Dollarization and Financial Integration[*]

Cristina Arellano

University of Minnesota and
Federal Reserve Bank of Minneapolis

Jonathan Heathcote

Federal Reserve Board
Georgetown University and CEPR

ABSTRACT

How does a country's choice of exchange rate regime impact its ability to borrow from abroad? We build a small open economy model in which the government can potentially respond to shocks via domestic monetary policy and by international borrowing. We assume that debt repayment must be incentive compatible when the default punishment is equivalent to permanent exclusion from debt markets. We compare a floating regime to full dollarization.

We find that dollarization is potentially beneficial, even though it means the loss of the monetary instrument, precisely because this loss can strengthen incentives to maintain access to debt markets. Given stronger repayment incentives, more borrowing can be supported, and thus dollarization can increase international financial integration. This prediction of theory is consistent with the experiences of El Salvador and Ecuador, which recently dollarized, as well as with that of highly-indebted countries like Italy which adopted the Euro as part of Economic and Monetary Union: in each case, around the time of regime change, spreads on foreign currency government debt declined substantially.

1 Introduction

The recurrence of currency and financial crises in emerging markets has generated an intense debate on the appropriate exchange rate regime. Dollarization has attracted special attention, in part because of the recent official dollarization of Ecuador and El Salvador.[1]

The key difference between dollarizing and simply pegging the exchange rate is that dollarizing represents more permanent restrictions on domestic monetary policy. Thus thinking about dollarization leads one to thinking about what a government might have to gain by tying its hands more tightly with regards to monetary policy, which in turn leads to the issue of credibility. In discussing papers in a conference volume on the topic of dollarization, Sargent (2001) writes

> "In their papers and verbal discussions, proponents of dollarization often appealed to commitment and information problems that somehow render dollarization more credible and more likely to produce good outcomes. Those proponents presented no models of how dollarization was connected with credibility. We need some models."

In this paper we explore one avenue via which dollarization may increase credibility. In particular, we develop a model in which dollarization enhances a sovereign borrower's credibility in international financial markets, and thereby increases international financial integration.

Retaining the ability to print one's own currency gives governments a flexible way to raise revenue. Emerging markets economies are typically subject to big shocks, and large fractions of government revenue are linked to volatile commodity prices. Moreover, increasing traditional tax rates is difficult, and does not guarantee additional revenue when evasion is widespread and the informal sector is large. In this context seigniorage is a valuable fiscal instrument, since extra money can rapidly be printed as required. Click (1998) documents that seigniorage accounted for a large share of government spending in many Latin American countries in the 1970s and 1980s and that countries with more volatile spending relied more heavily on seigniorage as a fiscal instrument. Calvo and Guidotti (1993) find that inflation taxes tend to be much more volatile than regular taxes in practice. They rationalize this finding by developing a model in which it is optimal to let changes in the inflation tax do all the work in adjusting to unanticipated fluctuations in spending.[2]

At the same time, emerging markets economies issue debt on international markets to smooth fluctuations and to ease temporary liquidity problems. In the model developed in this paper, dollarization may help strengthen fragile sovereign debt markets. The logic is that because dollarizing rules out the use of monetary policy to respond to shocks, it may increase the value

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[1]Dollarization is meant in the broad sense of unilaterally adopting a stronger foreign currency such as the U.S. dollar, euro, or yen.

[2]Canzoneri and Rogers (1990) explore the importance of seigniorage in the European Union. They find that the optimal inflation rate is country-specific and depends on the efficiency of the domestic tax collection system.

to the sovereign of maintaining access to the debt instrument. Thus if default is punished by exclusion from debt markets, dollarization effectively reduces the sovereign's incentive to default, and thereby increases the amount of borrowing that can be supported in equilibrium.

Our theoretical model is a small open exchange economy designed to highlight the trade-off that arises in the decision to dollarize between the loss of seigniorage as a flexible fiscal instrument on the one hand, and the potential gain from increased financial integration on the other. Consumers value private and public consumption goods. To ensure a role for two policy instruments, the growth rate of money and international debt, we assume the economy is subject to two sources of risk. First, output is stochastic, which introduces a motive for inter-temporal smoothing. Second, consumers' relative taste for private versus public consumption fluctuates, which introduces a motive for intra-temporal reallocation between the private and public sector.

In the tradition of the literature on optimal policy, we assume that the government is benevolent and rational, and seeks to maximize the utility of a representative consumer.[3] Changes in the money growth rate affect the division of output between consumers and the government because of a cash-in-advance friction. In addition to revenue from seigniorage, the government also trades one period bonds in international financial markets at a constant real interest rate. However, the government cannot commit to repay international debts: contracts must be self-enforcing as in Zhang (1997). Thus foreign creditors set borrowing limits such that the government always has the incentive to honor its obligations, where the penalty in case of default is permanent financial autarky.

We compare a floating exchange rate regime to a dollarized regime. Under floating, the government sets the money growth rate and thus the inflation and devaluation rates at every date. Under dollarization, the inflation rate is constant, and the government's only policy instrument is its international debt position.

After defining the Ramsey problem for the government, we explore what determines how much international borrowing can be supported in equilibrium, and how this varies across exchange rate regimes. In an extensive sensitivity analysis we find that dollarizing can either increase or reduce the amount of borrowing that can be supported in equilibrium. Relative to a float, borrowing constraints tend to be looser under a dollarized regime (i) the larger are shocks to the relative taste for public versus private consumption, (ii) the less synchronized are periods of high output (and tax revenue) and high demand for government consumption, (iii) the lower is the interest rate, and (iv) the higher is the rate of time preference. In the floating economy, the process for demand shocks has no impact on the position of the borrowing constraint, since these shocks can always be perfectly smoothed with monetary policy. Comparing welfare across regimes, we find that dollarizing is welfare-improving in regions of the parameter space where dollarizing supports sufficient additional borrowing to offset the welfare loss associated with

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[3]See, for example, Lucas and Stokey (1983) and Chari and Kehoe (1999). Most of the literature on Ramsey optimal taxation has been developed for closed economies.

losing control of the rates of money growth, inflation and devaluation.

Finally, to get a sense of the quantitative relevance of the trade-off we explore, we consider a calibration to El Salvador (which dollarized in 2001) and to Mexico (which has been discussed as a potential candidate for dollarization). We find that in both cases large taste shocks are required to account for the high volatility of government spending relative to GDP. The model successfully replicates some key features of the data, such as the co-movement at business cycle frequencies between government consumption on the one hand, and output, private consumption, the inflation rate, and the change in the government's net foreign asset position on the other.

Comparing across the two regimes, we find that in the calibration to El Salvador the dollarized economy exhibits looser borrowing constraints and less frequent debt crises, identified as periods in which the borrowing constraint is binding. At the maximum value for debt that can be sustained in the floating regime, lifetime utility can be higher when dollarized, reflecting the benefit of a looser borrowing constraint. The results for the Mexico calibration are quite different: in this case, less borrowing can be supported in the dollarized economy. We interpret the different results for these two countries in terms of differences in the covariance matrix for the underlying shocks.

In Section 2 of the paper we describe a range of empirical evidence consistent with our thesis that reducing devaluation risk might also reduce default risk. We focus in particular on Ecuador, El Salvador, and countries that adopted the euro, and argue that for these countries abandoning an independent monetary policy has led to a reduction in financial markets' perceptions of default risk.

There is a large literature on the pros and cons of dollarization, and an even larger related literature on the relative merits of fixed versus floating exchange rates. Perhaps the two most discussed arguments in favor of dollarization are that it can reduce inflation by importing monetary policy credibility, and can increase trade by eliminating currency risk and foreign exchange transaction costs (Alesina and Barro 2002). The model we develop in this paper is deliberately designed to abstract from these potential benefits in order to clarify the trade-off in the dollarization decision between the loss of seigniorage as a flexible fiscal instrument on the one hand, and the potential increase in international financial integration on the other. However, because additional mechanisms would come into play in a richer model, we now briefly review the existing debate, and explain how it connects to the theory developed in this paper.

The evidence on the boost to trade from eliminating currency risk is mixed. Frankel and Rose (2002) find that currency unions boost bilateral trade significantly with other currency union countries in a sample of 186 countries. However, Lane (2006) notes that to date the Economic and Monetary Union (EMU) in Europe has not increased the importance of intra-euro-zone trade relative to trade outside the euro area. In contrast, there *is* strong evidence that the EMU has increased financial integration across the euro area along many dimensions,

in particular by reducing bond spreads across member countries.

Dollarization does bring lower and less volatile inflation to countries adopting a stronger currency (Edwards 2001). A common interpretation of the high and volatile inflation rates in some emerging markets economies is that these countries face more severe time-consistency problems in setting monetary policy than countries whose currencies are being adopted (see, for example, Cooper and Kempf 2001). A competing explanation for why monetary independence leads to higher inflation is that countries perceive control of the printing press as an opportunity for beggar-thy-neighbor policy. Cooper and Kempf (2003) build a model in which inflation acts as a tax on foreigners wishing to purchase domestic goods, prompting competitive governments to choose inefficiently high inflation rates in equilibrium. Similarly, Cooley and Quadrini (2001) argue that Mexico may prefer a higher inflation rate than the US because higher nominal interest rates can have favorable effects on the terms of trade. In the model of this paper, there is no time consistency problem in monetary policy, and international prices are taken as given. Thus the key difference between the floating and dollarized economies is the *volatility* of the inflation rate, rather than the average *level* of inflation.

If dollarization is permanent, it eliminates the possibility of currency crises. Mendoza (2001) argues that eliminating distortionary uncertainty over the duration of stabilization policies can deliver substantial welfare gains (see also Calvo 1999 and Berg and Borensztein 2000). Dollarization also solves the "fear of floating" problem (Calvo 2001) which arises when international liabilities are denominated in dollars and currency devaluations therefore precipitate debt crises. In our endowment economy, devaluations are non-distortionary. Furthermore, the law of one price holds, so periods of inflation and devaluation do not make it more difficult to repay dollar debts.

Finally, Sims (2001) argues that dollarization is costly because it prevents the economy from issuing (state-contingent) nominal debt, without affecting dollar interest rates. However, governments in emerging markets are largely unable to issue external debt in their own currency, no matter what exchange rate regime they have, so it is not clear that this constitutes a strong argument against dollarization in practice.

2 Historical Experience

In the context of our theory, a country's choice for its exchange rate regime has implications for the volatility of its inflation rate, and for its ability to sell bonds in international sovereign debt markets. In practice, easier access to international credit should translate into some combination of additional borrowing or lower sovereign risk spreads. In this section we provide some empirical evidence that is consistent with the hypothesis that by surrendering monetary independence a government can effectively improve its credit rating as a sovereign borrower.

We first look at the experiences of four countries that recently delegated monetary policy

offshore: Italy and Portugal, which adopted the European single currency in 1999, and Ecuador and El Salvador, which dollarized in 2000 and 2001 respectively. Figure 1 plots time series for sovereign spreads for loans issued by these four countries.[4] Spreads are defined as the difference in yields between domestic and foreign government issued bonds, where paired bonds share similar maturities, coupon rates and currency. In each case, we are able to isolate default risk from devaluation risk by pairing bonds denominated in the same currency. For example, we compare the yield to maturity on a deutsche mark (DM) denominated bond issued by Italy to a DM denominated bond issued by Germany.

Italy and Portugal are interesting case studies among the set of European countries participating in the Economic and Monetary Union (EMU) because in addition to having issued foreign currency bonds that are traded in secondary markets, they have lived with very high levels of government debt relative to GDP: 116% and 95% respectively in 1996. The European single currency was officially introduced on January 1st 1999, but more relevant for markets' perceptions of default risk is the date when it became clear that these countries would be allowed to adopt the euro at the new currency's inception. For Italy, Bassetto (2006) argues that 1996 was the key year. The first panel of Figure 1 shows that spreads on Italian deutsche mark denominated bonds decreased substantially in that year, by about 100 basis points in total. The second panel plots spreads for Portuguese bonds. As in the Italian case, spreads on these bonds also decreased significantly in 1996 and 1997.[5]

Ecuador dollarized in 2000 in the midst of a severe economic crisis with a collapsing banking system, a sliding local currency, and after defaulting on its Brady bonds in late 1999. The regime was implemented in an attempt to reduce inflation, bring stability to the economy, and gain credibility with international investors. Since dollarization, Ecuador's inflation has been significantly reduced to single digits. Figure 1 shows that default risk increased significantly in 1998 prior to the 1999 crisis and default. In July 2000 spreads came down again after Ecuador dollarized and renegotiated its debts. Since the dollarization plan was implemented, spreads on Ecuadorian government bonds have decreased cumulatively by about 800 basis points.

El Salvador implemented its dollarization plan in 2001. Figure 1 shows that the spread on dollar loans has decreased by over 400 basis points since 2001. In fact the very day after the new currency was adopted, the interest rate on consumer mortgages fell from 17 to 11 percent. Consumer credit has been growing, and the government and the corporate sector have benefited

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[4]Data for Italy and Portugal are from Bloomberg. Italian bonds are matured in 12-31-97 and 12-31-06 respectively. The Portuguese bond matured 7-02-03. We do not report spreads when the time to maturity drops below one year. Ecuador's spread is the JP Morgan Emerging Market Bond Index (EMBI) Spread for Ecuador. Data for El Salvador are the difference between the domestic dollar prime interest rate on loans of maturity greater than one year and the yield on a U.S. government bill with one year maturity. We use this spread measure for El Salvador because El Salvador issued its first Global Bonds in international markets only in 2001.

[5]Bernoth, von Hagen and Schuknecht (2006) document that spreads on newly issued DM-denominated bonds decreased prior to the start of EMU for all member countries.
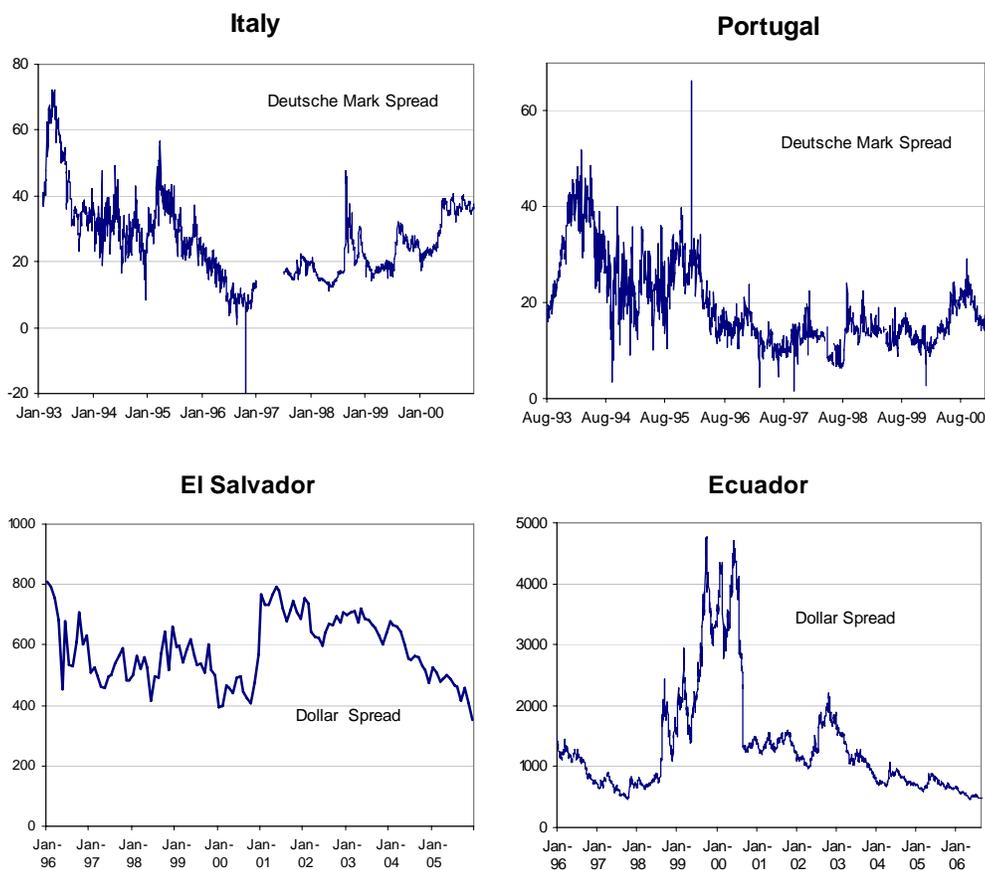
Figure 1: Spreads and Dollarization

from cheaper international borrowing.

Table 1. Correlations with International Investor Ratings

Inflation	St.Dev Inflation	Fixed Exch. Rate	Debt / GDP	log(GDP/capita)
-0.46	-0.43	0.29	-0.31	0.89

Thus, in time series data for countries that have surrendered monetary policy, there is evidence that this reform has reduced the cost of international credit. We now turn to cross-sectional data, and consider a much larger set of countries. Here we find complementary evidence that countries with less flexibility in setting monetary policy - as evidenced by having a fixed exchange rate or less volatile inflation - are viewed as safer borrowers.

We study the relationship between inflation, the exchange rate regime, and default risk for the 76 countries that are rated by Moody's for its International Investor Ratings. These credit ratings are intended to convey default risk for foreign currency sovereign bonds. We use credit ratings as opposed to direct measures of spreads as our proxy for ease of access to international credit because ratings are available for a broader set of countries (in practice, ratings and spreads correlate very strongly). For each country in our sample, the statistics we record are (1)

Moody's ratings for 2000 converted to a linear scale (higher numbers equate to better ratings), (2) CPI inflation in 2000, (3) the standard deviation of CPI inflation over the period 1985-2000, (4) GDP per capita in dollars in 2000, (5) a dummy variable corresponding to a fixed exchange rate regime in 2000, and (6) the ratio of foreign debt to GDP in 2001.[6]

Table 1 shows the correlations of credit ratings for government debt with these other variables. Ratings tend to be better for countries with low and stable inflation, low levels of foreign debt to GDP, fixed exchange rate regimes, and higher GDP per capita. These correlations are consistent with the notion that too much flexibility in monetary policy can crowd out flexibility in debt policy. Still, one should not over-interpret this evidence, for at least two reasons. First, nominally fixed exchange rate regimes vary enormously in how frequently and easily exchange rate parities can be adjusted, while our theory will strictly apply only to very hard pegs. Second, the exchange rate regime is a policy choice that likely correlates with institutional factors that also impact credibility in financial markets. Thus, to properly understand the relationship between dollarization and financial integration, we need an explicit model.

3   Model

We consider a small open economy populated by a large number of identical consumers, a representative firm, and a government. Consumers work for firms, and each period produce a stochastic quantity of goods that can be used for private or public consumption. Firms sell these goods in exchange for cash. Once the goods market has closed, firms pay their workers. Thus the cash that consumers spend on goods in the current period must be carried over from the previous period.

The government is benevolent and chooses policies to maximize consumer welfare. We compare two alternative exchange rate regimes. The first is a simple float. Under a float, trade in the cash goods market is conducted using the currency issued by the domestic government, which we label the peso. We allow the government to print new money after observing the firm's output and to spend it immediately to purchase goods that will be provided publicly. The second regime we consider is dollarization. Only foreign currency circulates in a dollarized economy. Thus the domestic government has no control over monetary policy and enjoys no seigniorage.

We assume that under both regimes, the government is the only actor in the economy with

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[6]The series for GDP per capita and inflation (2, 3 and 4) are from the World Bank's World Development Indicators. The exchange rate dummy (5) is from a classification by Levy-Yeyati and Sturzenegger (2003). The dummy variable takes the value of 1 for countries with fixed exchange rates. It takes the value of 0 if the regime is "Flexible" or "Interim" in their classification. The ratio of foreign debt to GDP (6) is from the World Bank Statistics on External Debt and the Central Government Debt Statistical Yearbook. We use debt data for 2001 due to limited data availability for 2000. For the developed countries that are not present in the World Bank Statistics on External Debt, we use central government foreign debt, estimated as the percentage of marketable debt held by non-residents times total central government debt.

access to a competitive international bond market.[7] In the bond market the domestic government can sell bonds that take the form of one-period dollar-denominated loans. International lenders decide whether to lend, how much to lend, and at what price to lend. However they cannot make the price of loans contingent on the borrowing government's net foreign asset position, or on the shocks that will hit the economy in the next period. Thus asset markets are far from complete. However, the assumed market structure is appropriate for most emerging markets economies, whose bonds typically specify repayment in foreign currency and on non-contingent terms.[8]

International debt contracts are notoriously difficult to enforce directly. We assume that lenders can commit to honor their contractual obligations, but that the domestic government cannot commit to repay any debt obligations. In the event of default, creditors are assumed to credibly punish the government by permanently excluding it from the bond market: a government that has defaulted in the past can neither buy nor sell bonds. When it is impossible to impose direct sanctions on defaulting sovereigns, this is the harshest feasible punishment.[9]

We assume that international lenders can earn a safe real return r on the world market. Competition among lenders combined with the assumption that lending rates must be non-contingent drives all lenders to sell bonds at the same price $1/(1+r)$ and to ensure repayment by rationing credit.[10] Thus lenders impose endogenous borrowing limits on the sovereign such that no borrowing occurs beyond the point at which the probability of subsequent default becomes positive. A key point of the paper is that because default incentives depend on the menu of policy instruments available to the government, the position of these endogenous borrowing constraints will generally differ across the floating and dollarized regimes.

We now lay out the model formally and describe in detail the problems solved by each agent in our economy.

In each period $t = 0, 1, ...$ the economy experiences one of finitely-many events $s_t \in S$. An event is a stochastic realization for output, y_t, and a stochastic realization for a preference parameter λ_t. We assume that the pair of shocks $s_t = (y_t, \lambda_t)$ evolves according to a first-order

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[7]In reality, non-government international trade in financial assets is growing, but it is still the case that most external debt in countries where dollarization is considered a possibility represents government borrowing. For example, as of March 2003, Argentinean government debt accounted for 67% of the total stock of foreign debt; in Mexico and Ecuador the corresponding figures were 56% and 73%.

[8]The difficulty emerging-markets face in borrowing abroad in their own currencies is referred to as "original sin." See Chapter 1 of Eichengreen and Hausmann (2005) for empirical evidence on the currency denomination of sovereign debt.

[9]Permanent exclusion from trade might sound counter-factually harsh. However, since default is not an equilibrium outcome, what matters for observed allocations is the value of the threatened punishment, and not precisely how it is implemented. Kletzer and Wright (2000) develop a model of sovereign debt in which the effective punishment for default is equivalent to permanent autarky, but where the punishment is delivered in a way that permits trade to continue, but on worse terms from the borrower's perspective.

[10]One could imagine an alternative market structure in which lenders offer a menu of contracts, each of which specifies a loan amount and an interest rate. Contracts for greater loan amounts would then be associated with higher interest rates to compensate for greater risk of default. In equilibrium the unconditional expected return to the lender would be equalized across contracts. This market structure is adopted in Arellano (2005).

Markov process. We denote by $s^t = (s_0, ...s_t) \in S^t$ the history of events up to and including period t. The probability, as of date 0, of a particular history s^t is $\phi(s^t)$.

Output $y(s^t)$ is produced by the representative firm and can be converted into a private consumption good $c(s^t)$ or a public consumption good, $g(s^t)$. Output is produced at the start of the period, and then allocated between consumers and the government in a cash market in the middle of the period. At the end of the period, firms pay their workers (consumers) nominal wages $w(s^t)$.

Consumers are infinitely-lived, discount at rate β, and derive utility from both privately and publicly provided consumption goods. Expected lifetime utility is given by

$$\sum_{t=0}^{\infty} \beta^t \sum_{s^t} \phi(s^t) u(c(s^t), g(s^t), \lambda(s^t)) \tag{1}$$

where period utility is

$$u(c(s^t), g(s^t), \lambda(s^t)) = \lambda(s^t) \ln c(s^t) + (1 - \lambda(s^t)) \ln g(s^t) \qquad \text{and } 0 < \lambda(s^t) < 1.$$

Variation in the taste parameter $\lambda(s^t)$ can be interpreted as capturing changes through time in household preferences for public versus private goods, or changes in the taste for the allocation mechanism (government provision versus market provision). One possible manifestation of these changes in taste would be electoral cycles in which populist free-spending governments and more fiscally conservative market-oriented governments take turns in power. In the context of the model, these shocks play two roles. First, a second source of uncertainty introduces a clear role for a second policy instrument, and suggests a downside to renouncing the monetary instrument by dollarizing. Second, when we later calibrate the model to El Salvador and Mexico, we find that demand-side shocks of some sort are required to account for the high volatility of private and public consumption in the data.

We assume that cash is the only savings vehicle available to consumers. The representative consumer enters the period with money savings from the previous period $m^s(s^{t-1})$ and wages from the previous period $w(s^{t-1})$. He observes the endowment shock $y(s^t)$, the taste shock $\lambda(s^t)$, and the price level $P(s^t)$. He then decides how much of his money to spend, subject to the cash-in-advance constraint and the budget constraint:

$$P(s^t)c(s^t) \leq m^s(s^{t-1}) + w(s^{t-1}) \equiv m(s^{t-1}) \tag{2}$$

$$m^s(s^t) = m(s^{t-1}) - P(s^t)c(s^t) \tag{3}$$

where $m(s^{t-1})$ denotes total nominal balances carried into period t. In the floating economy consumers can only save and purchase goods using pesos.[11] Note that we do *not* assume at the

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[11] Later we will argue that in equilibrium consumers in the flexible economy would not want to save in the

outset that shocks are small enough to rule out money saving because the variance of shocks is an important determinant of the position of borrowing constraints. In fact, for realistic amounts of volatility, we will find that money saving typically does occur in equilibrium.

The household problem is to choose sequences for money savings $m^s(s^t)$ and consumption $c(s^t)$ to maximize expected lifetime utility (eq. 1) subject to the cash-in-advance constraint (eq. 2), the budget constraint (eq. 3) and a non-negativity constraint on consumption, $c(s^t) \geq 0$, taking as a given a complete set of date and state contingent endowments $y(s^t)$, taste shocks $\lambda(s^t)$, wages $w(s^t)$, prices $P(s^t)$, probabilities $\phi(s^t)$, and initial money holdings m_{-1}.

The inter-temporal first order condition for the household's problem is

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\begin{aligned}
\phi(s^t)\frac{\lambda(s^t)}{c(s^t)} &\geq \beta \sum_{s_{t+1}} \phi(s^t, s_{t+1}) \frac{\lambda(s^t, s_{t+1}))}{\pi(s^t, s_{t+1})c(s^t, s_{t+1})} \\
&= \quad \text{if } m^s(s^t) > 0
\end{aligned}
\tag{4}
$$

where $\pi(s^t, s_{t+1}) = P(s^t, s_{t+1})/P(s^t)$ denotes the gross inflation rate when next period's state is s_{t+1}.

The transversality condition is

$$
\lim_{s^t \to s^\infty} \beta^t \sum_{s^t} \phi(s^t) \frac{\lambda(s^t)}{c(s^t)} \frac{m^s(s^t)}{P(s^t)} = 0.
\tag{5}
$$

3.1   Government Problem When Floating

At time zero, the government in the floating regime decides on a policy $\Lambda = \{g(s^t), B(s^t), M(s^t)\}$ which defines government consumption $g(s^t)$, dollar-denominated assets $B(s^t)$, and the quantity of pesos in circulation $M(s^t)$ for all $t \geq 0$ and for all s^t given some initial assets B_{-1} and nominal balances M_{-1}.

The government is not subject to a cash-in-advance constraint since it can print new money after observing $y(s^t)$ and $\lambda(s^t)$ and use this money immediately to help finance public consumption, $g(s^t)$. Let $M(s^t) = M(s^{t-1}) + N(s^t)$ denote the aggregate stock of money in circulation at the end of period t. Thus the money growth rate $\mu(s^t)$ is equal to

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\mu(s^t) = \frac{M(s^t)}{M(s^{t-1})} = \frac{M(s^{t-1}) + N(s^t)}{M(s^{t-1})}.
$$

In addition to seigniorage and revenue from international borrowing, the government also seizes a constant fraction τ of the endowment directly, with no money changing hands. This can be interpreted as a constant tax rate on private-sector output or, alternatively, as the government producing fraction τ of output. We assume the law of one price holds, so that the nominal exchange rate measured in units of pesos per dollar is equal to the domestic price level:

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form of dollars, even if they were allowed to do so.

$E(s^t) = P(s^t)$. Thus the government nominal budget constraint, prior to default, is given by

$$P(s^t)g(s^t) = \tau P(s^t)y(s^t) + N(s^t) - P(s^t)B(s^t) + (1+r)P(s^t)B(s^{t-1}) \tag{6}$$

where $B(s^t)$ are dollar-denominated riskless foreign assets purchased at s^t.

In addition, assets purchased must exceed some state-contingent limit:

$$B(s^t) \geq \underline{B}(s^t). \tag{7}$$

The government is allowed to default at any date. If the government chooses to default, then for all future histories the government budget constraint becomes

$$P(s^t)g(s^t) = \tau P(s^t)y(s^t) + N(s^t). \tag{8}$$

However, as noted above, lenders will not lend beyond the point at which the default probability becomes positive. We assume that the constraints $\underline{B}(s^t)$ are tight enough to deter the government from ever defaulting in equilibrium, but "not too tight" in the sense of Alvarez and Jermann (2000). In particular, constraints would be too tight if it were possible to loosen the constraint marginally for at least one s^t without this change ever inducing a borrowing-constrained agent to default.

3.2   Government Problem When Dollarized

The problem for the government in a dollarized economy differs from the one described above in two respects.

First, the money growth rate is not a domestic policy instrument but is chosen by the foreign government to maintain a constant price level which we normalize to one. We assume that the domestic dollar cash market for goods is open to foreigners as well as domestic consumers. Thus arbitrage equates the domestic price level to the foreign one: $P(s^t) = P^*(s^t) = 1$. Given that the domestic government cannot print new money, the term $N(s^t)$ drops out of the government budget constraints pre and post default (eqs. 6 and 8) and the pre default constraint becomes

$$g(s^t) = \tau y(s^t) - B(s^t) + (1+r)B(s^{t-1}). \tag{9}$$

Second, as we have already emphasized, the maximum amount of borrowing allowed at a point in time, $\underline{B}(s^t)$, will differ across regimes. In particular, suppose debt is used more actively under dollarization to compensate for the lack of a monetary instrument. Then the prospect of losing the debt instrument in the event of default should be of greater concern in the dollarized regime, and it may therefore be possible to support more sovereign debt in equilibrium.

3.3 Equilibrium Relationships

The following relationships apply to both economies.

At the end of the period, firms pay as wages all the cash they hold. Thus

$$w(s^t) = P(s^t)(1 - \tau)y(s^t). \tag{10}$$

Since all the money circulating in the economy at the end of the period is held by households

$$M(s^t) = M(s^{t-1}) + N(s^t) = m(s^t). \tag{11}$$

In the floating regime, $N(s^t)$ denotes the domestic government's newly printed money, while in the dollarized economy, $N(s^t)$ denotes dollar net purchases of domestically-produced goods by foreigners.[12]

The market clearing condition for the cash goods market is

$$
\begin{aligned}
P(s^t)(1 - \tau)y(s^t) &= M(s^{t-1}) - m^s(s^t) + N(s^t) \\
&= M(s^t) - m^s(s^t)
\end{aligned}
\tag{12}
$$

Note that if households do no money saving $(m^s(s^t) = 0)$ we get the standard quantity equation with velocity equal to one. Initial money holdings equal the initial money supply $m_{-1} = M_{-1}$

The aggregate resource constraint under flexibility is:

$$c(s^t) + g(s^t) = y(s^t) - B(s^t) + (1 + r)B(s^{t-1}) \tag{13}$$

while the corresponding constraint under dollarization is

$$c(s^t) + g(s^t) + N(s^t) = y(s^t) - B(s^t) + (1 + r)B(s^{t-1}). \tag{14}$$

These conditions can be interpreted as follows. Under a float, all international borrowing and lending is conducted by the government, and thus the change in the government's bond position is the only item on the capital account. In the dollarized economy, there is an additional private source of capital flows associated with changes in the quantity of dollars circulating domestically, $N(s^t)$. For domestic households, dollar bills can be viewed as international bonds that can be used to smooth shocks to wages and preferences. However, their value as a self-insurance device is limited by two factors: (i) they pay zero real interest, and (ii) dollar holdings are bounded below by the cash-in-advance constraint: the household must always carry at least

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[12]Negative $N(s^t)$ can be interpreted as follows. Under a float the domestic government is borrowing goods abroad, selling them on the domestic market, and taking the domestic money it receives in exchange out of circulation. Under dollarization, domestic consumers are buying goods from abroad.

$w(s^{t-1}) = (1 - \tau)y(s^{t-1})$ dollars from period $t - 1$ into period t.

For each regime, combining the government budget constraint and the aggregate resource constraint (eqs. 6 and 13, or eqs. 9 and 14) gives an alternative expression for private consumption:

$$P(s^t)c(s^t) = (1 - \tau)P(s^t)y(s^t) - N(s^t). \tag{15}$$

Let $x(s^t)$ denote the fraction of aggregate cash on hand that agents save at s^t :

$$x(s^t) = \frac{m^s(s^t)}{M(s^{t-1})}.$$

For solving the equilibrium allocations in the floating economy it is convenient to express private consumption and the real money variables in terms of the sequences $y(s^t)$, $\mu(s^t)$ and $x(s^t)$, with no reference to nominal variables $M(s^t)$, $P(s^t)$ or $N(s^t)$.

First, from the goods market clearing condition, eq. 12, the price level is given by

$$P(s^t) = \frac{M(s^t) - m^s(s^t)}{(1 - \tau)y(s^t)} = \frac{\mu(s^t) - x(s^t)}{(1 - \tau)y(s^t)}M(s^{t-1}). \tag{16}$$

Substituting $P(s^t)$ into the consumer's budget constraint (eq. 15) gives

$$c(s^t) = \left(\frac{1 - x(s^t)}{\mu(s^t) - x(s^t)} \right) (1 - \tau)y(s^t) \tag{17}$$

Note that if the household is not doing any money saving ($x(s^t) = 0$), then $c(s^t) = (1 - \tau)y(s^t)/\mu(s^t)$. However in general, the money growth rate has a direct effect on consumption and an indirect effect via $x(s^t)$.[13]

The real return to money saving (the inflation rate) is given by

$$\pi(s^{t+1}) = \frac{P(s^{t+1})}{P(s^t)} = \left(\frac{\mu(s^{t+1}) - x(s^{t+1})}{\mu(s^t) - x(s^t)} \right) \mu(s^t) \frac{y(s^t)}{y(s^{t+1})}. \tag{18}$$

In the dollarized regime $\pi(s^t) = 1$ for all s^t and thus the money growth rate $\mu(s^t)$ is endogenous and depends in equilibrium on households' choices regarding money savings $x(s^t)$. In the floating economy the money growth rate $\mu(s^t)$ is the domestic government's policy choice and the inflation rate $\pi(s^t)$ is endogenous and depends on money savings $x(s^t)$.

Making repeated use of the expression for the price level, eq. 16, real balances, real money savings, and the real value of seigniorage (corresponding to net purchases by foreigners in the

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[13]The direct effect is that faster money growth reduces purchasing power and reduces consumption. The indirect effect is that faster money growth reduces the savings rate $x(s^t)$ (we show this in the appendix) which from eq. 17 *increases* consumption, as long as $\mu(s^t) > 1$.

dollarized regime) can be expressed, respectively as:

$$\frac{M(s^t)}{P(s^t)} = \left(\frac{\mu(s^t)}{\mu(s^t) - x(s^t)}\right)(1-\tau)y(s^t) \tag{19}$$

$$\frac{m^s(s^t)}{P(s^t)} = \left(\frac{x(s^t)}{\mu(s^t) - x(s^t)}\right)(1-\tau)y(s^t) \tag{20}$$

$$\frac{N(s^t)}{P(s^t)} = \frac{M(s^t) - M(s^{t-1})}{P(s^t)} = \left(\frac{\mu(s^t) - 1}{\mu(s^t) - x(s^t)}\right)(1-\tau)y(s^t). \tag{21}$$

Note that $x(s^t) \in [0, 1]$. Setting $\mu(s^t) = 1$ implies zero seigniorage. As $\mu(s^t) \to \infty$, $\frac{N(s^t)}{P(s^t)} \to$
$(1-\tau)y(s^t)$ and thus $c(s^t) \to 0$. Note that for $\mu(s^t) \geq 1$ seigniorage is (weakly) positive. For
$\mu(s^t) < 1$, seigniorage is negative.

4   Definition of Equilibrium

We first define equilibria for two economies that are not of direct interest, but that are useful for
constructing borrowing constraints that are not too tight. The first economy is one in which:
(i) the borrowing constraints $\{\underline{B}(s^t)\}$ are exogenous, and (ii) the government must respect the
constraints and is not allowed to default. The second economy is one in which the government
has defaulted in the past and has no access to the international debt market. The third economy,
which is the economy of interest, features endogenous borrowing constraints that are not too
tight. In this economy default is permitted but never occurs in equilibrium.

Definition 1 *Equilibrium with exogenous borrowing constraints.* *Consider a set of con-
straints $\widetilde{B} = \left\{\widetilde{B}(s^t)\right\} \forall t \geq 0$ and for all s^t. A competitive equilibrium given initial assets B_{-1}
and M_{-1} is a policy Λ, and an associated allocation rule mapping policies into prices $P(\Lambda)$ and
$w(\Lambda)$ and private choices $c(\Lambda)$ and $m^s(\Lambda)$ such that for all t and s^t : (i) the household choices
solve the household's problem, (ii) the government budget constraints are satisfied given initial
assets B_{-1} and the constraints $\widetilde{B}$, (iii) markets clear (eqs. 10 through 12).*

Definition 2 *Post-default equilibrium.* *A post default equilibrium is defined in exactly the
same way, except that feasibility for the government requires $B(s^t) = 0$.*

Definition 3 *Ramsey problem.* *The Ramsey problem is to choose a policy Λ that maximizes
expected lifetime utility given assets B_{-1} and M_{-1} under the associated competitive equilibrium.
The Ramsey equilibrium is the solution to the Ramsey problem.*

We will look for borrowing constraints that are tight enough, but not too tight. They are
tight enough in that if the sovereign is at the borrowing constraint, then the probability that

he will strictly prefer to default in the next period is zero. They are not too tight in that there is at least one combination of shocks under which he will be indifferent between repaying or defaulting. To formalize the difference between the values of repaying debts and defaulting, we introduce some new notation.

Let $W_{t+1}(b, (m), (s^t, s_{t+1}) ; \widetilde{B})$ be a function defining the value associated with a date $t+1$ Ramsey problem given history (s^t, s_{t+1}), arbitrary bonds b (and in the dollarized economy money m), and a set of borrowing constraints $\underline{B}$. Let $D_{t+1}(b, (s^t, s_{t+1}) ; \widetilde{B}))$ be a function defining the difference between the value of the Ramsey equilibrium and the value of default $V_{t+1}((m), (s^t, s_{t+1}))$:

$$D_{t+1}(b, \left(s^t, s_{t+1}\right) ; \widetilde{B})) = W_{t+1}(b, (m), (s^t, s_{t+1}) ; \widetilde{B}) - V_{t+1}\left((m), (s^t, s_{t+1})\right)$$

We now note some useful properties of these functions:

1. The function $W_{t+1}(b, (m), (s^t, s_{t+1}) ; \widetilde{B})$ is strictly increasing in b for any (s^t, s_{t+1}) while the value of default is independent of the quantity of debt defaulted on. It follows immediately that if for some history s^t the government weakly prefers not to default in every possible s_{t+1} given bonds b, then the government will strictly prefer to repay for any $b' > b$. Conversely, if the government is indifferent about default for some b given s_{t+1}, then if $b' < b$ and s_{t+1} is realized, the government will strictly prefer to default.

2. The function $D_{t+1}(b, (s^t, s_{t+1}) ; \widetilde{B}))$ does not depend on the stock of money balances consumers carry into the start of the period. In the floating economy the nominal quantity of pesos is irrelevant, since it has no impact on real allocations (we return to this point in Proposition 1). In the dollarized economy, the Ramsey planner is powerless to impact the time series for private consumption, and we have assumed separability in utility between private and public consumption. Thus the *difference* between the values of repaying and defaulting does not depend on cash balances.

3. Under the solution to the date 0 Ramsey problem, the continuation value at (s^t, s_{t+1}) given equilibrium bonds $B(s^t)$ is equal to $W_{t+1}(B(s^t), (M(s^t)), (s^t, s_{t+1}) ; \widetilde{B})$. This reflects the fact that there is no time consistency problem in these economies, a point we will return to later.

Definition 4 *Borrowing constraints that are not too tight.* *A set of borrowing constraints* $\underline{B} = \{\underline{B}(s^t)\}$ *such that*

$$\min_{s_{t+1} \in S \ s.t. \ pr(s_{t+1}|s^t) > 0} D_{t+1}(\underline{B}(s^t), \left(s^t, s_{t+1}\right) ; \underline{B}) = 0 \tag{22}$$

If the not-too-tight condition is satisfied then by virtue of properties (1) and (2) $B(s^t) \geq \underline{B}(s^t) \Rightarrow W_{t+1}(B(s^t), (M(s^t)), (s^t, s_{t+1}) ; \underline{B}) \geq V_{t+1}((M(s^t)), (s^t, s_{t+1}))$. From property (3),

$W_{t+1}(B(s^t), (M(s^t)), (s^t, s_{t+1}) ; \underline{B})$ is equal to the continuation value at s^t under the original date 0 Ramsey problem. Thus the not-too-tight condition (22) guarantees that the values associated with the solution to the date 0 Ramsey problem are sufficient to ensure that the sovereign will never strictly prefer to default.

Definition 5 *Monetary equilibrium with competitive riskless lending. This is defined in exactly the same way as the economy with exogenous borrowing constraints, except that (i) the borrowing constraints are defined by the solution to eq. 22 (i.e. they are not too tight), and (ii) at each t and s^t the government has the option of defaulting.*

Note that if all lenders but one were in aggregate willing to lend an amount strictly less than $\underline{B}(s^t)$ given s^t, then the last lender could make a positive profit on a marginal additional loan by charging a real interest rate greater than r and bearing no default risk. Thus the only equilibrium in the lending market in which no excess profits remain is one in which lenders are willing in aggregate to lend up to $\underline{B}(s^t)$ at the safe world interest rate r.

In the appendix we show that for a given feasible policy there is a unique monetary equilibrium in this economy.

4.1 Ramsey Equilibria

We now describe how we solve for the Ramsey equilibrium in our economies. Solving the Ramsey problem in the dollarized economy is simpler, because monetary policy in this case is exogenous, and the planner only needs to decide on the optimal debt policy.

4.1.1 Dollarized Economy

The Ramsey equilibrium in the dollarized monetary economy with riskless lending can be characterized by solving the following planner's problem. Consider a planner who maximizes expected lifetime utility (eq. 1) subject to budget constraints

$$g(s^t) = \tau y(s^t) - B(s^t) + (1+r)B(s^{t-1}) \tag{23}$$

and a set of borrowing constraints of the form eq. 7.

Sufficient conditions for a solution to this problem are the optimality conditions for bonds:

$$\phi(s^t)\frac{(1-\lambda(s^t))}{g(s^t)} \;\; \geq \;\; \beta(1+r) \sum_{s_{t+1}} \phi(s^t, s_{t+1})\frac{(1-\lambda(s^{t+1}))}{g(s^{t+1})} \tag{24}$$
$$= \;\; \text{if } B(s^t) > \underline{B}(s^t)$$

$$\lim_{s^t \to s^\infty} \beta^t \sum_{s^t} \phi(s^t)\frac{(1-\lambda(s^t))}{g(s^t)} \left(B(s^t) - \underline{B}(s^t) \right) = 0. \tag{25}$$

Note that in the dollarized economy, separability between private and public consumption in preferences implies that consumers and the government end up solving completely separate problems. Consumers use dollar money savings to smooth the marginal utility of private consumption through time, taking as given inflation rates. The government uses debt to smooth the marginal utility of public consumption through time, taking as given the world interest rate and state-contingent borrowing constraints.

4.1.2 Floating Economy

Proposition 1. *The Ramsey equilibrium in the floating monetary economy with riskless lending can be characterized by solving the problem of a planner who maximizes expected lifetime utility eq. (1) subject to an aggregate resource constraint (13) and a set of borrowing constraints of the form eq. (7) where these constraints are "not too tight."*

Proof: See the appendix.

This result greatly simplifies the Ramsey problem because it effectively eliminates the constraint that the allocations chosen by the Ramsey planner must constitute a competitive equilibrium. At the simplest level, the intuition for the result is that control of the money growth rate is equivalent to access to lump-sum taxation in this economy: by choosing money growth rates appropriately, the government can achieve any possible division of total resources between private and public consumption. Since the government's problem reduces to a standard consumption-savings problem, there is no time-consistency problem in our economies, in the sense that the government never has an incentive to deviate from its pre-announced policy.[14]

Sufficient conditions for a solution to this planner's problem are the optimality conditions for bonds (eqs. 24 and 25) described above and an intra-temporal first order condition

$$\frac{\lambda(s^t)}{c(s^t)} = \frac{(1 - \lambda(s^t))}{g(s^t)} \tag{26}$$

which says that the planner wants to equate the marginal utilities of privately and publicly provided goods at each date and state.

Combining 13 and 26 gives

$$c(s^t) = \lambda(s^t)R(s^t) \tag{27}$$
$$g(s^t) = (1 - \lambda(s^t))R(s^t) \tag{28}$$

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[14]Potential deviations from the pre-announced policy would be to default on outstanding debts, or to deviate from pre-announced debt or monetary policy. Default will reduce welfare, given borrowing constraints that are not too tight. Deviating from pre-announced debt policy will reduce welfare, since the pre-announced policy smooths the marginal utility of government consumption as effectively as possible. Deviating from pre-announced monetary policy will be welfare-reducing, because such a change can only alter the mix between private and public consumption (in a welfare-reducing fashion) without changing the total resources $R(s^t)$ (eq. 29) in the economy.

$$R(s^t) = y(s^t) - B(s^t) + (1+r)B(s^{t-1}) \tag{29}$$

Note that because the marginal utilities of private and public consumption are equated state by state, the inter-temporal first order condition 24 can be expressed in terms of total resources available for domestic consumption $R(s^t)$:

$$\frac{\phi(s^t)}{R(s^t)} \geq \beta(1+r) \sum_{s_{t+1}} \frac{\phi(s^t, s_{t+1})}{R(s^t, s_{t+1})}. \tag{30}$$

Thus in this case, the planner simply wants to smooth fluctuations in the endowment through time, irrespective of the process for taste shocks: a floating, credit-worthy government will typically issue debt when the endowment is relatively low, and repay when the endowment is high. Monetary policy will be used primarily to adjust the mix between private and public consumption in response to taste shocks. When $\lambda(s^t)$ is high, indicating a preference for private consumption, the money growth rate $\mu(s^t)$ and thus seigniorage will be relatively low.

4.2 Questions

1. *Could the government do better by internalizing the relationship between policy choices and not-too-tight borrowing constraints in the floating regime?*

   In defining the Ramsey problem, we assumed that the government took borrowing constraints as given. Taking as given borrowing constraints that are not-too-tight, the Ramsey solution maximizes value. To increase value, an alternative policy would have to imply looser borrowing constraints. However, we can argue that not-too-tight constraints can only be tighter under alternative policies. First, note that changing policy prior to default will not change default values $V_t(s^t)$ under a float. Second, since values inside the contract, $W_t(B(s^t), s^t \; ; \underline{B})$, could only be lower under alternative policies, not-too-tight borrowing constraints could only be tighter. A similar argument applies to the dollarized economy.

2. *Would domestic consumers like to be able to buy dollars in the floating regime?*

   Suppose households in the floating economy were able to exchange pesos for dollars, and buy or sell goods on an international market. We can argue that prior to default, dollars will not be used as a private savings vehicle. The first order condition for dollar savings will be
   $$\frac{\lambda(s^t)\phi(s^t)}{c(s^t)} \geq \beta \sum_{s_{t+1}} \left[\frac{\lambda(s^t, s_{t+1})\phi(s^t, s_{t+1})}{c(s^t, s_{t+1})} \right].$$
   However, combining 27 and 30 gives

   $$\frac{\lambda(s^t)\phi(s^t)}{c(s^t)} \geq \beta(1+r) \sum_{s_{t+1}} \left[\frac{\lambda(s^t, s_{t+1})\phi(s^t, s_{t+1})}{c(s^t, s_{t+1})} \right]$$

Comparing these two inequalities, it is clear that as long as $r > 0$, households will never want to save in the form of dollars. The intuition is that the government can save dollars at a positive interest rate, while households can only hold dollar cash. Since they value consumption in different states equally, it is efficient for the government to conduct all international borrowing and lending.[15] In the event of default, households might want to save in the form of dollars. Thus if allowed to do so, the value of default under a float would be increased, and consequently borrowing constraints would be tighter.

3. *Is there a role for domestic debt in these economies?*

   In the floating economy, control over the money-growth rate by itself effectively amounts to having access to a state-contingent lump-sum tax. Thus domestic debt instruments, whether peso or dollar denominated, would be superfluous. In the dollarized model economy, endowing the government with the ability to buy and sell dollar-denominated bonds with domestic consumers would effectively introduce a valuable new instrument for re-allocating resources between the private and public sector. In many emerging markets, domestic debt's usefulness as a re-allocative policy instrument is limited by poorly developed financial markets. By contrast, virtually the entire population is active in the cash goods market, and thus subject to the inflation tax associated with growth in the money supply.

5   Quantitative Analysis

5.1   Comparing debt constraints and welfare across regimes

Conditional on a particular exchange rate regime, the borrowing constraint is looser the more valuable is access to the debt instrument prior to default, or, equivalently, the more painful is the loss of the instrument post default. Comparing across regimes, the constraint tends to be looser in the regime in which debt is used more actively, which in turn depends on the nature of shocks hitting the economy.

It is instructive to consider two simple examples, in which only one type of shock is operative.

First, suppose there are only shocks to λ, the relative taste for public versus private consumption. In this case the only goal for policy is to allocate constant output efficiently between public and private consumption. Control of the money growth rate and thus the inflation rate can achieve this perfectly. Thus, under a float there is no incentive for the government to repay any debts, and the borrowing constraint is at zero. Under dollarization, debt is a valuable though imperfect instrument since it is the only way for the government to smooth through

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[15]The government enjoys an additional advantage relative to private households: it can borrow, while private households cannot hold negative quantities of dollar currency.

taste shocks. Thus borrowing can be supported in this case.

Second, consider the case with only shocks to output y. Under a float, in response to a transitory increase in output it is optimal to increase the money growth rate in order to tax away some of the increase in private income via inflation. Debt is used aggressively, since debt repayments must both offset the increase in direct tax revenue and the increase in seigniorage revenue. Activist debt policy translates into strong repayment incentives and a loose borrowing constraint. Under dollarization, by contrast, debt is used less prior to default, and consequently the borrowing constraint is tighter.

When both types of shocks are operational, the relative volatility and correlation of shocks are key to understanding the relative position of borrowing constraints under the two regimes.

Ranking welfare across the two regimes is more complicated than ranking borrowing constraints. Even if dollarizing means looser constraints, the associated benefits must be weighted against the costs of losing monetary policy as an instrument. If the economy is subject to only one source of risk, it is easy to see that a float necessarily welfare dominates. With only taste shocks, a float achieves the efficient allocation of resources across sectors and through time, even though no borrowing is supported in equilibrium. With only endowment shocks, a float welfare dominates because more borrowing can be supported in equilibrium. We conclude that a necessary condition for dollarization to be welfare-improving in our environment is that the variance of both types of shocks is positive.

5.2 Sensitivity

To understand how the choice of exchange rate regime impacts debt constraints and welfare, we consider a simple baseline parameterization, and conduct an extensive sensitivity analysis with respect to alternative parameter values. We assume that both shocks are drawn independently from the same two-point distribution, with a mean of 0.85 and a standard deviation of 5 percent. Thus $\lambda, y \in \{0.8075, 0.8925\}$. We set the constant tax rate τ so that absent any shocks, efficient allocations could be achieved with constant debt and a constant money supply. Thus $\tau = E[1 - \lambda] = 0.15$. Finally we set the discount factor β to 0.96 and the interest rate r to 2 percent. By exploring variations on this particular parameter configuration we will learn a lot about the differences between the two exchange rate regimes. Later we will introduce more discipline in the choice of parameter values by calibrating the model to some specific countries.

In this section we explore how borrowing constraints and welfare change as we vary (i) the variance of the taste shock λ, (ii) the correlation between λ and y, (iii) the discount factor β, and (iv) the interest rate r. Comparing borrowing constraints across regimes is easy, because in our example the position of the constraint is independent of the current state.[16] Comparing welfare

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[16]This reflects the fact that the date t probability of each possible event s_{t+1} is always strictly positive, irrespective of s_t.
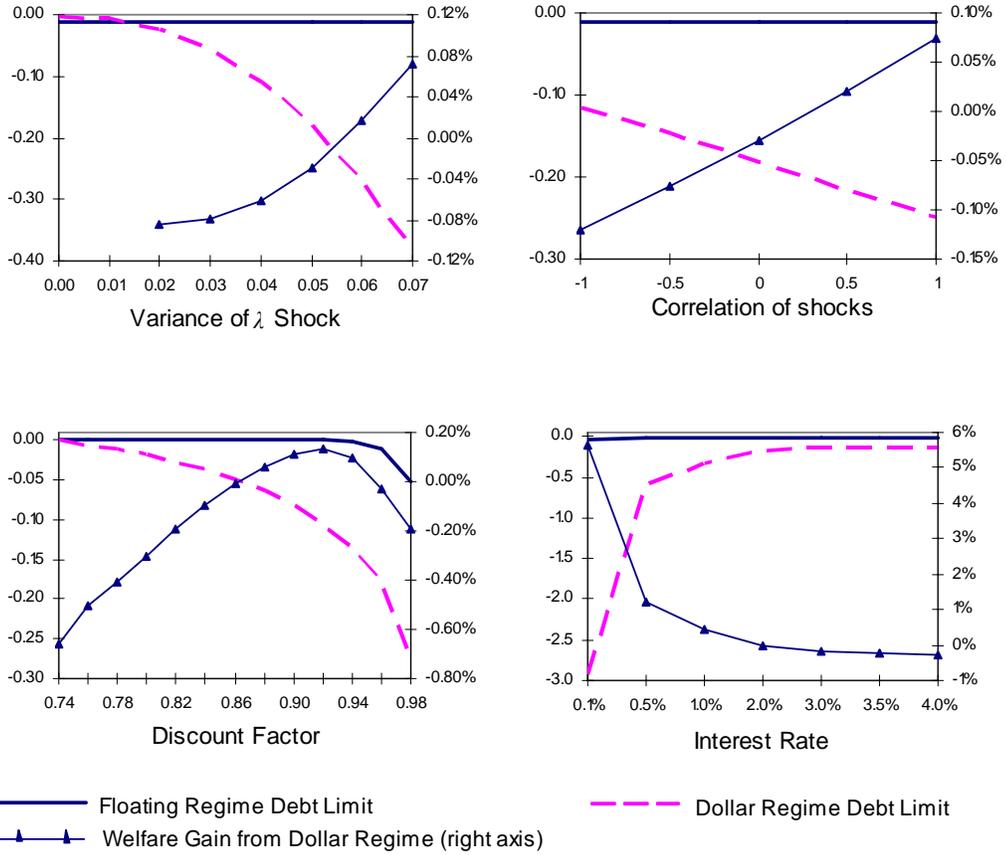
Figure 2: Borrowing Constraints and Welfare

is more difficult because expected lifetime utility is conditional on all the state variables in the economy. Moreover, in addition to the values for shocks and for sovereign debt, there is one additional endogenous state variable in the dollarized economy, namely domestic consumers' holdings of dollars. We compare welfare by (i) setting sovereign debt in both regimes equal to the value of the borrowing constraint in the floating economy (which almost always exceeds the constraint under dollarization), (ii) setting the real value of dollars in the dollarized economy equal to the real value of pesos in the floating economy, and (iii) taking an unconditional average across lifetime utility under each possible configuration of shocks. The welfare difference is reported as percentage difference in lifetime aggregate consumption across regimes.

At the parameter configuration described above, the borrowing constraint is extremely tight under a float, while the government can borrow almost twenty percent of GDP in the dollarized economy. Welfare is very similar. The intuition for these findings will become clear in the context of our sensitivity analysis.

5.2.1 Variance of λ

We first vary the variance of λ, holding all other parameters constant. The first panel in Figure 2 shows the impact on the position of the borrowing constraints as a fraction of mean output, and relative welfare in the two economies.

First, note that the variance of λ plays no role in determining the position of the constraint or debt dynamics in the floating economy. As discussed above, this is because shocks to λ can be perfectly insured with the money growth instrument. In the dollarized economy, the borrowing constraint is looser the larger are the taste shocks, since bigger shocks increase the role for international borrowing and lending. When taste shocks are small enough, the ranking of constraints across regimes switches. This is consistent with the previous result for the economy with only endowment shocks.

How the welfare ranking across regimes changes with the variance of taste shocks is also intuitive. Obviously, when taste shocks are very small, so that more borrowing is possible in the floating regime, then a float welfare dominates: dollarizing would mean losing an instrument, with no credibility gain in financial markets. For more volatile taste shocks, there is an interesting trade-off. Figure 2 shows that when taste shocks are large enough, the welfare gain from looser borrowing constraints in the dollarized economy more than offsets the loss of seigniorage as a policy instrument, and thus dollarizing is welfare-improving.

5.2.2 Correlation between y and λ

The second panel in Figure 2 shows the effect of varying the correlation between endowment and taste shocks. This correlation has no impact on the position of the borrowing constraint in the floating economy for the reason discussed above: taste shocks are perfectly insured via monetary policy.

In the dollarized economy, a positive correlation between the two shocks means that when output (and tax revenue) is high, government consumption is not especially valued (and vice versa). Thus the government would like to use debt aggressively, and the threat of losing the debt instrument in the event of default is potent. Thus the higher is the shock's correlation, the looser is the endogenous borrowing constraint.

The fact that increasing the correlation of shocks loosens the borrowing constraint is one reason why higher correlation makes dollarization relatively more attractive in welfare terms. A second reason is that for higher correlations, the loss of the monetary policy instrument under dollarization is less painful. The logic is that if y and λ co-move positively, then private income tends to rise automatically in times when private consumption is highly valued. Thus increasing $corr(y, \lambda)$ reduces the role for monetary policy.

5.2.3 The discount factor β

The third panel in Figure 2 shows the effect of varying β. As in standard repeated games, the more impatient are consumers, the less effective is the threatened default punishment of exclusion from international borrowing. Thus borrowing constraints become tighter as β is reduced. For sufficiently low β, no borrowing can be supported in equilibrium. This threshold β is much higher in the floating regime, reflecting the fact that in this case monetary policy perfectly insures taste shocks, and endowment shocks are small. Borrowing can be supported for a wider range of values for β in the dollarized economy, because in this regime debt has an additional valuable role smoothing preference shocks. As β increases towards the discount rate, $1/(1+r)$, the borrowing limit loosens substantially in the dollarized economy, such that when $\beta = 0.98$ it is at 27.5% of GDP, compared to 18.1% when $\beta = 0.96$.

When no borrowing can be supported in either regime, floating clearly welfare-dominates, since dollarizing means losing an instrument with no credibility gain in financial markets. The welfare gap between the two regimes narrows as β is increased over the range where the borrowing constraint is becoming looser in the dollarized economy, but is still zero in the floating economy. As the consumer's rate of time preference approaches the interest rate, the position of the borrowing constraint becomes increasingly irrelevant. The reason is that as the opportunity time cost of holding bonds shrinks, the government is willing to hold an increasingly large buffer stock of precautionary bonds, and consequently the borrowing constraint binds ever less frequently. This is why for large enough values for β, the welfare ranking across regimes flips once more.

5.2.4 The interest rate r

In the last panel of Figure 2 we consider the effect of varying the interest rate, r. The results are rather striking. The position of the borrowing constraint is minimally sensitive to the interest rate in the floating regime, while the constraint becomes extremely loose for low interest rates in the dollarized economy. When $r = 0.1\%$, the government can borrow up to three times GDP at a risk-free interest rate.

To build some intuition for these results, first suppose there were no shocks in these economies. With a small but positive interest rate and no enforcement frictions, the government would like to borrow heavily initially, and enjoy a downward-sloping profile for consumption looking forward. This simply reflects the standard relationship between the desired growth rate for consumption and the differential between the rate of interest and the rate of time preference. If this differential is large, moving from a flat consumption profile to the optimal one can generate large welfare gains. But in a risk-free version of a model in which debt repayment cannot be enforced directly, these gains can never be realized. The reason is simply that the position of the borrowing constraint depends only on the borrower's incentives to maintain a good credit

rating *ex post*: the *ex ante* potential gains from reallocating consumption inter-temporally are irrelevant. We conclude that when the interest rate is far below the rate of time preference, there are large welfare costs associated with the lack of an enforcement mechanism.

Now consider introducing shocks. As we reduce the interest rate, default incentives change in two ways. First, it becomes cheaper to pay interest on loans, and the incentive to default is reduced. Second, the cost of engaging in precautionary savings is larger because having bond holdings in excess of the borrowing constraint is expensive. In the limit, if the interest rate is sufficiently low relative to the rate of time preference, it is never optimal to move off the constraint, and since there is no use for debt, there is no cost to defaulting.

In the floating regime, as we have argued previously, the only shocks relevant to debt repayment incentives are endowment shocks. These shocks are quite small, so for sufficiently low r (holding constant β), it will rarely be worth doing any precautionary saving. Thus, even though maintaining a good credit report is cheap (because r is low), there is not much incentive to do so. This is why the borrowing constraint remains very tight in the floating economy.

Under dollarization, by contrast, the government also wants to use debt to smooth preference shocks. In this case debt is used more aggressively, and the punishment for default remains significant even for $r = 0$. Thus in this economy the effect that debt repayment becomes cheaper when r is reduced dominates, and the borrowing constraint becomes extremely loose as $r \to 0$.

As $r \to 0$, the welfare gains from dollarizing become quite substantial, reaching 5.7 percent of consumption when $r = 0.1\%$. These welfare gains are too large to be attributed solely to improved smoothing of endowment shocks, since the endowment shocks are relatively small, and Lucas' (1987) expressions for the welfare costs of business cycles would suggest small welfare gains to eliminating them. Rather, the bulk of the welfare gains in this example comes from inter-temporal reallocation. Starting at the tight floating constraint, dollarizing allows the government to raise government spending in the short run and to then gradually reduce spending over time.

5.2.5   Relation to literature

There is now quite a large literature that explores this class of models with endogenous debt constraints. While these models are intuitively appealing and can shed light on some features of sovereign debt markets, several important features of the data remain hard to explain. One is that observed debt levels drastically exceed the amount of borrowing that can typically be supported in calibrated versions of these models. The usual fix to this problem has been to assume that default comes with additional negative consequences, in addition to exclusion from future credit markets. For example, many papers assume that post default, the mean endowment is permanently reduced by several percentage points.

The analysis above suggests an alternative resolution. In particular, as long as the variance of

shocks is positive, then as $r \to 0$ and $\beta(1+r) \to 1$ the borrowing constraint becomes arbitrarily loose. The intuition is simple: as $r \to 0$, so does the cost of repaying debts. As $\beta(1+r) \to 1$ the cost of holding precautionary savings approaches zero, so that as long as the borrower faces some risk, the borrower will want to self-insure with debt, and will wish to avoid the punishment associated with default. Thus it is tempting to conclude that if the model is calibrated to a sufficiently short period length, one can support realistic debt levels in equilibrium. However, validating this hypothesis requires a careful evaluation of the nature of high frequency risk that is beyond the scope of this paper.

5.3 Calibration

We now apply our model to the study of actual countries in which dollarization has been discussed or implemented. Given that the relative performance of the floating and dollarized regimes in terms of financial integration and welfare is very sensitive to various parameter values, it is important to consider parameterizations that are appropriate for specific countries. We calibrate to two countries: El Salvador, which dollarized in 2001, and Mexico, which retains the peso, but where dollarization has been discussed in the past (see, for example, Cooley and Quadrini, 2001). The strategy is to calibrate the model assuming a floating regime, and to then compare across exchange rate regimes holding all parameter values constant.

   We solve the model at a quarterly frequency and compare annualized output from the model to the annual data that is available for these countries. The variables we focus on are real output, government consumption, household consumption, the change in government net foreign assets, and the inflation rate. The series for output, public and private consumption and inflation are from the World Development Indicators for 1960-2002.[17] Inflation is the annual percentage change in consumer prices. To study the dynamics of foreign public debt in our model we use the series for Government Foreign Financing as a percentage of GDP from the IMF's International Financial Statistics for 1980-2002. We log the series for output and consumption, and filter all the data with a 15 year Band-Pass Filter.[18]

   The stochastic structure for the shocks is country-specific. We assume that λ and y are drawn from a time-invariant bivariate lognormal distribution, with potentially correlated innovations:

$$\log(y_t) = \varepsilon_t^y$$

$$\log(\lambda_t) = \varepsilon_t^\lambda$$

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[17] The specific series we used from WDI are: General government final consumption expenditure, Household final consumption expenditure, GDP and Inflation. All these series (except inflation) are in per capita terms, and in real units of local currency.

[18] We use a longer filter to keep some of the lower frequency movements that have been documented by Aguiar and Gopinath (forthcoming) to be important for emerging-markets economies.

$$E[\varepsilon^y] = E[\varepsilon^\lambda] = 0$$

$$E[\varepsilon^{y\prime}\varepsilon^\lambda] = \Sigma = \begin{bmatrix} \sigma_y^2 & \sigma_{y\lambda} \\ \sigma_{y\lambda} & \sigma_\lambda^2 \end{bmatrix}$$

The three parameters in the variance-covariance matrix Σ are chosen so that the floating economy replicates the annualized volatilities of output and government consumption, and the correlation between government consumption and output. Shocks are discretized into a 9-state Markov process following the Hussey and Tauchen (1991) procedure.

The quarterly interest rate r is set to 1%, which is the average quarterly yield on a one-year U.S. Treasury Bill for the period 1996 to 2006. The time preference parameter β is set to 0.98, which is consistent with the 2% average quarterly interest rate in El Salvador on domestic dollar-denominated loans.[19] For the sake of simplicity, we assume the same value for β in both countries.

The mean value for λ is set to 0.85, so that the mean government consumption to GDP ratio is 15%. This is approximately equal to the government consumption to output ratio in both countries. As in the sensitivity section we assume a constant labor tax rate $\tau = 0.15$. Table 2 summarizes the parameter values used.

Table 2: Calibration

Country-specific parameters		Mexico	El Salvador
std. dev. output	σ_y	0.0787	0.105
std. dev. pref. shock	σ_λ	0.013	0.035
shock correlation	$\sigma_{y\lambda}/\sigma_y\sigma_\lambda$	−0.524	0.372
Common parameters			
mean pref. shock	$E\left[\lambda\right]$		0.85
interest rate	r		0.01
labor tax rate	τ		0.15
discount factor	β		0.98

5.4 El Salvador

Table 3 presents business cycle statistics for the El Salvadorean data, and for the corresponding model economy under the floating and dollarized regimes. Business cycle statistics from the model are based on annualized output from a long simulation designed to approximate the limiting distribution of asset holdings. Model output is filtered in the same way as the data.

In the data, government consumption is almost twice as volatile as output and private consumption is substantially more volatile than output. In the context of our calibration procedure, this generates an important role for taste shocks. Inflation and government consumption

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[19]The series used is the prime lending rate in dollars for loans of more than one year, as reported by the El Salvador Central Bank, for the post-dollarization period.

co-move positively, and are both counter-cyclical. To replicate the counter-cyclicality of government consumption, the calibration calls for positively correlated shocks (see Table 2). The change in net foreign public assets is acyclical and negatively correlated with government consumption in the data. Thus periods of high government expenditure are associated with both higher inflation and greater foreign borrowing.

Table 3: Business Cycle Statistics, EL SALVADOR

	Data			Floating Economy			Dollarized Economy		
	σ_x	$\rho_{x,y}$	$\rho_{x,g}$	σ_x	$\rho_{x,y}$	$\rho_{x,g}$	σ_x	$\rho_{x,y}$	$\rho_{x,g}$
Output	5.27	–	-0.05	5.27	–	-0.05	5.27	–	-0.05
Government cons.	9.73	-0.05	–	9.74	-0.05	–	8.30	-0.05	–
Private cons.	7.58	0.90	-0.38	4.68	0.81	-0.25	4.37	0.79	0.11
Inflation	4.46	-0.29	0.19	8.92	-0.22	0.68	–	–	–
Δ net foreign public assets	0.48	0.03	-0.19	3.11	0.67	-0.25	3.27	0.54	-0.84

	Floating	Dollarized
Borrowing constraint / GDP (%)	7.01	8.31
Mean money savings / GDP (%)	0.80	1.20
Mean debt / GDP (%)	3.96	6.40
Frequency constraint binds (%)	10.0	6.0

The floating regime model calibrated to El Salvador fits the data well. The model replicates the negative empirical correlation between private and public consumption, the positive correlation between inflation and government consumption, and the countercyclicality of inflation. Given the shock process, periods of low output - when inter-temporal smoothing dictates additional foreign borrowing - also tend to be periods when the demand for government consumption is high - and intra-temporal smoothing dictates high inflation. Thus the model is able to replicate the fact that inflation is counter-cyclical, and the fact that the accumulation of net foreign assets is negatively correlated with government consumption.

Table 3 also presents the statistics for the dollarized regime. Dollarization increases financial integration for El Salvador. The dollarized economy is able to borrow a larger proportion of annual output (8.3 versus 7.0 percent in the floating regime) and debt is used more aggressively. Dollarization also reduces the frequency of financial crises, defined as periods in which the borrowing constraint is binding: the probability mass at the constraint is 10% under a float compared to 6% when dollarized. More active use of debt in the dollarized regime appears to be a good substitute for the loss of the inflation instrument, as evidenced by the similar volatility of government consumption across regimes. In the dollarized economy, the sovereign wants to borrow when output is low or when the taste for government consumption is high. Since these events tend to coincide in the El Salvador calibration, a single instrument can go a long way towards accommodating both sources of risk. We find that expected welfare under

the dollarized regime is very similar to the floating regime. In light of the sensitivity analysis, the reason why dollarization looks quite attractive is twofold: (i) taste shocks are large, and (ii) taste and productivity shocks are positively correlated.

Average money savings - in excess of those dictated by the cash-in-advance constraint - are quite small in these economies, on the order of one percent of annual GDP. Nonetheless, adjustment of money savings is quite a powerful instrument for smoothing the marginal utility of private consumption inter-temporally. One indication of the role played by money comes from comparing the volatilities of output and private consumption in the dollarized economy. In the absence of money saving, the consumer's budget constraint would reduce to $c(s^t) = (1 - \tau)y(s^{t-1})$, in which case private consumption and output would be equally volatile. In contrast, in the monetary equilibrium the percentage standard deviation of output is 5.27, while the corresponding figure for private consumption is 4.37. Note also that on average there is more demand for money when dollarized than under a float. This does not reflect a difference in the average inflation rate across regimes. Rather private consumers compensate for the absence of monetary policy as a device for buffering shocks by engaging in additional precautionary saving and self-insurance.

5.5   Mexico

Table 4 presents business cycle statistics for the data in Mexico and for the corresponding models. Consumption and output are roughly equally volatile in Mexican data, while government consumption is much more volatile than output. Inflation has been extremely volatile. In terms of correlations, the Mexican economy differs dramatically from El Salvador's. In Mexico, the correlations between private consumption, public consumption and output are all strongly positive. In further contrast to El Salvador, the change in net foreign assets is positively correlated with output and weakly positively correlated with government consumption. Thus the Mexican government borrows in recessions, while booms in government spending are typically financed by inflation or growth in the tax base rather than by international borrowing.

Our calibration suggests that in Mexico taste shocks are smaller than in El Salvador. Replicating the large positive correlation between government spending and output requires taste shocks that are negatively correlated with output.

Table 4: Business Cycle Statistics, MEXICO

	Data			Floating Economy			Dollarized Economy		
	σ_x	$\rho_{x,y}$	$\rho_{x,g}$	σ_x	$\rho_{x,y}$	$\rho_{x,g}$	σ_x	$\rho_{x,y}$	$\rho_{x,g}$
Output	3.95	–	0.78	3.95	–	0.79	3.95	–	0.79
Government cons.	5.67	0.78	–	5.66	0.79	–	3.76	0.79	–
Private cons.	3.84	0.94	0.67	2.83	0.80	0.69	3.37	0.76	0.77
Inflation	19.10	-0.09	0.24	5.84	0.24	0.40	–	–	–
Δ net foreign public assets	1.31	0.41	0.14	2.10	0.64	0.28	0.30	0.35	-0.17

Borrowing constraint / GDP (%)	3.47	0.66
Mean money savings / GDP (%)	0.38	0.66
Mean debt / GDP (%)	1.66	0.19
Frequency constraint binds (%)	12.1	14.8

As was the case with El Salvador, the floating economy calibrated to Mexico successfully matches many features of the data. Output and private and public consumption are strongly positively correlated with each other. In our formulation of taste shocks, an increase in λ makes households simultaneously value private consumption more and public consumption less, which tends to make the correlation between the two negative. Productivity shocks, by contrast, induce a positive correlation. Because productivity shocks are the most important source of risk for Mexico, the model reproduces the strong positive correlation between public and private consumption observed empirically.

The floating model economy also predicts a positive correlation between inflation and government spending, in line with Mexican data. A positive correlation emerges because the government finances taste-shock driven fluctuations in government consumption by adjusting the inflation tax rate. However, because periods of high output tend to be periods of high demand for government consumption ($\rho_{\lambda y} < 0$), the inflation rate does not have to fluctuate too much to deliver the efficient level of government consumption. This is why the model fails to account for the high volatility of inflation observed in Mexico. The model does match the procyclicality of changes in foreign assets because debt is used to smooth output fluctuations: the government runs down its assets in periods of low output, and engages in precautionary savings in periods of relatively high output.

Table 4 also presents statistics for the dollarized economy. Dollarization reduces international financial integration for Mexico by several metrics: the borrowing constraint is much tighter, the change in net foreign assets is much less volatile, and the frequency of periods in which the constraint binds is greater. Because dollarization means both the loss of an instrument *and* the loss of credibility in international financial markets, it comes as no surprise that welfare is higher under a float, on average by 0.2% of lifetime consumption.

6 Conclusion

This paper presents a simple model designed to study the interaction between the choice of exchange rate regime and integration in international financial markets. The advantage of a floating regime is that control of the money growth rate and thus of seigniorage constitutes a flexible policy instrument for cushioning shocks. At the same time, dollarization may be attractive precisely because eliminating the monetary instrument can strengthen incentives to repay debts, and thereby increase access to international credit. This is a new way to think about how relinquishing monetary independence may strengthen credibility. It is a complement to the existing literature, which has largely focused on dollarization as a source of external credibility in environments in which monetary independence would lead to excessive inflation.

We find that the historical experience of countries that have delegated control of monetary policy is consistent with the idea that dollarizing can make it easier for a country to borrow. In particular, countries that have dollarized saw the cost of sovereign borrowing fall around the time they abandoned the domestic currency.

An important message from our model is that the effect of dollarization on financial integration and on welfare depends critically on the type of shocks economies face, and on the level of international interest rates. Low interest rates make dollarization especially attractive, because debt becomes a very cheap instrument for smoothing fluctuations. We also find that economies in which the demand for government revenue is counter-cyclical will likely experience the greatest gains from relinquishing control of monetary policy. In part this is because debt is used very actively to respond to shocks in this case. Thus the loss of the debt instrument in the event of default is costly, which means that a lot of borrowing can be supported in equilibrium.

When calibrating our model to actual countries, El Salvador, which dollarized in 2001, appears a better candidate for dollarization than Mexico. The model indicates that dollarization in El Salvador should improve the country's degree of integration with financial markets, which is consistent with empirical evidence, and can even increase consumer welfare. By contrast, the model suggests that for Mexico dollarization would reduce access to foreign credit, since demand side shocks appear small and government spending is pro-cyclical.

We conclude by noting that while the decision of whether to conduct an independent monetary policy or to adopt another country's currency is a very important one, the basic economic mechanisms we emphasize in this paper have much broader potential application. In related work, Krueger and Perri (2005) study the connection between the extent of government insurance against idiosyncratic risk at the household level, and the depth of private domestic credit markets. They find that progressive taxation can increase incentives to default on private debts, and thus crowd out private insurance. In the international arena, there are various examples of international policy choices that shrink a country's choice set for domestic policy, and which may thereby increase a country's access to international credit. One example is the decision to

joint a customs union, such as the North American Free Trade Area, which requires candidate member countries to give up control of taxes on trade. A second example is the Economic and Monetary Union in Europe, which requires eliminating restrictions on cross-border flows of capital and labor and thus limits countries' ability to respond to shocks by adjusting domestic tax rates. In these and many other examples the theory outlined in this paper suggests a connection between the extent of domestic economic sovereignty and the treatment a country can expect in sovereign debt markets.

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Appendix

Proof for decentralization proposition in the floating economy

We want to show that the government in the monetary economy, in which control of the money growth rate is the only way to reallocate resources between the public and private sectors, can achieve the same allocations as a planner who can effectively use lump-sum taxes and transfers to redistribute freely period by period. In particular, we need to show that there exist sequences for the money growth rates $\mu(s^t)$, associated savings rates $x(s^t)$, and inflation rates $\pi(s^t)$ that satisfy (i) the consumer's budget constraint (eq. 17) given the planner's target values for private consumption (eq. 27) (ii) the government's budget constraint (eq. 6) given the planner's target values for government consumption (eq. 28), (iii) the conditions for household optimization (eqs. 4 and 5).

Consider an arbitrary future date and state, T and s^T, and an arbitrary feasible monetary policy from s^T onwards. For our desired decentralization result it is sufficient to show that for all s^t and for all $t \leq T$ the planner in the monetary economy can implement any value for $c(s^t) \in (0, R(s^t))$, where total resources $R(s^t)$ are given by eq. 29, given an appropriate choice for $\mu(s^t)$.

To show this we begin by making a few useful observations.

1. Because this is an endowment economy, neither money growth nor inflation have any distortionary effects on factor supplies.

2. Past monetary policy does not restrict the set of feasible allocations that can be achieved looking forward, because current and future policy determine the real value of the pesos consumers carry into the period, which is what matters for real allocations.[20]

Given T and s^T we first show that the government can implement any value for $c(s^T) \in \left(0, R(s^T)\right)$, and in particular can implement the target value from eq. 27. We then work backwards to compute the value for $\mu(s^{T-1})$ that delivers the target $c(s^{T-1})$, exploiting the fact that changes in $\mu(s^{T-1})$ do not impact $c(s^{T-1}, s_T)$. In this fashion we can work backwards all the way to period 0, along the way deriving sequences for $\mu(s^t)$, $\pi(s^{t+1})$ and $x(s^t)$ that decentralize the planner's solution.

We guess, and will verify, that given a particular monetary policy from tomorrow onwards, there will be a critical money growth rate $\overline{\mu}(s^t)$ such that for any $\mu(s^t) \geq \overline{\mu}(s^t)$ the money

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[20]The real purchasing power of consumers' money balances entering the goods market at (s^t, s_{t+1}) is given by

$$\frac{M(s^t)}{P(s^t, s_{t+1})} = \left(\frac{1}{\mu(s^t, s_{t+1}) - x(s^t, s_{t+1})}\right)(1 - \tau)y(s^t, s_{t+1})$$

and thus does not depend on $\mu(s^t)$ or $x(s^t)$.

savings rate $x(s^t)$ is constant and equal to zero, while for $\mu(s^t) < \overline{\mu}(s^t)$ the savings rate $x(s^t)$ is continuous and decreasing in $\mu(s^t)$, with the property that $x(s^t) \to 0$ as $\mu(s^t) \to \overline{\mu}(s^t)$.

If the target value for $c(s^t)$ is less than or equal to

$$\overline{c}(s^t) = \frac{(1-\tau)y(s^t)}{\overline{\mu}(s^t)}.$$

then from the consumer's budget constraint 17 it can be implemented with a money growth rate $\mu(s^t)$ defined by

$$\mu(s^t) = \frac{(1-\tau)y(s^t)}{c(s^t)}. \tag{31}$$

where $\mu(s^t) \geq \overline{\mu}(s^t)$ and $x(s^t) = 0$. In this case, the lower is the target value for $c(s^t)$, the higher is the required $\mu(s^t)$. As $\mu(s^t) \to \infty$, $c(s^t) \to 0$. From eq. 18 the inflation rate $\pi(s^{t+1})$ in this case is given by

$$\pi(s^{t+1}) = \left(\mu(s^{t+1}) - x(s^{t+1})\right) \frac{y(s^t)}{y(s^{t+1})}. \tag{32}$$

If the target value for $c(s^t)$ is greater than $\overline{c}(s^t)$, then it will not be possible to implement in a monetary economy without money savings. In this case, the required money growth rate will be low or negative, savings $x(s^t)$ will be positive, and the inter-temporal first order condition for money saving will be an equality. From the consumer's budget constraint, eq. 17, $c(s^t, s_{t+1}) > 0$ implies $\mu(s^t, s_{t+1}) > x(s^t, s_{t+1})$ for all s_{t+1}. Given the expressions 17 and 18 for current consumption and the inflation rate between t and $t+1$ the inter-temporal first order condition equation implicitly defines $x(s^t)$ as a continuous function of $\mu(s^t)$. In particular, the inter-temporal first order condition may be written

$$\frac{\lambda(s^t)}{c(s^t)} = \beta \sum_{s_{t+1}} \frac{\phi(s^t, s_{t+1})}{\phi(s^t)} \frac{\lambda(s^t, s_{t+1})}{c(s^t, s_{t+1}; \Lambda_{t+1})} \frac{\left(\mu(s^t) - x(s^t)\right) y(s^{t+1})}{\mu(s^t) \left(\mu(s^t, s_{t+1}; \Lambda_{t+1}) - x(s^t, s_{t+1}; \Lambda_{t+1})\right) y(s^t)} \tag{33}$$

Using eq. 17 to express consumption as a function of $x(s^t)$ and $\mu(s^t)$ gives

$$\frac{\lambda(s^t)\mu(s^t)}{(1 - x(s^t))(1 - \tau)} = \beta \sum_{s_{t+1}} \frac{\phi(s^t, s_{t+1})}{\phi(s^t)} \frac{\lambda(s^t, s_{t+1})}{c(s^t, s_{t+1}; \Lambda_{t+1})} \frac{y(s^{t+1})}{\left(\mu(s^t, s_{t+1}) - x(s^t, s_{t+1}; \Lambda_{t+1})\right)} \tag{34}$$

It is immediate from this expression that the savings rate $x(s^t)$ is everywhere decreasing in $\mu(s^t)$.[21] For $\mu(s^t) \leq \overline{\mu}(s^t)$, given (i) a continuation policy Λ_{t+1}, (ii) future money growth rates

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[21] Here is some intuition for the response of $x(s^t)$ to $\mu(s^t)$. Absent a change in the savings rate, a reduction in the money growth rate $\mu(s^t)$ reduces the current price level $P(s^t)$ and increases expected inflation $\pi(s^{t+1})$, which tends to reduce savings. It also increases current consumption, and reduces the marginal utility of consumption, making consumers want to save more. With no change in the savings rate the second effect would dominate, leaving the marginal utility of consumption at s^t too low (see 34). Of course, in equilibrium prices and decisions adjust so that the household's inter-temporal first order condition is satisfied. The equilibrium adjustment mechanism is that the expected inflation rate rises by more than under the no-savings-adjustment hypothsis, and the savings rate rises. This increase in the savings rate is consistent with the inflation dynamic, and the

$\mu(s^t, s_{t+1})$, (iii) future savings rates $x(s^t, s_{t+1}; \Lambda_{t+1})$, and (iv) future consumption $c(s^t, s_{t+1}; \Lambda_{t+1})$, the current money growth rate $\mu(s^t)$ is defined by the solution to eq. 34 when the money savings rate $x(s^t)$ is given by re-arranging eq. 17, i.e.

$$x(s^t) = \frac{c(s^t)\mu(s^t) - (1-\tau)y(s^t)}{c(s^t) - (1-\tau)y(s^t)} \tag{35}$$

The critical money growth rate $\overline{\mu}(s^t)$ is the value of $\mu(s^t)$ that solves 34 when $x(s^t) = 0$. For $\mu(s^t) > \overline{\mu}(s^t)$ the inter-temporal first order condition will be a strict inequality with $x(s^t) = 0$, confirming the guess that for money growth rates exceeding $\overline{\mu}(s^t)$, household maximization will imply no money saving.

The important point relating to our decentralization result is that with log utility the savings rate $x(s^t)$ is uniformly decreasing in the money growth rate $\mu(s^t)$. The implication is that if the government had infinite resources, it could make seigniorage arbitrarily small and consumption arbitrarily large by reducing $\mu(s^t)$ towards the point at which $x(s^t) = \mu(s^t)$ (see eq. 17). In practice, the government always has at least $R(s^t) - (1-\tau)y(s^t)$ resources from direct taxation and international borrowing. So it can reduce the money growth rate to the point at which seigniorage is equal to the negative of this number, in which case $c(s^t) = R(s^t)$. Thus we have shown that the monetary authority can implement any value for $c(s^t) \in (0, R(s^t))$ with an appropriate choice for $\mu(s^t)$.

Corollary: Equilibrium uniqueness

There is a unique monetary equilibrium in our economy. This follows immediately from the fact that the savings rate $x(s^t)$ is everywhere decreasing in $\mu(s^t)$. In particular, for any policy Λ_{T+1} defining policy from period $T+1$ and onwards, each possible money growth rate $\mu(s^T)$ at s^T implies a unique value for $x(s^T)$ and thus for $c(s^T)$ and $\pi(s^T, s_{T+1})$. A similar argument can be applied, recursively, at each date $t \leq T$.

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reduced return to saving reduces the right hand side of the intertemporal first order condition. At the same time, a higher savings rate actually increases equilibrium consumption (see eq. 17), reducing the left hand side of the first order condition, but for log utility the first effect dominates.