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Devaluation risk and the business-cycle implications of exchange-rate management*

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Abstract

What is the mechanism driving the business cycle associated with stabilization policies anchored on managed exchange rates? Perfect-foresight models used extensively to try to answer this question have been unable to explain key quantitative features of the data. To do so it is necessary to consider devaluation risk in an environment of incomplete insurance markets in which stochastic price and wealth distortions operate. Simulations applied to Mexican data show that these distortions are large and socially costly, and that they rationalize several stylized facts. These findings suggest focusing the debate on exchange-rate regimes on the credibility of policymakers and the stance of fiscal policy.

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1 Introduction

The devaluation of the Mexican peso in December of 1994 was the first tremble in the series of major financial tremors that hit emerging markets during the 1990s. The Mexican collapse was followed by the "Tequila Effect" in 1995, which nearly ended Argentina's convertibility plan, the South East Asian crises of 1997, the Russian crisis of 1998, and the crises in Brazil, Colombia, and Ecuador in 1999. The features of most of these crises are well-known: a large devaluation of the currency followed by a financial meltdown and a sharp contraction in production, employment, and expenditures. Recent empirical research has also identified several pre-existing characteristics common to the countries that suffered these crises, such as sharp appreciations of the real exchange rate, significant booms in private expenditures, and large external deficits (see Frankel and Rose (1996) and Kaminsky and Reinhart (1999)). While the relevance of these "early-warning" or "vulnerability" indicators as statistical predictors of currency crises is not disputable, our understanding of the economic forces behind the cyclical dynamics associated with managed exchange-rate regimes is still limited.

Consider for example the Mexican experience of 1987-1994. The 1994 crash marked the collapse of a stabilization plan introduced in December of 1987 under the name of "El Pacto de Solidaridad Economica" (The Pact for Economic Solidarity). El Pacto was a variant of a stabilization plan anchored on exchange-rate management which practically fixed the peso-dollar exchange rate while tightening sharply both fiscal and monetary policies. Four stylized facts characterized this period:

1. A boom in production and private expenditures followed by a recession that predated the currency crash.
2. A sharp appreciation of the real exchange rate that was highly correlated with the boom in private expenditures.
3. A marked widening of current-account and trade-balance deficits.
4. A large drop in the velocity of circulation of money.

What is striking is that similar phenomena preceded the devaluations of the peso in 1954, 1976, and 1982 (see Mendoza and Uribe (1997)) and have also been documented for a large list of exchange-rate-based stabilization plans elsewhere (see Helpman and Razin (1987), Kiguel and Liviatan (1992), and Végh (1992)). Thus, exchange-rate-based stabilizations seem to exhibit a syndrome defined by those four stylized facts.

The existence of this syndrome suggests that several of the "early-warning" indicators of currency crises are in fact typical features of stabilization policies anchored on exchange-rate management. The study of this syndrome has been the focus of an extensive research program initiated in the 1980s by the seminal studies of Dornbusch (1982), Rodriguez (1982), Calvo (1986), and Helpman and Razin (1987), and preceded by policy studies such as that of Gómez-Oliver (1981). Since the syndrome of exchange-rate-based stabilizations relates to the business-cycle implications of a policy action on a nominal variable (i.e., the nominal exchange rate), the study of the monetary transmission mechanism that drives the syndrome is at the core of this research program. However, despite significant progress in exploring important aspects of this transmission mechanism, existing research remains unable to account for key quantitative and qualitative features of the data, and thus a central element for the understanding of the gestation process of currency crises and for the design of policies to counter them is still missing. This paper aims to fill some of these gaps by studying the positive and normative implications of a monetary transmission mechanism capable of accounting for some of the stylized facts of business cycles associated with exchange-rate management.

The transmission mechanism proposed in this paper is based on the distortions induced by the risk of devaluation on the competitive equilibrium of an economy with incomplete insurance markets. This transmission mechanism operates by allowing devaluation risk to alter the nominal interest rate and money velocity in a small open economy with an open capital account. Changes in velocity affect the real sector of the economy because money helps agents economize transactions costs. The probability of devaluation thus creates a state-contingent differential between domestic and world nominal interest rates, and this devaluation-risk premium introduces stochastic distortions on the relative prices relevant for money demand, saving, investment, and labor supply. Market incompleteness adds endogenous state-contingent wealth distortions via suboptimal investment decisions and fiscal cuts induced by the time-variant pattern of the inflation-tax revenue. The model also features traded- and nontraded-goods sectors, so that the effects of these distortions on the real exchange rate and the sectoral allocations of output, factors of production, and consumption can be determined.

The main goals of this paper are to assess whether the quantitative features of the business cycles associated with exchange-rate management can be rationalized as properties of the competitive-equilibrium dynamics of the proposed model, and to measure the welfare costs associated with the distortions induced by devaluation risk. To this end, the paper develops a numerical solution method particularly suited for models of the small open economy with incomplete markets that feature policy shocks following absorbent Markovian chains (i.e., policy reversals that are perceived as permanent).

The model is calibrated to the Mexican experience of 1987-1994 and solved numerically to examine the resulting equilibrium dynamics. The results show that the model can produce cyclical dynamics roughly consistent with key features of the data, although some important empirical puzzles remain. The model can account for the observed high correlation between expenditures and the real exchange rate, booms followed by recessions that pre-date devaluations, and periods of real-exchange-rate stability inbetween sharp appreciations. The real appreciations in the model are smaller than those measured in the data, but they are nearly four times larger than those produced in the existing literature, and they are also in line with the fraction of the real appreciations that a Vector Autoregression (VAR) analysis of the data suggests can be attributed to currency risk.

The simulations also show that price and wealth distortions induced by devaluation risk entail large welfare costs and merit policy intervention. The welfare costs of devaluation risk exceed the negligible costs of lack of policy credibility obtained in perfect-foresight studies by a large margin (see Calvo (1988)). To the extent that devaluation risk reflects the lack of credibility of exchange-rate policy, these results indicate that credibility issues should be at the center of ongoing debates on exchange rate regimes and external sustainability in developing countries. Moreover, the results suggest a potentially important role for countercyclical tax policy. If tax policy is "credible" and the public's expectations of devaluation can be measured accurately, the model examined here produces a schedule of state-contingent consumption taxes that can fully offset the price distortions driven by devaluation risk.

The rest of the paper is organized as follows. Section 2 reviews the main findings of the existing literature on exchange-rate-based stabilizations, putting in context the framework proposed in this paper. Section 3 documents the empirical regularities of Mexico's 1987-1994 stabilization plan, which serve as the basis for the numerical simulations. Section 4 describes the model and the solution method. Section 5 presents the results of the numerical simulations, including the welfare analysis. Section 6 concludes.

2 Exchange-rate-based stabilization: survey of existing results

The literature on exchange-rate-based stabilization plans has produced four theories for explaining the boom-recession cycles, sharp real appreciations, and widening external deficits associated with these plans:

1. *Sticky prices approach*: Dornbusch (1982) and Rodriguez (1982) argued that a fixed exchange rate lowers the real interest rate, and thus causes an economic boom, because prices are sticky and expectations of inflation adjust slowly. The real interest rate falls because interest parity forces the nominal interest rate to fall, while expectations of inflation remain high. The real appreciation results from the slow deceleration of inflation and the fixed nominal exchange rate.

2. *Deterministic credibility approach*: This approach was proposed by Calvo (1986), who argued that the real effects of exchange-rate-based stabilizations result from the optimal response of the economy to the fact that government policy lacks credibility. In particular, when the government implements a stabilization plan based on a fixed exchange rate, agents anticipate with full certainty a devaluation and a return to high inflation at a known future date. Intertemporal substitution leads consumption to jump to a higher constant level for the duration of the plan, before collapsing in another discrete jump to a lower constant level when the plan is abandoned. Later, Calvo and Végh (1993) added nontraded goods and staggered prices to show that lack of credibility could also trigger a gradual real appreciation of the currency.

3. *Fiscal solvency approach*: Helpman and Razin (1987) and Drazen and Helpman (1987) proposed models in which, after an exchange-rate-based stabilization is introduced, fiscal policy is not tightened as required by the solvency constraints that determine the sustainability of a fixed exchange rate from the perspective of the intertemporal government budget constraint. In this setting, the real effects of the plan are caused by wealth effects resulting from the timing of expected changes in the inflation tax or in government expenditures.

4. *Successful disinflation approach*: Lahiri (1996), Roldós (1995), and Uribe (1997) proposed an approach that takes into account the supply-side implications of a successful disinflation. They argued that, even under perfect credibility and price flexibility, a permanent decline in the rate of depreciation of the currency can induce a gradual real appreciation, a boom in domestic absorption, and a deterioration of the current account. This is because a successful disinflation plan reduces inflation-induced distortions on the relative prices of leisure, capital, and other durable goods.

The four theories summarized above fit well some aspects of the country experiences of the 1970s and 1980s. For example, the Mexican crises of 1976 and 1982 featured several elements of the first three approaches, while the experience of Chile in the second half of the 1980s and the early 1990s seems in line with the fourth approach. Existing models are at odds, however, with important features of the recent crises. This is particularly true for the approaches based on lack of fiscal discipline and price stickiness because countries like Argentina and Mexico experienced the syndrome of exchange-rate-based stabilizations despite sharp declines in price inertia that followed drastic market-oriented reforms and despite large fiscal cuts.

Existing models of the real effects of exchange-rate management in high-inflation countries have also encountered serious difficulties in accounting for most of the quantitative features of the data and even some of their qualitative features. The extensive quantitative experiments conducted by Rebelo and Végh (1996) showed that these models face major challenges in accounting for the magnitude of the observed macroeconomic fluctuations. In particular, the models produce real appreciations that are roughly 1/8 of what is observed in the data.[1] Moreover, as shown later, existing models embody theoretical features that prevent them from explaining two qualitative features of the data: the positive correlation between the real exchange rate and expenditures and the periods of stable real exchange rates inbetween large appreciations.

Recent theoretical work sheds light on the origins of some of the above empirical shortcomings. Calvo and Drazen (1998) showed that uncertainty and incomplete contingent-claims markets, both issues generally abstracted from the existing literature, are required in order to account for the observed gradual consumption booms. If Calvo's (1986) model is altered so that the date of the policy reversal is uncertain (assuming that it follows an exogenous probabilistic process), producing a gradual consumption boom requires wealth effects resulting from incomplete markets and the unproductive use of tax revenue. In this setting, the intertemporal substitution effect driven by the expectation of the potential reversal of the policy before a terminal date can be offset by a fiscal-induced wealth effect. This fiscal-induced wealth effect results from the fact that, each period the policy remains in place, tax revenue and wasteful government expenditures turn out to be "surprisingly" low, thus adding to the agents' wealth resources that due to the incompleteness of markets they could not trade contingent claims on before. Still, the Calvo-Drazen *uncertain duration* framework cannot account for the observed cyclical dynamics (in particular the recessions that predate currency crises) because consumption is always nondecreasing, regardless of the time path of the probability of policy reversal (see Section 5 for details).

The model proposed in this paper features a stochastic environment similar to the Calvo-Drazen model. There is one important difference, however, because Calvo and Drazen examined a trade reform of uncertain duration in which the value of import tariffs while the reform is in place is not affected by the probability of reversal of the trade reform, while in our model the currency risk premium establishes an endogenous link between the uncertain duration of the currency peg and the variable driving the distortions on the real economy (i.e., the nominal interest rate). Our analysis also differs in that Calvo and Drazen focused on analytical results for consumption planning in an endowment economy, while the focus here is on studying pol-

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[1] Uribe (1997) is an exception that yields a large real appreciation and a large spending boom using a model in which inflation acts as a tax on purchases of intermediate materials as well as on final transactions.

icy uncertainty in a general-equilibrium context and with the emphasis on quantitative findings.

Uribe (1998a) showed that most of the existing models of exchange-rate-based stabilizations belong to a class that features the *price-consumption puzzle.* This puzzle implies that the positive correlation between private consumption and the real exchange rate found in the data cannot be a property of the competitive equilibrium of models in that class. Along the intertemporal-equilibrium path of these models, the real exchange rate appreciates *only* if consumption falls.

The class of models to which the price-consumption puzzle applies feature perfect foresight, perfect capital mobility, a standard time-separable utility function, and a linearly homogeneous, concave aggregator of traded and nontraded goods. These features imply that in equilibrium the following two conditions must hold: (a) the relative price of nontradables is increasing in the ratio of consumption of tradables to consumption of nontradables, and (b) the marginal utility of consumption of tradables equals the marginal utility of wealth times a monetary distortion (if the model features one) that depends on the nominal interest rate. Since perfect foresight implies that the marginal utility of wealth is constant, and interest parity implies that the monetary distortion is constant while the exchange rate is fixed, conditions (a) and (b) imply that consumption and the real exchange rate move in opposite directions along the equilibrium path while the stabilization plan is in place. The model we propose here breaks away from this limitation because uncertainty and market incompleteness result in a state-contingent marginal utility of wealth and a state-contingent nominal interest-rate differential.

3 Mexico's 1987-1994 exchange-rate-based stabilization plan

As noted in the introduction, the syndrome of exchange-rate-based stabilizations is described by four stylized facts:

1. Booms in production and private expenditures followed by recessions that often predate the collapse of the plans.

2. A large appreciation of the real exchange rate that may occur with periods of stability inbetween rapid appreciations and is highly correlated with the boom in private expenditures.

3. A widening of external imbalances that is reversed by the time of the collapse.

4. A fall in money velocity followed by a surge around the time of the collapse.

This section documents these empirical regularities for the Mexican stabilization plan of 1987-1994. Mendoza and Uribe (1997) documented similar stylized facts before the devaluations of the peso in 1954, 1976, and 1982. The section also provides evidence on other elements of the Mexican data that are important for the transmission mechanism of the model proposed in Section 4. Data on national accounts are from the *Banco de Información Económica del Instituto Nacional de Estadística, Geografía e Informática*, and data on consumer prices, monetary aggregates, interest rates, and the exchange rate are from *Indicadores Económicos del Banco de México.* A detailed data appendix is available from the authors on request.

3.1 *Exchange rates and consumer prices*

Figure 1 plots the monthly evolution of Mexico's real and nominal exchange rates during 1985-1995. The nominal exchange rate in the left scale is in pesos per dollar, so it increases as the peso depreciates. The real exchange-rate index, in the right scale, follows the IMF's convention and is measured as the ratio of Mexico's consumer price index (CPI) over the exchange-rate-adjusted CPI of the United States. An increase in this index indicates a real appreciation of the peso. As Figure 1 shows, Mexico fixed the peso-dollar exchange rate in February of 1988 and kept it fixed for the remainder of that year. This was done jointly with other stabilization measures announced with El Pacto in December of 1987, which preceded the economic reforms of the early 1990s.[2] After 1988 the exchange rate followed a slow-crawling peg system that went through several adjustments. The result was in effect a nearly-fixed exchange rate until the collapse of the peso in December of 1994.

The real exchange-rate index is plotted in Figure 1 with February 1988= 100, so that the base date coincides with the fixing of the nominal exchange rate. The peso depreciated sharply in real terms in 1985-1986, so the currency peg started from a low real exchange rate from a historical perspective. The peso appreciated sharply, by about 15 percent, during 1988, and then remained relatively stable during 1989-1990. The appreciation reemerged in 1991 and continued until it peaked at about 55 percent in March 1994. Measured from the beginning of the peg to the end (i.e., February 1988 to December 1994), the peso appreciated by 45 percent in real terms. At the quarterly frequency consistent with the model we study later, the real appreciation between the first quarter of 1988 and the last quarter of 1994 was 41.5 percent.

Since during the period in question both U.S. CPI inflation and changes in

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[2] Aspe (1993) provides a detailed description of the stabilization plan and the economic reforms.

the peso-dollar nominal exchange rate were negligible, compared to Mexico's CPI inflation, a closer analysis of the Mexican CPI provides key information for understanding the real appreciation of the peso. Figure 2 shows that the real appreciation was driven by a large increase in the relative price of nontradable goods to tradable goods in Mexico.[3] The inflation rate for tradables converged rapidly to international levels, but the one for nontradables fell very slowly. This pattern differs sharply from the evidence for industrial countries showing that real-exchange-rate fluctuations are unrelated to movements in the relative price of nontraded goods (see Engel (1995)).

Figure 3 illustrates the high correlation between private expenditures and the real exchange rate at a quarterly frequency. The cyclical components of private consumption and investment moved together with the real exchange rate from the beginning of the stabilization plan and until expenditures slowed down in 1993, while the real appreciation continued. The correlation coefficient for either consumption or investment and the real exchange rate is about 0.7, excluding the data from the second quarter of 1993 until the collapse of the plan. The fact that the real exchange rate and expenditures increased together for 3/4 of the duration of the plan is the empirical regularity that models affected by the *price-consumption puzzle* cannot explain.

3.2 *Production, private expenditures and net exports*

The literature on stabilization via exchange-rate management in high-inflation countries typically measures booms and recessions using the overall growth of output or consumption between the dates of introduction and abandonment of stabilization plans (see Végh (1992) and Kiguel and Leviatan (1992)). In contrast, the analysis undertaken here follows the approach of modern business-cycle theory and focuses only on the cyclical components of the data. This is important because the model of Section 4 is a model of business cycles, and hence should be assessed using data that exclude long-run trends. In addition, recent stabilization plans have been accompanied by extensive programs of economic reform, as was the case in Mexico. Hence, focusing on raw data can bias the analysis by picking up effects due to the transitional dynamics of economic reforms, as those studied by Albuquerque and Rebelo (2000) and Fernandez de Córdoba and Kehoe (2000).

Figure 4 plots cyclical components of GDP, private consumption, fixed investment, and the ratio of net exports to GDP using quarterly data for the period 1983:1-1994:4. Given the short sample, the data were filtered using

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[3] The CPI for tradables corresponds to durable goods and the one for nontradables corresponds to services. This is roughly consistent with the definitions based on sectoral trade-to-GDP ratios introduced later.

Figure 1. Mexico: Real and Nominal Exchange Rates 1985-1995

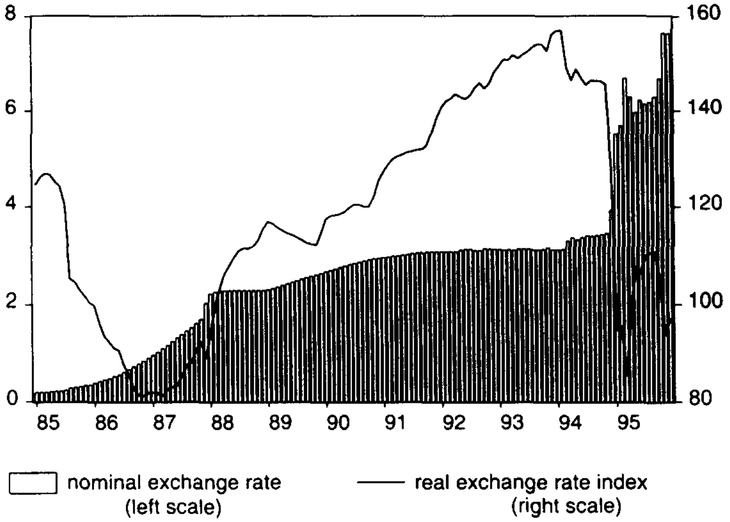
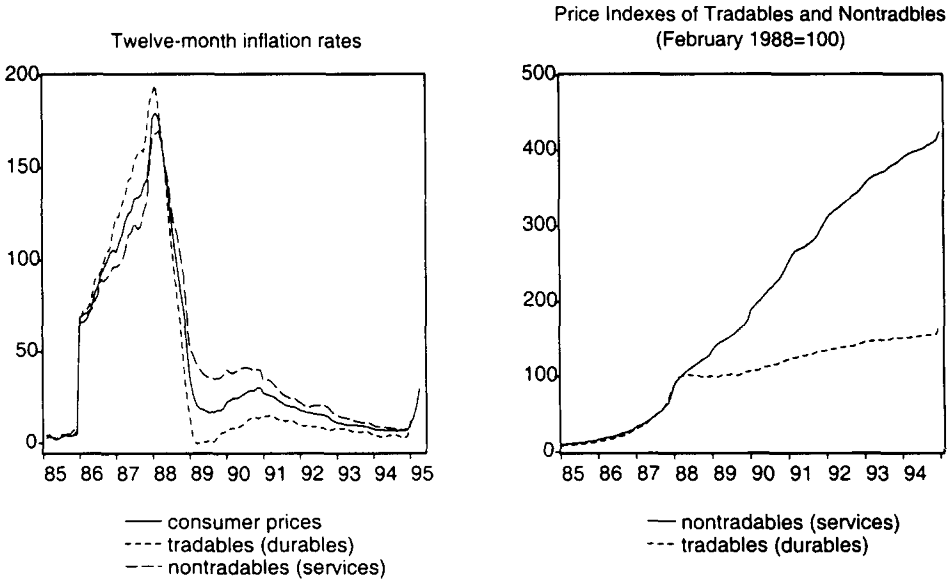
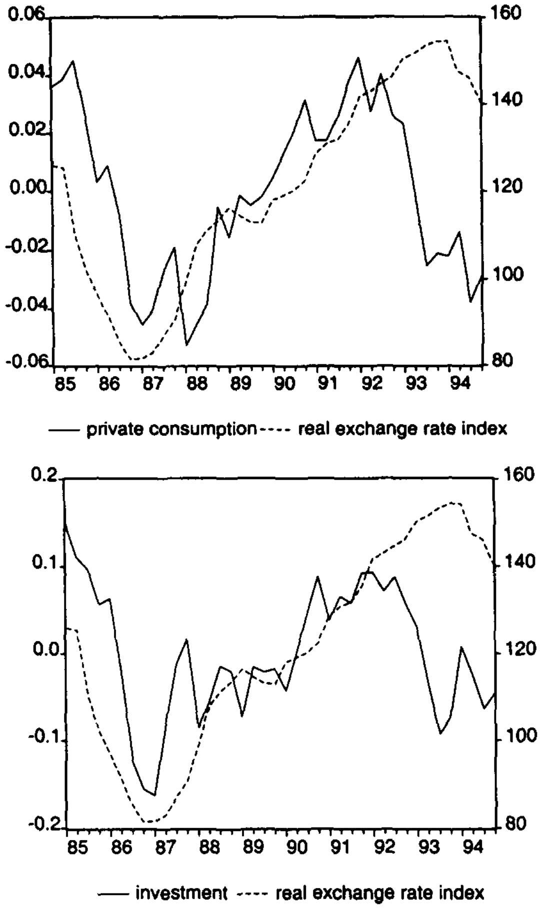


Figure 2. Mexico: Inflation Rates and Price Indexes


Twelve-month inflation rates

Price Indexes of Tradables and Nontradbles (February 1988=100)

Figure 3. Mexico: Domestic Expenditures and the Real Exchange Rate



Note: Private consumption and investment are plotted in the left scale. The data were logged and detrended with a quadratic time trend. The real exchange rate index is plotted in the right scale and is calculated as the quarterly average of the monthly figures used in Figure 1.

a quadratic trend, testing to confirm that it produced stationary cyclical components. Mendoza and Uribe (1997) showed that the main features of these cyclical components are robust to the choice of filters.

Investment, GDP, and consumption experienced significant booms during the first five years of the program, but in 1993 all three fell in recession. Thus, this was a typical stabilization plan in which recession predated currency collapse. Measuring from the first quarter of 1988 to the peak of the cycle in 1992, GDP and consumption increased by 4-5 percentage points, and investment by more than 10 percentage points. The trade balance as a share of GDP worsened from virtual balance in 1988 to a deficit of 6 percent of GDP by 1992, and remained around that level until it was suddenly reversed into a surplus in the first quarter after the devaluation.

In addition to focusing on the cyclical components of the data, an accurate characterization of the real effects of exchange-rate-based stabilizations must consider that observed business cycles in stabilizing economies are influenced by several factors. Studies like those of Calvo, Leiderman, and Reinhart (1993) and Mendoza (1995), for example, show that exogenous shocks to the world interest rate or the terms of trade are important for explaining business cycles in developing economies. Since these shocks, and changes in other determinants of developing-country business cycles, continue to take place while a country implements a stabilization plan, it seems inadequate to aim to explain the full extent of observed business cycles solely as an outcome of the stabilization plan. The contribution of each of these factors to explain observed macroeconomic fluctuations can be gauged using conventional time-series analysis techniques. In particular, variance decompositions of a VAR model can be used to measure the fraction of the Mexican business cycle that can be attributed to devaluation risk, which is the only driving force of business cycles considered in this paper. Ideal comparisons of the model with the data should be made against this fraction of the observed business cycle.

The VAR model used here is borrowed from Calvo and Mendoza (1996). The model is a parsimonious VAR system in which GDP, the net exports-GDP ratio, the real exchange rate, and real M2 money balances enter as endogenous, and the terms of trade and devaluation risk are exogenous. Devaluation risk is measured using the nominal interest-rate differential between Mexico's peso-denominated treasury certificates CETES and U.S. T-bills.[4] The VAR estimation uses 2 lags, as suggested by maximization of the Akaike Information Criterion. The results show that innovations in the interest-rate differential explain about 40 percent of the variability of each of the endogenous variables over 24 quarters. Thus, these results suggest that devaluation

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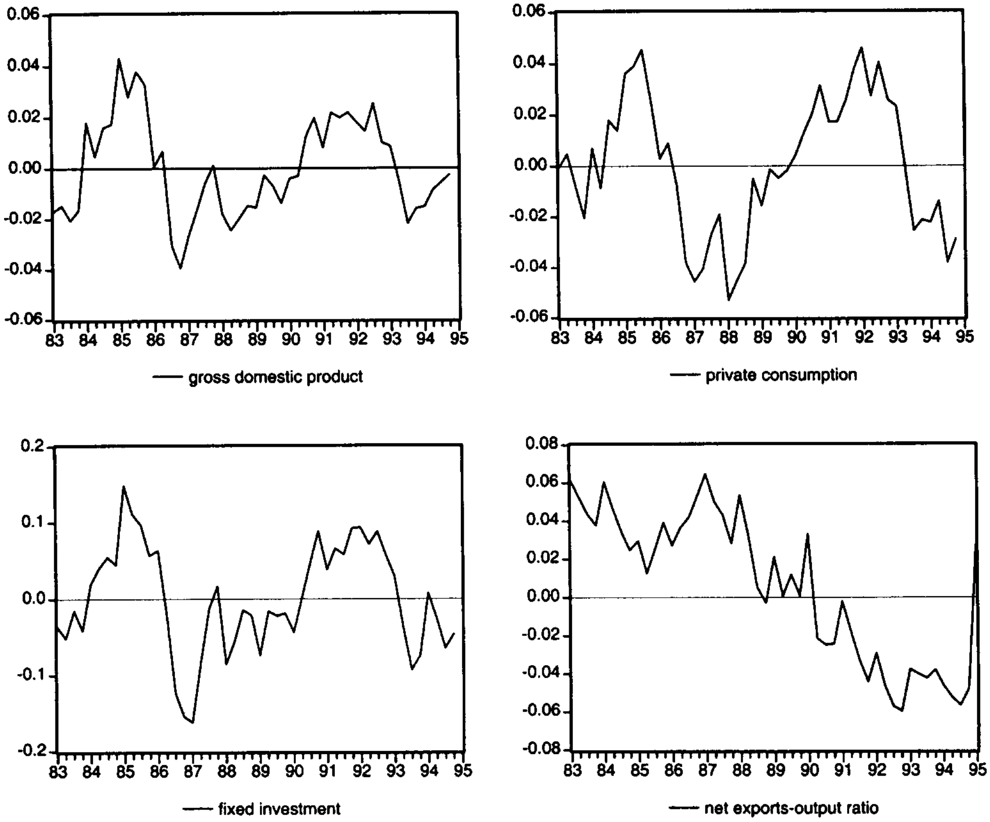
[4] Note, however, that as argued in 3.4, this differential is at best a noisy measure of market expectations of devaluation.

Figure 4. Mexico: Cyclical Components of Macroeconomic Aggregates



Note: GDP, consumption and investment were logged and detrended using a quadratic time trend, confirming with ADF tests that the cyclical components do not contain unit roots. The ratio of net exports to GDP was not detrended.

risk considered in isolation may explain real appreciations of up to 20 percent. The remaining 25 percentage points of the observed real appreciation are accounted for by other factors.

3.3 *Sectoral features of the data*

Microeconomic theory predicts that a large change in domestic relative prices as the one experienced in Mexico needs to be accompanied by large shifts in sectoral marginal rates of substitution in consumption and production. Assuming conventional, linear-homogeneous functions to represent preferences and technology, these shifts require in turn sectoral shifts in capital-labor ratios and in consumption. Unfortunately, evidence of these shifts is difficult to document because of serious limitations regarding sectoral data. A consistent sectoral breakdown of value added, gross output, investment, and consumption is only available at an annual frequency starting in 1988. This short sample does not allow us to isolate cyclical components, and hence we cannot determine the extent to which changes in sectoral data may have reflected structural changes in response to economic reforms. Moreover, data on sectoral capital stocks are not available and sectoral labor allocations are reported only in number of employees per sector. Nevertheless, available data do show evidence of sectoral shifts in the direction theory predicts.

We define the tradables and nontradables sectors following the conventional practice of examining the ratios of total trade to gross output in the nine industries in which total production is divided in the national income accounts. The nontradables sector is composed of the industries for which total trade is less than 5 percent of gross output at current prices. Taking averages over 1988-1996, the nontradables sector includes: (1) construction, (2) utilities, (3) retailing, restaurants and hotels, (4) financial services and real estate, and (5) social and personal services. The tradables sector consists of (1) agriculture, (2) mining, (3) manufacturing, and (4) transportation, storage, and communications.

The ratio of tradables-to-nontradables output at constant prices was nearly unchanged over the period 1988-1994, and averaged 0.89. The ratio of value added across sectors also remained approximately constant at an average near 0.60. In contrast, labor productivity (i.e., output at constant prices per paid employee) in the tradables sector relative to that in the nontradables sector increased from 0.59 in 1988 to 0.68 in 1994, while the ratio of employment in the tradables sector relative to the nontradables sector fell from 0.81 to 0.67 in the same period. Hence, there was roughly no change in relative value added across sectors because the reallocation of employment from tradables to nontradables was offset by an increase in relative labor productivity in favor of the tradables sector. Moreover, since further evidence from sectoral data documented in Section 4 favors modeling sectoral production functions as Cobb-Douglas technologies, we conjecture that: (a) the reallocation of labor from tradables to nontradables should have been accompanied by a sectoral reallocation of capital in the same direction, and (b) for the ratio of sectoral GDP to have remained constant, while both capital and labor were being reallocated to the nontradables sector, there must have been an offsetting increase in total factor productivity in the tradables sector.

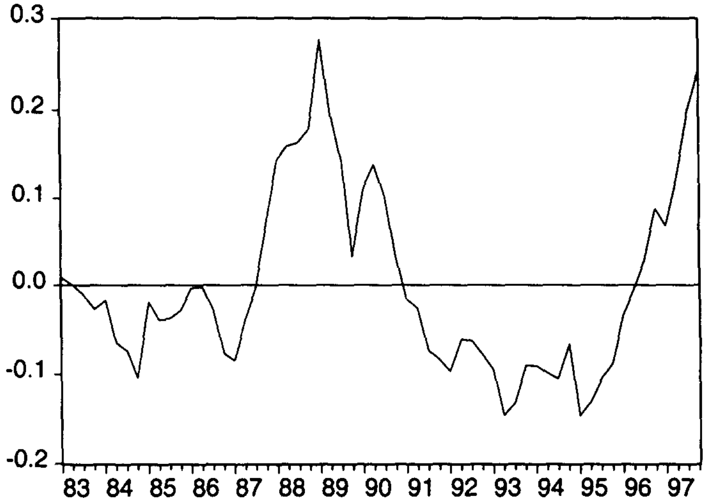
Sectoral consumption data at 1993 prices indicate that tradables consumption grew faster than nontradables consumption during the early stages of the plan. Tradables consumption grew 8.5 and 6.6 percent in 1989 and 1990 respectively, compared to 5.2 and 4.9 percent in the nontradables sector. Surprisingly, however, tradables consumption slowed down more sharply during the cyclical downturn. Tradables consumption grew only 0.3 percent in 1993, compared to growth of 3.9 percent in nontradables consumption, and consumption of manufactures actually declined. For the 1988-1994 period, tradables consumption increased 33.4 percent, compared to 30.3 percent for nontradables. This reallocation of consumption in favor of tradables is qualitatively in line with the movement required for the sectoral marginal rate of substitution in consumption to match the increase in the relative price of nontradables, but the sharper deceleration in tradables consumption during 1993 is a puzzle.

3.4 *Expenditure velocity and the rate of interest*

The transmission mechanism that drives the model proposed in Section 4 operates through the effect of devaluation risk on the nominal interest rate and the velocity of circulation of money. Figure 5 plots the cyclical component of the expenditure velocity of M2 (i.e., consumption plus investment over M2 money balances), which is the relevant measure for money balances used in transactions in Mexico. Velocity followed the U-shaped pattern typical of exchange-rate-based stabilizations during the period 1988-94. Measured from the maximum in early 1989 to the minimum reached in 1993, velocity fell by nearly 40 percentage points.

Evidence on the link between devaluation risk and the interest rate can be documented by examining again the CETES-Tbill interest-rate differential. This indicator suggests that devaluation risk was high, at near 60 percent, at the beginning of the program and then declined gradually until the end of 1991, when it stabilized around 15 percent until the devaluation of the peso. However, this indicator reflected only a slight increase in devaluation risk in the months before the devaluation, as the CETE rate did not increase sharply because of extensive sterilized intervention by the central

Figure 5. Mexico: Expenditure Velocity of M2



Note: Expenditure velocity is the ratio of consumption plus investment over M2 money balances. The ratio was logged, seasonally adjusted, and detrended with a quadratic trend.

bank. Other benchmark money-market interest rates did increase sharply – the differential between the interbank interest rate and the CETE rate widened by 10 percentage points before the crisis. Calvo and Mendoza (1996) and Kumhof (1999) proposed models that try to account for this anomaly by modeling banking fragility and temporary central bank sterilization of capital outflows. In addition, Becker, Gelos, and Richards (2000) show that expectations of devaluation measured by the relative performance of stocks in industries that are net exporters did increase continuously before the collapse of the peso.

3.5 *Fiscal Policy*

The stance of fiscal policy is another key ingredient of the model studied in Section 4. In particular, the model requires temporary reductions in wasteful government absorption that last for the duration of a currency peg. In this account, the Mexican experience is striking. The overall public deficit shifted by nearly 17 percentage points of GDP between 1987 and 1993, going from a deficit of 16 percent of GDP to a surplus of 0.7 percent of GDP. This sharp fiscal contraction reflected in part a marked decline in public debt service that resulted from the decline in the CETE rate after 1988, but it was also supported by a series of large cuts in government absorption that started in 1986. Real government absorption (defined as wages and salaries, goods purchases, federal remittances to state governments, and subsidies to public enterprises) fell by 32 percent between 1986 and 1988 (about 6 percentage points of GDP). Still, these figures underestimate the wealth effects of the fiscal consolidation because they do not capture efficiency gains resulting from the program of liquidation and privatization of public enterprises. Through this program, over 450 public enterprises were closed and several others sold. Subsidies to public enterprises fell from a peak of near 4 percent of GDP in 1985 to 1 percent of GDP in 1994.

The above figures also reflect poorly the temporariness of the fiscal adjustment because they exclude large expenses incurred to support the banking system since 1994. Adding financial intermediation by the government, the fiscal position switched from virtual balance to a deficit of 4.5 percent of GDP between 1993 and 1994. By 2000, the fiscal cost of the programs implemented to support commercial banks since 1995 had escalated to 21 percent of GDP.

4 A business-cycle model driven by devaluation risk

This section describes a model that features a monetary transmission mechanism of business cycles driven by devaluation risk. The model borrows from the existing literature on exchange-rate-based stabilizations the assumption of a small open economy that takes as given from world markets the real interest rate and tradable goods prices, and the assumption that money enters the model as a vehicle for economizing consumption and investment transactions costs. The main innovation of the model is in the treatment of uncertainty and incomplete contingent-claims markets in a general-equilibrium setting. This yields significantly different predictions for the behavior of the nominal interest rate and the monetary distortion that drives business cycles in the economy while a fixed-exchange-rate policy is in place.

4.1 *Preferences and technology*

Households are infinitely-lived and maximize the following expected utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{[C_t(1-L_t)^{\rho}]^{1-\sigma}}{1-\sigma} \tag{1}$$

$$C_t = [\omega(C_t^T)^{-\mu} + (1-\omega)(C_t^N)^{-\mu}]^{-\frac{1}{\mu}} \tag{2}$$

The single-period utility function is defined over consumption, C_t, and labor effort, L_t. The parameter $\sigma > 0$ denotes the inverse of the intertemporal elasticity of substitution in consumption and the parameter $\rho > 0$ determines the intertemporal elasticity of substitution of effort for a given value of σ $\beta \in (0,1)$ denotes the subjective discount factor. The expectations operator E_0 applies to the probability of devaluation of the currency, as defined below. Consumption is a composite of consumption of tradable goods, C_t^T, and nontradable goods, C_t^N. The aggregator function takes a CES form with $1/1+\mu > 0$ measuring the elasticity of substitution between tradables and nontradables.

Households maximize utility subject to the following constraints:

$$(1+S(V_t))(C_t^T + p_t^N C_t^N + I_t) =$$

$$= r_t K_t + w_t L_t + \frac{m_{t-1}}{1+e_t} - m_t - B_{t+1} + (1+r^*)B_t + T_t \tag{3}$$

$$K_{t+1} = (1-\delta)K_t + \varphi\left(\frac{I_t}{K_t}\right)K_t, \tag{4}$$

$$V_t = \frac{C_t^T + p_t^N C_t^N + I_t}{m_t} \tag{5}$$

$$lim_{j\to\infty} E_t \left[\frac{B_{t+j+1} + m_{t+j}}{(1+r^*)^j}\right] = 0. \tag{6}$$

Equation (3) is the households' budget constraint in units of the traded good. The left-hand-side of (3) represents total expenditures in consumption and investment, I_t, with p_t^N defining the relative price of nontradables, or the real exchange rate. Following Greenwood (1983) and Kimbrough (1986), real balances m are held because they help to economize transactions costs. Specifically, the unitary transactions cost is assumed to be an increasing function S of the expenditure velocity of money V. The unit transactions cost function is assumed to take the form $S = AV^{\gamma}$, where A and γ are nonnegative parameters.[5] The right-hand-side of (3) represents the sources of income: factor payments to labor and capital, K_t, at the rental rates w_t and r_t respectively, plus changes in the real value of money holdings, minus the net accumulation of real, one-period foreign bonds B that pay the time-invariant real interest rate r^*, plus lump-sum government transfers T_t. Since world asset trading is limited to noncontingent bonds, markets of contingent claims are incomplete. PPP in tradable goods holds and foreign prices are assumed to be constant, so that e represents both the inflation rate of tradables and the rate of depreciation of the currency. Real nominal balances are eroded by inflation at the rate e.

Equation (4) is the law of motion of the capital stock which embodies capital-adjustment costs as determined by the concave function $\varphi(.)$. Adjustment costs are introduced so as to differentiate capital and foreign assets as vehicles of saving, and thus avoid the excessive investment variability that would result otherwise (see Mendoza (1995)). To avoid capital-adjustment costs in the steady state, we assume that $\varphi(\delta) = \delta$ and that $\varphi'(\delta) = 1$. Equation (5) is the definition of expenditure velocity. Equation (6) rules out Ponzi games.

The firms that are part of the industries that produce tradable (T) and nontradable (N) goods operate in competitive goods and factors markets using standard Cobb-Douglas production technologies: $Y_t^i = A^i(K_t^i)^{\alpha i}(L_t^i)^{1-\alpha i}$ for $i = T, N$. This assumption is consistent with the evidence of constant factor income shares within each of the nine major industrial sectors in the National Income Accounts (as documented later in the calibration exercise). Since factor markets are competitive, factors of production earn their marginal products and the standard zero-profits condition holds: $w_tL_t + r_tK_t = Y_t^T + p_t^N Y_t^N$.

The equilibrium sectoral allocation of production and the relative price of nontradables are determined at the tangency point between the production possibilities frontier (PPF) of Y^T and Y^N and the corresponding isorevenue curve. In equilibrium, the slope of the PPF equals p^N. Thus, it follows that the slope of the PPF is a key determinant of the magnitude of the variations that the real exchange rate can exhibit in this model. This, however, represents a serious problem because of a well-known implication of the Balassa-

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[5] The exponential form of S belongs to the class of functions that yields implications of the transactions costs framework similar to those of models with money in the utility function (see Feenstra (1986)).

Samuelson hypothesis: if factors of production are homogeneous, and thus can be freely reallocated across sectors, Cobb-Douglas technologies yield a PPF with a slope determined by the fraction $\alpha T - \alpha N$ of the shift in sectoral capital-labor ratios. The problem emerges because, as documented later, αT and αN differ by a small margin in the data and there is little evidence of the massive sectoral shifts in capital-labor ratios needed to produce large changes in p^N in this case.

Large changes in the relative price of nontradables are made possible by discarding the assumption that factors of production are homogeneous across sectors. This assumption was widely regarded as unrealistic in the trade literature that developed the specific-factors models. These models recognized that factors of production are specific to each sector to some degree, and thus introduced transformation curves to represent feasible sectoral factor allocations. For simplicity, we adopt Mussa's (1978) specification, in which capital is sector-specific but labor remains a homogeneous factor. Thus, the factor transformation curves are:

$$K_t = \kappa(K_t^T, K_t^N) \quad \text{and} \quad L_t = L_t^T + L_t^N \tag{7}$$

For simplicity, $\kappa(\cdot)$ is assumed to be a CES function.

4.2 *Competitive equilibrium and solution method for an exchange-rate-based stabilization*

The first-order conditions of the maximization problems of households and firms can be combined in the following set of equilibrium conditions:

$$\lambda_t h(i_t) = \beta^t \omega \left(\frac{C_t^T}{C_t}\right)^{-(1+\mu)} C_t^{-\sigma} \left(1 - L_t^N - L_t^T\right)^{\rho(1-\sigma)} \tag{8}$$

$$p_t^N = \frac{1-\omega}{\omega} \left(\frac{C_t^N}{C_t^T}\right)^{-(1+\mu)} \tag{9}$$

$$\frac{\rho(C_t^T + p_t^N C_t^N) h(i_t)}{(1 - L_t^N - L_t^T)} = (1 - \alpha T) A^T \left(\frac{K_t^T}{L_t^T}\right)^{\alpha T} \tag{10}$$

$$\lambda_t[1 - S'(V_t)V_t^2] = E_t \frac{\lambda_{t+1}}{1 + e_{t+1}} \tag{11}$$

$$\lambda_t = E_t \lambda_{t+1}(1 + r^*) \tag{12}$$

$$\frac{\lambda_t h(i_t)}{\varphi'(\frac{I_t}{K_t})} = E_t \lambda_{t+1} \left[\frac{\alpha T A^T}{\kappa_1(K_{t+1}^T, K_{t+1}^N)} \left(\frac{K_{t+1}^T}{L_{t+1}^T}\right)^{-(1-\alpha T)} + \right.$$

$$+\frac{h(i_{t+1})}{\varphi'(\frac{I_{t+1}}{K_{t+1}})}\left[(1-\delta)+\varphi\left(\frac{I_{t+1}}{K_{t+1}}\right)-\varphi'\left(\frac{I_{t+1}}{K_{t+1}}\right)\frac{I_{t+1}}{K_{t+1}}\right]\Bigg] \tag{13}$$

$$(1-\alpha T)A^T\left(\frac{K_t^T}{L_t^T}\right)^{\alpha T}=(1-\alpha N)A^N\left(\frac{K_t^N}{L_t^N}\right)^{\alpha N}p_t^N \tag{14}$$

$$\alpha T A^T\left(\frac{K_t^T}{L_t^T}\right)^{-(1-\alpha T)}=\alpha N A^N\left(\frac{K_t^N}{L_t^N}\right)^{-(1-\alpha N)}p_t^N\left[\frac{\kappa_1(K_t^T,K_t^N)}{\kappa_2(K_t^T,K_t^N)}\right] \tag{15}$$

In these expressions, λ_t is the state-contingent Lagrange multiplier on the household's budget constraint (i.e., the marginal utility of wealth) and $h(i_t) \equiv 1+V(i_t)+V(i_t)S'(V(i_t))$ denotes the marginal transactions cost of private expenditures, where $1+i_t$ is the gross, risk-free domestic nominal interest rate (i.e., the reciprocal of the period-t price of a nominal bond that pays 1 unit of domestic currency in $t+1$). We refer to $h(i_t)$ as the model's monetary distortion. V is expressed as a function of i because it follows from (11) and (12) that in equilibrium the following condition holds:

$$S'(V_t)V_t^2=\frac{i_t}{(1+i_t)} \tag{16}$$

This condition equates the marginal benefit of holding an extra unit of real balances, in the left-hand-side of the equation, with the marginal opportunity cost of holding money, in the right-hand-side. Given the convexity of S, it is straightforward to show using (16) and the definition of the monetary distortion that both V and h are increasing in i.

The rest of the optimality conditions are also easy to interpret. Equation (8) determines the marginal utility of wealth. Equation (9) equates the marginal rate of substitution between C^T and C^N to p^N.[6] Equation (10) represents the optimal consumption-leisure tradeoff. Equations (11)-(13) are Euler equations that equalize the marginal cost of sacrificing a unit of current consumption with the marginal benefit of allocating the resulting extra savings into real balances, foreign assets, and aggregate capital respectively. Equations (14)-(15) indicate that optimal allocation of factors of production requires equalization of the sectoral marginal products of L and K, respectively.

The government issues money, from which it collects seigniorage, makes unproductive purchases of G units of traded goods, and makes transfer payments to households. We assume that a fraction η of the stream of inflation

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[6] Uribe (1998a) derived the price-consumption puzzle from expressions like (8)-(9), assuming perfect foresight and a fixed exchange rate. In this case, λ and i are time-invariant, so the right-hand-side of (8) is constant, and by (9) p^N is increasing in C^T/C^N. These results, and the fact that C is linear-homogeneous in (C^T, C^N) imply that C is decreasing in p^N.

tax revenue is allocated to public consumption, and the rest of the government revenue is rebated as a lump sum transfer. Hence the government budget constraint is:

$$G_t + T_t = m_t - \frac{m_{t-1}}{1+e_t}, \quad \textit{with}$$

$$\sum_{t=0}^{\infty} \frac{G_t}{(1+r*)^t} = \eta \sum_{t=0}^{\infty} \frac{m_{t-1}}{(1+r^*)^t} \left(\frac{e_t}{1+e_t}\right), \quad 0 \leq \eta \leq 1. \tag{17}$$

This constraint induces an endogenous tightening of fiscal policy at the time a currency peg begins. This is because, for as long as the peg is in place, the inflation tax is eliminated forcing the government to implement a cut in the primary deficit that exactly offsets the loss of revenue. Note that given the equilibrium process for seigniorage revenue, there are many processes for government spending consistent with the second equation in (17). However, all such processes imply identical equilibrium sequences for the endogenous variables in the model's competitive equilibrium defined below, except for lump-sum transfers and foreign bond holdings (and thus the current account and the trade balance).[7] To highlight the effects of adjustments in private expenditures on the cyclical dynamics of the trade balance during currency pegs, government expenditures are kept constant and equal to their prestabilization level while such a policy is in place.

The market-clearing conditions of each sector are the following:

$$C_t^N = A^N (K_t^N)^{\alpha N} (L_t^N)^{1-\alpha N} \tag{18}$$

$$C_t^T + I_t + G_t = A^T (K_t^T)^{\alpha T} (L_t^T)^{1-\alpha T} - B_{t+1} + (1+r^*)\, B_t - m_t V_t S(V_t) \tag{19}$$

Implicit in the market-clearing condition for the market of tradable goods (eq. (19)) is the assumption that the resources devoted to transactions costs are a deadweight loss for the economy as a whole. Alternatively, it could be assumed that revenue from transactions costs accrues to the government, and that the government decides what fraction of it to rebate and what fraction to spend in government purchases. If the government chose to use all transactions costs revenue to pay for government purchases, the results would be identical as in the case assumed in equation (19). Mendoza and Uribe (1997) explore alternatives in which the government may rebate a fraction of transactions costs revenue, and show how this affects the model's fiscal-induced wealth effect.

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[7] This is a form of Ricardian Equivalence that holds in the model because, given the present value of government purchases as determined by the present value of inflation-tax revenue, the timing of the government purchases does not affect consumption and leisure decisions. Decreases (increases) in public saving in any given period via changes in lump-sum transfers are offset by increases (decreases) in private saving via foreign bond holdings.

A competitive equilibrium for this model is defined by sequences of state-contingent allocations and prices $\left\{Ct, C_t^T, C_t^N,\ \lambda_t, L_t^T, L_t^N, L_t, K_t^T, K_t^N, K_{t+1},\right.$ $\left. I_t, m_t, i_t, V_t, p_t^N, G_t, T_t, B_{t+1}\right\}_{t=0}^{\infty}$ such that the conditions expressed in equations (2) and (4)-(19) hold for $t = 0, ...\infty$. When these conditions hold, households maximize utility subject to their budget constraint, firms maximize profits subject to the constraints imposed by sectoral production technologies and factor transformation curves, the government satisfies its budget constraint, and the market-clearing conditions in the markets of tradable and nontradable goods hold.

The focus of the paper is on examining the equilibrium dynamics of the model for the following policy experiment: The government implements an exchange-rate-based stabilization plan at date 0 but agents attach an exogenous positive probability to the abandonment of the plan. Specifically, at $t = 0$ the government sets $e_o = 0$ and announces the stabilization plan, but agents attach a time-dependent, conditional probability to the event that the plan may be abandoned with a devaluation of the currency.

The time-dependent devaluation probabilities, defined as $z_t = Pr[e_{t+1} > 0 | e_t = 0]$, are determined by the hazard rate function $Z(t)$. Following Calvo and Drazen (1998), Z is assumed to be exogenous and the reversal of the policy first implemented at date 0 is an absorbent state, thus $Pr[e_{t+1} > 0 | e_t > 0] = 1$. We also adopt their assumption that the policy variable has only two states. Hence, the depreciation rate is either $e_t = 0$ or $e_t = e > 0$, with e the same regardless of the date in which the devaluation occurs.[8] The post-collapse value of e is identical to its prestabilization value, which is the standard assumption of credibility models of exchange-rate-based stabilization (in which "collapse" is defined as a situation in which the rate of depreciation of the currency returns to its prestabilization value). Moreover, at some future date $J \leq \infty$ policy uncertainty is resolved, so if the stabilization plan is in place at $J - 1$, then at J the plan either fails permanently with probability Π or succeeds permanently with probability $1 - \Pi$.

The solution method used to compute the competitive equilibrium takes advantage of the two-state, Markovian specification of the expectations of devaluation. The solution method operates in the following manner. Since the state $e_t > 0$ is absorbent, each period the economy can either: (a) fol-

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[8] This assumption is not innocuous. As explained in Mendoza and Uribe (2001), a model in which the devaluation date and the post-collapse rate of depreciation of the currency are both endogenous would yield post-collapse values of the nominal interest rate and the monetary distortion $h(i)$ that vary with the timing of the collapse. Models of exchange-rate-based stabilization generally disregard these extra real effects because they emphasize real effects resulting from the fixed exchange rate, not from the magnitude of the devaluation with which the fixed exchange rate is abandoned.

low the optimal path corresponding to the state in which $e_t = 0$ at t, with z_t governing the probability of a switch to $e_{t+1} = e$, or (b) if $e_t = e$ at t there is a once-and-for-all switch to a perfect foresight path corresponding to that constant rate of depreciation. We then apply Uribe's (1998b) log-linear adaptation of the near-exact solution method used in the working-paper version of this paper (Mendoza and Uribe, (1997)) to solve for these two state-contingent equilibrium paths. In the Appendix of that working paper we described a near-exact solution method that solves directly the model's optimality conditions for a model similar to the one examined here, except that the perfect-foresight paths associated with $e_t = e$ feature constant trajectories for consumption and leisure. In that model, this property is a consequence of an extreme assumption regarding sectoral technologies, whereby firms in the nontraded sector were allowed to adjust only their use of labor and firms in the traded sector were allowed to adjust only their use of capital over the business cycle. In contrast, in the model studied here both sectors vary their use of capital and labor. As a result, all endogenous variables, except for the marginal utility of wealth, display time-dependent paths even under perfect-foresight. In this case, solving the model via the near-exact solution method becomes inefficient, and hence the switch to the log-linear method.

The log-linear algorithm keeps track of the state-contingent evolution of wealth, which is relatively easy to track given the two-state, absorbent Markovian specification of uncertainty. Similarly, the algorithm checks for the consistency of initial and terminal conditions so as to address the dependency on initial conditions of the model's deterministic stationary equilibrium (which is a typical feature of open-economy models with trade in noncontingent foreign bonds and standard preferences).[9]

4.3 *Benchmark calibration*

The values of most of the parameters set below were determined using Mexican data, but there are a few key parameters, particularly those that relate to the transformation curves for the sectoral allocation of capital, on which there is limited empirical evidence. The implications of varying these parameters are examined later by conducting a detailed sensitivity analysis.

Velocity and money demand. Given $S = AV^{\gamma}$ and equation (16), velocity is determined by: $V_t = (i_t/1+i_t)^{1/(1+\gamma)}(\gamma A)^{-1/(1+\gamma)}$. Since $V \equiv (C+I)/m$, it follows that the model predicts a log-linear relationship between money

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[9] If capital were homogeneous across sectors, the dependency on initial conditions can be addressed by solving directly the model's two-point boundary problem. With sector-specific capital, however, it is more efficient to circumvent the problem by allowing r^* to be a function of the stock of foreign debt with a negligible elasticity.

demand, expenditures, and the opportunity cost of holding money (i.e., $i/(1+i)$). The elasticity of money demand with respect to its opportunity cost is $-1/(1+\gamma)$ and the elasticity with respect to expenditures equals one. These predictions are strongly supported by the findings of recent econometric studies of the demand for M2 in Mexico before the 1994 crash (see Kamin and Rogers (1996) and Calvo and Mendoza (1996)). These studies used GDP, instead of private expenditures, as an explanatory variable of money demand, but we examined the performance of similar econometric models replacing GDP with $(C+I)$. The results are generally robust to this change. In particular, we obtained the same interest elasticity of money demand, -0.16 (with a standard error of 0.027), and we found strong evidence of a long-run, unitary expenditures elasticity and a robust cointegrating relationship between real M2, $i/(1+i)$, and $(C+I)$.[10]

Our estimate of the interest elasticity implies that $1/(1+\gamma) = 0.16$ so we set $\gamma = 5.25$. We then set A=0.548 by solving from $V_t = (i_t/1+i_t)^{1/(1+\gamma)}(\gamma A)^{-1/(1+\gamma)}$ setting V=0.374/4, which is the quarterly equivalent of the 1987 ratio $(C+I)$/M2 in the Mexican data, and setting i to 30 percent per quarter. The latter was determined by setting r^*=0.065 per year and by taking Mexico's observed tradables inflation rate of 170 percent per year (an average of annual inflation rates for the three-month period ending in February, 1988, when the exchange rate was fixed), and combining these figures with the assumptions of perfect capital mobility, PPP in tradables, and interest rate parity.

Preferences. The risk aversion coefficient, σ, is set at 5, which approximates the median of existing estimates for developing economies that range between 1.25 and 10 (see Reinhart and Végh (1995)). $\sigma = 5$ is also the lower-bound of estimates obtained for Mexico by Reinhart and Végh (1994). The elasticity of substitution between C^T and C^N is set to $1/(1+\mu) = 0.76$, reflecting the developing-country estimates produced by Ostry and Reinhart (1992). The parameter ω is set at a value such that, given the units in which the two consumption goods are measured, the steady-state share of consumption of nontradables in GDP is 0.56. The leisure exponent in utility is set imposing the standard real-business-cycle restriction that in steady-state households spend 20 percent of their time working. This implies $\rho = 1.5433$. For simplicity, the rate of time preference is assumed to be identical to r^*, so that $\beta = (1+r^*)^{-1}$.

Technology. The values of technology parameters are determined using national accounts data on sectoral factor payments and value added. The shares of labor income in value added are set to $1-\alpha^T = 0.26$ and $1-$

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[10] This implies that the money-demand regression can be efficiently estimated using as independent variables the logarithms of $i/(1+i)$ and lagged V, the annual change in $i/(1+i)$, and seasonal dummies (see Kamin and Rogers (1996)).

$\alpha^N = 0.36$, which are averages over the period for which data are currently available (1988-1996). The labor income shares of each of the 9 industries in which GDP is decomposed fluctuated very little over the sample period, suggesting that the Cobb-Douglas representation of sectoral value added is a reasonable approximation. The quarterly rate of depreciation of the capital stock, δ, is set at 1 percent, which, together with the other parameters of the model, implies a steady-state share of gross investment in GDP of 18 percent, consistent with Mexican data. This approach to calibrate δ to mimic the observed investment rate follows the calibration guidelines of Cooley and Prescott (1995).

The remaining technology parameters involve capital adjustment costs and the sectoral capital-transformation curve. Since these parameters cannot be directly related to Mexican data or existing econometric studies, we produced benchmark parameters aiming to match those features of the data that these parameters are likely to affect most directly. With regard to the capital-adjustment-cost function, the simulations require a value for the elasticity of investment with respect to Tobin's Q , which is given by $-1/[\delta\varphi''(\delta)]$. This elasticity is set so that the investment boom in the model is roughly consistent with Mexican data. The implied value of $\varphi''(\delta)$ is -1.8. For the capital transformation curve, the elasticity of substitution between K^T and K^N, defined as $\xi \equiv (\kappa_{12}\kappa)/(\kappa_1\kappa_2) \leq 0$, is set equal to -0.1, so as to match the increase in p^N that the VAR analysis attributed to devaluation risk (about 18 percent).

Policy variables. The fraction of the inflation tax assigned to government purchases, η, is set to 2/3 so as to match the observed share of government absorption in GDP at the end of 1987 (i.e., 18.5 percent). The rate of depreciation of the currency to which the economy switches when the stabilization plan ends is set so that the inflation rate of tradables returns to its prestabilization peak of *170* percent per annum.

Devaluation probabilities. The devaluation probabilities defined by Z are calibrated to be consistent with the existing empirical evidence on the time path of devaluation probabilities in managed exchange-rate regimes. Several studies provide strong evidence indicating that devaluation probabilities follow a J-shaped time path, both in Mexico and in many fixed-exchange-rate regimes across developing countries. This is true for studies that derive these probabilities from conditional one-step-ahead forecasts as well as for studies that derive them from within-sample regime-switching estimates.

Blanco and Garber (1986) estimated J-shaped devaluation probabilities for the Mexican peso before the devaluations of 1976 and 1982 using a Krugman-style model of balance-of-payments crises and one-step-ahead conditional forecast values of a money demand regression. The probability of collapse was 0.2 early in 1977, declining to near zero in about a year, rising slowly in 1978-79, and rising rapidly to about 0.4 before the 1982 devaluation. Goldberg (1994) extended the Blanco-Garber analysis to the 1980-86 period and found that the probability of collapse in early 1982 was in excess of 0.9. Klein and Marion (1997) used logit analysis to identify factors that influence the duration of currency pegs in a panel of monthly data for 17 countries over the 1957-91 period. They found strong evidence showing that sharp real appreciations predate devaluations and that devaluation probabilities are J-shaped. Probabilities of collapse one month before a devaluation are as high as 0.89, with 1/10 of the estimates higher than 0.55. In light of this evidence, we adopted a J-shaped hazard rate set below 0.5 when the program begins, falling to zero, and rising to about 0.8 prior to the collapse. J is set equal to 24, in line with the six-year duration of Mexican currency pegs observed since 1970, and it is also assumed that if the program survives until period $J-1$, then in period J it is abandoned for sure, that is, $\Pi = 1$.

5 Quantifying business cycles driven by devaluation risk

This section of the paper begins with a description of the transmission mechanism by which devaluation risk induces price and wealth distortions that drive business cycles. The series of quantitative experiments that follow are intended to assess the quantitative significance of these distortions.

5.1 *Devaluation risk as a source of business cycles*

The basic intuition for understanding the model's monetary transmission mechanism can be extracted from the optimality conditions that characterize the equilibrium. The key distortion that devaluation risk introduces in the model can be illustrated by rewriting equation (16):

$$S'(V_t^L)(V_t^L)^2 = \frac{r^*}{(1\ +\ r^*)} + \left[\frac{\lambda_{t+1}^H}{E_t[\lambda_{t+1}|e_t=0]}\right]\left(\frac{z_t e}{(1+e)(1+r^*)}\right) \qquad (20)$$

This is the equilibrium condition for the choice of m_t from the perspective of any date t in which the stabilization plan is in place, and hence the depreciation rate is currently at its low state $e_t^L = 0$, with the corresponding state-contingent choice for velocity V_t^L. In equilibrium, the marginal benefit of holding an extra unit of real balances, in the left-hand-side of (20), equals the opportunity cost of holding money in the right-hand-side. Thus, the term in the right-hand-side is also the nominal interest rate factor $i_t/(1+i_t)$.

Equation (20) shows that the domestic nominal interest-rate differs from the world interest rate because of the presence of currency risk in holding domestic money (recall that world inflation is assumed to be zero, so $r*$ in (20) denotes both the real and nominal world interest rates). In particular, the interest-rate differential reflects a distortion that takes the form of a risk-adjusted covered interest rate parity (IRP) condition. The second term in the right-hand-side of (20) shows that the time path of this distortion is governed by two effects: (a) changes in the expected rate of depreciation of the currency $z_t e$ and (b) fluctuations in the marginal utility of wealth in the high-depreciation-rate state of nature λ^H_{t+1} relative to its conditional mean $E_t[\lambda_{t+1}|e_t = 0]$. The first effect is exogenous to the model and corresponds to the standard IRP expected-depreciation premium under risk neutrality. The second effect, in contrast, is endogenous and reflects the risk-averse nature of households and the incompleteness of insurance markets (without either of these assumptions $\lambda^H_{t+1}/E_t[\lambda_{t+1}|e_t = 0] = 1$, and the conventional IRP condition holds). Moreover, we can also infer that the wealth effect enlarges the interest rate differential (i.e., $\lambda^H_{t+1}/E_t[\lambda_{t+1}|e_t = 0] > 1$) because a return to high inflation and high unproductive government purchases reduces wealth, which increases λ.

The interest-rate distortion affects the real sector via the monetary distortion $h(i)$, which has a direct effect on the relative prices governing the margins of decision-making that determine saving, investment, and labor supply. By combining equations (8) and (12), using the assumption that $\beta(1 + r*) = 1$, it is possible to show that $h(i)$ acts as a stochastic tax that alters the intertemporal relative price of C^T:

$$U_{C^T}(C^T_t, C^N_t, \ell_t) = E_t\left[U_{C^T}(C^T_{t+1}, C^N_{t+1}, \ell_{t+1})\left(\frac{h(i_t)}{h(i_{t+1})}\right)\right] \tag{21}$$

Since $h(i)$ is increasing in i and i increases with the probability of devaluation, the effective tax on saving (in terms of units of C^T) rises (falls) when the probability of devaluation rises (falls). Thus, an increasing (decreasing) probability of devaluation induces an intertemporal substitution effect that favors a decreasing (increasing) tradables consumption path.

The fact that devaluation risk induces a state-contingent interest-rate differential between the domestic economy and the rest of the world *even if the exchange rate is fixed* is a key feature that distinguishes this model from the existing models in the literature on exchange-rate-based stabilizations. In these models, the assumptions of perfect foresight and interest-rate parity imply that the domestic nominal interest rate cannot deviate from the world interest rate as long as the exchange rate is fixed. This is particularly important for comparing the model proposed here with models based on the perfect-foresight credibility approach of Calvo (1986). Consumption booms in those models result from an intertemporal substitution effect reflected in the perfect-foresight variant of condition (21) that holds *only* between the last period of a currency peg and the first post-collapse period. Between any two periods t and $t+1$ in which the exchange rate is fixed there is no substitution effect at work because under perfect foresight $i_t \approx r*$, and hence the intertemporal relative price of consumption equals 1. Moreover, the size of the substitution effect that hits the economy at the date of the collapse is also different in our model because, while the post-collapse nominal interest rate is the same as in the perfect-foresight models (i.e., the interest rate jumps to $i \approx r^* + e$ when a devaluation occurs), the last precollapse nominal interest rate in our model is state contingent and depends on the relevant values of z_t and the risk premium $\lambda^H_{t+1}/E_t[\lambda_{t+1}|e_t = 0]$.

As mentioned in Section 2, devaluation risk as modeled in this paper also introduces state-contingent wealth effects because of the assumed market incompleteness. The wealth and substitution effects operate jointly in a similar fashion as in Calvo and Drazen (1998). If the inflation tax were fully rebated to households, the distortions affecting the model would be limited to intertemporal and atemporal substitution effects. For as long as it lasts, a currency peg represents a sequence of "favorable" intertemporal relative price shocks. At each date t in the fixed-exchange-rate period, agents attach a certain probability to the scenario that prices at $t+1$ will rise with a devaluation, and hence have an incentive to over-consume. As $t+1$ arrives they realize they over-consumed and adjust consumption accordingly. In contrast, when the inflation tax finances G, the intertemporal substitution effect can be offset by a wealth effect. Each period that the peg survives, the households' wealth rises by the amount of the foregone unproductive expenditures. If the elasticity of intertemporal substitution is sufficiently low, the wealth effect dominates and consumption rises over time.

The model's optimality conditions can be rearranged to show how the devaluation risk also imposes the equivalent of stochastic taxes on capital and labor income via the monetary distortion:

$$U_{C^T}(C_t^T, C_t^N, \ell_t)\left[\varphi'(\frac{I_t}{K_t})\right]^{-1} =$$

$$E_t \frac{U_{C^T}(C_{t+1}^T, C_{t+1}^N, \ell_{t+1})}{h(i_{t+1})} \left[\frac{\alpha T A^T}{\kappa_1(K_{t+1}^T, K_{t+1}^N)} \left(\frac{K_{t+1}^T}{L_{t+1}^T}\right)^{-(1-\alpha T)} \right.$$

$$\left. + \frac{h(i_{t+1})}{\varphi'\left(\frac{I_{t+1}}{K_{t+1}}\right)} \left[(1-\delta) + \varphi\left(\frac{I_{t+1}}{K_{t+1}}\right) - \varphi'\left(\frac{I_{t+1}}{K_{t+1}}\right)\frac{I_{t+1}}{K_{t+1}} \right] \right] \tag{22}$$

$$\frac{U_\ell(C_t^T, C_t^N, \ell_t)}{U_{C^T}(C_t^T, C_t^N, \ell_t)} = \frac{(1-\alpha T)A^T}{h(i_t)} \left(\frac{K_t^T}{L_t^T}\right)^{\alpha T} \tag{23}$$

The monetary distortion taxes the marginal product of newly installed capital at a rate of $1/h(i_{t+1})$ and the real wage on current labor supply at a rate of $1/h(i_t)$. These distortions are similar to the so-called "supply side" distortions induced by the transaction costs setup under perfect foresight (see

Uribe (1997) and Lahiri (1996)). These distortions affect both transitional dynamics and the steady state because a once-and-for-all disinflation cuts transaction costs permanently, thereby releasing resources to finance a permanently higher capital stock and reducing permanently the wedge between the real wage and the marginal rate of substitution between consumption and leisure.

The intuition for the behavior of the real exchange rate can be derived by combining equations (14) and (15) to solve for p^N as the slope of the PPF of tradables and nontradables and taking logs of the resulting expression (assuming for simplicity that $\kappa(K^T, K^N) = [(K^T)^{-\nu} + (K^N)^{-\nu}]^{-1/\nu}$, where $\xi = 1/(1+\nu)$ and $\nu \leq 0$):

$$Ln(p_t^N) = \left[Ln\left(\left(\frac{1-\alpha T}{1-\alpha N}\right)^{1-\alpha T} \left(\frac{\alpha T}{\alpha N}\right)^{\alpha T} \left(\frac{A^T}{A^N}\right) \right) + \right.$$

$$\left. (\alpha T - \alpha N) Ln\left(\frac{K_t^N}{L_t^N}\right) \right] - \frac{\alpha T}{\xi} Ln\left(\frac{K_t^N}{K_t^T}\right) \tag{24}$$

This expression illustrates how sector-specific capital alters the determination of p^N relative to the Balassa-Samuelson result described in Section 4. The Balassa-Samuelson result is the term in square brackets in the right-hand-side of (24). This term shows that the time series variation of p^N is determined by the fraction $\alpha T - \alpha N$ of the change in the capital-labor ratio of the nontradables sector. Sector-specific capital modifies this result by introducing changes in p^N as a result of sectoral reallocations of capital, even if capital-labor ratios remain constant or if $\alpha T = \alpha N$. The elasticity of the real exchange rate with respect to K^N/K^T is given by $-\alpha T/\xi$, which is nonnegative because $0 \leq \alpha T \leq 1$ and $\xi \leq 0$. Note, however, that (24) is not a closed-form solution for the real exchange rate, but only a condition that reflects efficient factor allocation. The equilibrium real exchange rate also depends on the optimal sectoral allocation of consumption, as determined by equation (9). Both (9) and (24) include terms that depend on the entire equilibrium dynamics of the model, which in general cannot be reduced to closed-form solutions.

It is also important to note that the monetary distortion does not affect directly the slope of the PPF in the right-hand-side of (24), or the marginal rate of substitution between C^T and C^N in the left-hand-side of (9). Hence, the monetary distortion affects the real exchange rate only indirectly through its effects on capital accumulation, labor supply, and sectoral allocations of capital, labor, and consumption.

5.2 *Benchmark simulation*

The state-contingent dynamics that characterize the competitive equilibrium under the benchmark calibration are summarized in Table 1 and Figure 6. Table 1 compares the amplitude of the fluctuations in major macroeconomic aggregates in the model with those obtained from the data. Figure 6 provides charts that plot the percent deviations from the prestabilization steady state of output, velocity, net exports, aggregate consumption, sectoral consumption allocations, the real exchange rate, gross investment, and labor supply, together with the J-shaped hazard rate function. The continuous line in each chart represents the equilibrium path that a variable follows in the state of nature in which the exchange rate remains fixed. The dotted line indicates the value to which the variable jumps on impact when a devaluation occurs on the corresponding date in the horizontal axis. Thus, the dotted lines do not reflect trajectories in time of macroeconomic aggregates but just their "jump values."

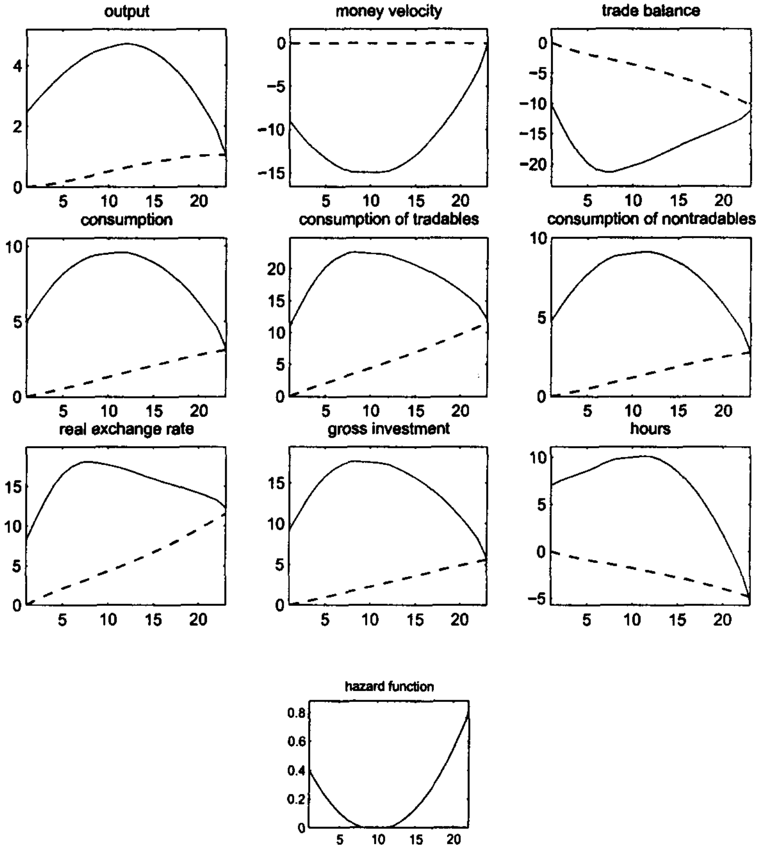
Table 1 and the charts in Figure 6 show that the benchmark simulation produces cyclical dynamics that are roughly in line with several of the stylized facts documented in Section 2:

1. The model produces boom-recession cycles in GDP, consumption, and investment with recessions that predate the devaluation. The amplitude of the booms in GDP and consumption are roughly consistent with the empirical evidence. The investment boom is also in line with the data, but this result reflects the criterion used to calibrate the investment elasticity of Tobin's Q.

2. Consumption and the real exchange rate are highly, but not perfectly, correlated as found in the data. This result shows that the price-consumption puzzle can be solved by introducing uncertainty and incomplete markets. These two features make the monetary distortion and the marginal utility of wealth contingent on the state of nature, allowing currency risk to yield equilibrium dynamics in which the relative price of nontradables and consumption increase at the same time. With $\xi = -0.1$, the model yields a sharp real appreciation of about 18 percent in the first two years of the program. The real exchange rate then stabilizes and begins to depreciate gradually, but still ends appreciated by about 13 percent even if the stabilization plan lasts to its maximum duration.

3. The model is also consistent with the qualitative pattern of expansion followed by contraction observed in sectoral data. The short sample of

Figure 6: The Dynamics of a Currency Peg of Uncertain Duration



All variables, except for the hazard rate, are expressed in percentage deviations from their pre-stabilization steady-state levels. Solid lines denote pre-collapse values and broken lines denote at-collapse values.

Table 1

Amplitude of Business Cycles During an Exchange-Rate-Based Stabilization 1/
(cyclical components of Mexican data, 1988-1994 and model simulations)

	Mexican Data	Model Simulations		
		Benchmark (J-shaped hazard rate)	Flat Hazard rate	Perfect foresight
Gross domestic product (peak 88:2, trough 92:3)	5.01	4.73	3.93	5.81
Private consumption (peak 88:1, trough 92:1)	9.91	9.57	8.55	10.93
Fixed investment (peak 88:1, trough 92:1)	17.92	17.69	15.06	19.60
Net exports/GDP ratio (trough 88:1, peak 92:4)	11.31	6.00	5.47	7.38
Money Velocity (trough 88:1, peak 93:1)	28.92	14.93	10.93	14.93
Real exchange rate	41.50	18.15	18.81	22.42

1/ Absolute values of the distance from trough to peak or peak to trough in percentage points, except the real exchange rate which was not detrended.

the sectoral data does not allow us to isolate the cyclical components needed for an accurate quantitative comparison, but still the model is consistent with the data in showing faster growth in tradables consumption than in nontradables consumption in the early stages of the peg.

4. The private trade balance (i.e., net exports excluding public absorption, which remains constant for the duration of the plan) worsens markedly on impact, continues to decline for the first two years of the program, and then displays a gradual recovery. Still, even if the plan lasts to its maximum duration, net exports remain 12 percent below the prestabilization level.

5. Velocity falls sharply in a sudden jump of 10 percent when the program begins, and continues to fall gradually for the first 10 quarters of the program, before it begins to rise gradually for the rest of the duration of the peg. The amplitude of the fluctuations in velocity in the model is nevertheless significantly smaller than that measured in the data. Note also that velocity always switches to its prestabilization value whenever the currency is devalued. This follows from equation (16) and the assumption that the post-collapse rate of depreciation of the currency is identical to its prestabilization value.

The results of the benchmark simulation reflect the time path of the stochastic distortions that currency risk imposes on the relative prices relevant for money demand, investment, saving, and labor supply. Since in equilibrium there is a monotonic, increasing relationship between V and either i or $h(i)$, it follows that both the nominal interest rate and the monetary distortion follow similar U-shaped paths as velocity does in Figure 6. Thus, the taxes on capital and labor fall for the first 10 quarters that the stabilization plan is in place, and rise for the remainder of the peg. The tax on saving, which is the ratio $h(i_t)/h(i_{t+1})$, also falls for the first 10 quarters and increases during the latter stages of the peg. Consumption, labor supply, and investment expand while the taxes decline and contract during the period in which the taxes increase.

5.3 *Comparison with quantitative perfect-foresight studies*

Overall, the benchmark simulation shows that the quantitative implications of the distortions induced by devaluation risk are significant. This deviates from the findings of existing quantitative studies on the syndrome of exchange-rate-based stabilizations based on perfect-foresight models. For example, Reinhart and Végh (1995) simulated Calvo's (1986) endowment-economy model using the observed temporary declines in nominal interest rates, duration of stabilization plans, and econometric estimates of σ. They found that for the model to predict realistic consumption booms, the fall in interest rates needed to be significantly larger than observed in the data. Even if this were the case, consumption jumps on impact as the stabilization begins, and remains constant until it collapses when the program is abandoned, so cyclical dynamics and the price-consumption puzzle cannot be accounted for.

The comprehensive study of Rebelo and Végh (1996) simulated several variants of a two-sector, general-equilibrium framework, including the staggered-price credibility model of Calvo and Végh (1993). They found that consumption booms and real appreciations are still underestimated by a large margin. In their best-case scenario, which requires staggered prices, the real exchange rate appreciates gradually and peaks at about 5 percent. Their results also established other important drawbacks of deterministic models in trying to account for the dynamics of consumption and output. Consumption of tradables (nontradables) rises on impact by 5 percent and then rises (falls) gradually until it collapses on the date of the devaluation. The real appreciation is driven by a fall in the supply of nontradable goods that begins immediately after the announcement of the plan. This sustained decline in nontradables production and consumption is sharply at odds with empirical evidence, which (as documented in Section 3) shows large booms in both during the early stages of the Mexican plan. Moreover, the models simulated by Rebelo and Végh belong to the class in which the price-consumption puzzle remains unresolved.

The flexible-price models examined by Rebelo and Végh differ from the typical deterministic credibility model a'la Calvo (1986) in that they do not display the sudden jump of consumption at the time the stabilization plan is introduced to a constant level for the duration of the stabilization plan. This is a result of the combination of four features of their analysis: (a) capital adjustment costs, (b) the presence of investment in transaction costs, (c) perfect sectoral labor mobility with Cobb-Douglas technologies, and (d) the utility function proposed by Greenwood, Hercowitz, and Huffman (1988), which eliminates the wealth effect on labor supply. However, investment and real balances still display sudden jumps which are at odds with the cyclical pattern observed in the data, and without features (c) and (d) the discrete consumption jumps re-emerge. Rebelo and Végh also found that labor supply exhibits a counter-factual fall if the Greenwood-Hercowitz-Huffman specification of preferences is replaced with the standard isoelastic utility function.

Comparing with the quantitative findings of Reinhart and Végh (1995) and Rebelo and Végh (1996), the benchmark simulation of the devaluation-risk model produces larger real appreciations and business cycles, and is able to account for the price-consumption puzzle. In accounting for these differences, it is worth recalling that the devaluation-risk model shares several features of the deterministic models in terms of the specification of preferences and technology (such as the CES aggregator of sectoral consumption, the constant-returns-to-scale technologies, and the use of money to economize transactions costs). Thus, the marked differences in equilibrium dynamics result directly from the introduction of uncertainty and the assumed asset-market structure (with the implicit fiscal-induced wealth effects).

The 18-percent real appreciation in the benchmark simulation is more than three times larger than those produced by deterministic models. As the sensitivity analysis undertaken later confirms, the larger real appreciation results from the combination of incomplete markets and the temporary fiscal cuts. In the deterministic studies cited above, government revenue is fully rebated to the public, so there is no temporary cut in government expenditures while the stabilization plan is in place. Even if fiscal revenue were not rebated in the deterministic models, they would still have difficulty producing large real appreciations and cyclical dynamics because they would behave as complete-markets models in which the wealth effect of the nonrebated fiscal revenue leads to a once-and-for-all change in the marginal utility of wealth on the same date that the stabilization plan is introduced. Moreover, the assumptions that stabilization is accompanied by substantial fiscal retrenchment and that the duration of this fiscal adjustment is as uncertain as the duration of the currency peg seem in line with the stance of fiscal policy observed in Mexico during 1987-1994 and in the aftermath of the crisis in 1995.

Despite the larger real appreciation compared to the results of deterministic models, the 18-percent real appreciation produced by the benchmark simulation is still less than 1/2 the full real appreciation identified in the Mexican data – even though it is close to the 20-percent appreciation that the VAR analysis attributed to devaluation risk. Hence, devaluation risk still leaves unexplained an important fraction of the change in relative prices observed in Mexico.

Resolving this "real exchange rate puzzle" remains an important task which would likely require combining the effects of various relevant factors affecting the relative price of nontradables. One factor is the far-reaching economic reform that Mexico (and other emerging markets) experienced at the same time that exchange-rate-based stabilization was undertaken. Fernández de Córdoba and Kehoe (2000) show in an exercise applied to Spain that, as long as production technologies feature sector-specific inputs analogous to those present in the model studied here, the liberalization of capital flows can produce a large real appreciation. Another potentially critical factor is the "credit channel" or "financial accelerator multipliers" that might have been at work because stabilizing economies may operate under binding borrowing constraints, due to credit-market frictions like margin requirements or collateral constraints. Mendoza (2001) provides some early results gauging the contribution of these frictions.

5.4 *Sensitivity analysis*

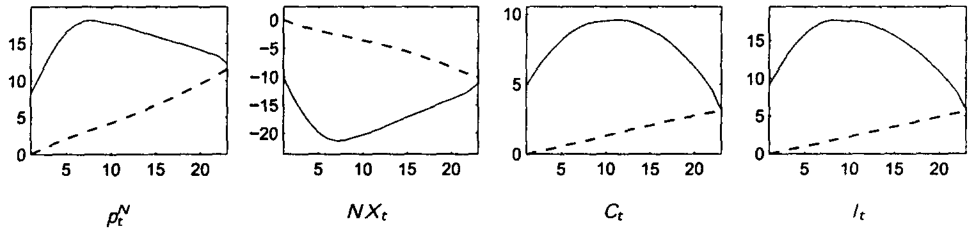
The robustness of the results obtained in the benchmark simulation is assessed by conducting an extensive sensitivity analysis. This analysis serves to identify those features of the model that are critical for producing the positive results of the benchmark simulation, and it also serves to isolate the features of the model that may account for its weaknesses. For instance, the sensitivity analysis shows that two important drawbacks of the benchmark simulation (i.e., that it cannot mimic the observed pattern of a stable real exchange rate inbetween periods of sharp appreciation, and that it produces a boom in tradables consumption larger than observed in the data) can be remedied with plausible alternative parameterizations of the model.

Figure 7 summarizes the results of the sensitivity analysis by presenting plots for the dynamics of the real exchange rate, net exports, aggregate consumption, and investment for several alternative model specifications. The first row reproduces the results of the benchmark simulation and the rest are for the following experiments: (1) a flat, linear hazard rate, set such that the conditional probability of devaluation is 28 percent for all $0 \leq t < J$ (a value that reflects the same unconditional expectation of devaluation implicit in the J-shaped hazard-rate function of Figure 6), (2) a perfect-foresight case ($z_t = 0$ for $0 \leq t < J$ and $z_t = 1$ for $J - 1 = 23$), (3) no adjustment in government expenditures (full rebate of the inflation tax revenue, $\eta = 0$), (4) extended maximum duration of the stabilization plan ($J = 36$), (5) unitary elasticity of substitution between C^T and C^N ($\mu = 0$), (6) high labor share in nontradables ($1 - \alpha^N = 0.6$), (7) low elasticity of substitution between K^T and K^N (ξ = -0.0001), (8) high elasticity of substitution between K^T and K^N (which is the case in which capital is homogeneous across sector, or $\xi = -1$), (9) nonzero long-run probabilities of success of the stabilization program ($\Pi = 1/10$ and $\frac{1}{2}$), (10) production with intermediate inputs, (11) high prestabilization money velocity (V= 15.4 per year, which corresponds to Mexico's M1 money balances), (12) logarithmic utility (σ =1), and (13) inelastic labor supply (ρ =0).

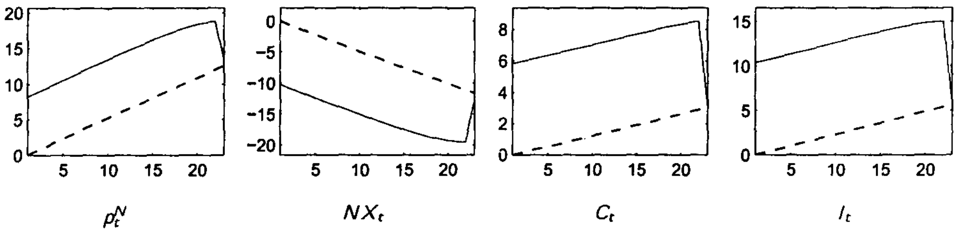
The results for the flat-hazard-rate case, compared to the benchmark case, show that the J-shaped Z is an essential element of the analysis. The flat hazard rate produces a sustained boom for the entire duration of the currency peg, and hence cannot explain the observed cyclical dynamics and

Figure 7: Sensitivity Analysis

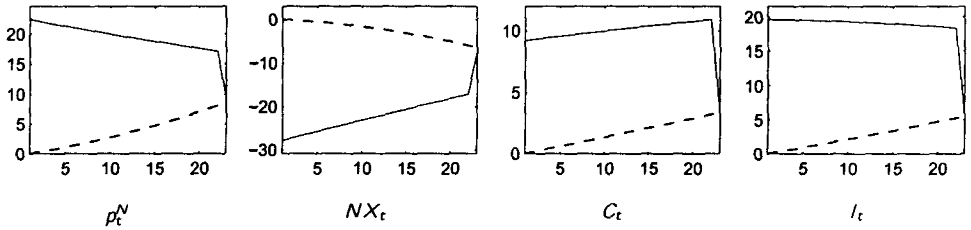
The benchmark model



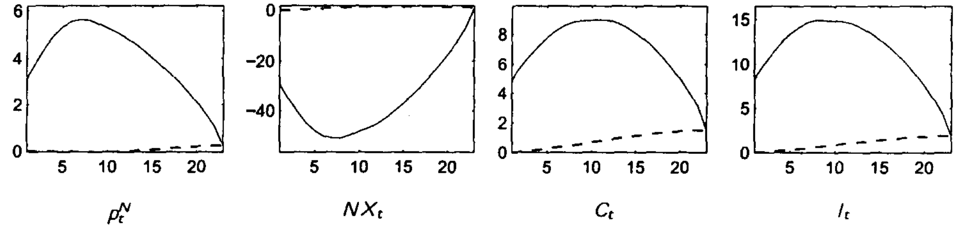
Flat hazard rate



Perfect foresight



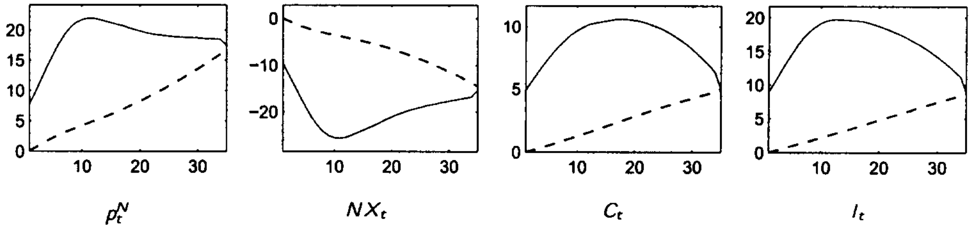
Full rebate of the inflation tax ($\eta = 0$)



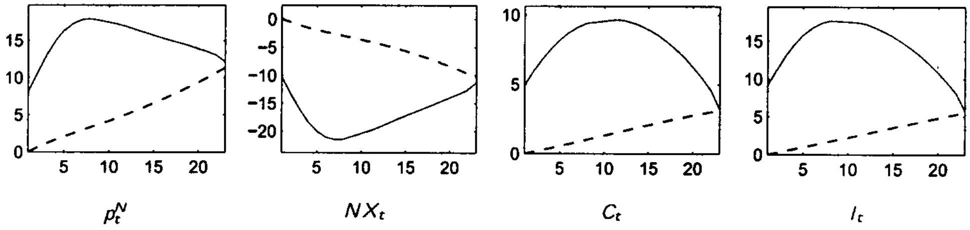
* All variables are expressed in percentage deviations from their pre-stabilization steady-state levels. Solid lines denote pre-collapse values and broken lines denote at-collapse values.

Figure 7: continued

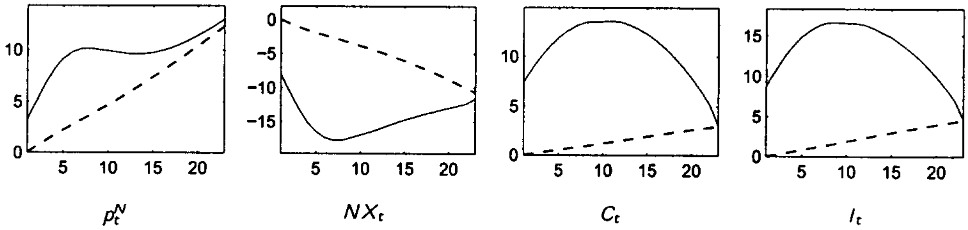
Extended maximum duration ($J = 36$)



Cobb-Douglas aggregator function ($\mu = 0$)



High labor share in nontradables ($\alpha^N = .6$)



Low elasticity of substitution between traded and non-traded capital ($\xi = -10^{-5}$)

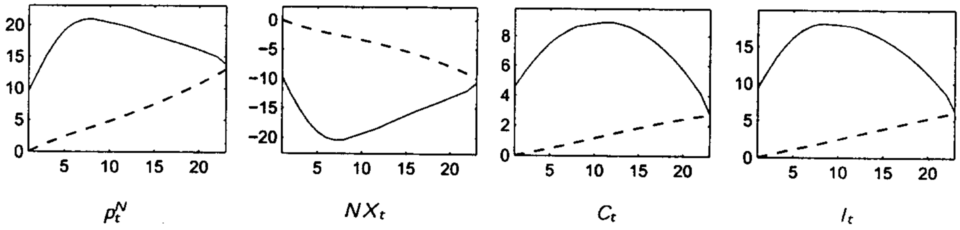
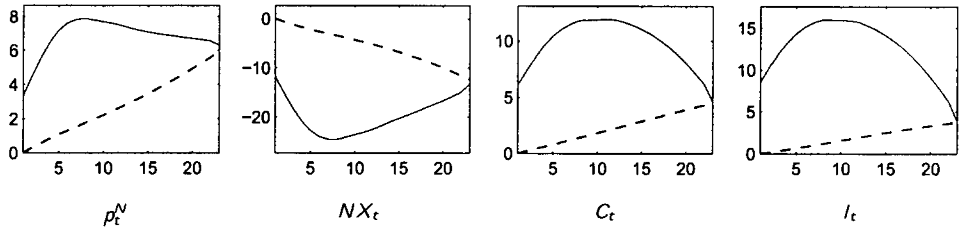


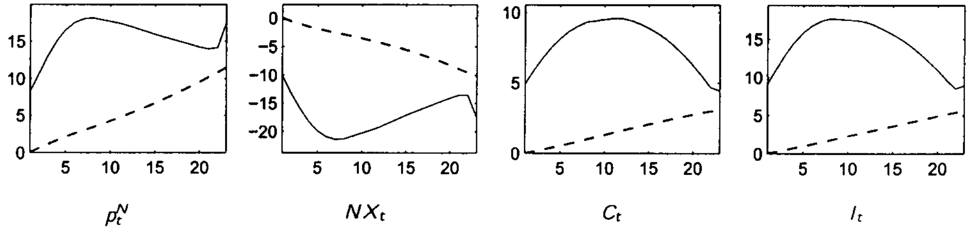
Figure 7: continued

Unitary elasticity of substitution between traded and non-traded capital ($\xi = -1$)

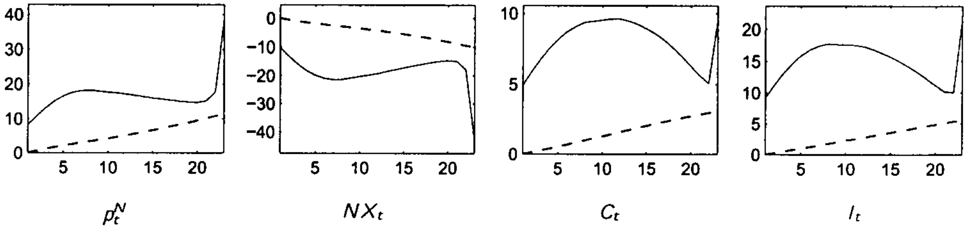


Non-zero probability of long-run success

$Pr(e_J = e^H / e_{J-1} = e^L) = .9$ and $Pr(e_{J+j} = e^i / e_J = e^i) = 1$ for $i = H, L$ and $j > 1$



$Pr(e_J = e^H / e_{J-1} = e^L) = .5$ and $Pr(e_{J+j} = e^i / e_J = e^i) = 1$ for $i = H, L$ and $j > 1$



Intermediate materials

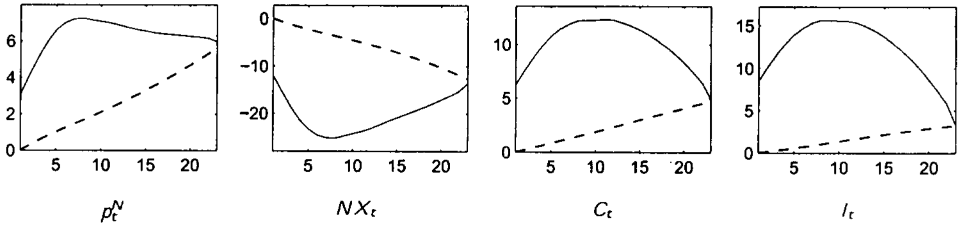
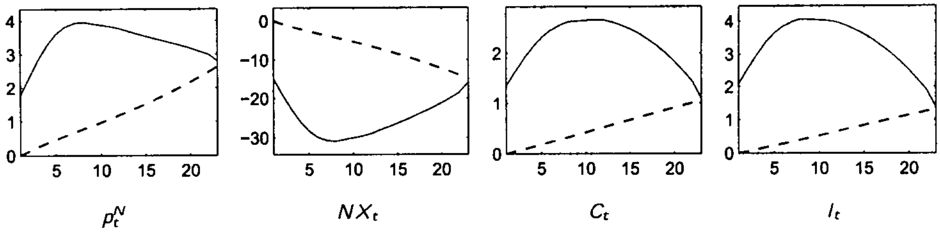
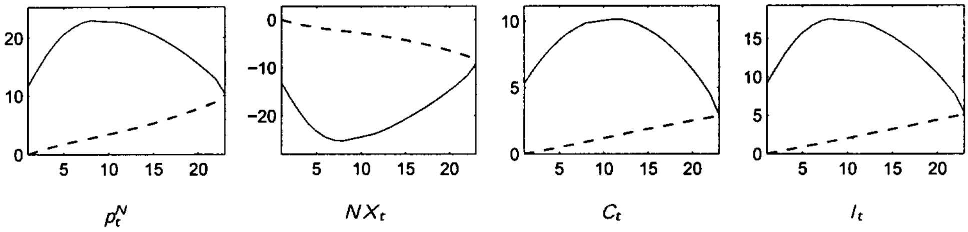


Figure 7: continued

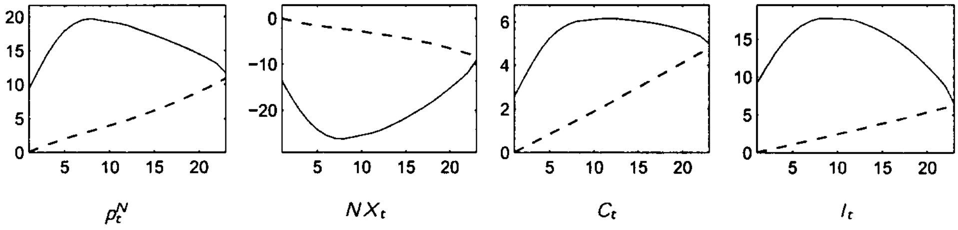
High money velocity ($V^H = 15.4$ per year)



Log period utility ($\sigma = 1$)



Inelastic labor supply ($\rho = 0$)



the nonlinearities of real appreciations. The flat hazard rate also lowers the amplitude of the fluctuations in output, expenditures, and the real exchange rate (see Table 1). The sustained booms in consumption and investment result from the manner in which the flat hazard rate sets the time path of the stochastic tax-like distortions driving the model. A flat Z implies that the expected rate of depreciation, $z_t e$, is constant for $t = 0, ..., J-1$. Hence, it follows from equation (20) that any time-series variation in the interest rate differential, which governs $h(i)$ and thus the taxes defined in (21)-(23), is driven only by the currency risk premium resulting from state-contingent fluctuations in wealth (i.e., the ratio $\lambda^H_{t+1}/E_t[\lambda_{t+1}|e_t = 0]$). The numerical results show that these wealth fluctuations result in declining taxes on saving and investment for the entire duration of the peg. This is because every period that the peg survives increases the households' wealth by adding to permanent income the foregone government expenditures that would have been absorbed under high inflation.

The above result highlights an important difference between the devaluation-risk model and the uncertain-duration model of Calvo and Drazen (1998). Calvo and Drazen obtained an analytical result showing that consumption always follows a strictly-increasing path for the entire duration of a tariff cut of uncertain duration, regardless of the time path of the probability of reversal of the tariff cut. They proved this result in a partial-equilibrium setting with incomplete markets and fiscal-induced wealth effects (and also with $\sigma > 1$). In their setting, consumption is strictly increasing because at any date t in which the tariff cut continues, the addition to permanent income implied by foregone tariff revenue dominates the intertemporal substitution effect implied by the fact that the expected tariff for $t+1$ is *always* higher than the tariff at t. In contrast, Figure 7 shows that their result does not hold in the devaluation-risk model: a flat hazard rate produces linear, upward-sloping dynamics, in line with their result, but a J-shaped hazard rate yields cyclical dynamics.

The shape of the hazard-rate function is a key determinant of the shape of equilibrium dynamics in the devaluation-risk model because the distortions driving the model are time-variant (i.e., the expected nominal interest rate at $t+1$ can be higher or lower than at t). This in turn reflects the fact that, in the Calvo-Drazen setup, uncertain duration of a tariff cut affects the timing of the reversal of the cut but not the value of the reduced tariff during the period that the cut is in place. In contrast, the risk of devaluation affects both the timing of a jump in the nominal interest rate *and* the time path of the interest rate while the peg is in place. The devaluation-risk model also differs from the Calvo-Drazen framework in that the general-equilibrium effects provide a channel for the shape of Z to affect investment and labor, and hence the dynamics of wealth and consumption. Through these state-contingent wealth effects, the model provides as well a channel for the time-varying pattern of the nominal interest rate to reflect not only the *exogenous* devaluation probabilities defined in Z, but also the endogenous currency-risk-premium that captures the households' aversion to the fluctuations in the marginal utility of wealth across the devaluation and nondevaluation states of nature.

The perfect-foresight simulation in Figure 7 shows that in the absence of uncertainty the model's dynamics virtually revert to the standard results of Calvo's (1986) deterministic credibility model. Consumption, investment, and the real exchange rate jump up on impact as the program begins, and collapse when the program ends, but for the duration of the plan they remain nearly unchanged – although the overall amplitude of the fluctuations in these variables is similar to that in the benchmark case (see Table 1). Consumption and the real exchange rate both rise when the stabilization plan is introduced, but for the rest of the duration of the plan they move in opposite directions because under perfect foresight the model displays the price-consumption puzzle. Note that consumption does not remain constant while the plan is in place but displays a trivial boom instead. This deviates from Calvo's findings. However, Mendoza and Uribe (1997) show that if the specific-factors technology is taken to the extreme capital (labor) is a fixed factor in the production of tradables (nontradables), the perfect-foresight simulation reproduces *exactly* Calvo's results – despite the presence of investment with adjustment costs and the supply-side distortions of the transactions costs technology.

The simulation with full rebates of the inflation tax sheds light on another key element of the benchmark simulation: the state-contingent, fiscal-induced wealth effects that result from the endogenous surge in government expenditures accompanying the collapse of the stabilization plan. The simulation with full rebates rules out these wealth effects. The model produces cyclical dynamics *qualitatively* similar to those of the benchmark model, but from a *quantitative* standpoint one major difference emerges: the model produces a modest real appreciation that peaks at 5 percent, followed by a near full-reversal to the prestabilization value of p^N if the program lasts to its maximum duration. Thus, state-contingent wealth effects are critical for explaining large real appreciations. There remains an open question as to whether effects of this kind are commonly present in countries affected by the syndrome of exchange-rate-based stabilizations. The empirical evidence documented for Mexico in Section 3 suggests that these effects were nontrivial in the Mexican case, but further evidence for other countries would have to supplement this finding.

The values of the utility parameter determining the elasticity of substitution in consumption of tradables and nontradables (μ) and the date of resolution of policy uncertainty (J) do not alter the outcome of the simulations significantly – except for the fact that $J = 36$ produces a larger real appreciation and a slightly larger consumption boom than the benchmark case. The quantitative results suggest that the move to Cobb-Douglas preferences, in which $1/(1+\mu) = 1$, is not a radical departure from the 0.76 elasticity in the benchmark case. However, as equation (9) suggests, this elasticity has the potential for affecting significantly sectoral consumption allocations, and thus the behavior of the real exchange rate, if it were allowed to vary more widely. Still, for the resulting adjustment to be reflected more in p^N than in the sectoral allocation of consumption, the change in the elasticity would need to be complemented with consistent changes in the sectoral allocation of factors of production.

The simulation that increases the share of labor income in the nontradables sector to 0.6, a value more in line with evidence from industrial countries, yields results similar to the benchmark simulation except for one major change: the real exchange rate now displays the nonlinear path observed in the Mexican data, with a period of stability inbetween two rapid appreciations. This result needs to be interpreted with caution. Equation (24) implies that, everything else the same, the change in sectoral factor intensities induced by increasing $1 - \alpha N$ while keeping $1 - \alpha T$ constant can make p^N increase instead of fall in the latter stages of the program. However, the change in factor intensities applies to the entire simulation period, and hence it alone cannot explain why the shape of the time path of p^N deviates from that in the benchmark simulation when t approaches J but not before. Thus, the change in factor intensities is working jointly with the frictions introduced by sector-specific capital and capital-adjustment costs so that, as investment declines gradually in the latter stages of the program, the ratio of K^N relative to K^T increases.

The next two experiments examine alternatives of the specific-factors setup. We reduced sharply the elasticity of substitution between K^T and K^N by setting $\xi = -0.0001$, compared to -0.1 in the benchmark, and tried also increasing the elasticity significantly to the point that capital is homogeneous across sectors: $\xi = -1$. In the first case, the reduced elasticity of substitution results in a larger real appreciation, which now peaks at around 21 percent (three percentage points more than in the benchmark), as equation (24) would predict. The reduced ability to shift capital across sectors weakens the aggregate consumption boom, as the supply response of the nontradables sector in the early stages of the peg is also weakened. In the second case, with unitary elasticity of substitution, the maximum real appreciation is about 7 percent (less than $\frac{1}{2}$ that produced in the benchmark case). These results are illustrative of the importance of sector-specific factors of production in allowing equilibrium models to explain large variations in the relative price of nontraded goods. Unfortunately, there are serious gaps in empirical research in this area, and as a result there is little evidence to defend a particular parameterization of sectoral elasticities of factors of production. The aim here was to illustrate the key role that these elasticities play in accounting for the dynamics of the real exchange rate rather than take a position on particular values for them.

The results of the benchmark simulation do not depend critically on the assumption that the program fails with probability 1 after six years. If the long-run probability of collapse after six years is 1, 0.9, or 0.5, equilibrium dynamics before the 20th quarter are nearly identical in all three experiments, although after that date they differ markedly. This result reflects again the state-contingent nature of wealth under incomplete markets: the wealth effects of a stabilization plan that manages to last 20 quarters or more, hence keeping wasteful government absorption low for that long, cannot affect optimal plans until that state of nature is realized. The same result also shows that the syndrome of exchange-rate-based stabilization can occur *regardless of the long-run probability of success of the stabilization plan.* Whether the plan fails for sure or with 50/50 odds does not alter the fact that the economy experiences an expansion in output and expenditures, a sharp real appreciation, and a decline of money velocity of roughly the same magnitude in the early stages of the plan. However, as we discuss later in the welfare analysis, the normative implications of the model do vary significantly depending on the long-run probability of success of the plan and the implied sharp differences in equilibrium dynamics after the 20th quarter.

The next simulation modifies the production technologies to explore the implications of incorporating intermediate inputs. This is done by following the specification proposed by Kehoe and Kehoe (1994). In particular, we use Leontieff production functions in terms of a mix of intermediate inputs and value added, while retaining the Cobb-Douglas specification to represent value added. We calibrate the model to match the observed sectoral ratios of gross production to value added in Mexico's national income accounts, and set the values of the Leontieff coefficients that measure the use of intermediate inputs in each industry using the 1989 Mexican input-output matrix (further details are available from the authors on request). This change results in a sharp *decline* in the size of the maximum real appreciation that the model produces (the maximum appreciation is now about 7 percent). Hence, explaining the observed real appreciation in this environment would require lowering more the elasticity of substitution between the sectoral capital stocks (ξ) relative to the benchmark case. Interestingly, the model with intermediate inputs yields similar results as the scenario in which ξ is high. This suggests a form of equivalence in which production technologies with intermediate inputs can be reasonably approximated by specific-factors technologies.

The simulation calibrated to M1 velocity is motivated by the fact that while M2 is a good proxy for money balances used in transactions in Mexico, it includes some interest-bearing assets on which the inflation tax is collected at a rate smaller than the rate of inflation. Thus, the M2 specification approximates well transaction costs, but exaggerates inflation tax revenue, while the M1 specification is better at measuring inflation tax revenue but underestimates transaction costs. The simulation using M1 produces dynamics that are qualitatively similar to the benchmark case, but from a quantitative standpoint the magnitude of the booms in consumption and investment, and of the real appreciation, are now small. This occurs because the wealth effects at work using M1 are weakened considerably since government purchases now increase by a smaller amount in the devaluation state of nature (as inflation tax revenue is smaller) and the amount of resources lost to cover transactions costs is also smaller. Hence, these results show that the larger wealth effects at work in the benchmark case using M2 are critical for the model's ability to explain the magnitude of booms and real appreciations.

Changes in σ and ρ, lowering the former to represent log-utility and the latter to make labor supply inelastic, alter the results mainly by enlarging the maximum real appreciation that the model can produce by 5 and 2 percentage points, respectively. These two scenarios are related because changes in σ in fact affect both the intertemporal elasticity of substitution in consumption $(1/\sigma)$ and the intertemporal elasticity of leisure $(1/[1-\rho(1-\sigma)])$. The case with inelastic labor supply also weakens significantly the decline in aggregate consumption during the late stages of the peg because in this case the supply of nontradables is very slow to adjust. It can only be adjusted by changing K^N, which is difficult to do because of the adjustment costs in aggregate capital and the low elasticity of substitution between capital across sectors. Hence, the general-equilibrium effects that result from endogenizing labor supply play an important role in allowing the benchmark simulation to produce recessions that predate the collapse of the currency, particularly in the nontraded goods sector. As a corollary, the J-shaped hazard rate is necessary but not *sufficient* to yield realistic business-cycle dynamics. The J-shaped hazard rate combined with a low elasticity of labor supply renders the model unable to mimic the downturn in consumption.

5.5 *Welfare implications*

Stabilization policy anchored on exchange-rate management poses a serious trade-off in the setting examined here. On the one hand, disinflation is desirable because the initial high-inflation steady state features a high nominal interest rate, which embodies significant distortions on velocity, investment, and labor supply - note that with constant inflation, and thus constant i, the saving distortion identified in eq. (21) vanishes. On the other hand, attempting to stabilize when agents attach some probability to the collapse of the plan (i.e., when stabilization policy lacks credibility) introduces state-contingent, time-varying price and wealth distortions. These distortions make disinflation undesirable. Thus, in order to explore the normative implications of the model, one needs to quantify and compare the welfare effects of no stabilization with those of stabilization in the presence of devaluation risk.

Table 2 reports the welfare effects of exchange-rate-based stabilization plans under different scenarios. The welfare effects are computed using the standard compensating variation in consumption across time and states of nature suggested by Lucas (1987). Hence, we compute the percent increase in aggregate consumption in the prestabilization, high-inflation steady state that renders agents indifferent, in terms of expected utility, between the state-contingent intertemporal allocations of C^T, C^N and ℓ implied by a stabilization plan and those that correspond to the high-inflation status quo. Table 2 reports welfare effects for all the cases explored in the sensitivity analysis, simulating each case under perfect foresight, a flat hazard rate, and the J-shaped hazard rate of the benchmark case. Each simulation is also conducted with and without rebating inflation tax revenue to households.

Two features of these welfare calculations are important to emphasize. First, as suggested by Uribe (1999), under plausible parameter specifications, the presence of wealth effects can make noncredible stabilizations welfare increasing, even under perfect foresight. All of the welfare effects reported in Table 2 correspond to stabilization plans with a varying degree of lack of credibility, yet all of them produce an increase in welfare. The welfare gains range from about $\frac{1}{4}$ of a percentage point to 9.1 percent, which are large figures compared to the negligible benefits of consumption stabilization reported by Lucas (1987). The large welfare gains also deviate sharply from Calvo's (1988) analysis in which lack of credibility is always welfare-reducing and the welfare losses trivial. In his setting, lack of credibility is always costly because it is identical to a temporary tax on saving at a constant rate with the proceedings fully rebated to households (in the context of a perfect-foresight endowment economy). In our model, even under a full rebate of the inflation tax that neutralizes the fiscal-induced wealth effect, a temporary currency peg is preferred to continued high inflation because of the wealth effects introduced by changes in investment and labor supply. Of these two, the labor-supply effect seems less important because the welfare gains in the inelastic labor case are similar to those of the benchmark model.

The second key welfare result is that devaluation risk entails substantial welfare costs. In the simulations of Table 2 that include the fiscal-induced wealth effect, an exchange-rate-based stabilization that is known to last 24

Table 2: Welfare Analysis

Model	Rebate of 1/3 of inflation tax			Full rebate of inflation tax		
	J-shaped Hazard	Flat Hazard	Perfect Foresight	J-shaped Hazard	Flat Hazard	Perfect Foresight
Benchmark	1.27	0.95	5.56	0.51	0.34	2.53
$J = 36$	1.11	0.98	7.94	0.43	0.36	3.65
$\mu = 0$	1.24	0.92	5.40	0.51	0.34	2.53
$s_{HN} = .6$	1.21	0.90	5.25	0.50	0.34	2.46
$\xi = -10^{-5}$	1.14	0.85	5.00	0.50	0.34	2.52
$\xi = -1$	1.76	1.34	7.78	0.51	0.35	2.56
$z_{J-1} = .5$	1.27	0.95		0.51	0.34	
$z_{J-1} = .9$	1.28	0.95		0.51	0.34	
Materials	1.87	1.42	8.28	0.51	0.35	2.56
High money velocity	2.02	1.54	9.11	0.51	0.34	2.53
Log preferences	1.32	0.96	5.56	0.50	0.33	2.47
Inelastic labor supply	1.30	0.97	5.70	0.42	0.28	2.13

The welfare gain from a stabilization program is computed as the percentage increase in the equilibrium path of consumption under no stabilization necessary to make the representative household indifferent between stabilization and no stabilization (thus a positive number means that the program is welfare increasing).

quarters with full certainty increases welfare by 5.6 percent, but under uncertainty (with the J-shaped devaluation probabilities identified in the data) the welfare gain is only 1.27 percent. Thus, the welfare gain falls by a factor of 4.4, or 4.3 percentage points, as a result of devaluation risk. A flat hazard rate results in an even smaller welfare gain at 0.95 percent, indicating that a time path for devaluation risk that induces a switch from declining to increasing distortions on saving, investment, and labor, is preferred to a time path of devaluation risk in which these distortions are constant over time.

If the inflation tax revenue were fully rebated to households, the welfare gain under perfect foresight nearly halves to 2.5 percent, compared to the same scenario under the benchmark-case assumption that only a fraction of the tax revenue is rebated. This is a measure of the welfare effect associated with the fiscal-induced wealth effects. However, even across simulations in which wealth effects are ruled out, the welfare gains when devaluation risk is present are significantly smaller than under perfect-foresight (the gain is 0.5 percent with a J-shaped hazard rate and 0.3 percent with a flat hazard rate). Thus, the implicit stochastic taxes that devaluation risk imposes on saving, investment, and labor supply are very costly distortions, even if the model did not feature a fiscal-induced wealth effect.

The quantitative analysis established that devaluation risk under incomplete markets induces large price and wealth distortions with important effects on both the competitive-equilibrium dynamics of the economy and welfare. Since the price distortions are analogous to stochastic taxes on factor incomes and the return on saving, it seems natural to consider tax policy as a key instrument to counter those distortions. If the time path of devaluation probabilities were known with certainty, the numerical solution of the model could be combined with the equations analyzed in Section 5.1 to calculate exactly a schedule of state-contingent, time-variant consumption taxes that would fully offset the effects of the monetary distortion on the relative prices relevant for saving, investment and labor supply decisions. Alternatively, if the time path of devaluation probabilities were unknown, the government could use observed effective interest rate differentials to try to extract information regarding the risk of devaluation as perceived by private agents, and use this information to adjust tax policy accordingly. These tax adjustments would seek to increase the relative price of future consumption when the interest rate differential is declining, so as to hamper the expansion in output and expenditures that originates in the lack of credibility of stabilization policy, and to reduce it when the interest rate differential is rising, so as to offset the contraction in output and expenditures that also results from lack of credibility.

In summary, the findings of this paper suggest that, in assessing explanations of the syndrome of exchange-rate-based stabilizations and in evaluating potential solutions, it is useful to broaden the focus from pure monetary and exchange-rate policy considerations into the realm of fiscal policy, particularly tax policy. The lack of credibility of managed exchange-rate regimes, expressed in the risk of devaluation, may be partially remedied by a credible commitment to a set of fiscal rules compatible with the desired target levels for the exchange rate. These rules include a commitment to the permanence of fiscal cuts enacted when a stabilization program begins, and a preannounced strategy of tax adjustments aimed at countering the price distortions induced by devaluation risk.

6 Concluding remarks

This paper shows that the risk of devaluation or collapse of managed exchange rate regimes induces large distortions on wealth and relative prices in an environment of incomplete insurance markets. These distortions produce macroeconomic dynamics that mimic some important features of the stylized facts typical of exchange-rate-based stabilization plans implemented in high-inflation countries. These findings were derived by studying the quantitative implications of a dynamic, stochastic general-equilibrium model of a two-sector, small open economy in which agents expect a devaluation and a switch to a permanently-higher rate of depreciation of the currency with positive probability. Devaluation risk induces a time-variant, state-contingent premium on the domestic nominal interest rate that affects not only money demand and money velocity, but also the relative prices that determine saving, investment, and the supply of labor. Endogenous changes in unproductive government expenditures, resulting from fluctuations in the revenue derived from the inflation tax, combine with changes in capital accumulation to supplement the price distortions of devaluation risk with wealth distortions.

The model was calibrated to Mexican data from the 1987-1994 exchange-rate-based stabilization plan. A key element of this calibration is the time path of the probability of devaluation, which was set to mimic the J-shaped pattern that empirical studies have identified for Mexico and for a large group of developing countries during periods in which these countries followed managed exchange-rate regimes. The equilibrium dynamics of the model were then computed using an algorithm designed to solve incomplete-markets models driven by absorbent Markovian chains, which are a natural setup to examine the case of a policy that is in place at present but is expected with some probability to be reversed permanently in the future.

The model accounts for these four key features of the data: (1) booms in output and expenditures (in the aggregate and across sectors) followed by recessions that predate devaluations, (2) sizable real appreciations with a strong positive co-movement between aggregate and sectoral consumption and the real exchange rate, (3) a sharp widening of the trade deficit followed by a reversal, and (4) a sharp fall in the velocity of circulation of money that is reversed by the time of the collapse. Under some parameter specifications, the model can also account for the observed nonlinear pattern of real appreciations, with periods of stability inbetween sharp appreciations. These results differ from the findings of previous quantitative studies based on perfect-foresight models, in which the anticipation of the certain collapse of a currency peg accounted only for a small fraction of the observed magnitude of boom-recession cycles and real appreciations, and could not explain the high positive correlation between expenditures and the real exchange rate (i.e., the price-consumption puzzle). Still, the model accounts for only 1/2 of the magnitude of the real appreciation experienced in Mexico, leaving an important fraction of the observed change in the relative price of nontradable goods unexplained.

The favorable quantitative results of the devaluation-risk framework depend critically on four of its elements. First, the shape of the hazard-rate function that governs devaluation probabilities must follow a J pattern in order to produce cyclical dynamics. Second, accounting for the observed magnitude of booms in production and expenditures, and large real appreciations, requires endogenous wealth effects induced by the incompleteness of financial markets and the assumption that some degree of temporary fiscal adjustment accompanies exchange-rate-based disinflations. Third, production technologies must feature sector-specific factors of production. Without this feature, Cobb-Douglas sectoral production functions with nearly-identical factor intensities, as suggested by the data, yield a quasi-linear PPF for tradables and nontradables that results in negligible real appreciations. Fourth, realistic cyclical co-movements, in particular recessions in the production and consumption of nontradables that predate devaluations, require supply-side effects that result from the distortions that devaluation risk induces on investment and labor supply.

It is important to recognize that the price and wealth distortions critical for the performance of the model may not originate exclusively in the risk of devaluation. For instance, less-than-fully credible programs of economic reform, which accompanied several of the more recent exchange-rate-based stabilization plans, could have analogous effects as devaluation risk per se. This would be the case if, for example, the model were enriched with a temporary cut in import tariffs, assuming that tariff revenue finances unproductive government expenditures. Thus, broadly speaking, the policy uncertainty driving economic fluctuations in the model can be envisaged as not just limited to the rate of devaluation of the currency, but also as encompassing a rich set of conditions that are expected to switch from "favorable" to "unfavorable" in terms of their influence on price and wealth distortions as a country enters into an economic crisis.

The welfare analysis shows that devaluation risk entails much larger welfare costs than the negligible costs of lack of credibility obtained using perfect-foresight models. Thus, policies aimed at lessening the impact of the stochastic distortions induced by devaluation risk are desirable. One possible policy strategy is a to introduce state-contingent, time-varying consumption taxes such that the consumption tax rises (falls) when devaluation risk declines (rises). In general, the findings of this analysis suggest that a broader fiscal perspective, which goes beyond the bottom-line figure of the public deficit and gives greater consideration to tax policy, would be beneficial to add to the approach with which the problems of exchange-rate management in emerging markets are being addressed. This approach could be generalized further into a framework in which the policy strategy used to resolve the crisis of an unsustainable exchange rate involves choosing a value for the inflation tax, as well as values for other tax rates and changes in the absolute level and sectoral allocation of government purchases. The theoretical analysis of Drazen and Helpman (1988) and the quantitative exploration of Mendoza and Uribe (2001) are early attempts in this direction, but further research is still needed in this area.

Further research also needs to focus on unifying the theory of the real effects of exchange-rate-based stabilization plans with the theory of currency crises, which are two research agendas that for the most part have evolved independently. One approach to develop this unified theory using the framework examined here is to endogenize devaluation probabilities. For example, the findings of the literature on "early warning indicators," showing that variables like real appreciation or foreign reserve losses are robust predictors of currency crashes, can be used to specify the information set on which private agents condition the probability of currency collapse. Devaluation probabilities can then be modeled as an outcome of a rational expectations equilibrium in which the dynamics of the real exchange rate and reserves influence the probability of devaluation and vice versa. Endogenous balance-of-payments crises can exist in this environment if the setup is enriched by imposing the standard constraint on the central bank's ability to borrow foreign reserves. Mendoza and Uribe (2001) study a model with these features.

The paper ends with an important policy consideration. The analysis undertaken here shows that, regardless of whether stabilization plans fail or not in the long run, and even in an environment of perfect capital mobility, flexible prices, and fiscal discipline, those plans go through difficult early stages in which the exchange rate is highly overvalued and the trade deficit is large because private agents question the credibility of policymakers, and this lack of credibility represents a source of noninsurable risk. Policy lessons must then be drawn carefully. In particular, just aiming to make insurance markets partially "more complete" could be counterproductive. As Calvo (2000) showed, introducing state-contingent contracts can be welfare-reducing for an economy where there is imperfect policy credibility. Moreover, a large trade deficit and an appreciated real exchange rate can be the result of a gradual build-up of confidence on the stabilization plan (i.e., a declining monetary distortion in the context of the model examined in this paper), and not necessarily an "early warning" indicator of the impending collapse of the plan. Real overvaluation and large trade deficits are endogenous outcomes of the equilibrium of an economy and cannot be treated as exogenous determinants of a country's ability to manage the value of its exchange rate, as is too often suggested.

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