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Credit, Prices, and Crashes: Business Cycles with a Sudden Stop¹

by

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“Sudden Stops” of capital inflows during emerging-markets crises triggered unusually large declines in private expenditures, production, asset prices and prices of nontradable goods relative to tradable goods. This paper offers an interpretation of these observations as features of the equilibrium dynamics of a flexible-price economy with imperfect credit markets. Foreign debt is denominated in units of tradables but partially leveraged on the income generated by the nontradables sector via a liquidity constraint. A Sudden Stop occurs when real or policy-induced shocks make this constraint suddenly binding. Sudden Stops are not reflected in long-run business cycle co-movements, but even so their welfare costs can be significant. An asset-pricing variation of the model is offered as a potential account of the asset-pricing implications of Sudden Stops.

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1. Introduction

The epidemic of capital-markets crises that hit emerging economies in the 1990s displayed the empirical regularities of a phenomenon that Calvo (1998) defined as a “Sudden Stop.” Sudden Stops featured a sharp reversal in private capital inflows, or a shift to large outflows, and a corresponding sharp reversal from large current-account deficits into much smaller deficits or small surpluses. These abrupt reversals in foreign financing forced in turn sharp contractions of domestic production and private expenditures, collapses in the real exchange rate, the relative price of nontradable goods in terms of tradable goods, and asset prices, and sharp declines in credit to the private sector. In several cases, Sudden Stops followed from periods during which external deficits widened gradually, the relative price of nontradables and the real exchange rate appreciated sharply, and economic activity and asset prices boomed, often in tandem with explicit or implicit managed exchange-rate regimes.

The defining features of Sudden Stops resemble typical features of the balance-of-payments (BOP) crises that developing countries suffer chronically. The literature on contractionary devaluations, for instance, is built on the observation that in developing countries devaluation is generally followed by recession (see Edwards (1986)). Yet, behind this resemblance hide important differences that pose serious challenges both for research and for policy analysis. In particular, as the empirical analysis of Calvo and Reinhart (1999) showed, the changes in real and financial indicators observed in Sudden Stops largely exceeded those of typical BOP crises. Moreover, the economic collapses of Sudden Stops were deep, but the subsequent recoveries were also generally quick and sharp -- an observation labeled “the Mexican Wave” in a *Financial Times* editorial by Martin Wolf (August 8, 1999).

The unusual depth of the recessions and price corrections that accompanied Sudden Stops

and their short duration suggests that it may be useful to study this phenomenon within a framework of *excess volatility*. That is, a framework that can account for Sudden Stops as a short-lived feature of the cyclical dynamics of a small open economy that coexists with the less dramatic stylized facts of the economy's regular business cycle measured over the long run. The aim of this paper is to develop a basic model with these features. In particular, the paper proposes a model in which Sudden Stops are the result of financial frictions at work in an otherwise frictionless, flexible-price competitive environment. Financial frictions drive endogenous credit constraints that can be binding or nonbinding at a particular date depending on the state of nature -- although the distortions induced by these constraints are set in motion by the simple expectation that the constraints might bind in the future. Sudden Stops occur in states of nature in which the constraints become suddenly binding. The switch into a Sudden-Stop state can be the result of policy shocks or large real shocks of domestic or foreign origin. At the same time, the long-run business cycle features of the economy (implicit in the model's stochastic stationary state) are largely independent of Sudden-Stop events. Still, social welfare is sharply reduced by the occurrence of Sudden Stops.

This analysis provides three important policy lessons for crises-prevention strategies. First, regulatory policies implemented with the intent of containing large capital outflows, such as liquidity requirements, margin requirements or value-at-risk collateralization, can be counterproductive because they can increase the likelihood and/or severity of Sudden-Stop events. Second, since the resources needed to resolve or prevent a Sudden Stop vary widely depending on the state of the economy at the time credit constraints become suddenly binding, financial arrangements that can effectively pre-empt Sudden Stops need to either feature complex state-contingent clauses or commit *credibly* a large amount of funds. Third, a long-

term strategy to deal with Sudden Stops should emphasize policies aimed at addressing directly the informational and institutional frictions that are the ultimate determinants of credit-market imperfections. These include microeconomic policies (such as the development of credit bureaus undertaken recently in Mexico) as well as macroeconomic policies (such as dollarization, the formation of currency unions anchored on strong currencies, or the internationalization of financial systems).

From the standpoint of the growing research program on emerging-markets crises, this paper aims to add to the literature exploring the use of models of credit frictions to study Sudden Stops initiated by Calvo (1998). To date, this literature has built extensively on modern adaptations of two classic approaches to model “great depressions” driven by financial frictions in Macroeconomics: the Keynesian setup of price or wage stickiness with an external financing premium, examined by Bernanke, Gertler and Gilchrist (1998), and the Fisherian analysis of debt-deflations driven by collateral constraints, introduced by Kiyotaki and Moore (1997). This literature includes, among others, the works of Aghion, Bacchetta and Banerjee (2000), Caballero and Krishnamurty (1999), Cespedes, Chang, and Velasco (2000), Christiano, Gust and Roldos (2000)), and Paasche (2000).

The analysis conducted here differs from the above studies in its approach to model Sudden Stops as an excess volatility phenomenon. The models studied so far in the literature feature credit constraints that are always binding along an equilibrium path. Hence, in this class of models it is difficult to account for the abrupt economic collapses of Sudden Stops as an atypical phenomenon nested within the smoother co-movements of regular business cycles. The model proposed here also differs from the existing literature in that it emphasizes the interaction of uncertainty, risk aversion and incomplete contingent-claims markets in forming the

transmission mechanism linking financial frictions to the real economy. In this setting, which is in line with the models studied by Aiyagari (1993), Aiyagari and Gertler (1999), and Eaton and Gersovitz (1981), precautionary saving and state-contingent risk premia play a key role in driving the business cycle dynamics of the economy.² In contrast, existing models of Sudden Stops based on the Kiyotaki-Moore or Bernanke-Gertler-Girlchrist frameworks assume that borrowers and lenders are risk neutral and are often examined under perfect foresight. These assumptions facilitate the study of the effects of credit frictions by producing models that yield closed-form analytical results and that can be easily solved with linear-approximation algorithms, but leave behind the features of choice under uncertainty, risk aversion and precautionary saving that are often viewed as critical for the analysis of economies with imperfect credit markets. The tradeoff in emphasizing these features is that closed-form solutions are no longer feasible and numerical solutions based on linear approximations are inapplicable. Thus, the predictions of the model have to be derived with the aid of nonlinear numerical methods introduced in modern business cycle theory (see Cooley (1995)).

The credit constraints examined in this paper are designed with the intent of capturing some of the key elements of the credit frictions identified in the recent literature on emerging-markets crises (see Calvo and Mendoza (2000a)). The proposed credit constraints follow the Fisherian line in that they emphasize the credit-market effects of price shocks in an otherwise Neoclassical flexible-price environment. In particular, it is shown that Sudden Stops can be consistent with the optimal adjustment of a flexible-price economy in response to suddenly-binding credit constraints. The constraints can be of two forms: a *liquidity requirement*, which

²The model proposed here is also consistent with the predictions of models of the consumption function based on buffer-stock saving and liquidity constraints (see Carroll (2000)).

requires borrowers to finance a fraction of their current obligations out of current income, and a *margin requirement*, which limits the ability of borrowers to leverage foreign debt on the current value of their domestic equity holdings.

Liability dollarization is an essential feature of both credit constraints. Foreign debt is assumed to be denominated in the international unit of account (i.e., tradable goods), but is leveraged on income and assets valued at a different relative price. As a result, sharp fluctuations in the production and relative price of nontradable goods (in the case of the liquidity requirement) or in the price of equity (in the case of the margin requirement) can induce sharp and sudden adjustments in access to foreign financing. These Sudden Stops are possible even when the model is stripped from the powerful debt-deflation intertemporal channel, and without recurring to the Keynesian assumption that prices or wages are inflexible or to the existence of multiple equilibria emphasized in some recent studies (see Calvo (1998), Aghion, Bacchetta and Banerjee (2000) and Cespedes, Chang and Velasco (2000)).

The paper is organized as follows. Section 2 summarizes empirical evidence on Sudden Stops and the notion of Sudden Stops as excess macroeconomic volatility. Section 3 sketches the model with the credit friction in the form of a liquidity constraint. Section 4 explores the quantitative implications of this model including its welfare effects. Section 5 describes the variation of the model aimed to account for the asset-pricing features of Sudden Stops by introducing a margin requirement. Section 6 concludes.

2. The Sudden Stops Phenomenon

Calvo and Reinhart (1999) conduct a comprehensive cross-country analysis of Sudden Stops. They document 15 recent episodes of large reversals in net private capital inflows into emerging countries. These reversals exceeded 10 percent of GDP in 7 of the 15 cases, and the

smallest reversal was equivalent to 4 percent of GDP (Argentina, 1994-1995). The adjustments in real GDP that accompanied these Sudden Stops were also large. Sudden Stops (labeled as “recent experiences” in Tables 8 and 9 of Calvo and Reinhart’s paper) produced impact effects on output equivalent to an average decline of 13.3 percent for countries that experienced banking crises, and 12.3 percent for countries that experienced currency crises. These impact effects were much larger than those corresponding to average crises data for the period 1970-1994, which show declines of 3.2 and 2.7 percent for banking-crisis countries and currency-crisis countries respectively. Calvo and Reinhart also show that Sudden Stops produced larger adjustments in reserves and real exchange rates, and higher bills for bailing out bankrupt banking systems, than those produced by previous BOP crises. This is particularly the case for the East Asian crisis compared to other regions and to East Asia’s recent historical record.

The effects of Sudden Stops on equity prices are well documented in several recent reviews of emerging-markets crises by international organizations (see in particular International Monetary Fund (1999)). Although the extent of “true” contagion across equity markets is subject of debate (see Kaminsky and Reinhart (2000) and Forbes and Rigobon (2000)), stock market indexes fell sharply in countries that suffered Sudden Stops. By the end of January 1995, nearly a month after the devaluation of the peso, Mexico’s stock market index had fallen by more than 50 percent in dollar terms relative to November 1, 1994. The indexes in Brazil and Argentina fell about 20 percent in the same period. In the East Asian crisis, the collapses of equity prices between September 1 and December 31, 1997 ranged from about 20 percent in Hong Kong to almost 70 percent in South Korea. Equity markets rose from these crash levels but compared to industrial-country markets continued to performed poorly (see Chapter III in International Monetary Fund (1999)). Sudden Stops were also associated with higher asset price

volatility. The volatility of weekly emerging-market dollar returns doubled from 2 to 4 percent during the East Asian crisis in 1997 and the Russian collapse in 1998.³

The cross-country evidence on the macroeconomic features of Sudden Stops provided by Calvo and Reinhart (1999) is complemented here with a time-series analysis of the features of the Sudden Stop experienced in Mexico in the aftermath of the collapse of the peso of December, 1994. This analysis is also useful for formalizing the notion of Sudden Stops as an excess volatility phenomenon.

The analysis uses quarterly data for the period 1980:1 to 1997:4 (except for the world real interest rate which covers 1983:1 to 1996:3). Figure 1 plots fourth-quarter growth rates of national accounts data to illustrate the magnitudes of the Sudden Stop in private domestic absorption, the trade deficit as a share of GDP, and the output of tradables and nontradables. This Figure also shows the period of gradual but sustained expansion and widening trade deficit that preceded the crash, and the relatively rapid recovery after 1995. Note in addition that, from the perspective of this “raw data” without any statistical adjustments, the Sudden Stop in production was larger in the nontradables sector and the recovery in this sector was also more modest than in the tradables sector.

Figure 2 shows the movements in relative prices and exchange rates using monthly data. The picture shows that the severe drop in the real exchange rate at the time of the December, 1994 devaluation reflected, in addition to the nominal devaluation, a collapse in the price of nontradables relative to tradables within Mexico. This occurred after the gradual but substantial increase in that relative price and in the real exchange rate that took place for the duration of the

³These figures are means of rolling 13-week standard deviations of equity price indexes in U.S. dollars for 16 emerging markets (see Figure 3.8 in International Monetary Fund (1999)).

exchange-rate-based stabilization that started in 1988. Mendoza (2000) documents that the sharp real appreciation and increase in the price of nontradables resulted mainly from a major rise in the cost of use of housing. Guerra de Luna (1997) and (1998) show in turn that the high inflation in housing resulted from a large increase in real estate and land prices fueled by the surge in inflows of foreign capital and the expansion in domestic bank credit that preceded the Sudden Stop. Moreover, the Sudden Stop featured important corrections in house and land prices in 1995, coinciding with the large reversal of capital inflows and the collapse of domestic credit.

The stylized facts of the Mexican business cycle are computed using the Hodrick-Prescott (H-P) filter to isolate cyclical components of the data. These stylized facts are listed in Table 1. Mexico's stylized facts display the standard business-cycle pattern for large developing economies (see Mendoza (1995) and Agenor, McDermott and Prasad (2000)). The excess volatility implicit in the Sudden Stop of 1995 can be measured by comparing the depth of the observed recession of that year with regular Mexican business cycles -- defining the latter as deviations from H-P trends within two-standard-deviation bands. As Figure 3 shows, the collapses of aggregate GDP, tradables output, nontradables output, consumption, and fixed investment associated with the Sudden Stop in the second quarter of 1995 exceeded the two-standard-deviation limits by margins ranging from 1.5 to 6 percentage points. They are also the only deviations from trend that exceeded those limits during the entire sample period.

3. Sudden Stops in a Flexible Price Economy with Liquidity Constraints

This section of the paper proposes a modification of the conventional flexible-price intertemporal approach to current-account determination and business cycles in small open economies that allows for Sudden Stops. The need to modify the conventional approach is obvious in light of its serious empirical shortcomings: models that follow this approach predict

in general smooth movements in foreign debt and the current account driven by consumption-smoothing and investment-augmenting effects that are grossly inconsistent with the sudden reversals of capital inflows and collapses of private consumption observed during a Sudden Stop (see Edwards (2000) and Mendoza (1991a) and (1995)). A key element behind these counterfactual results is the assumption of perfect credit markets: in standard intertemporal models of the current account, agents can borrow or lend at the world-determined real interest rate limited only by the reach of their wealth (as implied by the No-Ponzi-Game condition). Hence, the key modification introduced here is to relax this assumption by considering a credit friction linking the agents' ability to borrow to the dynamics of prices and income.

Credit frictions are modeled in an exchange economy abstracting from the existence of money. This leaves behind important real-world features linking credit frictions to the money market, and sets aside an explicit analysis of the role of monetary and exchange-rate policies (which has been undertaken in other studies like those of Cespedes et al. (2000) or Mendoza (2000)).⁴ However, it is important to note that the central elements of the credit-channel transmission mechanism envisaged by Fisher (1933) are essentially features of the real credit flows of a non-monetary economy. This is shown by Calvo's (1998) analysis illustrating how Sudden Stops can be the outcome of the real-sector implications of frictions in credit markets.

3.1 *Structure of the Model*

Consider a small open economy with an exogenous, stochastic endowment of tradable goods $exp(\varepsilon_t^T)Y^T$, where ε_t^T is a Markovian shock to the mean endowment Y^T or to its world value (i.e., the terms of trade). The economy produces nontradable goods using a Cobb-Douglas

⁴Mendoza (2000) studies the effects of dollarization in a monetary economy with a liquidity requirement similar to the one examined here.

technology: $Y_t^N = \exp(\varepsilon_t^N)AK^{1-\alpha}L_t^\alpha$. K is a time-invariant capital stock with zero depreciation rate, ε_t^N is a Markovian productivity shock, and L is labor input. Details on the specification of the Markov processes driving all the shocks present in the model are provided in Section 4.

Firms choose labor demand so as to maximize profits π_t in units of tradable goods (which are the model's numeraire):

$$\pi_t = \exp(\varepsilon_t^T)Y^T + p_t^N \exp(\varepsilon_t^N)AK^{1-\alpha}L_t^\alpha - w_t L_t \quad (1)$$

The price of nontradables in units of tradables is p_t^N and the real wage in units of tradables is w_t .

At equilibrium, firms demand labor up to the point in which the value of the marginal product of labor equals the real wage:

$$p_t^N \alpha \exp(\varepsilon_t^N)AK^{1-\alpha}L_t^{\alpha-1} = w_t \quad (2)$$

Note that since the value of the marginal product of labor depends on p_t^N , a collapse in the relative price of nontradables (i.e., a collapse in the real exchange rate since PPP in tradables is assumed to hold) induces a negative shock to labor demand.

Households consume tradable goods C_t^T , nontradable goods C_t^N , and supply labor to firms. They maximize a form of expected utility that incorporates an endogenous rate of time preference (see Epstein (1983)). Endogenous discounting plays an important role not only in providing the small open economy with well-defined dynamics (which is the standard motivation for preferences like these in models of the small open economy), but also in allowing the model to support competitive equilibria in which credit frictions may bind or not, in the long run or in the short run, depending on the state of nature (see Mendoza (2000)). The utility function is:

$$U = E_0 \left[\sum_{t=0}^{\infty} \exp \left\{ - \sum_{\tau=0}^{t-1} v(C(C_\tau^T, C_\tau^N) - H(L_\tau)) \right\} u(C(C_t^T, C_t^N) - H(L_t)) \right] \quad (3)$$

In this expression, $U(\cdot)$ is lifetime utility, $C(\cdot)$ is a constant-elasticity-of-substitution (CES) aggregator of consumption of tradables and nontradables, $H(\cdot)$ is a positive, continuously differentiable and concave function that measures the disutility of labor, $u(\cdot)$ is an isoelastic period utility function, and $v(\cdot)$ is the time preference function. The specification of the arguments of the u and v in terms of the composite good $C-H$ is borrowed from Greenwood, Hercowitz and Huffman, GHH, (1988). In their one-good model, this assumption eliminates the interaction between consumption (or wealth) and labor supply by making the marginal rate of substitution between consumption and labor supply depend only on the latter. This is not the case in the two-sector model described here because the relevant real wage for labor supply decisions is measured in units of aggregate consumption, and hence changes in the relative price of nontradables and in the sectoral allocation of consumption affect labor supply. Still, the GHH specification simplifies the analysis significantly as illustrated below.

The four functions that characterize lifetime utility adopt the following functional forms:

$$C(C_t^T, C_t^N) = \left[\omega (C_t^T)^{-\eta} + (1 - \omega) (C_t^N)^{-\eta} \right]^{-\frac{1}{\eta}} \quad (4)$$

$$H(L_t) = \frac{L_t^\delta}{\delta}, \quad \delta > 0 \quad (5)$$

$$u\left(C(C_t^T, C_t^N) - H(L_t)\right) = \frac{\left[C(C_t^T, C_t^N) - H(L_t)\right]^{1-\sigma} - 1}{1-\sigma} \quad (6)$$

$$v\left(C(C_t^T, C_t^N) - H(L_t)\right) = \beta \left[\text{Ln}\left(1 + C(C_t^T, C_t^N) - H(L_t)\right) \right] \quad (7)$$

These functional forms are standard in real business cycle models of the small open economy (see Mendoza (1991a) and (1995)). The parameter η determines the elasticity of substitution between consumption of tradable goods and consumption of nontradable goods, which is given

by $1/(1+\eta)$, ω is the standard CES weighing factor, δ determines the elasticity of the supply labor with respect to the real wage, which is given by $1/(\delta-1)$, σ is the coefficient of constant relative risk aversion (CRRA), and β determines the sensitivity of the rate of time preference with respect to changes in the date-t arguments of the period utility function.

Households maximize utility subject to a standard budget constraint:

$$(1 + \tau_t^T)C_t^T + (1 + \tau_t^N)p_t^N C_t^N = \pi_t + w_t L_t - b_{t+1} + \exp(\varepsilon_t^R) R b_t - T_t^T - p_t^N T_t^N \quad (8)$$

Here, τ_t^T and τ_t^N are consumption taxes that apply to purchases of tradables and nontradables and T_t^T and T_t^N are lump-sum taxes levied in units of tradables and nontradables respectively. b represents the economy's net foreign asset position in terms of the only internationally-traded asset present in the model: one-period bonds that pay the world-determined gross real interest rate $\exp(\varepsilon_t^R)R$ in units of tradable goods (ε_t^R is a Markovian interest rate shock). Since this is the only asset households exchange with the rest of the world, markets of contingent claims are incomplete and the small open economy's wealth will vary with the state of nature. Given the CRRA form of $u(\cdot)$, insurance market incompleteness implies in turn that consumption will respond to fluctuations in the marginal utility of wealth induced by the exogenous shocks, and that households will undertake precautionary saving. The latter will induce households to effectively impose on themselves an endogenous borrowing constraint even in the absence of explicit credit constraints driven by credit-market imperfections (as in the buffer-stock saving models of Aiyagari (1993) and Carroll (2000)).

The credit-market imperfection present in this model takes the form of a liquidity constraint by which lenders require households to finance a fraction φ , for $0 \leq \varphi \leq 1$, of their current expenses (i.e., consumption, taxes, and debt payments) out of current income:

$$w_t L_t + \pi_t \geq \varphi \left[\left((1 + \tau_t^T) C_t^T + (1 + \tau_t^N) p_t^N C_t^N \right) - \exp(\varepsilon_t^R) R b_t + T_t^T + p_t^N T_t^N \right] \quad (9)$$

Given the budget constraint, this liquidity requirement is equivalent to a borrowing constraint that limits debt as a share of current income not to exceed $(1-\varphi)/\varphi$:

$$b_{t+1} \geq -\frac{1-\varphi}{\varphi} [w_t L_t + \pi_t] \quad (10)$$

Note that $\varphi=1$ implies a no-borrowing constraint (i.e., $b_{t+1} \geq 0$ for all t) and as φ converges to 0 the economy approaches the case in which the liquidity constraint can never be binding.

Since insurance markets are incomplete, the above credit constraint gives households an extra incentive to engage in precautionary saving, storing away extra assets in the “good” states of nature for the “bad” states in which the constraint may bind and they may not be able to borrow as much as they would desire in world markets. This contrasts sharply with the outcome that would be obtained under perfect foresight. Under perfect foresight (and a constant discount factor) households would hold the largest amount of debt allowed as long as the marginal utility of current consumption exceeds that of future consumption (see also Aiyagari (1993)).

The liquidity requirement is not formally derived as a feature of an optimal credit contract. However, the motivation for it is that it could result from traditional financial-market frictions such as monitoring costs or bankruptcy risk and institutional features of credit markets. In fact, the borrowing constraint in (10) that results from the liquidity requirement is consistent with standard lending criteria widely used in mortgage and consumer loans, even in the financial markets of the industrial world (see the evidence reported by Ludgvison (1996)). In the United States, for instance, the large financial companies that anchor the mortgage market (*Fannie Mae* and *Freddie Mac*) provide lenders with “scoring” guidelines that effectively require borrowers to

keep expected total debt service of prospective borrowers around 1/3 of gross income.⁵

Mortgage debt in the United States as of the second quarter of 2000 was of roughly the same size as the total outstanding corporate debt (about \$4.2 trillion), and total household debt was 42 percent larger than the total corporate debt. These figures suggest that credit constraints of the form postulated above may be as relevant to consider as the constraints on firm financing emphasized in other studies of the credit channel.

The liquidity requirement also has the advantage that it captures in a tractable manner the potentially crippling effects of “liability dollarization” in a flexible-price setting. This is because debt contracts are written in units of tradables but part of the income on which the debt is leveraged originates in the nontradables sector. As a result, a sharp fall in the output of nontradables and/or in the nontradables relative price can trigger a Sudden Stop.

The optimality conditions of the household’s problem (listed in Appendix I) have straightforward interpretation. The optimal allocation of consumption across tradable and nontradable goods is determined by equating the atemporal marginal rate of substitution between C_t^T and C_t^N with the relative price of nontradables. The optimal supply of labor is set by equating the marginal disutility of labor with the post-tax real wage relevant for household decisions, $w_t/[p_t^C(1+\tau_t^N)]$. Since households care for consumption in terms of the CES aggregator C , the relevant real wage for them is deflated by p_t^C , which is the relative price of aggregate consumption in units of tradables. Optimal saving is determined by equating the lifetime

⁵For example, as of October, 2000, Fannie Mae guidelines for conventional mortgages with 20 percent down-payment required that total housing expenses be kept below 33 percent of gross monthly income and total debt payments, including mortgage service, be kept below 38 percent of gross monthly income. Assuming a mortgage rate of 7.5 percent, these guidelines require debt to remain below 35 percent of gross monthly income.

marginal utility cost of sacrificing a unit of current consumption with the corresponding expected marginal benefit. Marginal lifetime utilities include the impatience effect by which changes to the arguments of period utility at any date t alter the rate at which all future period utilities are discounted. It is also critical to note that, since households desire to consume both tradables and nontradables, the effective return on saving is not just the world real interest rate but the “consumption-based” real interest rate $\exp(\varepsilon_t^R)R[p_t^C(1+\tau_t^T)/p_{t+1}^C(1+\tau_{t+1}^T)]$. Thus, the intertemporal relative price of consumption in this two-good economy is endogenous despite the small-open-economy assumption and depends on the dynamics of the relative price of nontradable goods (which is the key determinant of p^C).⁶

The specification of the model is completed with the description of the government sector. The government maintains a constant level of purchases of nontradable goods financed by a constant lump-sum tax. This is done so that the dynamics of the relative price of nontradables reflect only changes in demand and supply by the private sector and not changes in government purchases of nontradables induced by fluctuations in tax revenue. Fluctuations in tax revenue result in fluctuations of government purchases of tradable goods around a given initial amount of lump-sum taxes in units of tradables to be calibrated to the data. This assumption introduces the Calvo-Drazen fiscal-induced wealth effect that Calvo and Drazen (1988) and Mendoza and Uribe (2000) found critical for explaining key features of economic fluctuations in developing countries exposed to the risk of uncertain duration of government policy. Under these assumptions, the government budget constraint is given by:

⁶Given the CES form of C , p^C corresponds to the CES price index obtained from the standard duality problem of minimizing expenditure for a given level of period utility. This implies that p^C is an increasing, continuously differentiable function of p^N .

$$G_t^T + p_t^N G^N = \tau_t^T C_t^T + \tau_t^N C_t^N + T^T + p_t^N T^N \quad \text{with } G^N = T^N \quad (11)$$

Tax rates are assumed to be stochastic so as to explore the role of policy shocks, or the lack of credibility of existing policies, in triggering Sudden Stops. The model can accommodate differentiated tax rates and degrees of policy uncertainty with regard to tradable and nontradable goods, but for simplicity the analysis that follows considers the case of a uniform tax $\tau_t^T = \tau_t^N = \tau_t$. This case is interesting to examine because it yields price and wealth distortions on the labor-consumption and saving margins that are nearly equivalent to those produced by the rate of depreciation of the currency in conventional models of exchange-rate management in small open economies (see Mendoza and Uribe (2000) and Mendoza (2000) for details). Thus, a reversal from the low-tax regime to the high-tax regime can be interpreted as a shift from a currency peg to a floating exchange rate regime.

The government announces at date 0 the implementation of a policy reform by which taxes are to be reduced from a high level τ^H to a low level τ^L . The policy lacks credibility in the sense that agents assign an exogenous, time-invariant conditional probability to the reversal of the reform $z = Pr[\tau_{t+1} = \tau^H / \tau_t = \tau^L]$. The probabilistic process driving the tax rate follows a basic regime-switching specification for discrete-valued random variables governed by an irreducible, ergodic Markov chain. The transition matrix Π and the Vector Autoregression representation of the Markov process are:

$$\Pi = \begin{bmatrix} \zeta & z \\ 1 - \zeta & 1 - z \end{bmatrix}, \quad \zeta_{t+1} = \Pi \zeta_t + i_{t+1}, \quad (12)$$

where $\zeta = Pr[\tau_{t+1} = \tau^H / \tau_t = \tau^H]$, ζ is a 2x1 random vector such that $\zeta_t = (1, 0)'$ when $\tau_t = \tau^H$ and $\zeta_t = (0, 1)'$ when $\tau_t = \tau^L$, and $i_{t+1} \equiv \zeta_{t+1} - E(\zeta_{t+1} / \zeta_t, \zeta_{t-1}, \dots)$. The limiting probabilities of the tax regimes

are $P(\tau_t=\tau_t^H) = z/(1+z-\zeta)$ and $P(\tau_t=\tau_t^L) = 1-[z/(1+z-\zeta)]$, and the auto-regressive representation of the process is $\zeta_{j,t+1} = z + (\zeta-z)\zeta_{j,t} + i_{j,t+1}$ for $j=1,2$. The average duration of the high-tax regime is $1/(1-\zeta)$ and that of the low-tax regime is $1/z$.

3.2 *Competitive Equilibrium and The Business Cycle Transmission Mechanism*

Given an initial foreign asset position b_0 and the probabilistic processes driving the shocks to productivity, the world's real interest rate, and taxes, a competitive equilibrium for this model economy is defined by state-contingent intertemporal sequences for the allocations $[C_t^T, C_t^N, C_p, L_p, b_{t+1}, G_t^T, Y_t^N]$ and prices $[p_t^N, p_t^C, w_t]$ for $t=0, \dots, \infty$ such that: (a) firms maximize profits subject to their technological constraints, taking p_t^N and w_t as given, (b) households maximize lifetime utility subject to the budget constraint and the liquidity requirement, taking $p_t^N, p_t^C,$ and w_t as given, (c) the government budget constraint holds, and (d) the market-clearing conditions for the markets of tradable and nontradable goods and for the labor market hold.

The competitive equilibrium can be represented by the solution of a modified social planner's problem, which in turn can be solved numerically using dynamic programming methods (see Appendix II for details). This simplification is very useful because of the potentially high degree of non-linearity introduced by the borrowing constraint (see Aiyagari and Gertler (1999)). The model's numerical solution is summarized by two objects. First, a set of state-contingent optimal decision rules for the controls $(C_t^T, C_t^N, C_p, L_p, G_t^T, Y_t^N)$ and endogenous state (b_{t+1}) that depend on the current realizations of the states $(b_t, \varepsilon_t^T, \varepsilon_t^N, \varepsilon_t^R, \tau_t^T, \tau_t^N)$. Second, the joint transition and limiting probability distribution functions of these state variables, which jointly with the decision rules determine also the transition and limiting distributions of all of the model's endogenous variables. The equilibrium prices and their corresponding transition and limiting distributions can then be solved for recursively using the optimality conditions of the

maximization problems solved by households and firms.

If the liquidity requirement never binds, the model's equilibrium stochastic processes would feature cyclical dynamics driven by transmission mechanisms that are well-known from real business cycle models of the small open economy and from models of uncertain duration of policy reforms. In particular, the uncertain duration of a policy change entails analogous wealth and substitution effects as those examined in the studies of Calvo and Drazen (1998) and Mendoza and Uribe (2000). Faced with the realization of the low-tax state at any date t , the conditional expected tax rate for $t+1$ is higher than the tax observed at t . This triggers the intertemporal substitution effect familiar from the perfect-foresight models of the macroeconomic effects of non-credible policies initiated by Calvo (1986): prices are relatively low at t and hence agents substitute consumption intertemporally in favor of current consumption. Under uncertainty and in the presence of non-insurable income effects due to the incompleteness of financial markets, Calvo and Drazen (1998) showed that there is also a state-contingent wealth effect. Each period that low taxes prevail households benefit from the implicit lower level of government absorption, and this gain is added to their permanent income. This effect favors an increasing consumption path for the duration of the low-tax regime followed by a collapse when a permanent reversal of the reform takes place.

The uncertain policy duration modeled here differs from that in the Calvo-Drazen model in that the high-tax regime is not an absorbent state (i.e., even when the high tax is observed there is still some probability that the low tax can be reinstated), but the basic intuition of the wealth effects that result from market incompleteness remains valid.⁷ The model also differs

⁷The Calvo-Drazen case is the limiting case of the model in which $\zeta=1$.

from the Calvo-Drazen setup in that a reversal to the high-tax state features a “supply-side” effect reducing the supply of labor, as the post-tax real wage falls when the tax rate rises.

The above intuition is based on results that apply fully in a partial-equilibrium environment. In general equilibrium, a reversal of a tax cut is likely to be associated with a decline in the output of nontradables, labor allocation, and relative price of nontradables. For the price of nontradables to fall, the reduction in demand for nontradable goods induced by the above-mentioned wealth and intertemporal substitution effects must exceed the reduction in supply. In turn, for the supply of nontradables to fall in equilibrium, it must be the case that the combined effect of the reduction in the demand for labor (resulting from the reduced value of the marginal product of labor in the nontradables sector as p^N falls) and the negative effect of the tax hike on labor supply dominates the positive effect on labor supply resulting from the decline in p^C (which is caused by the fall in the relative price of nontradables).

The presence of the “occasionally binding” borrowing constraint adds important new elements into the model’s business cycle transmission mechanism. In particular, in states of nature in which the credit constraint binds the following effects occur:

- (a) The effective real interest rate faced by households increases because the binding borrowing constraint forces them to reduce consumption relative to the case with perfect credit markets. Hence, the collapse in aggregate consumption and in the demand for tradables and nontradables associated with a policy reversal would be magnified if such a reversal makes the economy run into its borrowing limit.
- (b) The effective marginal reward to labor supply rises because the extra unit of labor enhances the household’s ability to borrow. This moderates the negative effect of the tax hike on labor supply.

- (c) Consumption, saving, and net foreign asset accumulation (and hence the current account since b is the model's single means of saving) experience intertemporal distortions that depend on the combined *dynamic* effects of (a) and (b) in general equilibrium. This is because the effective intertemporal relative price of aggregate consumption is determined by the consumption-based real interest rate, which depends on the inverse of the rate of change of the relative price of consumption (p_t^C/p_{t+1}^C), which in turn depends on the inverse of the rate of change of the relative price of nontradables (p_t^N/p_{t+1}^N).

As a result of the above effects, households face an implicit risk premium in the use of foreign debt vis-a-vis their own saving in their efforts to smooth consumption that is analogous to the external financing premium faced by firms in models of Sudden Stops based on the Bernanke-Gertler financial accelerator. The differences are in that in the model proposed here the equilibrium risk premium is determined endogenously and is influenced by the risk-averse nature of the households' preferences, whereas existing open-economy extensions of the Bernanke-Gertler framework assume that the functional form representing the external financing premium in general equilibrium is identical to the partial-equilibrium solution of a costly-monitoring contracting problem under risk neutrality.

The potential for the liquidity requirement to enlarge output collapses as a result of the effects identified in (a)-(c) can be illustrated more clearly by combining the labor demand and supply conditions to derive the following expression for the percent impact effect on the equilibrium allocation of labor that can result from a switch from τ_t^L to τ_t^H :

$$\ln(L_t^H) - \ln(L_t^L) \approx \frac{1}{\delta - \alpha} \left\{ -[\tau_t^H - \tau_t^L] + \left[\ln\left(\frac{p_t^{NH}}{p_t^{CH}}\right) - \ln\left(\frac{p_t^{NL}}{p_t^{CL}}\right) \right] + \left[\frac{1 - \varphi}{\varphi} \left(\frac{\mu_t^H}{\lambda_t^H} - \frac{\mu_t^L}{\lambda_t^L} \right) \right] \right\} \quad (13)$$

where μ_t and λ_t are the non-negative Lagrange multipliers on the borrowing constraint and the budget constraint respectively and $1/(\delta-\alpha)$ is always positive because of the parameter restrictions $\delta > 1 \geq \alpha \geq 0$. This expression is not a closed-form solution because the relative prices and multipliers in the right-hand side of the expression are endogenous in general equilibrium.

Expression (13) breaks down the impact effect of a tax hike on the equilibrium labor allocation into three effects identified by the three terms in square brackets in the right-hand side. The first effect is the negative effect of the higher tax on labor supply. The second effect is the effect of the change in the price of C^N relative to C (i.e., the ratio p^N/p^C). This price effect is the combined effect of the change in the price of nontradables on labor demand with that of the change in the price of aggregate consumption on labor supply. Given that p^C is the CES price index for the consumption aggregator, it can be shown that p^N/p^C is increasing in p^N . Hence, if the price of nontradables falls with the tax hike, p^C also falls but the adverse effect of the fall in p^N on labor demand dominates the positive effect of the fall in p^C on labor supply. Thus, the decline in the equilibrium allocation of labor in response to a tax hike (and hence in output of nontradables) is magnified on account of the price effect.

The third effect operating on the equilibrium allocation of labor is the direct effect of the liquidity constraint and it is only present when the constraint binds. Consider for simplicity a case in which the constraint switches from non-binding to binding with the tax hike (i.e., $\mu_t^L=0$, $\mu_t^H>0$). In this case, the constraint makes the fall in equilibrium labor *smaller* because of the labor-supply incentive provided by the higher effective marginal reward on the extra unit of labor.⁸ However, the binding liquidity constraint also has an indirect effect on equilibrium labor

⁸This higher reward is given by $[(1-\varphi)/\varphi](\mu_t^H/\lambda_t^H)$, which depends on the ratio of the two Lagrange multipliers. The latter in turn is determined by intertemporal effects, since the same

because it distorts relative prices and thus alters the price effect. As shown in Section 4, when a tax hike triggers a Sudden Stop (i.e., when it makes the liquidity constraint suddenly binding), the resulting adjustment in consumption can induce a larger collapse in the price of nontradables than in the case without a Sudden Stop. This indirect effect can dominate the direct effect so that a binding liquidity constraint may enlarge the collapses in labor and nontradables output. Whether p^N falls or not will depend on how tight is the credit constraint and how much it reduces tradables consumption relative to nontradables consumption.

The binding credit constraint also has an important connection with the choice to model preferences with an endogenous rate of time preference. It is well-known that this class of preferences provide models of the small open economy with well-defined dynamics and well-behaved limiting distributions (see Mendoza (1991a)). In particular, it allows the small open economy to feature a long-run net foreign asset position independent of initial conditions while at the same time producing a long-run rate of time preference equal to the world's real interest rate. In the presence of borrowing constraints, the endogenous rate of time preference has the added benefit that it allows the model to determine endogenously whether a given value of φ results in a binding borrowing constraint at steady state for given values of the rest of the model's parameters.

Consider a perfect-foresight variant of the model. In this case, the steady-state consumption Euler equation is:

ratio determines the interest-rate distortion induced by the debt constraint (see Appendix I), and is likely to be nonlinear (if the constraint is marginally binding it might not affect consumption much and thus have a small effect on λ_t^H , so μ_t^H/λ_t^H increases as the constraint is tightened, but if the constraint is "very tight" it could force a large adjustment in consumption and a large increase in λ_t^H so that μ_t^H/λ_t^H may fall as the constraint is tightened).

$$\left(1 + C(C^T, C^N) - H(L)\right)^\beta \left(1 - \frac{\mu}{\lambda}\right) = R \quad (14)$$

where variables without time subscript correspond to steady-state values. The exponential term in the left-hand-side of this expression is the gross rate of time preference. Equation (14), combined with the rest of the steady-state equilibrium conditions, implies that for a given set of parameter values the model features a critical value φ^{crit} below which the borrowing constraint is not binding. Any such $\varphi \leq \varphi^{crit}$ yields the same steady state, since $\mu=0$ and R is exogenous. The borrowing constraint binds for $\varphi > \varphi^{crit}$ and the steady-state equilibrium then varies with μ/λ , because the latter depends on the tightness of the borrowing constraint relative to the marginal utility of wealth. In this case the rate of time preference rises as necessary to support the steady state with the binding borrowing limit. Clearly, a standard time-separable utility function with a constant rate of time preference cannot deliver this outcome. For any value of φ , the liquidity constraint is binding or not depending only on the exogenous values assigned to the interest rate and the rate of time preference. If they are equal, for example, the constraint is never binding at steady state.

4. A Quantitative Exploration of Sudden Stops Driven by Liquidity Requirements

4.1 Calibration

The numerical analysis starts from a baseline scenario in which the model's parameters are calibrated so that the deterministic stationary equilibrium of the model mimics several average ratios of macroeconomic aggregates taken from Mexican data. Parameters that cannot be directly related to the data are taken from existing econometric studies or set to values typically used in other studies. The calibration is set to a quarterly frequency, although some ratios of national accounts data are derived from annual figures.

One key aspect of the calibration is the determination of the parameters that reflect Mexico's access to world financial markets. These include both the value of the liquidity coefficient φ and the country's mean net foreign asset position. The deterministic steady-state ratio b/Y is set to -35 percent following the estimates of Mexico's net foreign asset position for the period 1970-1997 provided by Lane and Milesi-Ferretti (1999). This implies that the critical value of the liquidity coefficient is $\varphi^{crit}=0.741$. Thus, for the borrowing constraint to bind in the deterministic steady state φ needs to be set larger than 0.741, but a constraint driven by a lower value of φ may still bind in the deterministic transition to steady state or in the stochastic dynamics. The calibration assumes that the borrowing constraint does not bind at steady state (i.e., $\varphi < 0.741$). The stochastic simulations explore the effects of varying φ from a low value such that the constraint is never binding within the state space over which the model is solved (which the simulations show to be $\varphi=0.445$) to a value $\varphi=0.714$, which limits debt not to exceed 40 percent of income valued at tradable goods prices.

The model is calibrated to match several average ratios of macroeconomic time series calculated using aggregate and sectoral national accounts data. A consistent time series of Mexico's sectoral national accounts with sufficient detail to compute these ratios is available only for the period 1988 to 1996 or 1998, depending on the variable. The nontradables (tradables) sector is defined by the industries for which the average ratio of total trade to gross production is less (more) than 0.05. The industries that belong to the nontradables sector according to this definition are construction, utilities, retailing and commercial services, financial services, and personal, social and community services.

The model is calibrated to match the average *aggregate* and *sectoral* GDP (Y) shares of consumption (C), investment (I) and government expenditures (G) measured at current prices.

Since investment expenditures are not included in the model, they enter in the calibration as constant, lump-sum expenditures in each sector so that the calibration can match the observed GDP shares of consumption (otherwise consumption shares would be too large). Data for the period 1970-1995 yield these average expenditure shares: $C/Y=0.684$, $I/Y=0.217$, $G/Y=0.092$. The sectoral data are available for a shorter sample period and the information they provide yields only the average shares of aggregate investment and aggregate government expenditures allocated to tradables (I^T/I and G^T/G) and the ratio of tradables GDP to nontradables GDP (Y^T/Y^N). The 1988-1998 average of Y^T/Y^N is 0.648. The 1988-1996 averages of the other expenditure shares are: $I^T/I=0.576$ and $G^T/G=0.072$.

The above aggregate and sectoral ratios are combined to obtain the following estimates of the shares of sectoral investment and government purchases in each sector's GDP: $I^T/Y^T=0.32$, $G^T/Y^T=0.017$, $I^N/Y^N=0.151$, and $G^N/Y^N=0.141$.⁹ Estimates of sectoral consumption-output ratios are then derived using the expenditures definition of GDP and the average net exports-GDP ratio for 1970-1995, $NX/Y=-0.001$. The consumption-GDP ratios are $C^T/Y^T=0.665$ and $C^N/Y^N=0.708$.

The calibration is normalized by setting $Y^T=1$ and $p^N=1$. The average sectoral share of labor income in the nontradables sector for the 1988-1996 period yields $\alpha^N=0.364$. The elasticity of substitution between C^T and C^N , $1/(1+\eta)$, is set to the value estimated by Ostry and Reinhart (1992). Their estimate of η for developing countries is $\eta=0.316$. Estimates of the wage elasticity of labor supply in Mexico's nontradables sector are not available, so the calibration assumes unitary-elasticity as a benchmark, this implies $\delta=2$. The uniform consumption tax rate is set to $\tau=0.079$ which is the mean tax rate that results from the regime-switching Markov

⁹For example, given I/Y , I^T/I and Y^T/Y^N , I^T/Y^T is given by $(I/Y)(I^T/I)[1+(Y^T/Y^N)]$.

process specified below. R is set to the quarterly equivalent of a gross real interest rate of 1.065 per year and σ is set to 2, both standard values in Real Business Cycle theory.

The calibration values for A , ω , β , T^T and T^N and the corresponding steady-state levels of C^T , C^N , L , Y^N and b are jointly determined by solving the non-linear simultaneous equation system conformed by the steady-state equilibrium conditions of the model, imposing the calibration ratios and parameters described in the previous paragraphs and summarized in Table 2. The solution implies $A=1.958$, $\omega=0.342$, $\beta=0.027$, $T^T=-0.139$, and $T^N=0.119$. Note that the value of β implies a very small semi-elasticity of the rate of time preference to changes in consumption and labor supply, which makes impatience effects of second-order importance.

The remaining parameters that need to be set before solving the model are those pertaining to the stochastic processes of tax-rate, productivity, and interest-rate shocks. The process for the uniform tax rate is set to mimic the price distortions on saving and labor supply induced by sudden devaluations of the currency in a monetary variant of the model calibrated to Mexico (see Mendoza (2000) for details). The low-tax state (set to match a permanently fixed exchange rate) is 2.1 percent and the high-tax state (set to match an annual rate of depreciation of the currency of 50 percent) is 11.8 percent. The mean duration of the low-tax regime is 24 quarters (6 years), which matches the observed durations of the managed exchange rate regimes of 1970-1976, 1976-1982 and 1988-1994. The mean duration of the high-tax regime is set to 36 quarters (9 years) so as to yield a probability of staying in the high-tax regime higher than that of staying in the low-tax regime (which approximates the standard assumption of the literature on policy temporariness that treats the “bad policy” state as absorbent). The assumed mean durations of each regime imply that the probability of switching from the low tax to the high tax z is 4.2 percent per quarter and the probability of continuation of the high tax state ζ is 97.2

percent. The mean tax is 7.93 percent, with a standard deviation of 0.047 and a coefficient of first-order autocorrelation equal to 0.93.

The stochastic processes driving productivity shocks and world-interest-rate shocks are represented by standard two-state, symmetric Markov processes that satisfy the “simple persistence” rule following the same method applied in Mendoza (1995). These processes are statistically independent of the one driving the tax rates. For simplicity, the simulations assume common productivity shocks across sectors (i.e., $\varepsilon_t^N = \varepsilon_t^T = \varepsilon_t$). Since tradables output is treated as an endowment, the standard deviation of productivity shocks is set to mimic the standard deviation of tradables GDP in Mexico (3.36 percent). The standard deviation of interest-rate shocks is set to 0.881 percent, which is the standard deviation of the H-P filtered measure of the gross world real interest rate proposed by Agenor et al. (2000). The correlation coefficient between the two shocks matches the sample correlation of Mexico’s tradables GDP with the world’s real interest rate (-0.116). Symmetry and “simple persistence” imply that the shocks share a common first-order serial autocorrelation coefficient which is set to match the first-order serial autocorrelation of Mexican tradables GDP, 0.553 -- the autocorrelation of the world real interest rate is slightly higher at 0.771.

4.2 *Numerical Solutions: How Large and How Costly are Sudden Stops?*

The model is solved by value-function iteration over a discretized state space. The state space consists of the combinations of the two possible realizations of each of the three shocks, $\varepsilon = \{0.0336, -0.0336\}$, $\varepsilon^R = \{0.0088, -0.0088\}$, $\tau = \{0.118, 0.021\}$ and the 1200 values in an evenly-spaced grid of net foreign asset positions spanning the interval (-2.788, 2.608). Thus, there are 8 combinations of the triple $(\varepsilon, \varepsilon^R, \tau)$ that describe the possible realizations of the state of nature with regard to exogenous shocks at each date, and $1200 \times 8 = 9600$ coordinates in the state space.

Figure 4 plots the limiting probability distribution functions (PDF) of net foreign assets in the economies with perfect credit markets and with an occasionally-binding liquidity constraint. The mean net foreign asset position of the economy with perfect credit markets is -0.097, which is equivalent to a b/Y ratio of -4.5 percent. The implied amount of foreign debt is only 10.9 percent of that held in the deterministic steady state, which illustrates the large amount of precautionary saving that households undertake given the economy's aggregate uncertainty and the incompleteness of financial markets (even when the credit market functions perfectly). Adding the extra incentive for precautionary saving due to the liquidity constraint shifts the economy to a positive value for mean holdings of foreign assets of 0.258 (an average b/Y ratio of 9.3 percent). The economy with the liquidity constraint also differs in that there is a mass of probability (equal to 0.38 percent) concentrated at the threshold net foreign asset position in which the constraint switches from binding in some states to nonbinding for all states of nature. These features of the limiting distributions of assets in economies with precautionary saving with or without liquidity constraints are qualitatively identical to those obtained in the recent literature on the consumption function in partial equilibrium (see Carroll (2000)).

Table 3 lists the business cycle co-movements that correspond to the limiting distributions of the economies with and without liquidity constraints. The constraint has a clear effect in the first and second moments of net foreign assets and net exports, but the rest of the moments listed in the table vary only slightly between the two cases. The mean of net foreign assets increases and their variability diminishes when the liquidity constraint is binding in some states of nature. Clearly, except for the changes in external variables, the possibility of Sudden Stops that results from the liquidity constraint has a negligible effect on the long-run business cycle co-movements of the economy. However, as shown below, Sudden Stops can be very

large and imply nontrivial welfare costs.

Figure 5 plots the impact effects of a switch from the “best” state with regard to exogenous shocks (i.e., $\varepsilon=0.0336$, $\varepsilon^R=-0.0088$, $\tau=0.021$) to the “worst” state (i.e., $\varepsilon=-0.0336$, $\varepsilon^R=-0.0088$, $\tau=0.118$) as a function of the first 600 coordinates in the foreign-asset grid. Impact effects are reported again for the cases with and without liquidity constraint. For high foreign-asset positions (i.e., low debt) the constraint does not bind and the impact effects are the same in the two economies. A switch to the “worst” state increases the debt-GDP ratio and widens the current account deficit as a share of GDP. GDP at tradable goods prices, consumption, consumption of tradables, labor, the price of nontradables, and output of nontradables all fall sharply (the declines range between 10 and 20 percent relative to the level in the “best” state). These effects are in line with the wealth and substitution effects described in Section 3 for the economy without credit constraints. Note also that in the economy without liquidity constraints the magnitude of the effects is roughly the same for *any* foreign asset position (except that the decline in b_{t+1}/Y_t is larger the lower the initial b_t). Thus, the economy without liquidity constraints cannot produce Sudden Stops, even though it features precautionary saving and its long-run business cycle moments are similar to those of the economy with liquidity constraints.

For values of b_t lower than 364th value of the foreign asset grid, the liquidity constraint is binding regardless of the realizations of the shocks, and hence b_{t+1}/Y_t cannot change across states of nature. Still, the constraint is not equally binding in each state so the other impact effects in Figure 5 vary. In particular, for this range of foreign asset positions, the declines in Y_p , C_p , C_t^T , L_p , p_t^N and Y_t^N are smaller the higher the stock of initial debt (i.e., the lower b_t). For foreign asset positions lower than coordinate 100 in the grid, it is even possible to obtain declines in labor supply and nontradables GDP *smaller* than those obtained in the absence of the credit constraint,

as the effect of the higher marginal reward on labor supply outweighs all of the other supply and demand effects described earlier. However, this range of foreign asset positions is of little interest because it has a negligible limiting probability of being observed in the economy without credit frictions (see Figure 4), and even in the economy with credit constraints they represent states from which the economy departs very quickly and has zero probability of returning to. The latter can be observed in Figure 6 which plots the transitional dynamics of the PDF of foreign assets in the liquidity-constrained economy starting from the lowest value of b . There is zero probability of observing values of b lower than the 200th coordinate after just two quarters.

There is a third key range of foreign asset positions in which the credit constraint is not binding in some states of nature but shifts to become binding in others. In Figure 5, the constraint shifts from nonbinding to binding as the economy switches from the “best” to the “worst” state for values of b_t between the 364th and 417th coordinates in the foreign asset grid. There is still room for adjustment in the b/Y ratio because the constraint is not binding in the “best” state, but the adjustment is smaller than in the economy with perfect credit markets. At the high end of this range, the model yields Sudden Stop dynamics with a large reversal in the current account deficit and collapses in Y_p , C_p , C_t^T , L_p , p_t^N and Y_t^N larger than those of the economy with perfect credit markets. These larger collapses follow from the intuition developed to explain the impact effect a tax hike on labor supply in Section 3 using equation (13). However, note that in the Figure the shift is not only from low to high tax but also from high productivity and low world real interest rate to the opposite. This explains why in part of the Sudden Stop range it is possible for labor and nontradables output to fall sharply even in states in which the price of nontradables is actually rising sharply.

Sudden Stops are dramatic events but they are also relatively rare. The range of foreign

asset positions that supports Sudden Stops is nearly ruled out of the limiting PDF of foreign assets in the credit-constrained economy by the households' precautionary saving. The only relevant coordinate is the one with the "excess" probability mass identified earlier in which the economy is on the threshold of moving into states in which the constraint is not binding regardless of the realizations of the shocks. However, in contrast with the high-debt states from which the economy moves away nearly instantaneously, Figure 6 shows that even after 4 to 6 quarters of transitional dynamics (starting from a high-debt state) the economy is still in a range in which Sudden Stops are very likely. Thus, on account of both the skewness of the steady-state distribution of foreign assets around the Sudden Stop threshold and the high probability of transiting through states in which Sudden Stops are very likely off the steady state, one can conjecture that small *unexpected* real shocks or disturbances to market access can be a powerful trigger of Sudden Stops.

How costly are Sudden Stops in terms of social welfare? Figure 7 plots estimates of the welfare cost associated with the presence of the liquidity constraint. The welfare costs are percent compensating variations in consumption across time and states of nature that would render households indifferent between the lifetime utilities of the economies with and without the constraint, evaluated at each initial foreign asset position in the state space and for the "best" and "worst" realizations of exogenous shocks on the initial date. These welfare costs follow a similar pattern as the impact effects. In the low-debt (high b_t) range in which the liquidity constraint is not binding for any realization of the shocks there is virtually no welfare loss. Welfare costs start to rise as the initial foreign asset position falls into the Sudden Stop range. In this range, there is a negligible loss in the "best" state but a positive loss in the "worst" state. The largest loss in this range is about a 0.6 percent compensating consumption variation.

Finally, in the high-debt (low b_t) range in which the constraint binds regardless of the state of nature, the welfare costs rise rapidly as the initial net foreign asset position declines. The cost reaches 16 percent at the lowest point in the foreign asset grid and the “worst” state of nature.

The mean welfare loss computed using the PDF of the economy with perfect credit markets equals 1/3 of a percentage point. A comparison of Figures 4 and 7 shows that this average welfare cost reflects mainly the losses in the Sudden Stop range. A loss of 0.3 percent is very large when compared to the standard measures of the cost of business cycles in similar quantitative experiments. Lucas (1987) estimated this cost at about 0.01 percent in a closed-economy model calibrated to the U.S. economy. Mendoza (1991b) estimated the cost at 0.02 percent in a small open economy with incomplete insurance markets but perfect credit markets calibrated to Canada. The mean welfare cost of the liquidity constraint is 15 times larger. The average welfare cost is also very sensitive to the value at which the initial point with “excess mass” in the PDF of foreign assets settles in the credit-constrained economy relative to the mean foreign asset position of the economy with perfect credit markets. In the simulations conducted here, the coordinate with excess mass is lower than the mean b of the unconstrained economy. Mendoza (2000) finds a much larger mean welfare loss of 4.6 percent in a case in which the opposite is true.

Welfare costs of Sudden Stops would also be much larger if Sudden Stops were viewed as the outcome of systemic, structural shocks that permanently increase the value of φ , rather than rare occurrences resulting from unexpected shocks or small, temporary disturbances to capital-markets access for a given value of φ . The results presented here would then apply for a sudden, permanent shock that increases φ from a value $\varphi \leq 0.445$ to $\varphi = 0.714$, which are the values that support the unconstrained and constrained limiting PDFs in Figure 4. If the economy

has relatively high debt when this structural change occurs, it will follow transitional dynamics during which it is very likely to experience Sudden Stops like those depicted in Figure 5, but these events will be very rare in the long run. The welfare implications would differ dramatically, though, in that for countries starting from high debt the relevant welfare costs are the large costs depicted in the left side of Figure 7, which are markedly higher than the 0.3 percent mean welfare loss referred to earlier.

5. Equity Prices, Margin Requirements, and Excess Volatility of Portfolio Flows

The framework developed in Section 3 is modified here to propose a model in which a credit-market imperfection may induce large shifts in portfolio flows and equity prices. The model is based on a variation of a closed-economy model proposed by Aiyagari and Gertler (1999). The model considers agents in the domestic small open economy that trade shares of their capital stock with foreign securities firms while being subject to margin requirements. Foreign firms specialize in holding equity of the small open economy and face portfolio adjustment costs that result from their disadvantaged position in trading equity relative to residents of that economy in terms of information or institutional features. Frankel and Schmukler (1996) provide empirical evidence suggesting that indeed foreign traders are at a disadvantage relative to traders in domestic equity markets of emerging economies.

The model is simplified to consider only a single, homogeneous tradable good. This offers two important advantages in setting up the asset pricing model. First, it implies that the GHH specification of the argument of utility eliminates the wealth effect on labor supply and isolates completely the labor supply decision from the dynamics of consumption, saving and portfolio choices. Second, since the optimal labor demand and profits of firms are unaffected by credit frictions, the model features a supply-side that corresponds exactly to that of a frictionless

economy. As a result of these two features, equilibrium dividend streams and labor-market allocations are independent of saving decisions and credit frictions. The trade off is that in this setting a Sudden Stop does not induce an unusually large output collapse, even though it still causes excessive current account reversals and collapses of private consumption

Production is undertaken with the same Cobb-Douglas technology as before: $Y_t = \exp(\varepsilon_t)AK^{1-\alpha}L_t^\alpha$. Profit-maximizing firms choose labor demand so that at each date t labor demand is given by the standard productivity condition:

$$\exp(\varepsilon_t)A\alpha K^{1-\alpha}L_t^{\alpha-1} = w_t \quad (15)$$

Dividend payments are given by:

$$d_t = \exp(\varepsilon_t)A(1-\alpha)K^{-\alpha}L_t^\alpha \quad (16)$$

Expected lifetime utility is the same as before (except that C is now made of a single consumption good). Households maximize utility subject to the following budget constraint:

$$(1 + \tau_t)C_t = a_t K d_t + w_t L_t + q_t (a_t - a_{t+1})K - b_{t+1} + b_t \exp(\varepsilon_t^R)R \quad (17)$$

where τ_t is a random consumption tax (which can also be interpreted as an import tariff), a_t and a_{t+1} are beginning- and end-of-period shares of the domestic capital stock owned by domestic households, d_t are dividends paid by domestic firms and q_t is the price of equity. Households also face a *margin requirement* according to which they must finance a fraction κ of their equity holdings out of current saving:

$$a_t K d_t + w_t L_t + q_t a_t K + b_t \exp(\varepsilon_t^R)R - (1 + \tau_t)C_t \geq \kappa q_t a_{t+1} K \quad (18)$$

Given the budget constraint, the margin requirement imposes a “collateral” constraint on foreign borrowing of the form:

$$b_{t+1} \geq -(1 - \kappa)q_t a_{t+1} K \quad (19)$$

This constraint differs sharply from the liquidity requirement because it depends on the price of equity, which is a forward-looking variable. Note that the constraint can also be interpreted as restricting the stock of savings (i.e., $q_t a_{t+1} K + b_{t+1}$) to be larger than $\kappa q_t a_{t+1} K$.

The optimality conditions of the household's problem have similar features as before, except that a binding borrowing constraint does not distort labor supply and cannot induce distortions via the dynamics of relative goods prices. A binding borrowing constraint still increases the expected effective real interest rate of the small open economy relative to the world real interest rate. Furthermore, if the expected return on equity is defined as $E_t[R_{t+1}^q] \equiv E_t[(d_{t+1} + q_{t+1})/q_t]$, the optimality conditions on debt and equity yield the following expression for the equity premium:

$$E_t[R_{t+1}^q] - E_t[R_{t+1}^R] = \frac{\eta_t \kappa - COV(\lambda_{t+1}, R_{t+1}^q) + COV(\lambda_{t+1}, R_{t+1}^R)}{E_t[\lambda_{t+1}]} \quad (20)$$

where λ and η are the non-negative Lagrange multipliers on the budget constraint and the margin constraint respectively.

If the world real interest rate is deterministic, the last covariance term in the numerator of the right-hand-side of (20) vanishes. In this case, and if the margin requirement never binds (i.e., $\eta_t = 0$ for all t), the formula yields the standard equity-premium formula under perfect credit markets. In contrast, a binding margin requirement at date t (i.e., $\eta_t > 0$) causes an excess equity premium because the pressure that the margin call exerts on households to fire-sell equity depresses the current equity price. The effect of the binding margin constraint at t is likely to be persistent because, as shown below, foreign traders adjust their portfolios slowly.

Using the standard forward-solution method, it follows that optimal portfolio decisions

by agents in the small open economy require the equity price to satisfy:

$$q_t = E_t \left(\sum_{i=0}^{\infty} \left[\prod_{j=0}^i \frac{\lambda_{t+1+j}}{\lambda_{t+j} - \eta_{t+j}(1-\kappa)} \right] d_{t+1+i} \right) \quad (21)$$

If the margin requirement never binds, this expression reduces to a standard asset-pricing formula that will set a “fundamentals” equilibrium equity price consistent with the one perceived by foreign traders derived below. In the case that margin calls are possible at any date, the effects on the price of equity are easier to interpret if the definition $E_t[R_{t+1}^q] \equiv E_t[(d_{t+1}+q_{t+1})/q_t]$ is used to re-write (21) as follows:

$$q_t = E_t \left(\sum_{i=0}^{\infty} \left[\prod_{j=0}^i E_t[R_{t+1+j}^q] \right]^{-1} d_{t+1+i} \right) \quad (22)$$

where the sequence of $E_t[R_{t+1+j}^q]$ is given by (20). If margin requirements are binding at present, or expected to bind in the future, some or all of the expected returns on equity used to discount the future stream of dividends in the above formula increase and thus the current price of equity falls. Clearly, since a binding margin requirement implies an effective real interest rate that exceeds the risk-free rate, the price of equity under a binding margin requirement is always lower than the fundamentals price. Moreover, the date- t equity price is lower than the date- t fundamentals price whenever the margin requirement is expected to bind in the future, *even if it were not binding at date t* (i.e., all what is required for $q_t < q_t^f$ is that $\eta_{t+j} > 0$ for some $j > t$).

As in Section 3, the government sets the value of the tax or tariff rate τ_t and uses the revenue to finance unproductive expenditures G_t maintaining a balanced-budget policy:

$$G_t = \tau_t C_t \quad (23)$$

Thus, sudden changes in taxes or tariffs introduce the Calvo-Drazen fiscal-induced wealth effect present in the model with liquidity constraints.

Foreign securities firms maximize the present discounted value of dividends D to their global share-holders, facing a quadratic adjustment cost in adjusting equity positions in the small open economy. These firms choose their equity position α_{t+1}^* for $t=0, \dots, \infty$ so as to maximize:

$$D = E_0 \left[\sum_{t=0}^{\infty} M_t \left(\alpha_t^* K (d_t + q_t) - q_t \alpha_{t+1}^* K - q_t \left(\frac{a}{2} \right) \left((\alpha_{t+1}^* - \alpha_t^*) K + \theta \right)^2 \right) \right] \quad (24)$$

where $M_0 = 1$ and M_t for $t=1, \dots, \infty$ are the *exogenous* discount rates that apply to date- t dividends paid by foreign traders to their global customers. The parameter a is a “speed-of-adjustment” coefficient and θ is a long-run cost of holding a time-invariant equity position in the small open economy. This cost is assumed to be zero if the long-run equity price is to be equal to its “fundamentals” level, otherwise the cost is positive and time-invariant.

The first-order condition for the optimization problem of securities firms implies a partial-adjustment rule for their portfolio of the form:

$$(\alpha_{t+1}^* - \alpha_t^*) K = a^{-1} \left(\frac{q_t^f}{q_t} - 1 \right) - \theta \quad (25)$$

where q_t^f is the “fundamentals” price of equity defined as:

$$q_t^f = E_t \left(\sum_{i=1}^{\infty} \frac{M_{t+i}}{M_t} d_{t+i} \right) \quad (26)$$

According to (25), foreign firms increase their demand for equity by a fraction of the percent

deviation of the date- t equity price below the corresponding fundamentals level. This adjustment in demand is inversely related to the value of a . Thus, the informational friction behind the portfolio adjustment cost is key to support *equilibrium* equity prices below the fundamentals levels. If securities firms could adjust their portfolios at no cost, households could liquidate the shares they need to meet margin calls at an infinitesimal price discount.

If the margin requirement never binds, the small open economy is seen as one of infinitely-many identical small open economies conforming the world economy, so that the discount rates in (21) and (26) are the same. Thus, if the margin requirement never binds the equilibrium price is the fundamentals price and neither domestic residents or foreign traders alter their equity positions. If the constraint binds, however, q_t^f remains the same (since the discount rates of foreign traders are exogenous and the stream of dividends is independent of portfolio decisions), but the equilibrium equity price will fall below it depending on how much pressure the margin call puts on domestic residents to fire sell equity relative to how quickly the foreign traders are able to adjust their portfolios.

The effects of exogenous shocks to global capital markets (such as shocks to the world real interest rate) on asset prices and equity flows can be examined using this model in an analogous manner as the “liquidity shocks” examined by Aiyagari and Gertler (1999). The effects of productivity shocks, policy shocks, and shocks to the margin coefficient κ can also be studied. These experiments would capture some of the features of the episode of waves of margin calls observed in the aftermath of the Russian default in 1998. During this episode, margin calls were triggered by increasing estimates of potential portfolio losses produced by the value-at-risk models of investment banks that leveraged the operations of hedge funds like Long Term Capital Management. As market volatility increased and asset prices plummeted, value-at-

risk estimates worsened thereby mandating even larger margin calls. Similarly, in the model, shocks that make equity prices fall below fundamentals trigger an endogenous increase in the level of the margin requirement (even if κ remains unchanged). The sharper the decline in equity prices, the larger the size of the margin call.

Unfortunately, the model cannot be solved in closed-form analytically so the extent to which it can account for observed equity-price corrections and reversals of portfolio flows during Sudden Stops is left for further quantitative research (Mendoza and Smith (2000) are exploring the quantitative implications of this model in work in progress). Still, the model's deterministic steady state offers interesting insights on the long-run implications of the margin constraint for asset prices. If the margin constraint is not binding at steady state (and hence the long-run portfolio adjustment cost vanishes), the steady-state equity price equals the fundamentals price: $\bar{q} = \bar{q}^f = \bar{d} / (\bar{R} - 1)$. Implicit in this equality is the fact that the return on equity, $(\bar{q} + \bar{d}) / \bar{q}$, equals the gross rate of return on foreign assets (i.e., there is no equity premium). Note, however, that the steady-state equity and debt positions depend on initial conditions even though savings have a unique steady state independent of initial conditions. Portfolio holdings in place when the margin requirement becomes permanently nonbinding are never altered. Hence, these portfolio holdings are also the steady-state holdings, while foreign bonds adjust gradually to converge to the unique steady-state level of savings that yields a steady-state rate of time preference equal to the world interest rate.

If the margin requirement is binding at steady state (and hence $\theta > 0$), the partial-adjustment portfolio rule of securities firms implies that the steady-state equity price satisfies:

$\bar{q} = \bar{q}^f / (1 + a\theta) < \bar{q}^f$. This price is supported as an equilibrium price from the household's side

because the margin requirement and the endogenous rate of time preference result in a long-run equity premium: the steady-state rate of return on equity exceeds the world risk-free rate of return by the amount $\kappa(\eta/\lambda)$. Thus, under the assumed specification of preferences, the financial and informational frictions implied by the margin constraint and the portfolio adjustment cost combine to yield a stationary equilibrium in which equity prices can deviate permanently from their fundamentals value and the margin constraint always binds. Moreover, in this case the steady-state holdings of foreign bonds and equity are uniquely determined.

6. Conclusions and Policy Implications

This paper conducts a quantitative analysis of the macroeconomic effects of credit-market imperfections in a general-equilibrium model of a small open economy. The framework proposed here illustrates the potential for these imperfections to account for the Sudden Stops phenomenon as unusually large recessions that yet may go unnoticed in long-run business cycle co-movements. Sudden Stops occur when borrowing constraints become suddenly binding as a result of shocks to productivity, the world real interest rate or domestic policy variables. This is possible because debt contracts are written in units of tradable goods while part of the debt is leveraged on the income of the nontradables sector, or on collateral that reflects the value of domestic capital. Adverse real or policy shocks induce sharp collapses in the production and/or relative price of nontradable goods, or in the price of domestic equity, and thus contribute to tighten credit constraints. Sudden Stops and large fluctuations in the real exchange rate occur in this economy even though markets are competitive and prices are completely flexible. In addition, welfare analysis shows that the social costs of these Sudden Stops can be large.

The findings of this study suggest that policy intervention is worth considering but also that the type of policies that can be effective for managing Sudden Stops need to be carefully

chosen. Alternatives considered so far in the literature can be classified as siding with two approaches: an *isolationist* approach that seeks to avoid Sudden Stops by imposing capital controls and limiting currency trading and an *internationalist* approach that aims to minimize Sudden Stops by promoting the global integration of domestic financial institutions and by abandoning weak domestic currencies with the adoption of hard currencies (i.e., dollarization).

Policies advocated by internationalists counter two important determinants of Sudden Stops identified in the paper: the lack of credibility of economic policies in emerging-markets countries and the perverse combination of heavy-need with weak-incentives for gathering costly information about these countries by global investors and lenders that drives credit-market imperfections (see Calvo and Mendoza (2000b)). Dollarization, for example, does away with the need to keep track of country-specific monetary and exchange rate policies, which have proven extremely volatile and hard to predict in periods of capital-markets turbulence. A similar principle applies to fiscal and trade policies that follow regimes with uncertain duration, but which are harder to make credible. Mendoza (2000) finds that the benefits of increased policy credibility in the case of dollarization can be very large. The results of this paper show in addition that the potential gains of structural policies that improve the efficiency of credit markets can be substantial.

The analysis of the paper also sheds light on some of the drawbacks of policies advocated by isolationists. The dynamic general-equilibrium nature of the analysis fleshes out the tension between the short-term aim of using capital controls or liquidity requirements to prevent a Sudden Stop's reversal of capital flows and the dynamic implications of these policies. For these policies to effectively remove the risk of Sudden Stops, they must ensure that exposure to large outflows is fully avoided, but this can only be guaranteed if the stock of foreign liabilities is

severely restricted so that it is never allowed to be “too large.” However, relative to the environment with occasionally-binding credit constraints examined in the paper, this is a worst-case scenario equivalent to one in which borrowing constraints are very tight. Sudden Stops are avoided, domestic saving is high and long-run private consumption is high, but this is the result of very costly distortions. Policies not as tough as capital controls but with a similar aim of stabilizing capital flows, such as short-selling constraints, margin requirements, and collateral constraints linked to value-at-risk estimates have other negative features. Short-selling constraints exacerbate the loss of incentives to gather costly information, as Calvo and Mendoza (2000b) showed, while margin requirements and collateral constraints strengthen the mechanisms driving excess volatility of asset prices and international capital flows examined in this paper.

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Appendix I

Given the assumptions made in Section 3 about the lifetime utility function and its components u , v , C and H , it is easy, though lengthy, to show that the first-order conditions for the households' optimization problem can be simplified to the following expressions:

$$U_C(t) \left(1 - \frac{\mu_t}{\lambda_t}\right) = \exp(-v(t)) E_t \left[\frac{R p_t^C (1 + \tau_t^C)}{p_{t+1}^C (1 + \tau_{t+1}^C)} U_C(t+1) \right] \quad (\text{A1.1})$$

$$\frac{C_{C^N}(t)(1 + \tau_t^T)}{C_{C^r}(t)(1 + \tau_t^N)} = p_t^N \quad (\text{A1.2})$$

$$H'(L_t) = \left(\frac{w_t}{p_t^C (1 + \tau_t^N)} \right) \left[1 + \frac{\mu_t}{\lambda_t} \frac{1 - \varphi}{\varphi} \right] \quad (\text{A1.3})$$

The terms in U_C are derivatives of *lifetime* utility with respect to C . These include “impatience effects” by which changes in consumption or labor supply at any date t alter the rate at which all period utilities after t are discounted.

Appendix II

The competitive equilibrium of the small open economy described in Section 3 can be characterized as the solution to the following social planner's problem. The state variables of the system at any date t include: $b \equiv b_t$ and the observed realizations of the exogenous shocks $\psi \equiv (\varepsilon_t^T, \varepsilon_t^N, \varepsilon_t^R, \tau_t)$. Conditional on these state variables and the Markov processes driving the shocks, the planner chooses an optimal value for $b' \equiv b_{t+1}$ so as to solve the following Bellman equation:

$$V(b, \psi) = \max \left\{ u(\hat{C}) - H(\hat{L}) + \exp(-v(\hat{C} - H(\hat{L}))) E[V(b', \psi')] \right\} \quad (\text{A2.1})$$

subject to:

$$(1 + \tau)\hat{C}^T + \tau \hat{p}^N \hat{C}^N = \exp(\varepsilon^T)Y^T - b' + b \exp(\varepsilon^R)R - T^T \quad (\text{A2.2})$$

$$\hat{C}^N = \exp(\varepsilon^N)F(K, \hat{L}) - G^N \quad (\text{A2.3})$$

$$b' \geq -\left(\frac{1-\varphi}{\varphi}\right)\left(\exp(\varepsilon^T)Y^T + \hat{p}^N \exp(\varepsilon^N)F(K, \hat{L})\right) \quad (\text{A2.4})$$

The variables in “hats” represent solutions of a system of four nonlinear simultaneous equations in four unknowns for each coordinate (b, b', ψ) in the state space. If the liquidity constraint (A2.4) is not binding, the system includes the equilibrium conditions equating the marginal rate of substitution of C^T and C^N with p^N (equation (A1.2)) and the marginal rate of substitution between labor and C^T with the effective real wage (equation (A1.3)), and the market-clearing conditions (A2.2) and (A2.3). If the liquidity constraint is binding, (A2.4) holds with equality and replaces the labor-consumption optimality condition (A1.3). The solutions to this system are not the equilibrium of the model, they represent allocations of the “hat” variables that satisfy a subset of the equilibrium conditions given any arbitrary set (b, b', ψ) in the state space.

The dynamic programming problem defined above can be solved using different methods. In light of the inequality constraint imposed by the liquidity requirement, an exact solution method may be the best alternative. The strategy to follow with this method is to define a discrete representation of the state space and to solve the Bellman equation by value function iteration. While this method is time-consuming and memory intensive, it allows explicit control of the constraints to ensure that the effects of the “occasionally binding” liquidity constraint are calculated accurately.

Table 1. Stylized Facts of Mexican Business Cycles

	Minimum	Standard Deviation	Ratios relative to Nontradables GDP		First-order Autocorrelation	Correlation with:		
			Minimum	Standard Dev.		GDP	Tradables GDP	Nontradables GDP
GDP	-7.936	2.734	1.196	0.997	0.647	1.000	0.885	0.946
Tradables GDP	-10.145	3.368	1.529	1.229	0.553	0.885	1.000	0.685
Nontradables GDP	-6.633	2.741	1.000	1.000	0.657	0.946	0.685	1.000
Price of nontradables	-24.409	8.088	3.680	2.951	0.899	0.626	0.534	0.607
Consumption	-8.567	3.347	1.292	1.221	0.664	0.922	0.853	0.846
Government Expenditures	-9.126	4.544	1.376	1.658	-0.076	0.419	0.442	0.344
Investment	-28.007	11.083	4.222	4.043	0.783	0.892	0.834	0.815
Net Exports	-48.193	19.216	7.265	7.010	0.794	-0.608	-0.713	-0.456
World real interest rate	-1.458	0.881	0.220	0.321	0.771	-0.235	-0.116	-0.279

Note: These statistics were computed using quarterly seasonally-adjusted data for the period 1980:1-1997:4, except for the real interest rate which is for the period 1983:1-1996:3. The data were logged and detrended using the Hodrick-Prescott filter with the smoothing parameter set at 1600. The real interest rate is the London quote of the Eurodollar nominal interest rate minus the consumer price inflation of industrial countries, both reported in the IMF's International Financial Statistics as series 60d, code 112 and series 64, code 110 respectively. This is the same measure of the real interest rate proposed by Agenor, McDermott and Prasad (2000). Net exports are defined as detrended exports minus detrended imports. "Minimum" corresponds to the smallest deviations from the Hodrick-Prescott trends, which are all dated 1995:2 (except for the world real interest rate).

Table 2. Parameter Values for the Calibrated Deterministic Stationary State

<u>Technology:</u>		<u>Fiscal policy:</u>		<u>Credit market:</u>	
α	0.364	T	0.079	R	1.016
A	1.958	$T \text{ traded}$	-0.139	φ	0.740
YT	1.000	$T \text{ nontraded}$	0.119	b/Y	-0.350
 <u>Preferences:</u>		 <u>National accounts ratios:</u>			
β	0.027	C/Y	0.684	CT/YT	0.665
δ	2.000	I/Y	0.217	GT/YT	0.017
η	0.316	G/Y	0.092	IT/YT	0.323
ω	0.342	NX/Y	-0.001	CN/YN	0.708
σ	2.000	YT/YN	0.648	GN/YN	0.141
				IN/YN	0.151

Table 3. Business Cycle Comovements in the Limiting Distribution of Model Economies

	Mean	Standard Deviation	Standard Dev. relative to GDP of nontradables	First-order Autocorrelation	Correlation with GDP
<i>Economy with Perfect Credit Markets</i>					
Net foreign assets	-0.097	0.883	14.274	0.999	0.321
GDP in units of tradables	2.598	7.307	1.829	0.931	1.000
Tradables GDP	1.000	3.368	0.843	0.553	0.387
Nontradables GDP	1.548	3.995	1.000	0.633	0.387
Labor	0.524	5.003	1.252	0.928	0.976
Consumption	0.924	6.254	1.565	0.839	0.823
Consumption of tradables	0.683	10.162	2.544	0.934	0.996
Consumption of nontradables	1.097	5.635	1.411	0.633	0.387
Net Exports	0.002	25.987	6.504	0.623	-0.025
Price of nontradables	1.033	11.925	2.985	0.815	0.874
World real interest rate	1.016	0.880	0.220	0.553	-0.071
<i>Economy with Liquidity Constraint</i>					
Net foreign assets	0.258	0.679	10.957	0.999	0.313
GDP in units of tradables	2.612	7.323	1.830	0.931	1.000
Tradables GDP	1.000	3.368	0.842	0.553	0.391
Nontradables GDP	1.549	4.002	1.000	0.633	0.391
Labor	0.525	5.008	1.252	0.928	0.978
Consumption	0.927	6.266	1.566	0.838	0.823
Consumption of tradables	0.688	10.158	2.538	0.934	0.996
Consumption of nontradables	1.098	5.643	1.410	0.633	0.391
Net Exports	-0.004	9.150	2.287	0.599	-0.003
Price of nontradables	1.041	11.880	2.969	0.815	0.874
World real interest rate	1.016	0.880	0.220	0.553	-0.069

Note: All standard deviations are in percent of the corresponding mean, except for the one corresponding to the net foreign asset position.

Figure 1. Mexico's Sudden Stop
 (percent changes with respect to the same quarter of the previous year)

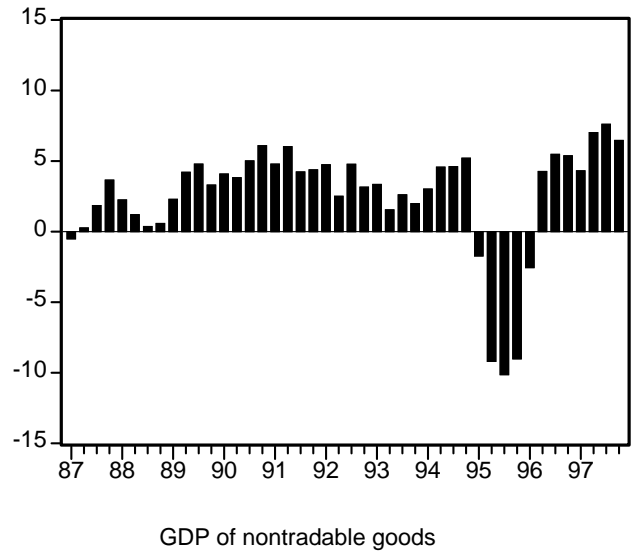
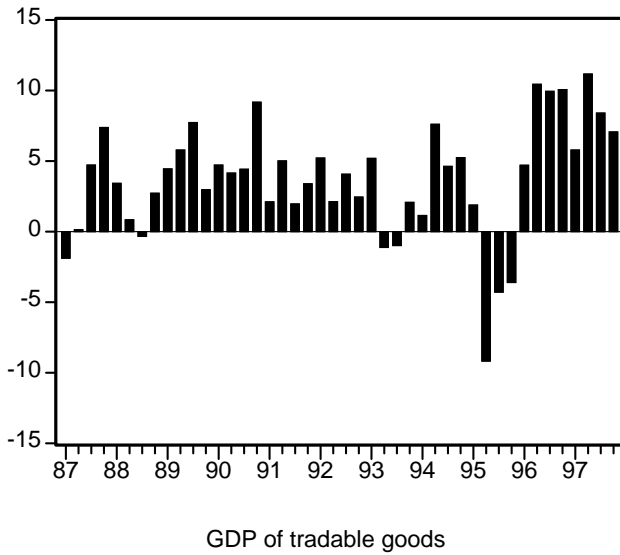
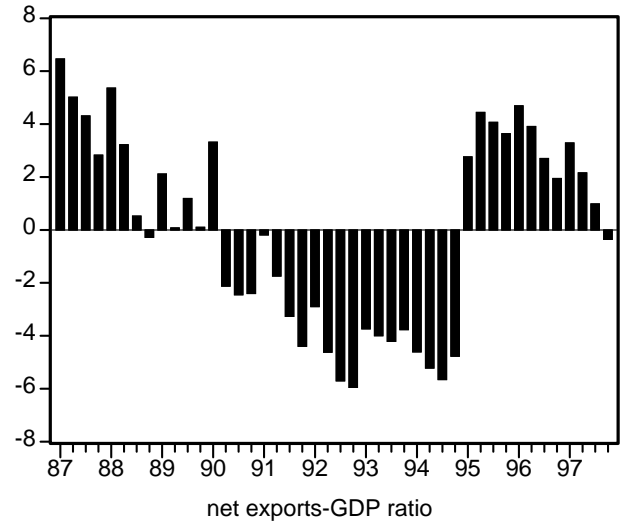
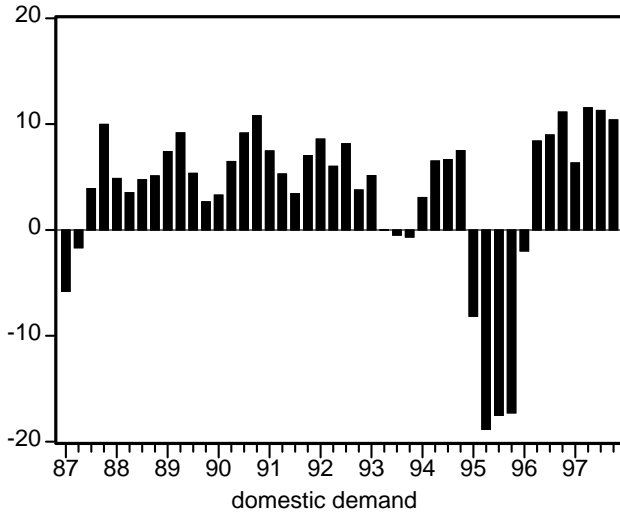
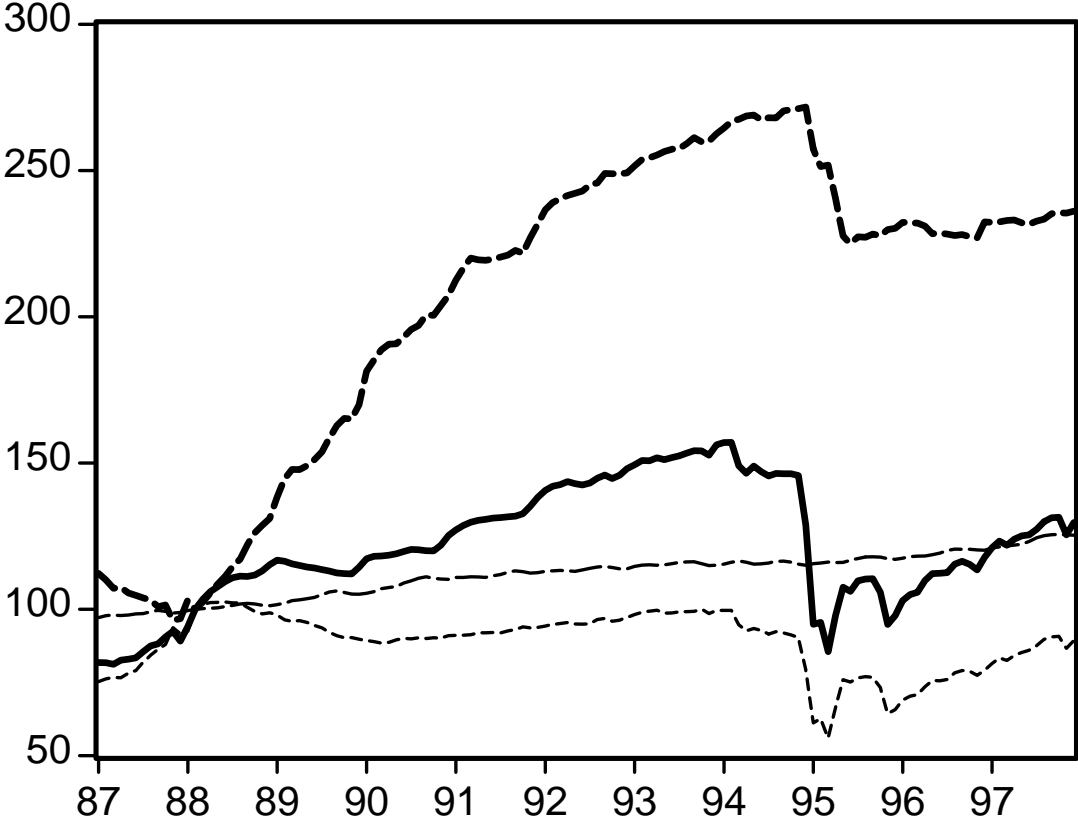


Figure 2. Mexico: Exchange Rates and Relative Prices
(indexes based 1988:02=100)



— real exchange rate (CPI based) - - - Mexico's nontradables prices
- - - - - nom. ex. rate & tradables prices ····· US nontradables prices

Figure 3a. Deviations from Trend in Output and Demand

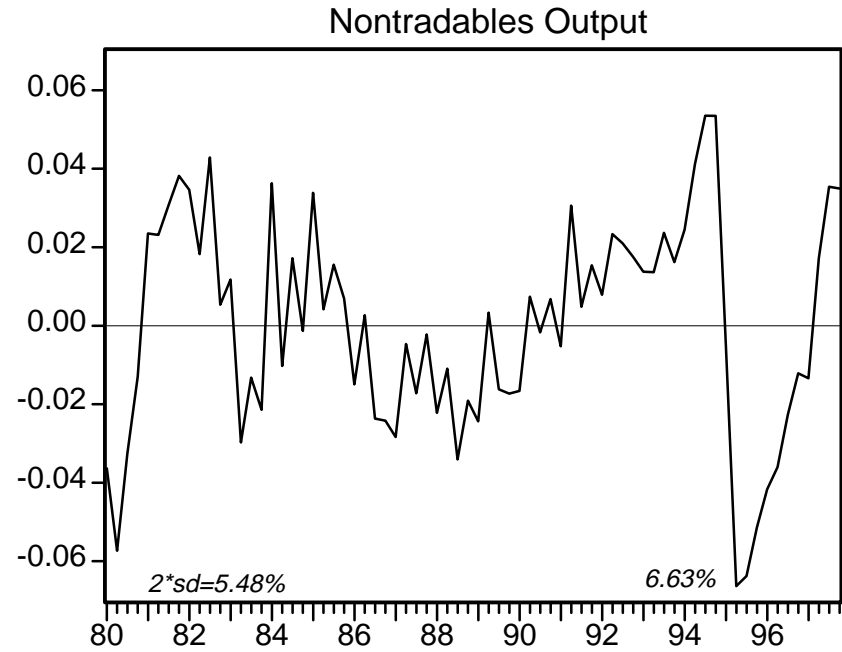
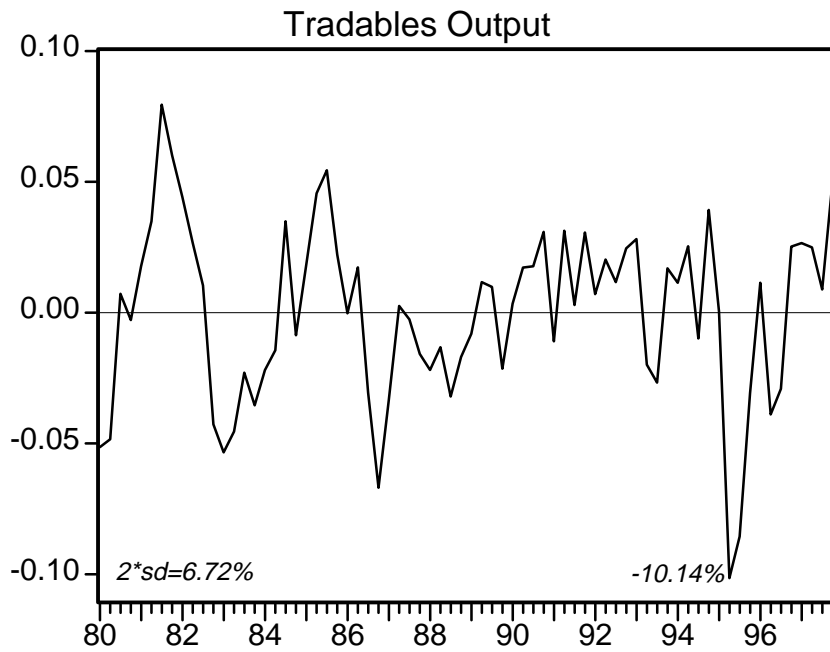
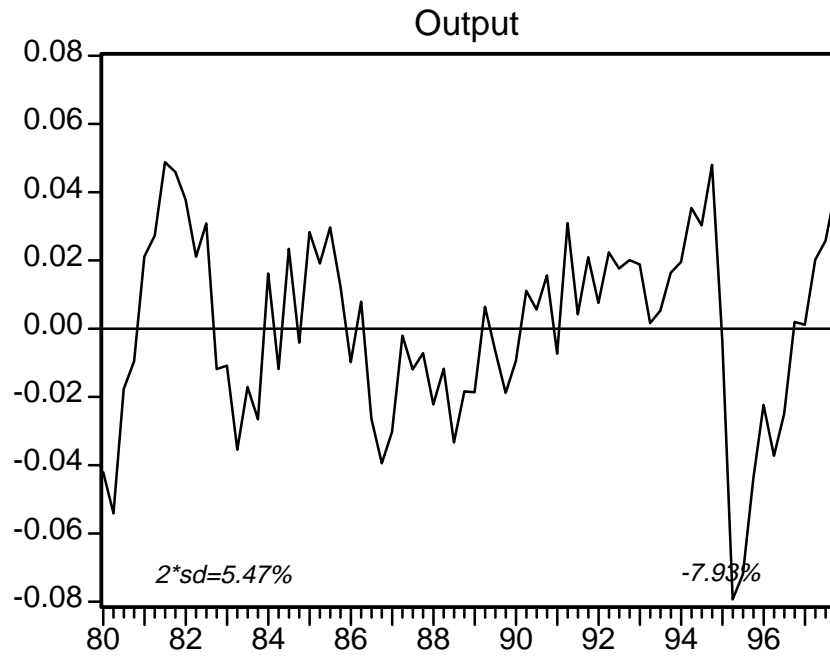


Figure 3.b. Deviations from Trend in Output and Demand

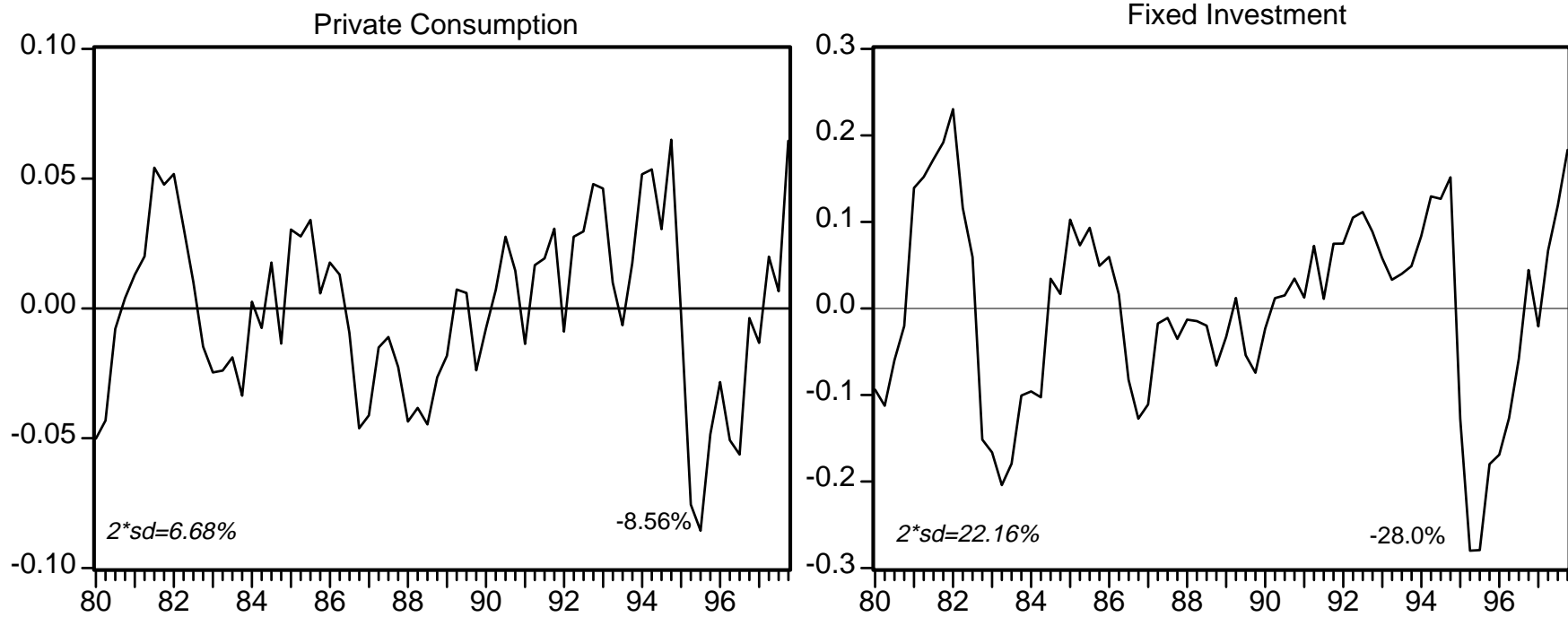


Figure 4. Limiting Distributions of Net Foreign Assets

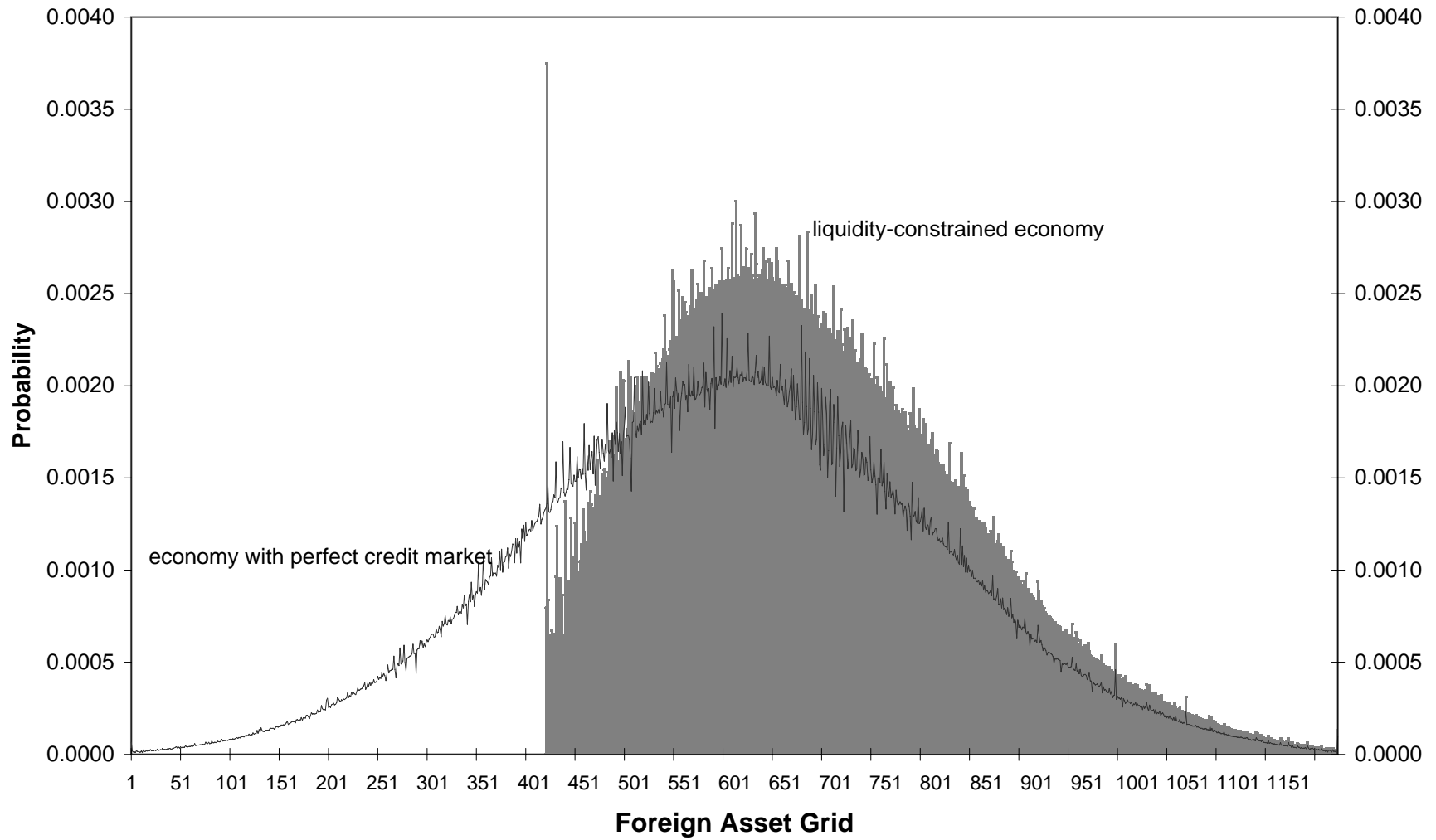
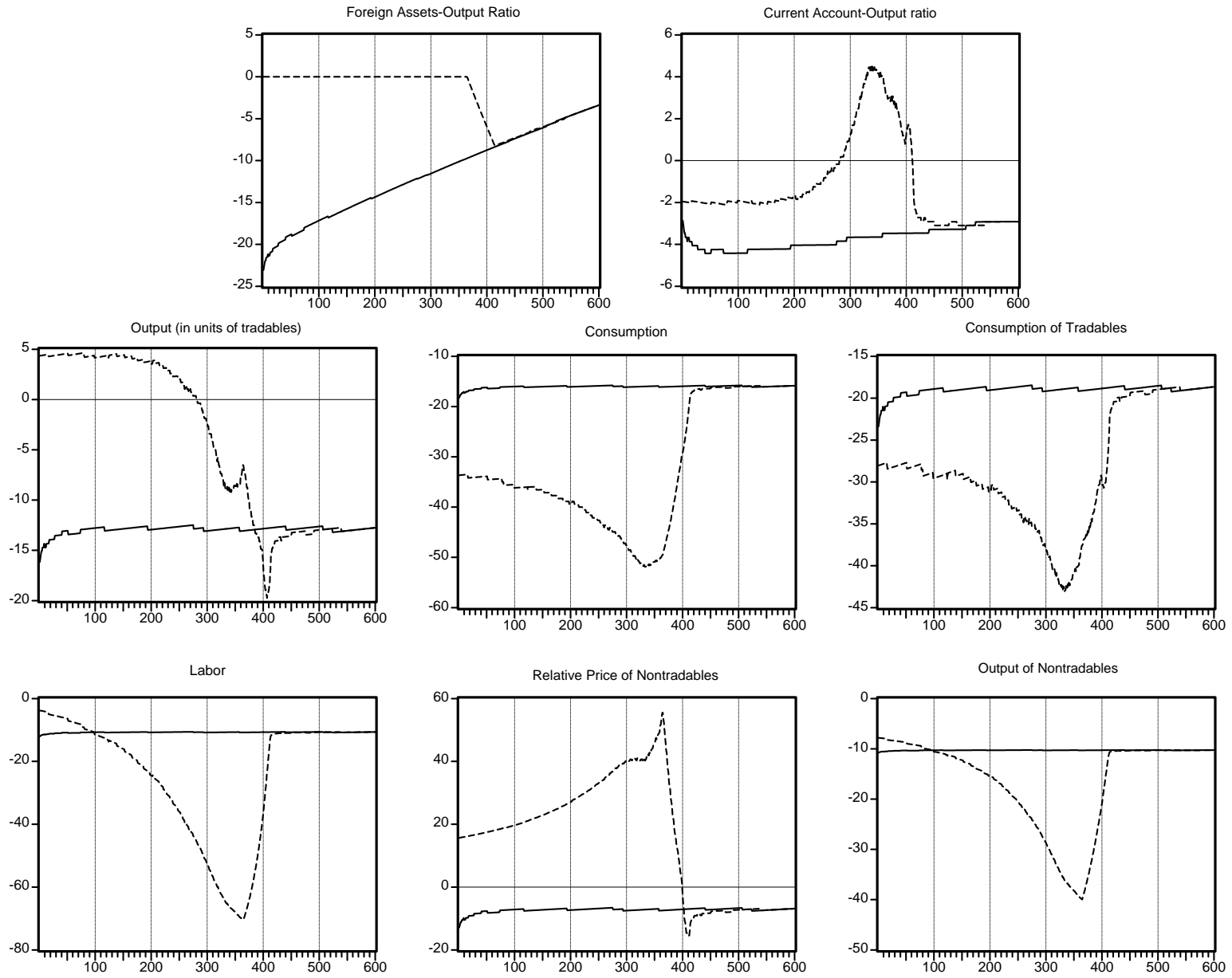


Figure 5. Impact Effects of a Shift from "Best" to "Worst" State



— economy w. perfect credit market --- liquidity constrained economy

Figure 6. Transition Distributions of Net Foreign Assets in Liquidity Constrained Economy
(from largest initial debt position and random shocks in state 1)

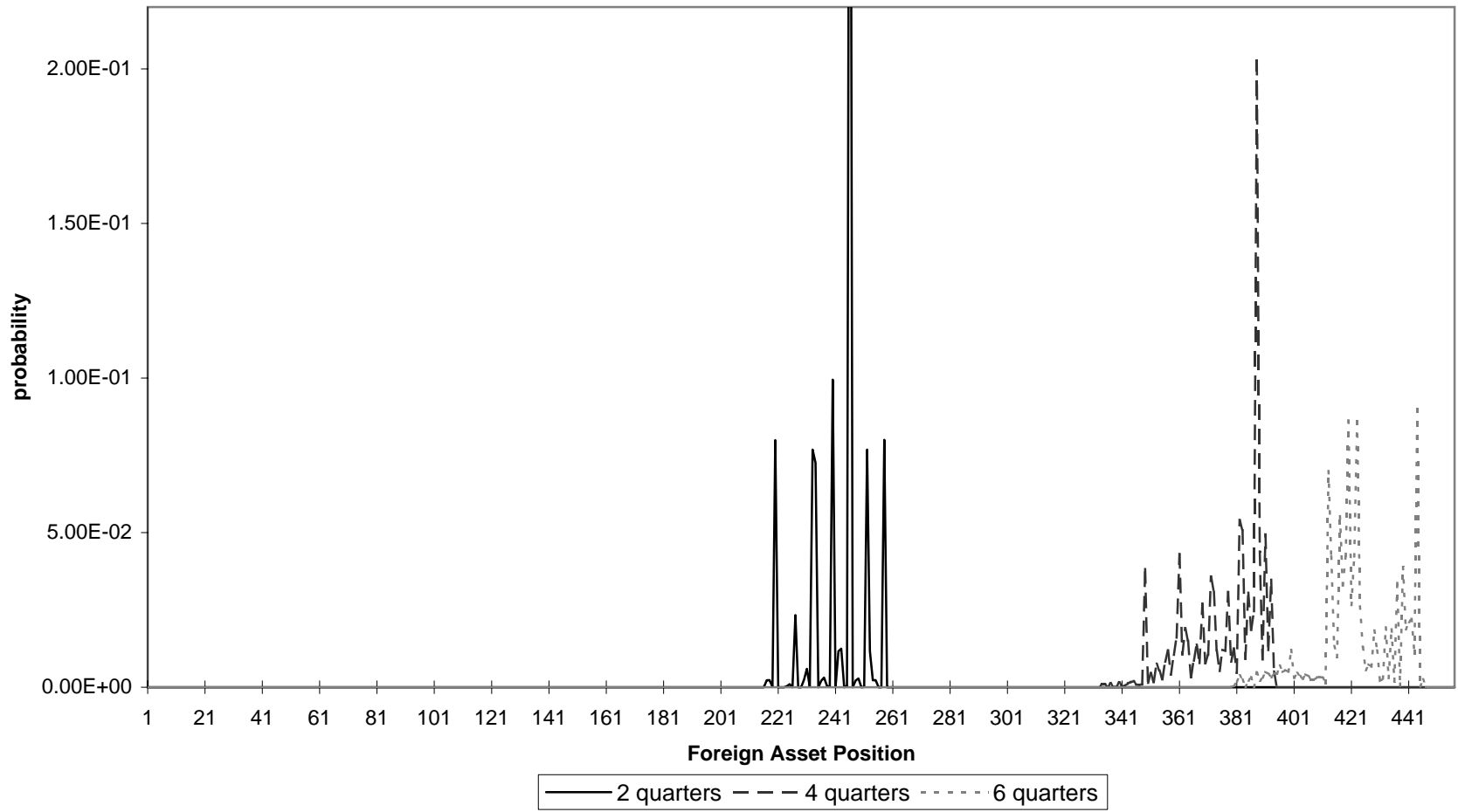


Figure 7. State-Contingent Welfare Losses Induced by Liquidity Constraints

