the fact that Mexico is relatively small in economic terms with respect to the U.S. economy.

After dollarization, the equilibrium in the goods markets do not change. For country 1 this condition is still given by equation (5). A similar condition holds for country 2.

The loans market becomes unified and the equilibrium condition can be written as:

$$(P_1 X_{11} + P_2 X_{12}) + (P_2 X_{22} + P_1 X_{21})\mu = D_1 + D_2 + T \tag{32}$$

where now P_1 and P_2 are nominal prices for goods produced in country 1 and 2 respectively but denominated in the same currency (currency of country 2). Similarly for deposits and monetary transfers.

In assuming that after dollarization Mexico is subject to the same monetary policy regime as the U.S., we also assume that Mexico will receive monetary transfers from the U.S. government. This is unlikely to be the case. However, as observed previously, the assumption that monetary policy interventions take the form of monetary transfers is made for analytical convenience. We should think of these interventions as open market operations conducted by the U.S. monetary authority with banks. To maintain the neutrality of monetary policy interventions in redistributing wealth between U.S. and Mexican citizens, we assume that monetary transfers are distributed according to a constant fraction to the households of the two countries. In this paper we neglect possible gains that the U.S. could obtain from dollarization, due to monetary seigniorage.

6 Calibration

The model is calibrated to the data for the United States and Mexico. Country 1 is Mexico and country 2 is the U.S. The period is assumed to be a quarter and the discount factor β is set to 0.985. The utility function takes the form $u(c) = c^{1-\sigma}/(1-\sigma)$, with $\sigma = 2$.

The production technologies are characterized by the parameters ν, ϵ, ϕ_1, ϕ_2 and by the levels of technology $\bar{A}_1 e^{z_1}$ and $\bar{A}_2 e^{z_2}$, where z_1 and z_2 are the technology shocks in country 1 and country 2 respectively. We assume that they both follow the autoregressive process $z' = \rho_z z + \varepsilon$ with $\rho_z = 0.95$. The innovation variables ε_1 and ε_2 are jointly normal with mean zero. Specifically we assume that $\varepsilon_1 = \rho_\varepsilon \varepsilon_2 + \upsilon$ where $\varepsilon_2 \sim N(0, \sigma_\varepsilon^2)$ and $\upsilon \sim N(0, \sigma_\upsilon^2)$. The parameter ρ_ε determines the correlation structure of the shocks in the two countries. We will consider several cases: the case of positive correlation, independence and negative correlation. Once we have fixed ρ_ε, the other two parameters, σ_ε and σ_υ, are calibrated so that the volatility of aggregate outputs in the two countries takes the desired values.[6] When we change ρ_ε, we also change σ_υ so that the standard deviation of z_1 does not change.

The fraction of liquid funds used by households for transaction purposes is approximately equal to $1 - \nu$. If we take the monetary aggregate M1 as the measure of liquid funds used for transaction by households and M3 as the measure of their total financial

[6]The volatility of outputs also depends on the process for the monetary shocks in the U.S. economy. However, once the process for the growth rate of money in the U.S. has been parameterized, the volatility of output in the two countries depends, residually, only on the technology shocks.

Table 1: Calibration values for the baseline model.

Intertemporal discount factor	β	0.985
Intertemporal discount rate	σ	2.000
Technology parameter	ν	0.820
Technology parameter	ϵ	-0.151
Technology parameter	$\bar{A}_2$	1.035
Technology parameter	ϕ_1	0.020
Technology parameter	ϕ_2	0.001
Persistence of the technology shock	ρ_z	0.950
Correlation of technology innovations	ρ_ε	0.600
Standard deviation of innovation	σ_z	0.002
Standard deviation of innovation	σ_υ	0.004
Persistence of the U.S. monetary shock	ρ_m	0.500
Standard deviation of the U.S. shock	σ_m	0.006
Relative population size of the U.S.	μ	2.900

assets, then ν is calibrated by imposing that $1-\nu$ equals the ratio of these two monetary aggregates. Accordingly, we set $1-\nu = 0.18$ which is the approximate value for Mexico.[7]

The parameter ϵ affects the degree of complementarity between domestic and foreign inputs. Assigning a value to this parameter is not easy. Therefore, we will consider different values and will analyze the sensitivity of the results to this parameter. For the baseline model the value of ϵ is chosen so that the quarterly inflation rate in country 1 is 3.0%, which is the approximate current inflation rate in Mexico. After the normalization $\bar{A}_2 = 1$ and after setting the population in the U.S. to be 2.9 times larger than in Mexico ($\mu = 2.9$), the technology parameters $\bar{A}_1$, ϵ, ϕ_1, ϕ_2 are calibrated by imposing the following steady state conditions: (a) Per-capita GDP in Mexico is 28% the per-capita GDP in the United States; (b) The inflation rate in Mexico is 3.0%; (c) The value of Mexican imports from the U.S. are 12% of the Mexican GDP; (d) The long-run real exchange rate, $\bar{e} = P_2 e/P_1$, is equal to 1. The full set of parameter values, for the baseline model, are reported in table 1.

Finally, the growth rate of money in the U.S. follows the autoregressive process $\log(1+g_2') = a + \rho_m \log(1+g_2) + \varphi$, with $\varphi \sim N(0, \sigma_m^2)$. The value assigned to a is such that the average growth rate of money (and inflation) in the U.S. is 0.008 per quarter. The calibration of the other two parameters follows Cooley & Hansen (1989) and set $\rho_m = 0.5$ and $\sigma_m = 0.0063$.

[7] By assuming that the parameter ν is the same for the two countries, we impose that the two countries have the same monetary structure. This is clearly not the case. The alternative would be to assume different parameters ν for the two countries. Because the basic results do not change significantly, for the sake of simplicity we assume a common parameter ν.

Table 2: Equilibrium variables before and after dollarization and associated welfare gains from dollarization. Values in percentage terms.

	$\epsilon = -0.151$		$\epsilon = -0.075$		$\epsilon = 0.075$		$\epsilon = 0.151$	
	Mexico	U.S.	Mexico	U.S.	Mexico	U.S.	Mexico	U.S.
Monetary independence								
Inflation	3.00	0.80	3.00	0.80	3.00	0.80	3.00	0.80
Interest rate	4.57	2.33	4.57	2.33	4.57	2.33	4.57	2.33
Optimal interest rate	4.57		3.93		2.88		2.45	
Dollarization								
Inflation	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Interest rate	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33
Consumption gains	-0.43	0.17	-0.19	0.15	0.21	0.12	0.39	0.10

7 Results

7.1 Optimal policy and equilibrium inflation without aggregate shocks

In this section we examine the properties of the calibrated economy without aggregate shocks. This allows us to quantify the welfare consequences of dollarization for Mexico that result from the reduction in long-term inflation.

Table 2 reports the equilibrium inflation and interest rates in Mexico and in the U.S. when Mexico conducts monetary policy optimally and after dollarization. The table also reports the welfare gains from dollarization. In the deterministic version of the economy the U.S. policy takes the form of a constant growth rate of money, which is equal to the quarterly long-term inflation rate of 0.8%. In the case of dollarization, the growth rate of money in Mexico is also 0.8%.

As can be seen from the table, dollarization is beneficial for the U.S. but not for Mexico. Moreover, the welfare losses for Mexico are quite substantial. In reaching this conclusion, however, we have made an important assumption: the assumption that the policy maker in Mexico is conducting monetary policy optimally, in the sense of choosing the growth rate of money that maximizes the welfare of the country without any constraints. Then we have calibrated the economy so that the current inflation rate in Mexico is optimal. Under these conditions it is not surprising that dollarization is not welfare improving for Mexico. Underlying the proposal of dollarization is the view that Mexico does not conduct monetary policy optimally. In this case, dollarization imposes some monetary discipline that the country would not be able to obtain by itself.

To allow for this possibility in the simplest possible way, we assume that there is some government spending in Mexico that needs to be financed with money. This government spending, denoted by G, is assumed to be a fraction γ of the gross output produced in Mexico, that is, $G = \gamma Y_1$. In addition, to eliminate possible income effects of government spending, we assume that this spending takes the simple form of government transfers. By making this assumption, a reduction in government spending imposed by a reduction in inflation does not affect households welfare beyond the removal of the distortionary effects induced by inflation.

The monetary authority still maintains the ability to make monetary transfers beyond $P_1 G$, although these transfers should be interpreted as open market operations. Denote by g_1^{OPT} the optimal growth rate of money chosen in absence of government spending. The actual growth rate of money will be $g_1 = \max\{\gamma, g_1^{OPT}\}$. Of course, the presence of government spending is relevant only if $g_1^{OPT} < \gamma$. The condition $g_1^{OPT} > \gamma$ captures the case in which the country lacks monetary discipline.

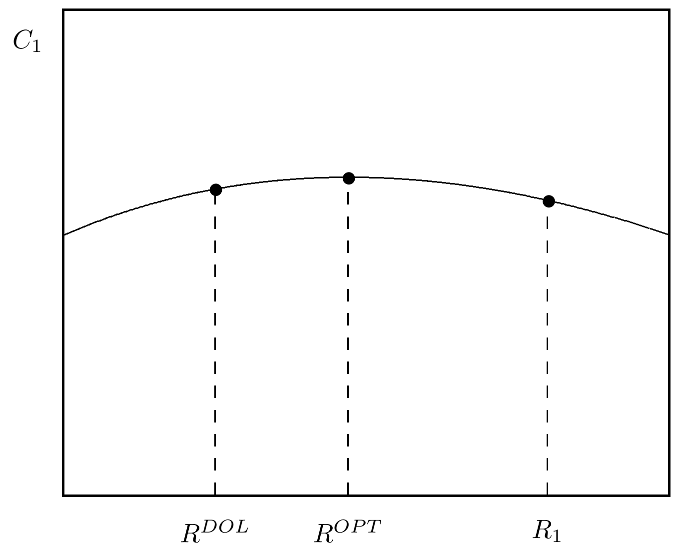
To consider this case, we increase the calibration value of the parameter ϵ but we assume that Mexico still maintains the same inflation and interest rates as in the previous version of the economy. Therefore, we set $\gamma = 0.03$. With a higher value of ϵ (lower complementarity between domestic and foreign inputs), if Mexico were to choose the growth rate of money optimally, it would reduce the interest and inflation rates. Therefore, $g_1^{OPT} < \gamma$.

This is shown in figure 3 which plots the households's consumption in country 1 as a function of the interest rate in country 1, for a given interest rate in country 2. The construction of the figure has been explained in section 3. The interest rate chosen by country 1 is $R_1 = (1 + \gamma)/\beta - 1$. This interest rate induces a level of welfare which is located on the right hand side of the maximum welfare. The optimal interest rate is $R^{OPT} < R_1$. After dollarization, the equilibrium interest rate is R^{DOL}. This interest rate delivers a higher level of welfare compared to the welfare induced by R_1. However, the figure also shows that R^{DOL} is not the first best interest rate. The optimal interest rate, denoted by R^{OPT} is greater than the one imposed by dollarization.

Table 2 reports the welfare computation when ϵ is larger than the baseline value (see the right section of the table). With lowers values of this parameter, the optimal long-term inflation rate in Mexico would be smaller than 3%. However, we now assume that Mexico is not conducting monetary policy optimally and the actual inflation rate is 3.0%. Under these conditions, dollarization can be welfare improving for Mexico as well as for the U.S.

In general, our conclusion is that, if the growth rate of money chosen in Mexico is not the optimal one, then the adoption of the dollar could be welfare improving for Mexico. It depends on how different the actual growth rate of money is from the optimal one. However, although dollarization could be welfare improving for Mexico, the exercise emphasizes that dollarization is not the best solution to the problem of monetary discipline. In other words, there is no reasons to believe that the long-term inflation rate in Mexico is exactly equal to the long-term inflation rate in the U.S. In particular, if the country could solve the discipline problem without adopting the external currency, then

Figure 3: Consumption in country 1 as a function of the domestic interest rate for a given interest rate in country 2.



monetary policy independence would be superior to dollarization.

7.2 The costs of losing cyclical monetary policy independence

One of the objectives of this paper is to quantify the welfare costs of losing the ability to use the monetary tools to respond to internal and external shocks. We compute the welfare costs of losing monetary discretion by comparing the level of expected welfare reached in the case in which Mexico conducts monetary policy optimally, with the welfare level obtained when the growth rate of money in Mexico follows the same U.S. process, but with a higher mean (which is equal to the average growth rate of money when Mexico conducts monetary policy optimally). Specifically, the process for the growth rate of money in Mexico is now $g_1 = \bar{g}_1 - \bar{g}_2 + g_2$, where $\bar{g}_1 = 0.03$, $\bar{g}_2 = 0.008$ and g_2 follows the same autoregressive process as described in the calibration section. This case describes the situation faced by Mexico after it looses its *cyclical* monetary policy independence, as a result of dollarization.

Table 3 reports the welfare losses (gains if negative) of loosing cyclical monetary policy independence. In calculating these losses we make three different assumptions about the nature of the asymmetry of real shocks. In the first case we assume that shocks are positively correlated with a correlation coefficient of 0.6. This is, in fact, the number we estimated using Solow residuals from both countries over the period from 1980 to 1996. We also assume that they are independent and negatively correlated (as they might be in the case of an oil shock).

Table 3: Welfare losses from loosing cyclical monetary policy independence. Losses are reduction in consumption after dollarization. Values in percentage terms.

	$\rho_\varepsilon = 0.6$		$\rho_\varepsilon = 0.0$		$\rho_\varepsilon = -0.6$	
	U.S.	Mexico	U.S.	Mexico	U.S.	Mexico
Welfare losses	0.010	-0.004	0.010	-0.007	0.011	-0.009

As can be seen from the table, the adoption of the U.S. currency and the subsequent loss of the ability to react optimally to shocks, imply welfare losses for Mexico. The cost of losing cyclical independence, however, is relatively small and is not sensitive to the asymmetry of the shocks. Consequently, the most important welfare implications of dollarization for Mexico derive from the loss of long-term monetary independence, that is, the ability to choose the optimal inflation and interest rates. Those welfare implications, documented in the previous section, dominate the welfare consequences of losing the ability to conduct discretionary cyclical monetary policy.

8 Endogenizing the U.S. monetary policy

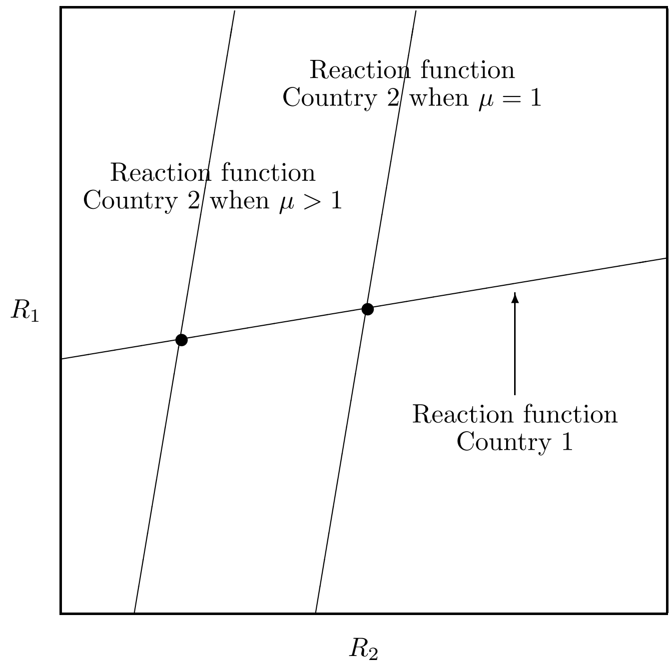
The analysis conducted in the previous sections assumed that the monetary policy conducted in the U.S. is exogenously given. If we assume that Mexico is able to conduct monetary policy optimally, it is reasonable to assume that also the U.S. chooses the instruments on monetary policy optimally. In particular, we should not expect that the U.S. reacts to the inflation and interest rate chosen by Mexico and this would introduce some strategic interaction between the two countries. In this environment the policy outcome will be determined by the Nash equilibrium of the strategic game played by the two countries.

In order to keep the paper self-contained, the analysis of the strategic interaction will be synthetic. A detailed analysis of this policy game is performed in **?**). In this section we will emphasizes the intuitive elements of this game rather than its analytical features.

In section 3 we derived the reaction function of country 1 to the interest rate chosen by country 2 (see figure 2). Using a similar procedure, we can construct the reaction function of country 2 to the interest rate chosen by country 1. The intersection of these reaction functions would determine the equilibrium interest rate. This is shown in figure 4. To show the impact of the relative size of the two countries, the reaction functions are plotted for two values of μ. As can be seen from the figure, smaller is country 1 relative to country 2, and higher is the interest rate in country 1 relative to the interest rate in country 2.

This result has a simple intuition. When countries are symmetric, they both have

Figure 4: Reaction functions and Nash equilibrium.



the same incentive to raise the nominal interest rate. In equilibrium none of them will then benefit from this and both countries will be characterized by lower production and welfare associated with higher nominal interest rates. Therefore, the strategic interaction between the two countries has the typical feature of the "Prisoner Dilemma" in which a lack of cooperation leads to an inferior outcome for both players.

When countries are asymmetric and one country is more economically dependent from the other, they use their monetary instruments differently. The less dependent country (the larger one) does not have a big incentive to increase the interest rate to get a more favorable real exchange rate: because the country is weakly dependent on foreign imports, the gains from having a more favorable real exchange rate are small compared to the costs of a higher interest rate. On the other hand, the more dependent country has a stronger incentive to use the monetary tools to affect the real exchange rate. Because the less dependent country does not find convenient to respond by a large extend to the interest rate increase of the more dependent country, this latter country can gain from this interaction. In this sense, given the limited economic dimension of Mexico, the assumption that the U.S. does not respond to the monetary policy chosen in Mexico can be considered a good approximation to the policy interaction between these two countries.

Table 4 reports the equilibrium inflation and interest rates in Mexico and in the U.S.

Table 4: Equilibrium variables before and after dollarization and associated welfare gains from dollarization. Values in percentage terms.

	$\epsilon = -0.151$		$\epsilon = -0.075$		$\epsilon = 0.075$		$\epsilon = 0.151$	
	Mexico	U.S.	Mexico	U.S.	Mexico	U.S.	Mexico	U.S.
Nash equilibrium								
Inflation	2.93	-1.17	2.34	-1.22	1.36	-1.28	0.95	-1.31
Interest rate	4.50	0.33	3.90	0.28	2.90	0.22	2.48	0.19
Dollarization								
Inflation	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52
Interest rate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption gains	-1.61	0.34	-1.23	0.26	-0.72	0.15	-0.54	0.11

when Mexico conducts monetary policy optimally and after dollarization. The table also reports the welfare gains from dollarization.

The first point to observe is that with dollarization, the U.S. is still conducting monetary policy optimally but it anticipates that its policy cannot change the domestic interest rate without changing the interest rate in Mexico. Consequently, the optimal policy is the Friedman rule of a zero nominal interest rate. In the Nash equilibrium the interest rate in the U.S. is positive but still quite small and inflation is negative. This is clearly counterfactual. However, in the model we only consider the strategic interaction between the U.S. and Mexico and we neglect any other possible interaction that the U.S. has with other countries. By accounting for these other interactions we should be able to get a positive optimal inflation rate also in the U.S. In terms of welfare, we observe that Mexico will face welfare losses from adopting the dollar. Therefore, the results in terms of welfare are not different from the case of exogenous U.S. policy. Now the losses are larger because the fall in the inflation rate is bigger.

The conclusion reached in section 7.2 for which the welfare consequences of loosing cyclical monetary policy independence are not quantitatively large, is extended to the case of strategic interaction between the U.S. and Mexico. In this case the welfare losses are even smaller. The reason is because, given the technological interdependence between the two countries, a shock in the U.S. affects the Mexican economy and vice versa. Consequently, the optimal way to react to shocks in the U.S. is not very different from what is optimal in Mexico.

9 Conclusion

In this paper we have analyzed the welfare consequences for Mexico from unilaterally adopting the U.S. dollar. We have developed a two-country model in which Mexico conducts its monetary policy optimally and responds to the monetary policy implemented in the U.S. After calibrating the model to data from the U.S. and Mexico, we computed the welfare consequences of losing long-term and cyclical monetary policy independence. The welfare consequences of losing the ability to conduct cyclical monetary policy is negligible compared to the welfare losses associated with the loss of long-term independence. We find that dollarization is not necessarily Pareto superior to monetary independence. Moreover, even if dollarization can improve the welfare level in Mexico, this is unlikely to be the first-best solution to its monetary problems. This conclusion does not derive from the inability of Mexico to react optimally to shocks, as argued by the Optimal Currency Area Theory, but it derives from the possibility that the optimal long-term inflation rate in Mexico is different from the long-term inflation rate chosen by the U.S.

A Derivation of equation (14)

Consider equation (12). After eliminating P_1 using the equilibrium condition in the loans market (equation (6)) we have:

$$\frac{Y_1}{X_{11} + \bar{e}X_{12}} = \frac{M_1 + T_1}{D_1 + T_1} \tag{33}$$

Using the production function (1) and the solutions for the firm problem, equations (3) and (4), it can be verified that the left-hand-side of the above equation is equal to the gross interest rate in country 1, that is,

$$1 + R_1 = \frac{1 + g_1}{D_1/M_1 + g_1} \tag{34}$$

Similar condition is derived for country 2:

$$1 + R_2 = \frac{1 + g_2}{B/M_2\mu + D_2/M_2 + g_2} \tag{35}$$

B Derivation of equations (16)-(18)

The final goods production in country 1 and country 2, and the equilibrium in exchange rate market are given by:

$$C_1 = \bar{A}_1(x_{11}^{\epsilon} + \phi x_{12}^{\epsilon})^{\frac{\nu}{\epsilon}} - x_{11} - \bar{e}x_{12} \tag{36}$$

$$C_1 = \bar{A}_2(x_{22}^{\epsilon} + \phi x_{21}^{\epsilon})^{\frac{\nu}{\epsilon}} - x_{22} - x_{21}/\bar{e} \tag{37}$$

$$\bar{e}x_{12} = x_{21}\mu \tag{38}$$

The solutions of the firms' problem in country 1 and 2 (see problem (2)) are:

$$x_{11} = \left(\frac{\nu\bar{A}_1}{1+R_1}\right)^{\frac{1}{1-\nu}} \left[1 + \phi_1\left(\frac{\phi_1}{\bar{e}}\right)^{\frac{\epsilon}{1-\epsilon}}\right]^{\frac{\nu-\epsilon}{\epsilon(1-\nu)}} \tag{39}$$

$$x_{12} = \left(\frac{\phi_1}{\bar{e}}\right)^{\frac{1}{1-\epsilon}} x_{11} \tag{40}$$

$$x_{22} = \left(\frac{\nu\bar{A}_2}{1+R_2}\right)^{\frac{1}{1-\nu}} \left[1 + \phi_2\left(\phi_2\bar{e}\right)^{\frac{\epsilon}{1-\epsilon}}\right]^{\frac{\nu-\epsilon}{\epsilon(1-\nu)}} \tag{41}$$

$$x_{21} = (\phi_2\bar{e})^{\frac{1}{1-\epsilon}} x_{22} \tag{42}$$

Using these conditions to eliminated x_{11}, x_{12}, x_{21} and x_{22} in equations (36)-(38) we get equations (16)-(18).

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