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Real Exchange Rate Volatility and the Price of Nontradables in Sudden-Stop-Prone Economies

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Abstract

This paper shows that the dominant view that the high variability of real exchange rates is due to movements in exchange rate-adjusted prices of tradable goods does not hold for Mexican data for periods with a managed exchange rate. The relative price of nontradables accounts for up to 70 percent of real exchangerate variability during these periods. The paper also proposes a model in which this fact, and the sudden stops that accompanied the collapse of Mexico's managed exchange rates, could result from a Fisherian debt-deflation mechanism operating via nontradables prices in economies with dollarized liabilities.

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I. INTRODUCTION

Movements in relative prices play a large role in economic fluctuations, particularly in emerging economies. Sudden stops in capital movements, for instance, are typically associated with sharp depreciations in the real exchange rate, which, in turn, can wreak havoc with private sector balance sheets. But this observation triggers another, deeper question: what is behind these real exchange rate fluctuations? Do the relative prices of traded goods move? Or is it the prices of nontradables in terms of tradables? Answering this empirical question is crucial for both building relevant models and designing policies to moderate the dramatic economic fluctuations that seem to plague emerging economies.

The dominant view in the empirical literature on real exchange rates is that exchange rate-adjusted relative prices of tradable goods account for most of the observed high variability of consumer price index-based real exchange rates (see the classic article by Engel (1999) and earlier work by Jenkins and Rogers (1995)). In an application of the variance analysis of his 1999 article applied to Mexican data, Engel (2000) concluded that this dominant view also applies to Mexico. Using a sample of monthly data from 1991 to 1999, he found that the fraction of the variance of the peso-dollar real exchange rate accounted for by the variance of the Mexico-U.S. ratio of prices of tradable goods, adjusted by the nominal exchange rate, exceeds 90 percent, regardless of the time horizon over which the data are differenced.

Engel's finding raises serious questions about the empirical relevance of a large literature that emphasizes nontradables prices as a key factor in explaining real exchange rates and economic fluctuations in emerging economies. The studies developed in the research program on "non-credible" exchange rate-based stabilizations surveyed by Calvo and Végh (1999) model the real exchange rate as a positive, monotonic function of the relative price of nontradables (with the latter determined at equilibrium by the optimality conditions for sectoral allocation of consumption and production). Lack of credibility in a currency peg leads to a temporary increase in tradables consumption and to a rise in the relative price of nontradables and, hence, to a temporary real appreciation of the currency. More recently, the literature on sudden stops in emerging economies has emphasized the phenomenon of liability dollarization (i.e., the fact that debts in emerging economies are generally denominated in units of tradable goods, or in hard currencies, but partially leveraged on the incomes and assets of the large nontradables sectors typical of these economies). With liability dollarization, real-exchange-rate collapses induced by sharp declines in the price of nontradables can trigger financial crashes and deep recessions. For example, Calvo (1998) showed how a sudden loss of world credit market access triggers a real depreciation of the currency and systemic bankruptcies in the nontradables sector. The real depreciation occurs because the market price of nontradables collapses as the lack of credit forces a reduction of tradables consumption while the supply of nontradables remains unaltered.

If nontradables prices account for only a negligible fraction of real exchange rate variability in emerging economies like Mexico, however, the above theories of sudden stops and of the real effects of exchange-rate-based stabilizations would lack empirical foundation. Moreover, the key policy lessons derived from these theories regarding strategies to cope with the adverse effects of non-credible stabilization policies, or to prevent sudden stops with their

dramatic consequences for economic performance and welfare, would be rendered irrelevant. For example, the push to develop foreign debt instruments better protected from the adverse effects of liability dollarization, by indexing debt to output or commodity prices or by issuing debt at longer maturities or in domestic currencies, would be a costly effort that a key piece of empirical evidence does not support, despite the benefits that it might seem to have in theory. Thus, determining the main sources of the observed fluctuations of real exchange rates in emerging economies is a central issue for theory and policy.

A closer look at the empirical evidence suggests, however, that the relative price of nontradables may not be irrelevant. Mendoza and Uribe (2000) reported large variations in Mexico's relative price of nontradables during the country's exchange rate-based stabilization of 1988–94. They did not conduct Engel's variance analysis, so although they showed that the price of nontradables rose sharply, their findings cannot establish whether or not the movement in the nontradables price was important for the large real appreciation of the Mexican peso. Nevertheless, their results suggest that one potential problem with Engel's analysis of Mexican data is that it did not separate periods of managed exchange rates from periods of floating exchange rates. There is also panel-data evidence on the role that liability dollarization has played in emerging market crises, which suggests that a link exists between the relative price of nontradables and the real exchange rate and is systematically related to the occurrence of sudden stops (see Calvo, Izquierdo, and Loo-Kung (2005) and the analysis of credit booms in Chapter 4 of International Monetary Fund (2004)).

This paper has two objectives. The first is to conduct a variance analysis to determine the contribution of fluctuations in domestic prices of nontradable goods relative to those of tradable goods, vis-à-vis fluctuations in exchange rate-adjusted relative prices of tradable goods, in explaining the variability of the real exchange rate of the Mexican peso against the U.S. dollar. The results show that Mexico's nontradables goods prices display high variability and account for a significant fraction of real-exchange-rate variability in periods of managed exchange rates. In light of these results, the second objective is to show that a financial accelerator mechanism at work in economies with liability dollarization and credit constraints produces amplification and asymmetry in the responses to exogenous shocks of the price of nontradables, the real exchange rate, consumption, and the current account. In particular, the model predicts that sudden, policy-induced changes in relative prices, analogous to those induced by the collapse of managed exchange rate regimes, can set in motion this financial accelerator mechanism. Thus, the model predicts that because of the effects of liability dollarization in credit-constrained economies, economies with managed exchange rates can display high volatility in their real exchange rates driven by the relative prices of nontradables.

The variance analysis is based on a sample of monthly data for the 1969–2000 period. The results replicate Engel's (2000) results for a subsample that matches his sample. The same holds for the full sample and for all subsample periods in which Mexico did not follow an explicit policy of exchange rate management. The results are markedly different in periods in which Mexico managed its exchange rate (including periods with a fixed exchange rate and with crawling pegs). In these periods, the fraction of real-exchange-rate variability accounted for by movements of tradable-goods prices and the nominal exchange rate falls sharply and varies widely with the time horizon of the variance ratios. Movements in Mexico's

nontradables relative prices can account for up to 70 percent of the variance of the real exchange rate. In short, whenever Mexico managed its exchange rate, the country experienced high real-exchange-rate variability *but* movements in the price of nontradables contributed significantly to explaining it.

The Mexican data also fail to reproduce two other key findings of Engel's work. In addition to attributing an overwhelming role of tradables goods prices in explaining real exchange rates, Engel found that (a) covariances across domestic nontradables' relative prices and cross-country tradables' relative prices tend to be generally positive or negligible, and (b) variance ratios corrected to take into account these covariances generally do not change results derived using approximate variance ratios that ignore them. Contrary to these findings, in periods in which Mexico had a managed exchange rate, the correlation between domestic nontradables' relative prices and international tradables' relative prices is sharply negative. The standard deviation of Mexico's domestic relative prices is also markedly higher during these periods. As a result, measures of the contribution of tradable goods prices to real-exchange-rate variability corrected to take into account these features of the data are significantly lower than those that are not.

Recent cross-country empirical studies provide further time-series and cross-sectional evidence indicating that the relative price of nontradables explains a significantly higher fraction of real exchange rate variability in the presence of managed exchange rates. Naknoi (2005) constructed a large dataset covering 35 countries and nearly 600 pairs of bilateral real exchange rates. She found that for many of these pairs Engel's (1999) result holds, but there are also many for which it does not, and in some instances the relative price of nontradables accounts for about 50 percent of real exchange rate variability. She also found that the variability of the relative price of nontradables rises as that of the nominal exchange rate falls; and in some cases it exceeds the variability of exchange rate-adjusted relative prices of tradable goods. Parsley (2003) examined the cross-paired and U.S. dollar-based real exchange rates of six countries of Southeast Asia using monthly data. He found that in subsamples with managed exchange rates for Hong Kong SAR, Malaysia, and Thailand, the relative price of nontradables could explain up to 50 percent of the variability of the real exchange rate. All these findings are also related to the well-known findings of Mussa (1986) and Baxter and Stockman (1989) showing that the variability of the real exchange rate is higher under flexible exchange rate regimes, although they did not study the decomposition of this variability in terms of the contributions of the relative prices of tradables vis-à-vis those of nontradables.

A common approach followed in the recent international macroeconomics literature is to take the above empirical evidence as an indication of the existence of nominal rigidities affecting price or wage setting. This approach has been the focus of extensive research examining the interaction of nominal rigidities with alternative pricing arrangements (e.g., pricing to market, local versus foreign currency invoicing) and with different industrial organization arrangements (e.g., endogenous tradability). Unfortunately, the ability of these models to explain the variability of real exchange rates, even among country pairs for which the "dominant view" holds, is limited. Chari, Kehoe, and McGrattan (2002) found that models with nominal rigidities cannot explain the variability of real exchange rates in industrial countries unless the models adopt preferences separable in leisure and values for coefficients

of relative risk aversion and capital adjustment costs, and for the periodicity of staggered price adjustments, that are at odds with empirical evidence. Moreover, theoretical analysis shows that it does not follow from the observation that the variance analysis of the real exchange rate changes in favor of the price of nontradables under managed exchange rates that nominal rigidities *must* be at work. This is because the equilibria obtained for monetary economies under alternative exchange rate regimes, and with or without nominal rigidities, can be reproduced in monetary economies with flexible prices, or even in non-monetary economies, with appropriate combinations of tax-equivalent distortions on consumption and factor incomes (see Adao, Correia, and Teles (2005); Coleman (1996); Mendoza (2001); and Mendoza and Uribe (2000)).

Instead of emphasizing the role of nominal rigidities, this paper shows, using a simple non-monetary model of endogenous credit constraints with liability dollarization, that a strong amplification mechanism driven by a variant of Irving Fisher's debt-deflation process can induce high variability in the price of nontradables and in the real exchange rate in response to exogenous shocks. In particular, policy-induced shocks to relative prices akin to those triggered by a currency devaluation can set in motion this amplification mechanism. The financial accelerator that amplifies the responses of consumption, the current account, and the price of nontradables to shocks of "usual" magnitudes combines a standard balance-sheet effect (because of the mismatch between the units in which debt is denominated and the units of the assets or incomes on which some of this debt is leveraged) with the Fisherian debt-deflation process (because an initial fall in the price of nontradables triggered by an exogenous shock further tightens credit constraints, leading to a downard spiral in access to debt and the price of nontradables).

A set of basic numerical experiments suggests that the quantitative implications of this financial accelerator are significant. The Fisherian debt-deflation process is a powerful vehicle for inducing amplification and asymmetry in the responses of the economy to exogenous shocks (particularly to changes in taxes that approximate the relative price effects of changes in the rate of devaluation of the currency). The magnitude of the effects that the Fisherian deflation has on the nontradables price, the real exchange rate, and the current account dwarf those that result from the standard balance-sheet effect that has been widely studied in the sudden stops literature. In this way, the model can account simultaneously for high variability of the real exchange rate and key features of the sudden stop phenomenon as the result of (endogenous) high variability of the relative price of nontradables.

The model is analogous to the models with liquidity-constrained consumers of the closed-economy macro literature and to the sudden stop dynamic, stochastic general equilibrium models reviewed by Arellano and Mendoza (2003). The setup provided in this paper is simpler in order to focus the analysis on the amplification mechanism linking sudden stops and real exchange rate movements driven by the relative price of nontradables.

The rest of the paper is organized as follows. Section II conducts the variance analysis of the Mexico-U.S. real exchange rate. Section III develops the model of liability dollarization with financial frictions in which "excess volatility" of the real exchange rate is caused by fluctuations in the relative price of nontradables. Section IV presents conclusions and policy implications.

II. Variance Analysis of the Peso-Dollar Real Exchange Rate

This section presents the results of a variance analysis that follows closely the methodology applied in Engel (1999) and (2000). The analysis uses non-seasonally-adjusted monthly observations of the consumer price index (CPI) and some of its components for Mexico (*MX*) and the United States (*US*) covering the period January, 1969 to February, 2000. Mexican data were retrieved from the Bank of Mexico's web site (http://www.banxico.org.mx), and those for the U.S. from the site maintained by the Bureau of Labor Statistics (http://stats.bls.gov). Three price indexes were retrieved for each country: the aggregate CPI (P^{i} for i=*MX*, *US*) and the consumer price indexes for durable goods (PD^{i} for i=*MX*, *US*) and services (PS^{i} for i=*MX*, *US*). The dataset also includes the nominal exchange rate series for the monthly-average exchange rate of Mexican pesos per U.S. dollar (*E*) reported in the IMF's *International Financial Statistics*. The real exchange rate was generated using the IMF's convention: $RER=P^{MX}/(EP^{US})$. The data were transformed into logs, with logged variables written in lowercase letters.

Durable goods are treated as tradable goods and services are treated as nontradable goods. This definition is in line with standard treatment in empirical studies of real exchange rates, and is also roughly consistent with a sectoral classification of Mexican data based on a definition of tradable goods as those pertaining to sectors for which the ratio of total trade to gross output exceeds 5 percent (see Mendoza and Uribe (2000)).

Following Engel (2000), simple algebraic manipulation of the definition of the real exchange rate yields this expression: $rer_t = x_t + y_t$. The variable x_t is the log of the exchange-rate-adjusted price ratio of tradables across Mexico and the United States: $x_t = pd_t^{MX} - e_t - pd_t^{US}$ (this is the negative of Engel's measure because the real exchange rate is defined here using the IMF's definition). If the strong assumptions needed for the law of one price to hold in this context were satisfied, x_t should be a constant that does not contribute to explain variations in rer_t. The variable y_t includes the terms that reflect domestic prices of nontradables relative to tradables inside each country: $y_t = b_t^{MX}(ps_t^{MX} - pd_t^{MX}) - b_t^{US}(ps_t^{US} - pd_t^{US})$, where b_t^{MX} and b_t^{US} are the (potentially time-varying) weights of nontradables in each country's CPI. The logs of the relative prices of nontradables are therefore: $mxpn_t \equiv ps_t^{MX} - pd_t^{MX}$ and $uspn_t \equiv ps_t^{US} - pd_t^{US}$.

The results of the variance analysis of the peso-dollar real exchange rate are summarized in the four plots of Figure 1, which are based on the detailed results reported in Table 1 of Mendoza (2000). This Table reports, in addition to the variance ratios for the real exchange rate, the standard deviations and correlations of *rer*, *y*, *x*, *mxpn*, and *uspn*. As argued below, changes in these moments are useful for explaining the changes in the results of the variance analysis across fixed and floating exchange rate regimes. The discussion of the results below refers to the changes in the relevant moments, but the reader is referred to Mendoza (2000) for the complete set of moments.

Each plot in Figure 1 shows curves for five different sample periods: (1) the full sample, (2) the sample studied by Engel (2000), which is a sample retrieved from *Datastream* for the period September, 1991 to August, 1999, (3) a sample that includes only data for the

post-1994 floating exchange rate, (4) a fixed exchange rate sample covering January, 1969 to July, 1976, and (5) a sample that spans the duration of the managed exchange rate regime that anchored the stabilization plan known as *El Pacto* (March, 1988-November, 1994). This regime included an initial one-year period with a fixed exchange rate followed by a crawling peg within a narrow band (the boundaries of which were revised occasionally).

Each of the four plots shows results for an alternative measure of the variance ratio that quantifies the fraction of real exchange rate variability explained by x_t (i.e., the relative price of tradables). The ratios are plotted as functions of the time frequency over which the data were differenced (1, 6, 12, 24 and, for the samples with sufficient observations, 72 months). The four variance ratios considered are the following:

(1) Engel's (2000) *basic* ratio $\sigma^2(x)/\sigma^2(rer)$. Since in general $\sigma^2(rer) = \sigma^2(x) + \sigma^2(y) +2\, cov(x,y)$, where $cov(x,y)$ is the covariance between x and y, this basic ratio is accurate only when x and y are independent random variables (i.e., when $cov(x,y) = 0$). For this reason, Engel (1995) computed the following second and third ratios as alternatives that adjust for covariance terms.

(2) The *independent variables* ratio, $\sigma^2(x)/[\sigma^2(rer) - cov(x,y)]$, deducts from the variance of *rer* in the denominator of the variance ratio the effect of $cov(x,y)$.

(3) The *half covariance* ratio, $[\sigma^2(x) + cov(x,y)] / \sigma^2(rer)$, measures the contribution of x to the variability of *rer* by assigning to x half of the effect of $cov(x,y)$ on the variance of *rer*. Since this half covariance ratio can be written as the product of the basic ratio multiplied by $1+\rho(x,y)(\sigma(y)/\sigma(x))$, where $\rho(x,y)$ is the correlation between x and y, the basic ratio approximates well the half covariance ratio if $\rho(x,y)$ is low and/or the standard deviation of x is large relative to that of y.

(4) The *nontradables weighted covariance* ratio, controls only for the covariance between x and the domestic relative price of nontradables in Mexico by re-writing the variance ratio as $[\sigma^2(x)/\sigma^2(rer)]\,\{1 + \rho(x,mxpn)\,[b^{MX}\sigma(mxpn) / \sigma(x)]\,\}$. The basic ratio approximates accurately this fourth variance ratio when the correlation between x and *mxpn* is low and/or the standard deviation of x is large relative to that of *mxpn*.

The motivation for the fourth ratio follows from the fact that, while the half covariance ratio aims to correct for how much of the variance of *rer* is due to variables x and y taking their covariance into account, it is silent about the contributions of the various elements that conform y itself. The latter can be important because y captures the combined changes in domestic relative prices of nontradables in Mexico and the United States, as well as the recurrent revisions to the weights used in each country's CPI (which take place at different intervals in each country). Moreover, since the aggregate CPIs include nondurables, in addition to durables and services, y captures also the effects of cross-country differences in the prices of nondurables relative to durables. Computing an exact variance ratio that decomposes all of these effects requires to control for the full variance-covariance matrix of y, x, *mxpn*, *uspn*, b^{MX} and b^N . Since data to calculate this matrix are not available, the nontradables weighted covariance ratio is used as a proxy that isolates the effect of the covariance between *mxpn* and *rer*. The complement (i.e., 1 minus the fourth variance ratio) is

a good measure of the contribution of *Mexico's* relative price of nontradables to the variance of the real exchange rate to the extent that: (a) movements in the CPI weights play a minor role, and (b) the correlation between *mxpn* and *uspn* is low and/or the variance of *mxpn* largely exceeds that of *uspn*.[2]

The potential importance of covariance terms in the calculation of a variance ratio, and hence the need to consider alternative definitions of this ratio, is a classic problem in variance analysis. Engel considered this issue carefully in his work on industrial country real exchange rates and on the peso-dollar real exchange rate, and he concluded that it could be set aside safely. As shown below, however, the features of the data that support this conclusion are not present in the data for Mexico's managed exchange rates, and hence in this case the variance ratios that control for covariance effects play a crucial role. Engel (1995) argued that in the case of the components of the real exchange rate of the United States vis-a-vis industrial countries, "*comovements between x and y are insignificant in all cases, except when we use the aggregate PPI (producer price index) as the traded goods price index*" (p. 31). In addition, Engel (2000) noted that the basic ratio "*tends to underestimate the importance of the x as long as the co-variance term (between x and y) is positive (which it is at most short horizons), but any alternative treatment of the covariance has very little effect on the measured relative importance of the x component*" (p. 9). Under these conditions, the basic ratio is either very accurate (if $\rho(x,y)$ is low) or in the worst-case scenario it represents a lower bound for the true variance ratio (if $\rho(x,y)$ is positive). In either case, a high ratio $\sigma^2(x)/\sigma^2(rer)$ indicates correctly that real-exchange-rate fluctuations are mostly explained by movements in tradable goods prices and in the nominal exchange rate.

The results shown in the four plots of Figure 1 for the full sample period are firmly in line with Engel's findings, except in the very long horizon of 72 months. At frequencies of 24 months or less, the basic ratio always exceeds 0.94, and using any of the other ratios to correct for covariances across *x* and *y*, or across *x* and *mxpn*, makes no difference. These results reflect the facts that, for the full sample, the correlations between *x* and *y* and between *x* and *mxpn* are always close to zero, and the standard deviation of *x* is 3.5 to 3.7 times larger than that of *y* and 2.9 to 3.7 times larger than that of *mxpn* (see Table 1 in Mendoza (2000) for details). Covariances of *x* with *uspn* are also irrelevant because the correlations between these variables are generally negligible and the standard deviations of *uspn* are all small. Moreover, the correlations between *mxpn* and *uspn* are also negligible.

A very similar picture emerges for Engel's (2000) sample and for the post-1994 floating period. The one notable difference is that at frequencies higher than 1 month there are marked negative correlations between *x* and *uspn* and between *mxpn* and *uspn*. These correlations could in principle add to the contribution of domestic relative price variations in explaining the variance of *rer*. However, they can be safely ignored because the standard deviation of *x* dwarfs those of *uspn* and *mxpn* at all time horizons, and the latter still have to

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[2] Computing this variance ratio requires an estimate for a constant value of b^{MX}, which was determined using 1994 weights from the Mexican CPI, extracted from a methodological note provided by the Bank of Mexico ($b^{MX} = 0.6$).

be reduced by the fractions b^{MX} and b^{US} respectively. In summary, in periods in which the Mexican peso is floating, the variability of exchange-rate-adjusted tradables goods prices is so much larger than that of nontradables relative prices that covariance adjustments cannot alter the result that the relative price of nontradables is of little consequence for movements in the real exchange rate.

The picture that emerges from Mexico's managed exchange-rate regimes is very different. For both the fixed rate sample and the sample for *El Pacto*, the basic ratio is very high but it often exceeds 1, indicating the presence of large covariance terms. The other three variance ratios show dramatic reductions in the share of real-exchange-rate variability attributable to *x* compared to the results for periods without exchange rate management. For instance, the half covariance ratio for the fixed exchange rate sample shows that the contribution of *x* to the variability of the real exchange rate reaches a minimum of 0.29 at the 6-month frequency and remains low at around 0.36 for 12- and 24-month frequencies. The nontradables weighted ratio, which corrects for the covariance between *x* and *mxpn*, is below 0.61 at frequencies higher than one month. In the sample for *El Pacto*, the independent variables and half covariance ratios indicate that the contribution of *x* to the variability of the real exchange rate is below 0.6 at all frequencies (except for the half covariance ratio at the 12-month frequency, in which case it increases to 0.7). The nontradables weighted ratio shows that, if only the covariance between *x* and *mxpn* is considered, the variance of *rer* attributable to *x* reaches a lower bound of 0.55 at the one-month frequency (although it increases sharply at the 24-month frequency before declining again at the 72-month frequency).

These striking differences in the outcome of the variance analysis for periods of exchange rate management reflect two critical changes:

(a) The standard deviations of the Mexican relative price of nontradables and the composite variable *y* increase significantly relative to the standard deviations of *x* (the ratios of the standard deviation of *x* to that of *y* now range between 0.7 and 1.2); and

(b) The correlations between *x* and *y*, and between *x* and *mxpn* fall sharply and become markedly negative (approaching -0.6 in most cases).

Two other important features are worth noting in comparing periods of managed and floating exchange rates: (a) The correlation between *x* and *rer* is much lower in the former than in the latter (the correlation between *x* and *rer* is almost 1 at all time horizons in periods of floating exchange rates, while it ranges between 0.29 and 0.7 in the samples of managed exchange rates), and (b) in some of the managed exchange rate scenarios, particularly the 12- and 24-month horizons of the sample for *El Pacto*, the correlation between nontradable goods relative prices in Mexico and the United States is positive (it can be as high as 0.32). This second result actually reduces the share of fluctuations in *rer* that can be accounted for by *y* because, as U.S. and Mexican relative prices of nontradable goods are more likely to increase together, differences in these domestic relative prices across countries tend to offset each other more, and hence are less important for real-exchange-rate fluctuations.

It is also worth noting that the only feature of the statistical moments of the data examined here that is robust to changes in the exchange rate regime is the fact that the variability of

nontradables relative prices in Mexico always exceeds by a large margin that of the United States. For the full (*El Pacto*) sample, the ratio of the standard deviation of *mxpn* to that of *uspn* ranges from 3.7 (3.4) at the one-month frequency to 4.9 (7.1) at the 24-month frequency. It is also true, however, that Mexico's nontradables relative prices tend to be more volatile during currency pegs than when the exchange rate floats. The ratio of the standard deviation of *mxpn* for the sample for *El Pacto* to that for the post-1994 floating period doubles from 1 at the one-month frequency to about 2 at the 24-month frequency. The higher volatility of the relative price of nontradables in Mexico than in the United States, and when Mexico manages the exchange rate than when the peso floats, are significant features of the data that, according to the theoretical analysis of the next section, can play a central role in explaining why the price of nontradables accounts for a nontrivial fraction of the variability of Mexico's real exchange rate in periods of exchange rate management.

III. Sudden Stops and Nontradables-Driven Real Exchange Rate Volatility

Section II showed that in periods in which Mexico managed its exchange rate, the relative price of nontradables accounted for a significant fraction of the high variability of the real exchange rate. This evidence raises the question: should we be concerned about volatility of the real exchange rate driven by nontradables goods prices? This Section argues that we should. The main argument is that, in economies that suffer from liability dollarization, the Sudden Stop phenomenon and the high variability of the real exchange rate may both be the result of high volatility in nontradables goods prices. To make this argument, the Section examines a simple model in which endogenous credit constraints and liability dollarization produce a financial accelerator mechanism that amplifies the responses of consumption, the current account, the price of nontradables and the real exchange rate to exogenous shocks.

Credit frictions and liability dollarization have been widely studied in the Sudden Stops literature. The goal here is to provide a basic framework that highlights how balance sheet effects and the Fisherian deflation process interact to trigger high volatility of the real exchange rate and Sudden Stops. The mechanism is similar to the ones that have been explored in more detail in the studies reviewed by Arellano and Mendoza (2003), particularly the two-sector dynamic stochastic equilibrium setup of Mendoza (2002).

Consider a conventional non-stochastic intertemporal equilibrium setup of a two-sector, representative-agent small open economy with endowments of tradables (y_t^T) and nontradables (y_t^N). The households of this economy solve the following problem:

$$\max_{\{c_t^T, c_t^T, b_{t+1}\}_0^\infty} \sum_{t=0}^{\infty} \beta^t u\left(c\left(c_t^T, c_t^N\right)\right) \tag{1}$$

subject to:

$$c_t^T + (1+\tau_t) p_t^N c_t^N = y_t^T + p_t^N y_t^N - b_{t+1} + b_t R + T_t \tag{2}$$

$$b_{t+1} \geq -\kappa\left(y_t^T + p_t^N y_t^N\right) \geq -\Omega \tag{3}$$

Utility is defined in terms of a composite good *c* that depends on consumption of tradables

(c_t^T) and nontradables (c_t^N). This composite good takes the form of a standard constant-elasticity-of-substitution (CES) function, and the utility function *u(·)* is a standard increasing, twice-continuously-differentiable and concave utility function. Since *c* is a CES aggregator, the marginal rate of substitution between nontradables and tradables satisfies $\frac{c_2\left(c_t^T, c_t^N\right)}{c_1\left(c_t^T, c_t^N\right)} = \Phi\left(\frac{c_t^T}{c_t^N}\right)$, where Φ is an increasing, strictly convex function of the ratio c_t^T / c_t^N. The price of tradables is determined in competitive world markets and normalized to unity without loss of generality p_t^N denotes the price of nontradable goods relative to tradables.

As is evident from the budget constraint (2), international debt contracts are denominated in units of tradables, so this economy features liability dollarization. The only asset traded with the rest of the world is a one-period bond that pays a constant gross real interest rate of *R* in units of tradables.

World credit markets are imperfect. In particular, constraint (3) states that foreign creditors limit their lending to the small open economy so as to satisfy a liquidity constraint up to a debt ceiling. The liquidity constraint limits debt to a fraction κ of the value of the economy's current income in units of tradables. The debt ceiling requires the debt allowed by the liquidity constraint not to exceed a maximum level Ω. This maximum debt helps rule out "perverse" equilibria in which agents could satisfy the liquidity constraint by running very large debts that finance high levels of tradables consumption and prop up the price of nontradables.

The above credit constraints can be the result of informational frictions or institutional weaknesses affecting credit relationships (such as monitoring costs, limited enforcement, costly information, etc). The contracting environment that yields the constraints is not modeled here for simplicity. Instead, following the line of the studies on endogenous borrowing constraints surveyed by Arellano and Mendoza (2003), we take the credit constraints as given to focus on their implications for equilibrium allocations and prices. Note also that credit limits set in terms of the debt-income ratio as in (3) are common practice in actual credit markets, particularly in household mortgage and consumer loans.

The government imposes a tax τ_t on private consumption of nontradable goods, which is intended to approximate some of the effects of a change in the rate of depreciation of the currency that would emerge in a monetary model in which money economizes transaction costs or enters in the utility function (see Mendoza (2001)).[3] The government also maintains time-invariant levels of unproductive government expenditures in tradables and nontradables, $(\bar{g}^T, \bar{g}^N)$, and it is assumed to run a balanced budget policy for simplicity. Hence, any

[3] Adao, Correia and Teles (2005), Coleman (1996), and Mendoza and Uribe (2000) provide other examples in which the equilibria of monetary economies with alternative exchange rate regimes, and with or without nominal rigidities, can be reproduced in non-monetary economies with appropriate combinations of tax-equivalent distortions.

movements in the primary fiscal balance due to exogenous policy changes in the tax rate, or endogenous movements in the price of nontradables, are offset via lump-sum rebates or taxes T_t. The government's budget constraint is therefore:

$$\tau_t p_t^N c_t^N = \overline{g}^T + p_t^N \overline{g}^N + T_t \tag{4}$$

A competitive equilibrium for this economy is a sequence of allocations $\left[c_t^T, c_t^N, T_t, b_{t+1}\right]_0^\infty$ and prices $\left[p_t^N\right]_0^\infty$ such that: (a) the allocations represent a solution to the households' problem taking the price of notradables, the tax rate, and government transfers as given, (b) the sequence of transfers satisfies the government budget constraint given the tax policy, government expenditures, private consumption of nontradables and the relative price of nontradables, and (c) the following market-clearing condition in the nontradables sector holds:

$$c_t^N + \overline{g}^N = y_t^N \tag{5}$$

Note also that given (2), (4) and (5), the resource constraint in the tradables sector is:

$$c_t^T + \overline{g}_t = y_t^T - b_{t+1} + Rb_t \tag{6}$$

The analysis that follows shows that, in the economy described by equations (1)–(6), the responses of consumption, the current account, the real exchange rate, and the price of nontradables to exogenous shocks exhibit endogenous amplification via a financial accelerator mechanism when the credit constraints bind, and that this mechanism operates via balance-sheet and Fisherian-deflation effects triggered by movements in the relative price of nontradables. Since other studies have examined the quantitative implications of more sophisticated variants of this model that incorporate uncertainty, incomplete financial markets, and labor demand and supply decisions in the nontradables sector (see Mendoza (2002)), we focus here on the key aspects of the economic intuition behind the model's financial accelerator.

A. Equilibrium When the Credit Constraints Never Bind: Perfectly Smooth Consumption

Consider first a scenario in which the credit constraints never bind. In this case, the model yields an equilibrium identical to the one that would be obtained with perfect credit markets. The economy borrows or lends at the world-determined interest rate with no other limitation that the standard no-Ponzi-game condition, which requires the present value of tradables absorption to equal the tradables sector's wealth. The latter is composed of nonfinancial wealth (W_0) and financial wealth (Rb_0), so that the economy faces this intertemporal budget constraint:

$$\sum_{t=0}^{\infty} R^{-t} c_t^T = \sum_{t=0}^{\infty} R^{-t}\left(y_t^T - \overline{g}^T\right) + Rb_0 = W_0 - \left(\frac{R}{R-1}\right)\overline{g}^T + Rb_0 \tag{7}$$

Next we adopt a set of assumptions that imply that, when the credit frictions never bind, the equilibrium reduces to a textbook case of perfectly smooth consumption. In particular, assume that the economy satisfies the traditional stationarity condition $\beta R=1$ and that the nontradables output is time invariant ($y_t^N = \overline{y}^N$ for all *t*). Hence, it follows from (5) and the standard Euler equation for tradables consumption that $c_t^T = \overline{c}^T$ for all *t*. The intertemporal constraint in (7) implies then that the equilibrium sequence of tradables consumption is perfectly smooth at this level:

$$\overline{c}^T = (1-\beta)[W_0 + Rb_0] - \overline{g}^T \tag{8}$$

In addition, the optimality condition that equates the marginal rate of substitution in consumption of tradables and nontradables with the after-tax relative price of nontradables implies that the equilibrium price of nontradables is:

$$p_t^N = \overline{p}_t^N = \frac{c_2\left(\overline{c}^T, \overline{y}^N - \overline{g}^N\right)}{c_1\left(\overline{c}^T, \overline{y}^N - \overline{g}^N\right)}(1+\tau_t)^{-1} = \Phi\left(\frac{\overline{c}^T}{\overline{y}^N - \overline{g}^N}\right)(1+\tau_t)^{-1} \tag{9}$$

Since consumption of tradables is perfectly smooth and both the endowment and government consumption of nontradables are time-invariant by assumption, the result in (9) states that any variations in the relative price of nontradables result only from government-induced variations in the tax on nontradables consumption. Tax policy is neutral in the sense that variations in the tax alter the price of nontradables but not consumption allocations or the current account. Thus, if credit constraints never bind, tax-induced real devaluations are neutral (i.e., changes in the exchange rate regime make no difference for the behavior of the real exchange rate).

As long as the credit constraints do not bind, the results in (8) and (9) hold for any time-varying, deterministic, non-negative stream of tradables endowments. To compare this perfectly smooth equilibrium with the equilibrium of the economy with binding credit constraints, we study a particular stream of tradables income that provides an incentive for the economy to borrow at date 0. Using standard concepts from the permanent income theory of consumption, we can define an arbitrary time-varying sequence of tradables endowments as an equivalent sequence with a time-invariant endowment (or "permanent income"). Hence, the level of nonfinancial wealth in (7) satisfies: $\overline{y}^T = (1-\beta)W_0$, where $\overline{y}^T$ is the time-invariant tradables endowment that yields the same present value of tradables income (i.e., the same wealth) as a given time-varying sequence paid to households. Define then a "wealth neutral" shock to date-0 tradables income as a change in the date-0 endowment offset by a change in the date-1 endowment that keeps the present value of the two constant (leaving the rest of the sequence of tradables income in W_0 unchanged). Thus, wealth neutral shocks to date-0 income satisfy:

$$y_1^T - \overline{y}^T = \beta^{-1}\left(\overline{y}^T - y_0^T\right) \tag{10}$$

Condition (10) states that, if the date-0 endowment falls below permanent income, the date-1 endowment increases above permanent income by enough to keep the present value constant.

Clearly, for any $0 < y_0^T < \overline{y}^T < y_1^T$ that satisfies (10) and for which the credit constraints do not bind, the economy maintains the perfectly smooth equilibrium with these results:

$$\begin{aligned} &\overline{c}^T = (1-\beta)[W_0 + Rb_0] - \overline{g}^T \\ &\overline{p}_t^N = \Phi\left(\frac{\overline{c}^T}{\overline{y}^N - \overline{g}^N}\right)(1+\tau_t)^{-1} \\ &\overline{b}_1 - b_0 = y_0^T - \overline{y}, \qquad \overline{b}_2 - \overline{b}_1 = -\left(\overline{b}_1 - b_0\right), \quad \overline{b}_t = b_0 \quad for \quad t \geq 2 \end{aligned} \tag{11}$$

Hence, consumption allocations and the price of nontradables remain at their first-best levels, and there is a current account deficit at date-0 of equal size as the current account surplus at date 1. Thus, the economy reduces asset holdings below b_0 at date 0 (i.e., borrows), and returns to its initial asset position at date 1. Policy-induced real devaluations of the currency are still neutral with respect to all of these outcomes.

B. The Economy with Binding Credit Constraints

Now consider unanticipated, wealth-neutral shocks to y_0^T that satisfy condition (10). If the shock to y_0^T is not large enough to trigger the credit constraints, the solutions obtained in (11) still hold, but if the shock lowers y_0^T to a level at or below a critical level, it will make the liquidity constraint bind. This critical level is given by:

$$\hat{y}^T = \frac{\overline{y}^T - b_0 - \kappa \overline{p}_0{}^N \overline{y}^N}{1+\kappa} \tag{12}$$

Since we restrict the analysis to strictly positive endowments, condition (12) also implies an upper bound for κ: $\kappa < \kappa^h = \left(1 - \frac{b_0}{\overline{y}^T}\right) \Big/ \left(\frac{\overline{p}_0{}^N \overline{y}^N}{\overline{y}^T}\right)$. If κ exceeds this critical value, the model allows for enough debt so that the liquidity constraint never binds for any positive value of y_0^T. On the other hand, κ has a lower bound at the level at which satisfying the liquidity constraint would make tradables consumption and the nontradables price fall to zero:

$$\kappa > \kappa^l = \frac{\overline{g}^T - y_0^T - Rb_0}{y_0^T}$$

A critical observation about the result in (12) is that, for a given wealth-neutral pair (y_0^T, y_1^T), a sufficiently large and unanticipated tax increase at date 0 (i.e., a policy-induced real depreciation) can also move the economy below the critical level of tradables income, and thus trigger the credit constraints, because it lowers the price of nontradables and the value of the nontradables endowment. Since, as shown below, this affects the equilibrium outcomes of consumption, the current account, the price of nontradables, and the real exchange rate, a policy-induced real depreciation of the currency is no longer neutral once the credit constraints bind. Now alternative policy regimes yield very different outcomes for real exchange rate behavior.

Assume a debt ceiling set at $\Omega = -\overline{b}_1$ for simplicity. For shocks that put y_0^T *below* its critical level, triggering the liquidity constraint, equilibrium allocations and prices for date 0 are:

$$c_0^T = y_0^T - \overline{g}^T + \kappa\left[y_0^T + p_0^N \overline{y}^N\right] + Rb_0 \tag{13}$$

$$p_0^N = \Phi\left(\frac{c_0^T}{\overline{y}^N - \overline{g}^N}\right)(1 + \tau_0)^{-1} \tag{14}$$

$$b_1 - b_0 = -\kappa\left[y_0^T + p_0^N \overline{y}^N\right] - b_0 > \Omega - b_0 \tag{15}$$

Since $b_1 = -\kappa\left[y_0^T + p_0^N \overline{y}^N\right] > \overline{b}_1$, it is clearly the case that $c_0^T < \overline{c}^T,\ p_0^N < \overline{p}_0{}^N,\ b_1 - b_0 > \overline{b}_1 - b_0$. Thus, when the credit constraint binds, tradables consumption and the price of nontradables are lower than in the perfectly smooth case, and the current account is higher. In other words, for shocks that put the tradables endowment below the critical level, the economy responds with a drop in tradables consumption, a real depreciation and a current account reversal (i.e., a sudden stop takes place).

The above argument is similar to Calvo's (1998): if the country cannot borrow, tradables consumption falls and this lowers the price of nontradables, which via a balance sheet effect and the liability dollarization feature of the credit constraint validates the country's reduced borrowing ability. The difference with Calvo's setup is that the equilibrium characterized by conditions (13)-(15) features also Fisher's debt-deflation mechanism.

The Fisherian deflation amplifies the responses of quantities and prices. In particular, the date-0 tradables consumption and price of nontradables are determined by solving the two-equation system formed by (13)–(14). Equation (13) shows that tradables consumption depends on the nontradables price when the credit constraint binds because of liability dollarization: changes in the value of the nontradables endowment affect the agents' ability to borrow in tradables-denominated debt. Equation (14) shows that the price of nontradables depends on the consumption of tradables via the standard optimality condition for sectoral consumption allocations. The Fisherian deflation occurs then because, as tradables consumption falls, the price of nontradables falls, and as this price falls the credit constraint tightens, which makes tradables consumption fall more, which then makes the price of nontradables fall more.

Figure 2 illustrates the determination of the date-0 equilibrium when this Fisherian deflation process is at work. The vertical line TT represents the perfectly smooth tradables consumption allocation, which is independent of the price of nontradables. The PP curve represents the optimality condition for sectoral consumption allocations, which equates the marginal rate of substitution between tradables and nontradables with the corresponding after tax relative price (i.e., equation (14)). Since the consumption aggregator is CES and nontradables consumption is constant at $\overline{y}^N - \overline{g}^N$, PP is an increasing, convex function of tradables consumption. TT and PP intersect at the equilibrium price of the perfectly smooth consumption case (point A).

The SS line represents equation (13), which is the tradables resource constraint when the liquidity constraint binds. SS is an upward-sloping, linear function of tradables consumption with a slope of $1/\kappa\overline{y}^N$. Since the horizontal intercept of SS is $Rb_0 - \overline{g}^T + (1+\kappa)y_0^T$, SS shifts to the left as y_0^T falls. In Figure 2, SS corresponds to the case when $y_0^T = \hat{y}^T$, so that tradables

output is just at the point where the credit constraint is marginally binding. In this case, SS intersects TT and PP at point A, so that the outcome with constrained debt is the same as the perfectly smooth case.

Consider a wealth-neutral shock to the date-0 tradables endowment such that $y_0^T < \hat{y}^T$. The SS curve shifts to SS' and the new equilibrium is determined at point D. If prices did not respond to the drop in consumption, or if the borrowing constraint were set as a fixed amount independent of income and prices, the new equilibrium would be at point B. At B, however, tradables consumption is lower than in the perfectly smooth case, so equilibrium requires the price of nontradables to fall. If the credit constraint were independent on the nontradables price (as, for example, in the setup of Calvo (1998)), the new equilibrium would be at point C, with a lower nontradables price and lower tradables consumption. This outcome reflects the balance sheet effect induced by liability dollarization. But at C the Fisherian deflation is not yet taken into account. With the lower price at C in the PP line, the liquidity constraint tightens because the value of the nontradables endowment falls, forcing tradables consumption to fall so as to satisfy the constraint at a point in SS', but at that point the nontradables price must fall again to re-attain a point along PP, but at that point tradables consumption falls again because the credit constraint tightens further. This Fisherian debt-deflation process continues until it converges to point D, at which the liquidity constraint is satisfied for a nontradables price and a level of tradables consumption that are also consistent with the equilibrium condition for sectoral consumption allocations. In short, the response to the tradables endowment shock, which would be at point A for any shock that satisfies $y_0^T \geq \hat{y}^T$, is amplified to point D because of the combined effects of the balance sheet effect and the Fisherian deflation.

The above results apply also to the case in which there is no shock to the tradables endowment but the government increases τ_0 by enough so that the resulting fall in p_0^N puts $\hat{y}^T$ above y_0^T. In this case, a policy change that could be intended to yield a "small" real depreciation of the currency can trigger the credit constraint, and result in a large current account reversal and collapses in tradables consumption, the price of nontradables and the real exchange rate. The policy neutrality of the perfectly smooth case no longer holds.

One caveat of this analysis is that for low enough y_0^T the economy would not be able to borrow at the competitive equilibrium. This occurs when y_0^T is so low that the level of debt that satisfies the liquidity constraint exceeds Ω (or, in this case, the debt that would be contracted in the perfectly smooth equilibrium). Setting debt at this debt ceiling would imply a nontradables price at which the liquidity constraint is violated, but on the other hand, the debt level that satisfies (13)–(14), so that the liquidity constraint holds, would violate the debt ceiling. At corners like these, debt is set to zero and the economy is in financial autarky. In the remainder of this paper we concentrate on situations in which shocks result in values $y_0^T \leq \hat{y}^T$ such that there are internal solutions with debt (i.e., solutions for which Ω is not binding).

Further analysis of Figure 2 could raise questions about the existence and uniqueness of the equilibrium with Fisherian deflation, depending on assumptions about the position and slope of the SS line and the curvature of the PP curve. The model produces results that shed light

on this issue, but these are highly dependent on the simplicity of the setup, which was motivated by the interest in deriving tractable analytical results to illustrate the effects of the Fisherian deflation. Hence, the following results regarding the conditions that can produce or rule out multiple equilibria need to be considered with caution, as they may not be robust to important extensions of the model (like including uncertainty, capital accumulation or a labor market).

Figure 2 suggests that a sufficiency condition to ensure a unique equilibrium with Fisherian deflation (for cases with $y_0^T \leq \hat{y}^T$ that yield internal solutions with debt) is that the PP curve be flatter than the SS line around point A. Since SS is an upward-sloping, linear function and PP is increasing and strictly convex, this assumption ensures that the two curves intersect only once in the interval between 0 and $\overline{c}^T$.[4]

Given (13) and (14), the assumption that PP is flatter than SS around A implies that:

$$\kappa < \frac{1}{1+\mu} z \quad with \quad z = \frac{\left(\dfrac{\overline{c}^T}{\overline{y}^T}\right)}{\left(\dfrac{\overline{p}_0^N \overline{y}^N}{\overline{y}^T}\right)} \tag{16}$$

where $1/(1+\mu)$ is the elasticity of substitution in consumption of tradables and nontradables.

This condition sets an upper bound for the liquidity coefficient κ (different from the upper bound identified earlier, which determined a value of κ that is high enough to make the liquidity constraint irrelevant). Since in most countries the nontradables sector is at least as large as the tradables sector, and consumption of tradables is lower than tradables output, it follows that z <1. Hence, (16) states that the sufficiency condition for a unique equilibrium with Fisherian deflation requires the liquidity coefficient to be lower than the fraction z of the elasticity of substitution.

Existing empirical studies for developing countries show that the elasticity of substitution is less than unitary, ranging between 0.4 and 0.83 (see Ostry and Reinhart (1992); Mendoza (1995); Gonzales and Neumeyer (2003); and Lorenzo, Aboal, and Osimani (2003)). The sectoral data for Mexico reported by Mendoza (2002) show that, on average over the 1988–98 period, $\left(\dfrac{\overline{p}_0^N \overline{y}^N}{\overline{y}^T}\right) = 1.543$, $\left(\dfrac{\overline{c}^T}{\overline{y}^T}\right) = 0.665$, so that in Mexico z = 0.43. Given this value of z, supporting a debt ratio equal to the lowest net foreign asset-output ratio estimated for Mexico by Lane and Milesi-Ferretti (2001), which is about -36 percent, requires using the upper bound of the estimates of the elasticity of substitution (i.e., $1/(1+\mu)$ = 0.83). With this

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[4] Unless P and SS are tangent at A, the curves also intersect once in the region with $c_0^T > \overline{c}^T$ because (13) and (14) can be satisfied by setting c_0^T high enough to yield a p_0^N at which the credit constraint supports the high debt needed to finance this high consumption. This outcome is not an equilibrium, however, because the resulting debt level violates the debt ceiling (which is the debt of the perfectly smooth case implicit at point A).

elasticity and z =0.43, condition (16) implies $\kappa < 0.357$. This result also meets the condition required for the credit constraint to bind at positive values of the tradables endowment, $\kappa < \kappa^h = \left(1 - \frac{b_0}{\overline{y}^T}\right) \Big/ \left(\frac{\overline{p}_0{}^N \overline{y}^N}{\overline{y}^T}\right)$, for any $b_0 \leq 0$. Hence, this rough review of empirical facts suggests that the sufficiency condition for which the model yields a unique equilibrium with Fisherian deflation is in line with the data.

C. Quantitative Implications: Balance-Sheet Effect Versus Fisherian-Deflation Effect

What are the relative magnitudes of the balance-sheet and Fisherian-deflation effects that move the economy from A to D in Figure 2? The figure suggests that, for a given value of the tradables endowment shock, the magnitude of the two effects depends on the curvature of the SS and PP curves, which, in turn, depends on the relative magnitudes of the liquidity coefficient and the sectoral elasticity of substitution in consumption.

A lower liquidity coefficient increases the slope of the SS curve. This strengthens the balance sheet effect but its effect on the Fisherian deflation is not monotonic. Starting from a high κ at which the credit constraint was just marginally binding (and hence the Fisherian deflation effect was irrelevant), lowering κ strengthens the Fisherian deflation. As κ falls further, however, the Fisherian deflation weakens because the feedback between the nontradables price and the ability to borrow weakens (in the limit, for $\kappa = 0$ there is no Fisherian deflation, but this is also the case when κ is too high for the credit constraint to ever bind). A higher elasticity of substitution between tradables and nontradables makes the PP curve flatter, which strengthens both the balance sheet effect and the Fisherian deflation.

The following numerical experiments illustrate the potential magnitudes of the balance- sheet and Fisherian-deflation effects, using a set of parameter values and calibration assumptions that match some empirical evidence from Mexico. We consider a constant relative risk aversion (CRRA) period utility function, $u(c) = \left(c^{1-\sigma}\right)/(1-\sigma)$, and a constant elasticity of substitution (CES) aggregator for sectoral consumption, $c = \left[a(c^T)^{-\mu} + (1-a)(c^N)^{-\mu}\right]^{-1/\mu}$.

The subjective discount factor and the coefficient of relative risk aversion are set to standard values of β =0.96 and σ =2. We take Mendoza's (2002) estimate of the share parameter of the CES aggregator for Mexico, a =0.342. The elasticity of substitution between tradables and nontradables is set to the upper bound of the range of estimates cited earlier (0.83), which implies μ =0.204.

The model is calibrated to match Mendoza's (2002) estimates of Mexico's ratio of nontradables GDP to tradables GDP at current prices (1.543), and the sectoral shares of tradables (nontradables) consumption in tradables (nontradables) GDP, which are 66 and 71 percent respectively. Total "permanent" output is normalized to 1, so that the results of the quantitative experiments can be interpreted as shares of "permanent" GDP. We also allow for "permanent" absorption of tradables and nontradables that include government purchases and private investment, so that the model can match the observed consumption-output ratios. The tax rate is set to zero, which implies a baseline scenario in which government expenditures are financed with lump sump taxation. Initial external debt is set to 1/3 of permanent GDP, in

the range of the time series of the net foreign asset-GDP ratio produced for Mexico by Lane and Milesi-Ferretti (2001). With these calibrated parameter values, the perfectly smooth equilibrium yields consumption allocations $\overline{c}^T = 0.26, \overline{c}^N = 0.56$, and an equilibrium price of nontradables of $\overline{p}^N = 0.77$, so that the aggregate consumption-output ratio matches the ratio from Mexican data: $\left(\overline{c}^T + \overline{p}^N\overline{c}^N\right)/\left(\overline{y}^T + \overline{p}^N\overline{y}^N\right) = 0.69$.

Figure 3 illustrates the quantitative predictions of the model for a range of values of the liquidity coefficient 0.21<κ<35, assuming a shock that lowers y_0^T to a level 3 percent below its permanent level. The lower bound of the liquidity coefficient is the lowest value of κ that can support positive tradables consumption with a binding liquidity constraint. The upper bound is the highest value of κ at which the constraint still binds (higher values would imply that the credit constraint does not bind for the 3 percent shock to tradables income, so that the perfectly smooth equilibrium would be maintained).

Figure 3.a shows the bond position of the economy at date 0 in three situations: the continuous curve is for the economy with the binding credit constraint, the dotted line is for the economy with perfect credit markets, and the dashed line is the value of the fraction κ of income valued at tradables goods prices in this same economy (i.e., it shows the value of bonds that would satisfy the liquidity constraint at the nontradables price of the perfectly smooth equilibrium). The credit constraint binds whenever the dashed line is above the dotted line. The vertical distance between the dashed line and the continuous curve represents the effect of the endogenous collapse in the price of nontradables on the ability to contract debt. This effect grows very rapidly as κ falls, and it can imply a correction in the debt position (and in the current account) of over 10 percentage points of permanent GDP.

Figures 3b and 3c illustrate the effects of the credit constraints on tradables consumption, the relative price of nontradables, and the real exchange rate (measuring each as a percent deviation from their values in the perfectly smooth equilibrium). The plots decompose the total effect of the constraints on tradables consumption and the nontradables price into two components, one that represents the balance sheet effect and another representing the Fisherian deflation. The total effect corresponds to a comparison of points A and D in Figure 2. The balance sheet effect compares A and C, and the Fisherian deflation compares C and D.

The negative effects of the liquidity constraint on tradables consumption and the relative price of nontradables are large and grow rapidly as κ falls. With κ set at 33 percent, tradables consumption and the price of nontradables fall by nearly 50 percent, and the CPI-based measure of the real exchange rate (i.e., the CES price index associated with the CES aggregator of sectoral consumption) falls nearly 37 percent. These declines are driven mainly by the Fisherian deflation, as the contribution of the pure balance sheet effect is less than 7 percent for both tradables consumption and the price of nontradables.

The effect of the Fisherian deflation is strongest with κ around 30 percent, and it becomes weaker for lower values of κ. In the worst-case scenario, with κ at 20 percent, tradables consumption and the nontradables price approach zero. However, even for these low values of the liquidity coefficient, the contribution to the collapses in consumption and prices are split about 50-50 between the balance-sheet effect and the Fisherian-deflation. Hence, the

contribution of the Fisherian deflation process is at least as large as that of the balance sheet effect.

Figure 3d shows the welfare cost of the sudden stops shown in Figures 3a-3c. Welfare costs are computed as compensating variations in a time-invariant consumption level that equates lifetime utility in the economy with credit constraints with that of the economy with perfect credit markets (in which the perfectly smooth equilibrium prevails at all times). With κ at 33 percent, the welfare loss measures 1.1 percent, and the loss increases rapidly as κ falls.

Figure 4 shows a similar set of results as Figure 3 but for adverse shocks to the date-0 tradables endowment of different magnitudes, fixing κ at 34 percent. The shocks range between 0 and 12.4 percent of the permanent tradables endowment (1-0.124 = 0.876 and 1 in the horizontal axes of the plots). Notice that in this experiment the smallest shock for which the liquidity constraint begins to bind is 1.9 percent, so shocks between 0 and 1.9 percent do not trigger the constraint and yield the perfectly smooth equilibrium. The upper bound of the shocks at 12.4 percent is the largest shock that satisfies the maximum debt constraint (i.e., the constraint stating that debt must not exceed the level corresponding to the perfectly smooth equilibrium).

The adjustment in the debt position is severe and increases rapidly with the size of the shock. A 5 percent shock to the tradables endowment implies a reduction in debt of about 15 percentage points of permanent income. Tradables consumption and the price of nontradables fall about 60 percent below the levels of the perfectly smooth equilibrium, with most of the decline accounted for by the Fisherian deflation. The CPI-based measure of the real exchange rate falls by about 47 percent. The welfare loss implied by the sudden stops triggered by this 5 percent shock measures 1.7 percent in terms of a compensating variation in a lifetime-utility-equivalent level of consumption. All these effects (except the contribution of the Fisherian deflation) grow rapidly as the size of the shock increases.

Finally, consider a policy experiment that switches from the tax rate consistent with a fixed exchange rate (i.e., $\tau=0$) to a floating rate for which the rate of depreciation of the currency settles at levels consistent with a fixed, positive value of τ (alternatively, this experiment can be viewed as a case in which the government aims to induce a real depreciation by increasing τ). This experiment sets $y_0^T = \hat{y}^T$, which by construction implies that at a zero tax rate the credit constraint is marginally binding (i.e., at $\tau = 0$ the economy is at point A in Figure 2). Figure 5 shows the results of tax increases varying from 0 to 5 percent. Note that, since for a zero tax rate and $y_0^T = \hat{y}^T$ the credit constraint is marginally binding, and since with a non-binding credit constraint the tax hike would induce at most a real depreciation of 3 percent (if the tax were raised to the 5-percent maximum), the government could have good reason to expect that the tax hike should induce a “small’ real depreciation. As the plots in Figure 5 show, however, the actual outcome would deviate sharply from this expectation because increasing the tax triggers the credit constraint. Increasing the tax rate by 5 percentage points induces a correction of 8 percentage points of permanent tradables income in the net foreign asset position of the economy. Consumption falls by 30 percent relative to the perfectly smooth equilibrium, the relative price of nontradables falls by 35 percent, and the real exchange rate depreciates by about 23 percent. As in the other two experiments, the

amplification in the declines of consumption, the price of nontradables, and the real exchange rate is largely due to the Fisherian debt-deflation effect, with a negligible contribution of the balance sheet effect. This policy-induced real depreciation results in a welfare loss of nearly 0.4 percent in terms of a stationary tradables consumption path.

In summary, the results of these numerical experiments suggest that, in the presence of liability dollarization and credit-market frictions, the Fisherian deflation mechanism can be an important source of amplification and asymmetry in the response of emerging economies to negative shocks. The Fisherian-deflation causes large declines in consumption and the price of nontradables, as well as large real depreciations and large reversals in the current account. Moroever, in this environment, policy-induced real depreciations can trigger the credit constraints and the Fisherian deflation mechanism, and therefore they can induce collapses in the price of nontradables and large real depreciations of the currency. These results suggest that the Fisherian deflation mechanism may help account for the empirical observation that the relative price of nontradables accounts for a significant fraction of the variability of the real exchange rate in economies with managed exchange rate regimes.

IV. Conclusions

This paper reported empirical evidence based on Mexican and U.S. monthly data for the 1969–2000 period showing that fluctuations in Mexico's relative price of nontradable goods account for 50 to 70 percent of the variability of the Mexico-U.S. real exchange rate when Mexico was under a managed exchange rate regime. The main lesson drawn from this evidence, and from cross-country studies by Naknoi (2005) and Parsley (2003) showing that this is a robust result across developing countries, is that the behavior of the determinants of the real exchange rate differs sharply between countries with features similar to Mexico's and the industrial countries to which variance analysis of real exchange rates is normally applied. In particular, the overwhelming role of movements in prices of tradable goods and nominal exchange rates found in industrial countries, or in developing countries with floating exchange rates, is sharply diminished in developing countries with managed exchange rates.

The finding that in a typical emerging economy like Mexico, large fluctuations in the real exchange rate can be driven by movements in the relative price of nontradables during periods of exchange rate management suggests that the phenomenon of liability dollarization emphasized in the sudden stops literature deserves more attention. This paper proposed a basic model to illustrate how liability dollarization introduces amplification and asymmetry in the responses of the economy to adverse shocks via a financial accelerator that combines a balance-sheet effect with Irving Fisher's debt-deflation mechanism. The balance-sheet effect and the Fisherian-deflation result in collapses in the real exchange rate that are driven by collapses in the relative price of nontradables. A set of basic numerical experiments suggests that the quantitative implications of these frictions, particularly the effects of the Fisherian deflation, can be significant. Of particular interest are the results for a policy-induced real depreciation (or a shift from a fixed exchange rate regime to a constant, positive rate of depreciation), showing that this paper's financial accelerator can produce large collapses in the relative price of nontradables, the real exchange rate, and consumption, together with a large current account reversal (starting from a situation in which credit constraints were marginally binding).

The results indicating that roughly a half of the variability of the real exchange rate can be attributed to movements in nontradables goods prices are in line with the quantitative findings that the recent literature on the business-cycle implications of exchange rate management has produced (see Mendoza and Uribe (2000)). Further empirical research, along the lines of the studies by Naknoi (2005) and Parsley (2003), should focus on comparing the experiences of industrial and developing countries to shed more light on whether variance analysis of other real exchange rates pairing emerging markets with industrial countries display similar sensitiveness to the exchange rate regime as to the peso-dollar real exchange rate. In addition, further analysis is needed to examine whether the role of the nontradables price in accounting for real-exchange-rate variability depends on the degree of liability dollarization of the economy.

The analysis undertaken here intentionally avoided taking a position on the best modeling strategy to account for the nontrivial fraction of real-exchange-rate variability explained by movements in tradable goods prices and the nominal exchange rate. In particular, the evidence reported here for periods without exchange rate management, in which a large fraction of real-exchange-rate variability is due to changes in relative prices of tradable goods and the nominal exchange rate, does not suggest per se that one should view fluctuations in the variable x as deviations from the law of one price or evidence of price or wage stickiness. It simply shows how much x (i.e., the ratio of exchange-rate-adjusted CPI prices of durable goods across Mexico and the United States) contributes to explaining the variance of the ratio of exchange-rate-adjusted aggregate CPIs. This is distant from the ideal scenario needed to interpret changes in x as deviations from the law of one price. The law of one price applies to single, homogeneous goods sold in a freely accessible market and in the absence of frictions like transportation costs and tax or tariff distortions. Clearly, aggregate data for the CPIs of Mexico and the United States violate these conditions. The goods included in these indexes are different and carry different weights, and the weights change at different intervals. Access to a "common market" has varied widely over the sample period and across goods, and similar caveats apply to transportation costs and tariffs.

There are detailed studies on purchasing power parity (PPP) and the law of one price that take these issues into account and still find evidence of large price differentials for highly disaggregated consumer goods. Some researchers are concerned with the impossibility of defining a pure concept of "tradable" goods, as required by the law of one, and are thus studying the "degree of tradability of goods" (see Betts and Kehoe (2000)) or distribution costs (see Burstein, Neves, and Rebelo (2000)).

The treatment of the data in the empirical analysis conducted here abstracts from medium-to-low-frequency considerations, including those related to mean-reverting properties of real exchange rates and to the long-run determination of real exchange rates. Research in this direction is also inconclusive, however, as the survey by Froot and Rogoff (1995) shows. For example, Asea and Mendoza (1994) find that although the data support predictions of long-run neoclassical models in which cross-country differences in the relative price of nontradable goods reflect differences in productivity across sectors that produce tradables and nontradables, measures of the long-run relative price of nontradables do poorly in explaining cross-country differences in CPI-based measures of the real exchange rate. At medium time frequencies, it is interesting to note that the variance ratios based on 72-month

differences of the data, which correspond to the 6-year periodicity of recent Mexican business cycles, the contribution of variable x to the variance of the real exchange rate is about 65 percent (for both the full sample and the period of the managed exchange rate that ended in 1994).

The findings of this paper provide an argument in favor of policies that seek to stabilize the real value of the currency. Traditional exchange rate management is not useful, because currency collapses trigger large movements in relative prices together with sudden stops in consumption and the current account. Instead, the model favors policies that can be successful at preventing large fluctuations in the real exchange rate. The setup of the model suggests, in particular, the use of sectoral tax policy, which would seek to contain the deflationary pressure on the relative price of nontradables as it builds up. This policy can be interpreted more broadly, however, to consider policies that can remove the liability dollarization problem (for example, the full adoption of a hard currency as the domestic currency) or monetary policies under de jure floating exchange rates that can prove effective in preventing large swings in the real value of the currency (as many emerging countries that claim adherence to inflation targeting rules could show in practice).

An alternative to policies that prevent large fluctuations in the relative price of nontradables is to consider changing the nature of emerging economies' debt instruments to make them less susceptible to the adverse effects of balance-sheet and Fisherian-deflation effects. This is in line with recent proposals favoring issuing bonds either only in domestic currencies or indexed to the evolution of output or key commodity prices (as was done by Argentina in its recent debt conversion using partially bonds indexed to output). Whether emerging economies can be successful at establishing liquid markets for these instruments unilaterally, however, or whether there is enough interest in them in world financial markets remain open questions. Clearly, if creating markets for the state-contingent claims that can neutralize financial accelerator mechanisms driving sudden stops is feasible, this is the most preferable policy. But assuming that this is not feasible, domestic policies aimed at stabilizing the relative price of nontradables are an appealing alternative.

Figure 1. Fraction of Mexico's Real Exchange Rate Variability Explained by Tradables Goods Prices at Different Time Frequencies

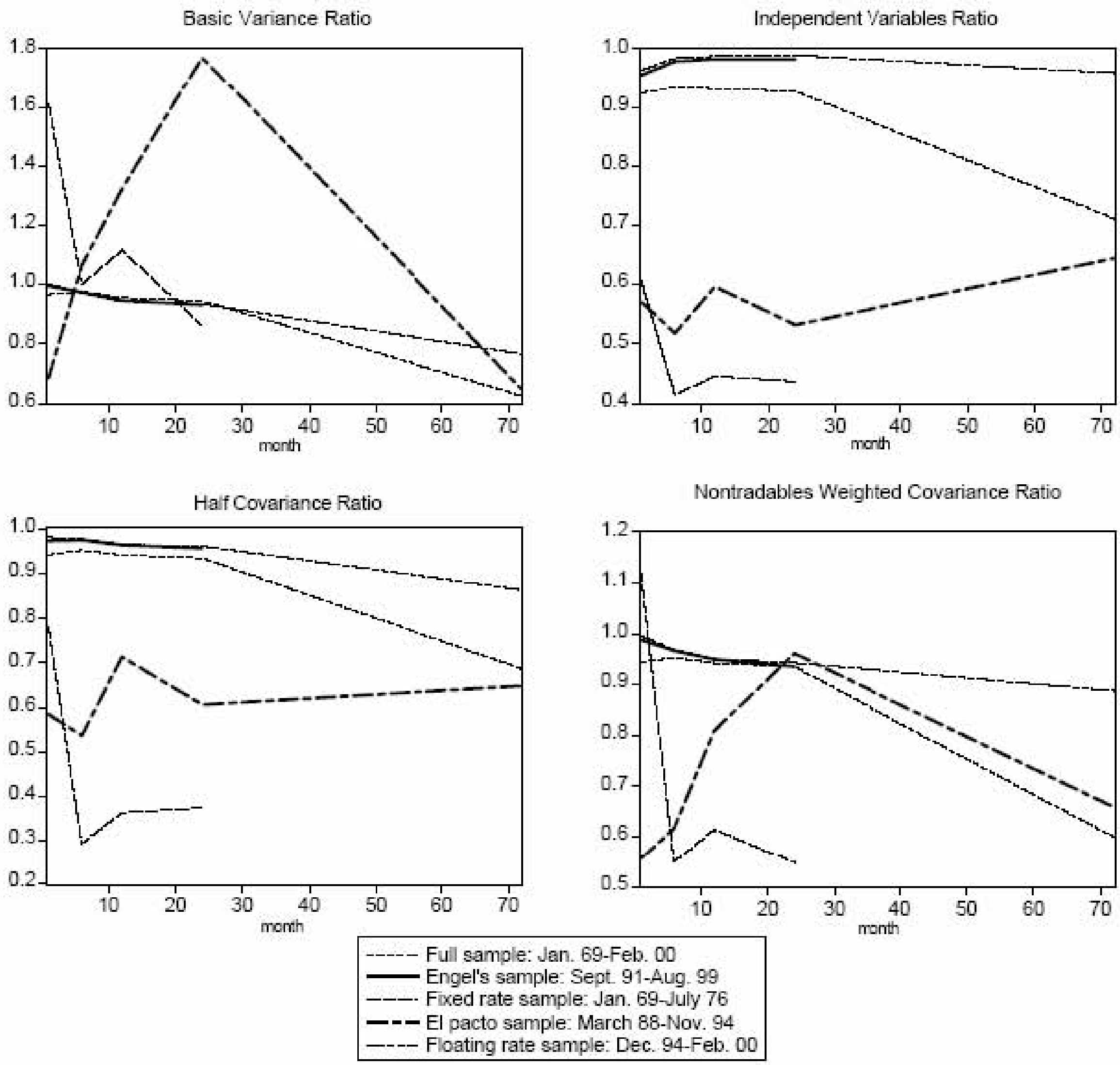


Figure 2. Equilibrium in the Nontradables Market with Fisherian Deflation

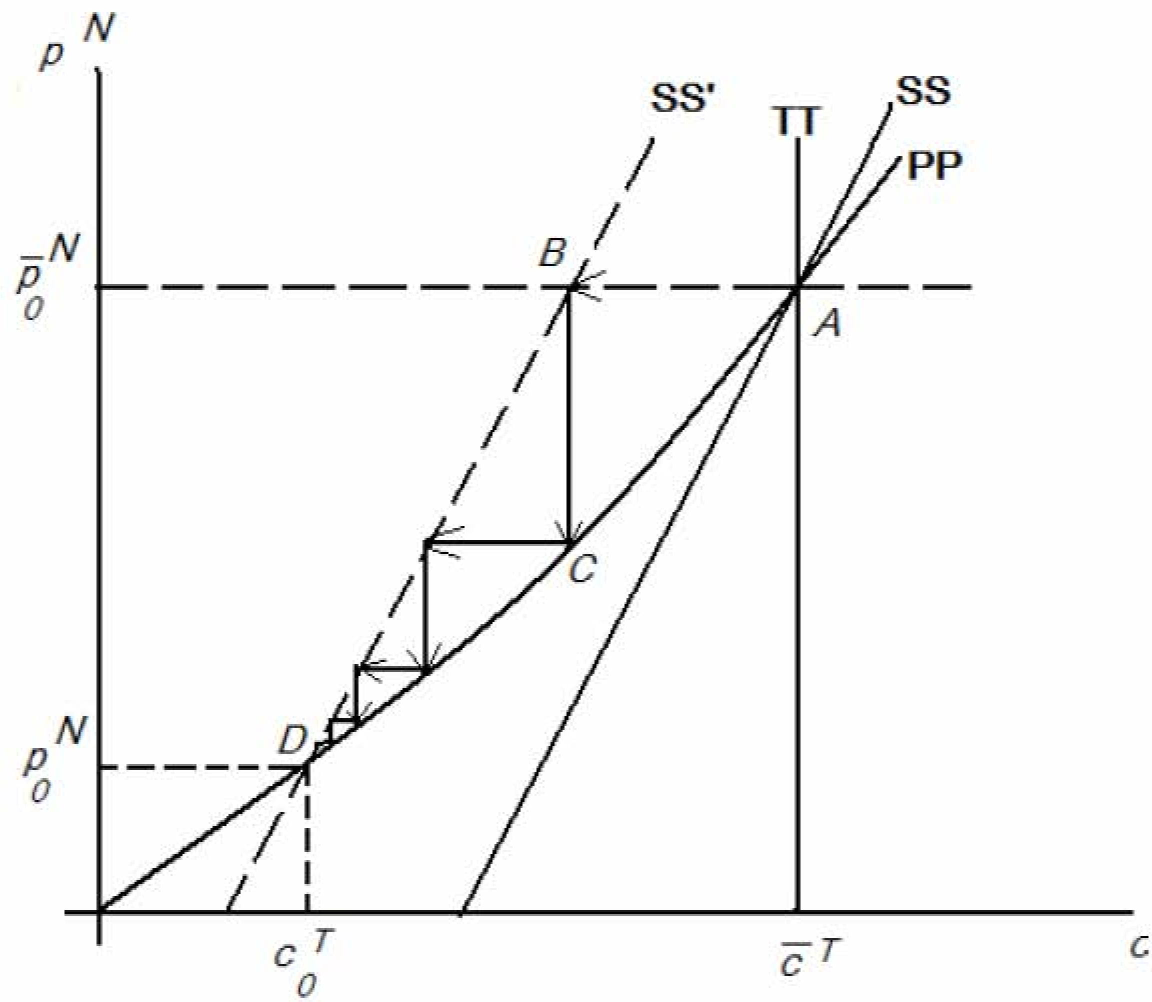


Figure 3. Date-0 Effects of Changes in Liquidity Coefficient

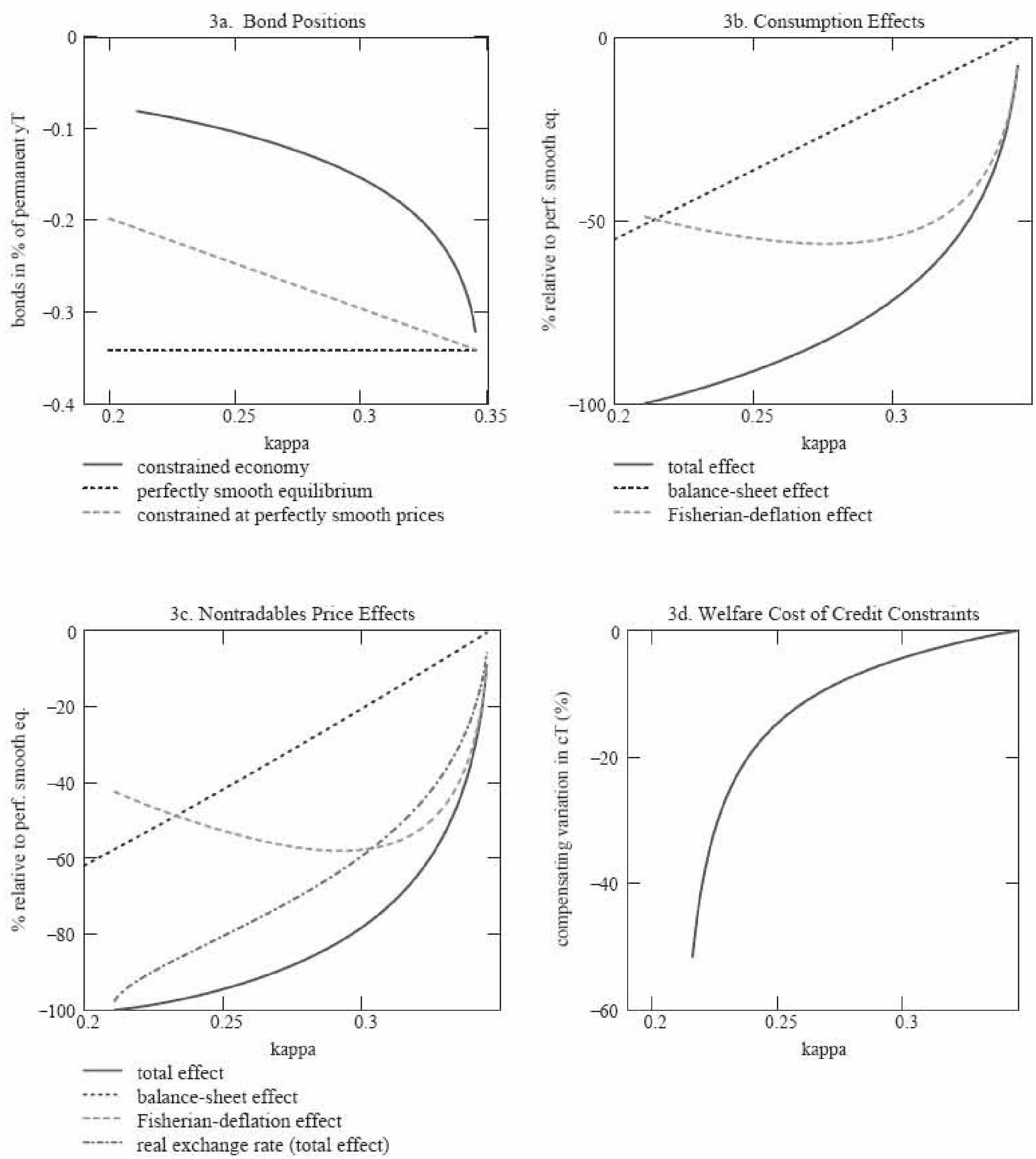


Figure 4. Date-0 Effects of Shocks to Tradables Endowment

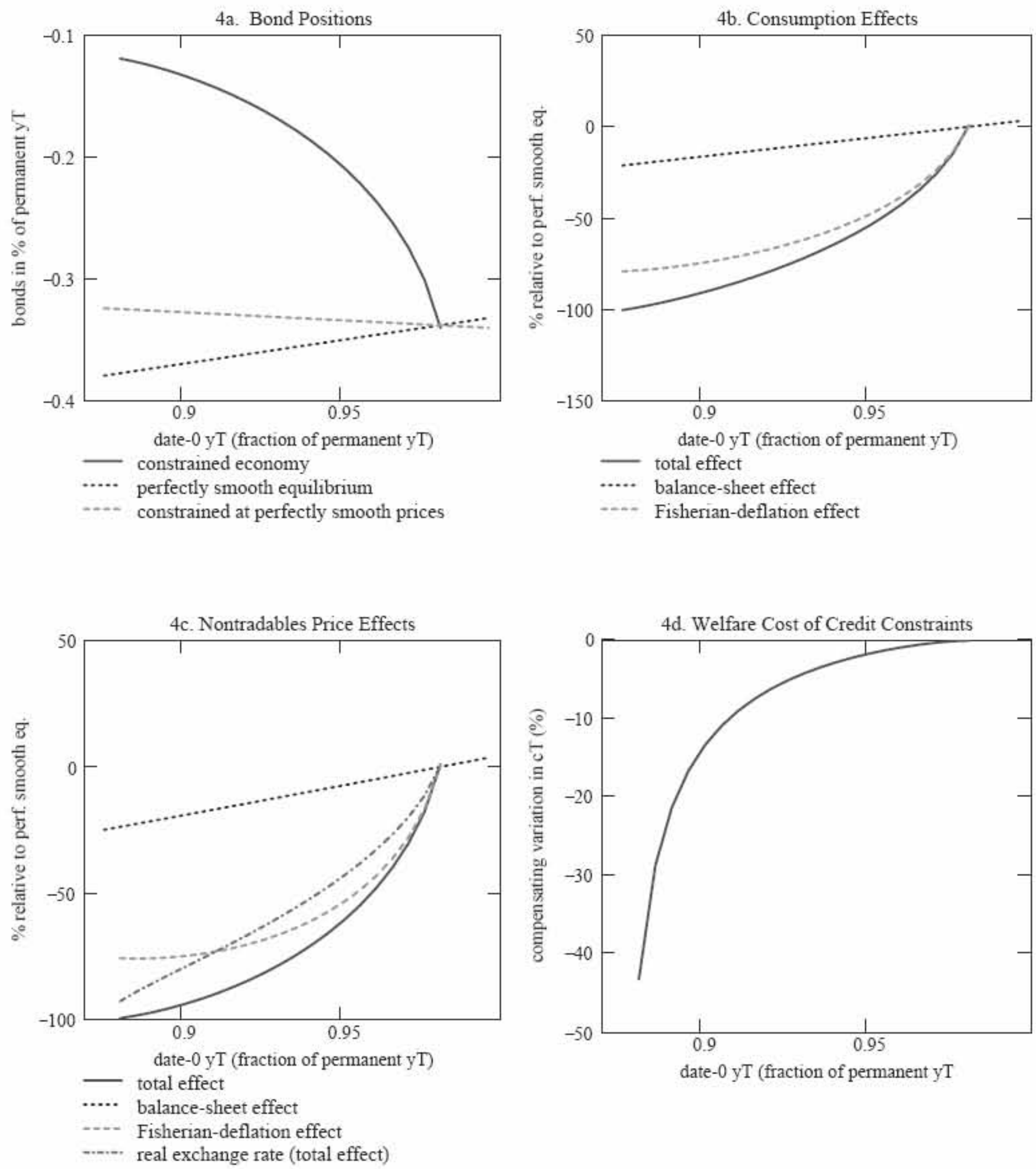
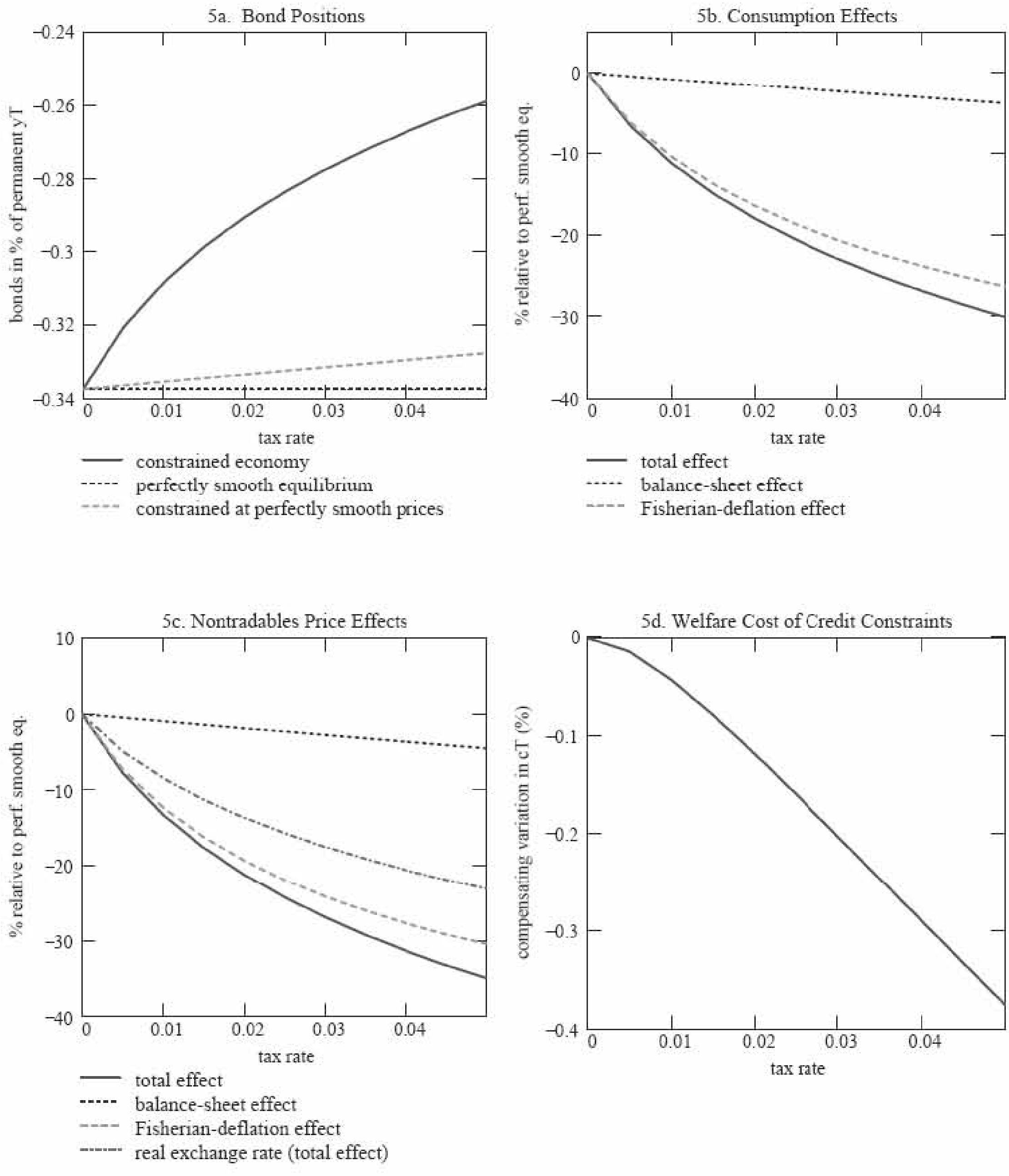


Figure 5. Date-0 Effects of Policy-Induced Real Depreciation



References

Adao, B., I. Correia, and P. Teles, 2005, "On the Relevance of Exchange Rate Regimes for Stabilization Policies" (unpublished; Lisbon: Department of Economic Studies, Bank of Portugal).

Arellano, C., and E.G. Mendoza, 2003, "Credit Frictions and 'Sudden Stops' in Small Open Economies: An Equilibrium Business Cycle Framework for Emerging Markets Crises," in *Dynamic Macroeconomic Analysis: Theory and Policy in General Equilibrium*, ed..by S. Altug, J. Chadha, and J. Nolan (Cambridge University Press).

Baxter, M., and A. C. Stockman, 1989, "Business Cycles and The Exchange Rate Regime: Some International Evidence," *Journal of Monetary Economics*, Vol. 23, No. 3, pp. 377–400.

Betts, C., and T.J. Kehoe, 2000, "Tradeability of Goods and Real Exchange Rate Fluctuations" (unpublished; Twin Cities, Minnesota: Department of Economics, University of Minnesota).

Burstein, A. T., João C. Neves, and S. Rebelo, 2000, "Distribution Costs and Real Exchange Rate Dynamics During Exchange-Rate-Based Stabilizations" (unpublished; Evanston, Illinois: Department of Economics, Northwestern University).

Calvo, G.A., 1998, "Capital Flows and Capital-Market Crises: The Simple Economics of Sudden Stops," *Journal of Applied Economics*, Vol. 1 (November), pp. 35–54.

Calvo, G.A., A. Izquierdo, and R. Loo-Kung, 2005, "Relative Prices Under Sudden Stops: Level and Volatility Effects," *Journal of International Economics*, forthcoming.

Calvo, G.A., and C. A. Végh, 1999, "Inflation Stabilization and BOP Crises in Developing Countries," in *Handbook of Macroeconomics*, Vol. C, pp. 1531–1614, ed. by J. Taylor and M. Woodford (Amsterdam: North-Holland).

Chari, V. V., P. J. Kehoe, and E. R. McGrattan, 2002, "Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates?" *Review of Economic Studies*, Vol. 69 (July), pp. 533–63.

Coleman, J. W., 1996, "Functional Equivalence Between Transactions-Based Models of Money and Distorted Real Economies" (unpublished; Durham, North Carolina: Fuqua School of Business, Duke University).

Engel, C., 1995, "Accounting for U.S. Real Exchange Rate Changes," NBER Working Paper No. 5394 (Cambridge, Massachusetts: National Bureau of Economic Research).

———, 1999, "Accounting for U.S. Real Exchange Rate Changes," *Journal of Political Economy*, Vol. 107 (June), pp. 507–38.

———, 2000, "Optimal Exchange Rate Policy: The Influence of Price-Setting and Asset Markets" (unpublished; Seattle, Washington:, Department of Economics, University of Washington).

Froot, K., and K. Rogoff, 1995, "Perspectives on PPP and Long-Run Real Exchange Rates," in *Handbook of International Economics,* Vol. 32, ed. by G.M. Grossman and K. Rogoff (Amsterdam: North-Holland).

Gonzales, M., and P.A. Neumeyer, 2003, "The Elasticity of Substitution in Demand for Non-Tradable Goods in Latin America. Case Study: Argentina" (unpublished; Buenos Aires: Universidad Torcuato Di Tella).

International Monetary Fund, 2004, *World Economic Outlook*, April (Washington).

Jenkins, M., and J.H. Rogers, 1995, "'Haircuts or Hysteresis? Sources of Movements in Real Exchange Rates," *Journal of International Economics*, Vol. 38 (May), pp. 339–60.

Lane, P., and G. M. Milesi-Ferretti, 2001, "The External Wealth of Nations: Measures of Foreign Assets and Liabilities for Industrial and Developing Countries," *Journal of International Economics,* Vol. 55 (December), pp. 263–94.

Lorenzo, F., D. Aboal, and R. Osimani, 2003, "The Elasticity of Substitution in Demand for Non-tradable Goods in Uruguay" (unpublished; Montevideo: Centro de Investigaciones Económicas (CINVE).

Mendoza, E.G., 1995, "The Terms of Trade, The Real Exchange Rate, and Economic Fluctuations," *International Economic Review*, Vol. 36, No. 1, pp. 101–37.

———, 2000, "On the Instability of Variance Decompositions of the Real Exchange Rate across Exchange Rate Regimes: Evidence from Mexico and the United States," NBER Working Paper No. 7768 (Cambridge, Massachusetts: National Bureau of Economic Research).

———, 2001, "The Benefits of Dollarization When Stabilization Policy Lacks Credibility and Financial Markets are Imperfect," *Journal of Money, Credit and Banking,* Vol. 33, No. 2, pp. 440–74.

———, 2002, "Credit, Prices, and Crashes: Business Cycles with a Sudden Stop," in *Preventing Currency Crises in Emerging Markets*, ed. by S. Edwards and J. Frankel (Chicago, Illinois: National Bureau of Economic Research, University of Chicago Press).

Mendoza, E.G., and M. Uribe, 2000, "Devaluation Risk and the Business Cycle Implications of Exchange Rate Management," *Carnegie-Rochester Conference Series on Public Policy*, Vol. 53 (December), pp. 239–96.

Mussa, M., 1986, "Nominal Exchange Rate Regimes and The Behavior of Real Exchange Rates: Evidence and Implications," *Carnegie-Rochester Conferences Series on Public Policy*, Vol. 25 (Autumn), pp. 117–214.

Naknoi, K., 2005, "Real Exchange Rate Fluctuations, Endogenous Tradability and Exchange Rate Regime" (unpublished; West Lafayette, Indiana: Department of Economics, Purdue University).

Ostry, J. D., and C. M. Reinhart, 1992, "Private Saving and Terms of Trade Shocks," *Staff Papers*, International Monetary Fund, Vol. 39 (September), pp. 495–517.

Parsley, D. C., 2003, "Accounting for Real Exchange Rate Changes in East Asia," Hong Kong Institute for Monetary Research Working Paper No. 6 (Hong Kong SAR).