From Sudden Stops to Fisherian Deflation: Quantitative Theory and Policy

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Abstract

In the 1990s, Sudden Stops in emerging markets were a harbinger of the 2008 global financial crisis. During these Sudden Stops, countries lost access to credit, which caused abrupt current account reversals, and suffered severe recessions. This article reviews a class of models that yield quantitative predictions consistent with these observations, based on an occasionally binding credit constraint that limits debt to a fraction of the market value of incomes or assets used as collateral. Sudden Stops are infrequent events nested within regular business cycles and occur in response to standard shocks after periods of expansion increase leverage ratios sufficiently. When this happens, the Fisherian debt-deflation mechanism is set in motion, as lower asset or goods prices tighten the constraint further, causing further deflation. This framework also embodies a pecuniary externality with important implications for macroprudential policy because agents do not internalize how current borrowing decisions affect collateral values during future financial crises.

1. INTRODUCTION

On the surface, the debacle of the Mexican economy that began on December 20, 1994, seemed to be a familiar event. Episodes of failed stabilization plans anchored on managed exchange rate regimes abound in the annals of the developing world, and in Mexico, in particular, this was a recurrent event that had coincided with every presidential election since 1976. Yet the 1994 Mexican crash was different. It was the beginning of a new era of financial instability in the newly created global financial system. It was the first of a collection of similar events that swept through emerging markets worldwide during the 1990s and that we now refer to as Sudden Stops.[1]

The defining characteristic of a Sudden Stop is a sharp reversal in external capital inflows, which is often measured by a sudden jump in the current account. At about the same time as access to foreign financing is lost, or shortly after, the economies afflicted by Sudden Stops experience deep recessions, in many countries the largest since the Great Depression; sharp real depreciations; and collapses in asset prices.[2] Moreover, Sudden Stops typically come in clusters: The 1994 Mexican crash triggered a Sudden Stop in Argentina in 1995—this spillover effect is often referred to as the Tequila effect. In 1997–1998, the East Asian crisis engulfed Korea, Malaysia, Indonesia, Thailand, Singapore, Hong Kong, and the Philippines. Before the end of the 1990s, there were Sudden Stops in emerging economies across the world, in Bulgaria, Chile, Colombia, Ukraine, Ecuador, Morocco, Venezuela, Russia, and Turkey.[3]

Academic research on Sudden Stops surged, starting in the second half of the 1990s, and led to many valuable contributions that aimed to connect the dots between the financial instability at the root of Sudden Stops and their disastrous macroeconomic consequences. Many of these contributions are collected in prestigious conference volumes and reviewed in related surveys [see, e.g., the symposia issues of the *Journal of International Economics* (Calvo et al. 1996, Mendoza & Velasco 2000, Devereux & Mendoza 2006), the *Journal of Money, Credit and Banking* (Del Negro et al. 2001), and the *Journal of Economic Theory* (Bansal et al. 2004), as well as the NBER conference volumes edited by Krugman (2000), Edwards & Frankel (2002), and Dooley & Frankel (2003)]. They were also published in leading academic journals (see, e.g., Calvo & Mendoza 1996, 2000; Kaminsky & Reinhart 1999; Cole & Kehoe 2000; Aghion et al. 2001, 2004; Caballero & Krishnamurthy 2001, 2003, 2004; Chang & Velasco 2001; Martin & Rey 2006; Lorenzoni 2008; Mendoza 2010). The central focus of research on Sudden Stops was precisely on the intersection of macroeconomics and finance, and especially on the connection between financial instability and macroeconomic collapse. This was at a time when many in the field of modern macroeconomics were not paying attention to financial frictions and their potentially catastrophic consequences for the real economy. Moreover, many developments in theoretical analysis and quantitative tools produced by this literature are now serving as a key building block in the growing literature on the 2008 financial crash and the renaissance of the macro/finance field (see, e.g., Gertler & Kiyotaki 2010).

In this article, we document the key stylized facts that characterize Sudden Stops and provide an analytical review of one of the dominant modeling approaches in the literature that emerged as a framework capable of yielding both qualitative and quantitative predictions in line with those

[1]The term Sudden Stop was first used in this context by Dornbusch et al. (1995), inspired by an old bankers' adage.

[2]Interestingly, nominal devaluations are not a necessary condition for Sudden Stops. In Argentina in 1995 and Hong Kong in 1998, the nominal exchange rate remained constant, yet the real exchange rate collapsed and deep recessions followed.

[3]Moreover, the 1998 Russian crash was followed by a sudden flight to quality in global capital markets, which caused the infamous collapse of the hedge fund Long-Term Capital Management. Conditions in US capital markets worsened to the point that the Federal Reserve was forced into lowering interest rates to ease access to liquidity and brokering an arrangement for the orderly winding down of Long-Term Capital Management among its creditors.

facts. This approach is based on occasionally binding collateral constraints that trigger a financial amplification mechanism similar to the debt-deflation mechanism originally proposed in the pioneering work of Fisher (1933). We start with a simple but general characterization of this Fisherian amplification mechanism and then discuss applications to Sudden Stop models that involve liability dollarization (i.e., debts denominated in units of tradable goods but backed by incomes or assets denominated in units of nontradable goods), asset price deflation, and a full-blown equilibrium business cycle model. Finally, we review the main policy implications that follow from this class of models, particularly for the design of macroprudential financial regulation that is at the center of the new efforts to reconstruct financial regulation in the aftermath of the 2008 crash.

Figure 1 illustrates the basic mechanics of financial amplification schematically: Assume an emerging economy that borrows from abroad and is subject to a collateral constraint. Because the current account is countercyclical, periods of expansion are also periods of leverage buildup. Hence, if at sufficiently high leverage ratios the collateral constraint becomes binding, it forces agents to reduce their spending and fire-sale the assets or goods posted as collateral, which lowers aggregate demand and causes a collapse in real exchange rates, relative prices, and asset prices. As the value of collateral is tied to these relative prices, such declines tighten the collateral constraint and force agents to cut back further on spending and engage in further fire sales of goods and/or assets, triggering a vicious circle of falling borrowing ability, falling spending, and collapsing exchange rates and asset prices.

The common thread of the applications of the Sudden Stops framework we study, and what distinguishes it from the rest of the literature, is the emphasis on studying the models' quantitative predictions using global, nonlinear numerical methods in experiments calibrated to data from actual economies. This is essential to capture the nonlinear dynamics of financial amplification that make financial crises so severe, the transition from states of loose financial constraints to states with binding financial constraints, and the associated implications for precautionary savings. The same tools also prove to be essential for the use of these models to analyze normative issues and examine issues such as the optimal design of macroprudential financial regulation.

It is worth noting that some issues raised in the analysis of Sudden Stops, particularly the adjustment problems induced by a large surge in capital outflows, have long been emphasized in the international economics literature. One example is the well-known work of Keynes and Olin on the transfer problem. Their discussion centered on the contractionary forces at play in post-WWI Germany, which owed massive reparations to France and therefore had to run a large current account surplus and suffer from a depreciated real exchange rate. There is also a large and

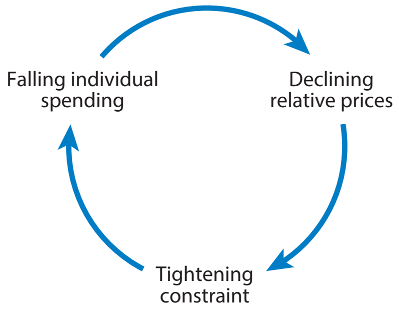

Figure 1

Schematic description of financial amplification effects.

well-established literature on financial amplification via asset prices in closed-economy settings that predates the Sudden Stop models with asset price deflation we examine in this article. These models can be traced back to the classic article by Fisher (1933), the work of Minsky (1986), the early formal models by Bernanke & Gertler (1989) and Greenwald & Stiglitz (1993) in simple two-period settings, and the more general models proposed by Kiyotaki & Moore (1997), as well as quantitative applications of these models using perturbation methods in DSGE (dynamic stochastic general equilibrium) environments, as in the work of Carlstrom & Fuerst (1997), Bernanke et al. (1999), and Iacoviello (2005).

2. STYLIZED FACTS

The key defining characteristic of a Sudden Stop is a sharp, sudden reversal in international capital flows, which is typically measured as a sudden increase in the current account or the balance of trade. A second empirical regularity involves large, negative deviations from trend in the main macroeconomic aggregates (GDP, private consumption, and investment) that follow the reversal in capital flows. That is, Sudden Stops are typically associated with deep recessions. A third characteristic involves sharp changes in relative prices, including exchange rate depreciations and declines in asset prices in both equity and housing markets.

The empirical literature on Sudden Stops generally focuses on the use of event analysis methods that apply filters to current account or net exports data to identify the dates of Sudden Stops and then construct event windows of macroeconomic aggregates centered on those dates to study the characteristics of Sudden Stops. In our empirical description of Sudden Stops, we follow the filter used by Calvo et al. (2006b). (Other classic articles on this subject include Calvo et al. 2006a, 2008. Earlier studies include Milesi-Ferretti & Razin 2000 and Reinhart & Calvo 2000.) They define a Sudden Stop as a large fall in capital flows, as measured by a year-over-year increase in the current account/GDP ratio by more than two standard deviations above the average change in this ratio. Furthermore, they define a Sudden Stop as systemic if the aggregate J.P. Morgan Emerging Markets Bond Index (EMBI) spread is more than two standard deviations above its mean.[4]

Figure 2 provides five-year event windows centered around Sudden Stop events at date t. To construct these event windows, we started with the list of 33 Sudden Stop events provided by Calvo et al. (2006a) using data for emerging markets from 1980 to 2004. We extended their analysis by adding emerging markets data from 2005 to 2012 and including advanced economies data from 1980 to 2012 so as to capture more recent Sudden Stops in both emerging markets (particularly in Eastern Europe) and advanced economies (especially around the 2008 crash). Readers are referred to **Supplemental Appendix A** for a full description of the data and the identification procedure used (follow the Supplemental Material link from the Annual Reviews home page at **http://www.annualreviews.org**). The event windows use annual data from 1978 to 2012 to show the cross-country medians of the cyclical components of output (Y), consumption (C), investment (I), the net exports-GDP ratio (TB/Y), the real exchange rate (RER), and real stock prices (indices rebased so that year $t-1$ equals 100), where we detrended Y, C, and I using the Hodrick-Prescott filter.

Supplemental Material

The event windows show that Sudden Stops are preceded by periods of expansion, with GDP, consumption, and investment above trend; the trade balance below trend; the real exchange rate appreciated (for emerging markets); and asset prices high. The typical Sudden Stop, defined as the

[4]In some of their work, Calvo et al. also apply a third filter to isolate Sudden Stops in which the drop in output is unusually large. We do not use this filter so as to let the data speak about the severity of the median recession across all Sudden Stop events.

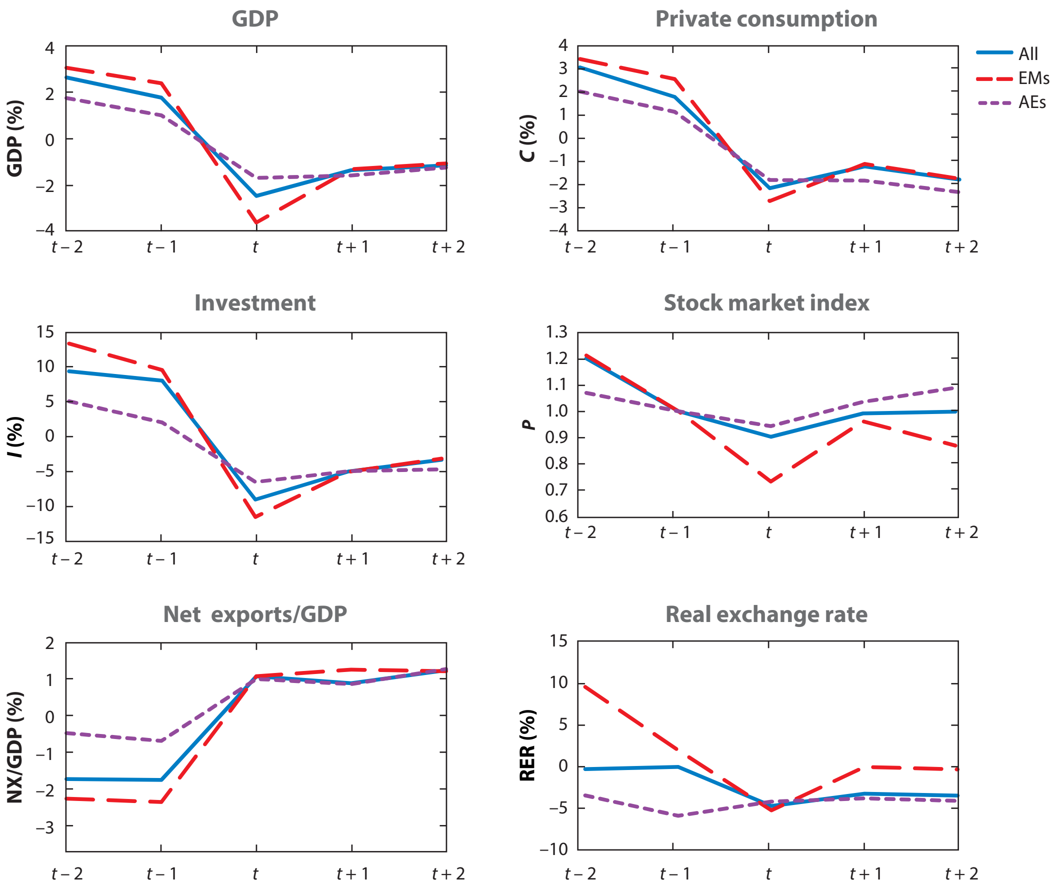

Figure 2

Dynamics of Sudden Stops. Abbreviations: AE, advanced economy; C, consumption; EM, emerging market; I, investment; NX, net exports; RER, real exchange rate; P, equity prices.

median across all events in the data, shows a reversal in the cyclical component of TB/Y of approximately 3 percentage points at date t. Consumption and GDP fall approximately 3% below trend, and investment drops 10% below trend. A weak recovery follows, but the economies that go through Sudden Stops remain below trend in all three key macro-aggregates (output, consumption, and investment), and the trade balance remains above trend two years later. Stock prices also reach their lowest point at date t, and they are sharply lower than in the pre–Sudden Stop peak. Two years later, they rise somewhat, but in emerging markets, in particular, they only recover a fraction of their losses.

The event windows also show a striking contrast in the Sudden Stop dynamics across emerging markets and advanced economies. In particular, advanced economies do not show the marked inverted-J pattern that emerging markets display. In fact, two years after the Sudden Stop event, output, consumption, and investment are still not beginning to climb back to their trends. This mainly results from the fact that almost half of the Sudden Stop events in advanced economies that we identified in our sample occurred around the 2008/2009 crisis, and they were indeed followed by a slow recovery.

Another important difference across Sudden Stops in emerging markets and advanced economies is that in the former, there is a clear and strong real appreciation before the Sudden Stops hit, followed by a real exchange rate collapse and then a modest, gradual recovery. In contrast, this pattern is absent from the Sudden Stops in advanced economies and in the combined sample. This is in line with the findings of Mendoza & Terrones (2012), who show that credit boom events display a similar asymmetry: real appreciation followed by collapse in emerging markets and no noticeable pattern in advanced economies.

Mendoza (2010) highlights three other important empirical regularities of Sudden Stops: (*a*) They are infrequent events nested within typical business cycles; (*b*) they generate negative skewness in macroeconomic aggregates because we do not observe symmetric episodes of sudden large capital inflows coupled with economic expansions; and (*c*) in a standard growth accounting exercise, a significant fraction of the drop in output during a Sudden Stop is accounted for by a drop in the Solow residual rather than a decline in measured capital and labor.[5]

Producing quantitative predictions in line with the stylized facts of Sudden Stops is a tall order for standard open-economy macro DSGE models, including real-business-cycle (RBC) models and New Keynesian models. In these models, credit markets are assumed to work as an efficient vehicle for consumption smoothing and investment financing. Even if state-contingent securities are absent, frictionless trading in non-state-contingent bonds allows agents to smooth out drops in output by borrowing from abroad and thus running larger current account deficits. This is precisely the opposite of what we observe during Sudden Stops: The external accounts rise sharply precisely when consumption and output collapse. This key observation indicates that a crucial starting point for developing a framework for explaining Sudden Stops must be to abandon the assumption that credit markets are perfect.[6]

3. GENERAL MODEL STRUCTURE

We start by describing a general structure for the class of models of Sudden Stops that follow the Fisherian debt-deflation approach. The essential feature of this structure is that borrowers are subject to a financial constraint that is itself a function of the endogenous aggregate states of the economy, which play a particularly important role as the determinants of the market prices at which collateral is valued. As we describe below, this endogeneity gives rise to rich dynamics: It reproduces the asymmetry and amplification of negative shocks observed during Sudden Stops when debt levels in the economy are high. In contrast, when debt levels in the economy are moderate and the financial constraint is loose, the standard underlying forces driving business cycles result in regular cyclical dynamics.

After describing the general setup, we impose additional structure on the financial constraint to highlight a number of particular channels through which the Fisherian deflation mechanism can operate, focusing on (*a*) contractionary real exchange rate depreciations, (*b*) contractionary asset price deflation, and (*c*) a general equilibrium extension of the latter with endogenous capital accumulation in which the collateral constraint also restricts working capital financing. This allows us to describe a full-blown equilibrium business cycle model with Sudden Stops.

[5]This results in part from factors that bias the Solow residual as a measure of effective total factor productivity (TFP), such as changes in the price of imported inputs, capacity utilization, and labor hoarding (see Mendoza 2006, Meza & Quintin 2007).

[6]A potential alternative explanation is the possibility of growth shocks, proposed by Aguiar & Gopinath (2007), although these shocks can be difficult to identify in the short samples of macro time series available for several emerging economies.

3.1. Model Setup

Assume a small open economy in infinite discrete time $t = 1, 2, \ldots$. The economy is inhabited by a representative agent who receives a stochastic endowment y_t every period and who values consumption c_t according to a standard time-separable expected utility function

$$U = E\sum \beta^t \left[u(c_t)\right], \tag{1}$$

where $\beta < 1$ is the subjective discount factor, and $u(c_t)$ is a standard twice-continuously differentiable, strictly concave period utility function that satisfies the Inada conditions.

Foreign creditors are large in comparison to the small open economy and trade one-period non-state-contingent discount bonds b with the domestic agent (i.e., $b < 0$ denotes that domestic agents are borrowing from abroad). International bonds carry an exogenous, time- and state-invariant price of $1/R$, where R $(r = R - 1)$ is the gross (net) world real interest rate. As explained below, we require $\beta R < 1$ to ensure the existence of a well-defined long-run distribution of b that characterizes the economy's stochastic steady state. The repayment on the bond holdings of the home agent at the beginning of period t is given by b_t, and the value of bond purchases carried as savings into the ensuing period is b_{t+1}/R. Because in this simple setup b is the only internationally traded asset, it also defines the country's net foreign asset (NFA) position. The period budget constraint is

$$c_t + b_{t+1}/R = y_t + b_t. \tag{2}$$

The assumption that bonds are not state contingent implies that asset markets are incomplete. Thus, the small open economy has an incentive to self-insure. In addition, we introduce a moral hazard problem that limits how much domestic consumers are able to borrow and that generates a second form of market incompleteness: After contracting debt in period t, we assume that they have an option to abscond. Lenders can detect this, and if they take immediate action, they can recover up to $\bar{b}$ units of the amount lent; otherwise the entire loan is lost, and lenders have no further recourse or means of punishment. For borrowers to refrain from absconding, lenders limit their lending to $\bar{b}$.

The borrowing limit $\bar{b}$ generally depends on the aggregate state of the economy because it is defined as a fraction of the market prices of goods or assets posted as collateral, and these prices depend on aggregate variables. For example, in a booming economy with an appreciated exchange rate and elevated asset prices, lenders will find it easier to recover funds than in a depressed economy with low exchange rates and asset prices. Similarly, a booming economy with high goods or asset prices enables agents to post collateral and borrow desired amounts easily, whereas in a depressed economy, collapsing asset and good prices reduce collateral values and hence borrowing ability. It proves convenient for ease of exposition to assume that the financial constraint depends on aggregate consumption C_t, which is taken as given by the representative agent. In equilibrium, of course, $C_t = c_t$. In the setting described so far, C_t serves as a sufficient statistic for aggregate demand and relative prices in the economy. We express the dependence of the borrowing constraint on aggregate conditions as

$$b_{t+1}/R \geq -\bar{b}(C_t), \tag{3}$$

where $\bar{b}'(C_t) > 0$; i.e., higher aggregate consumption, which implies higher collateral prices, increases borrowing capacity. In the following two sections, we examine more detailed variants of this setting based on relative price drops that are associated with declines in aggregate consumption. This is the defining characteristic of Fisherian models, namely that binding credit constraints force falling consumption and the liquidation of goods or assets that serve as collateral, leading to a spiraling decline in borrowing ability, consumption, and prices (asset prices or the real exchange rate in the cases we examine). We also allow for additional variables to affect the borrowing limit of domestic agents, such as individual holdings of assets or individual production plans. However, at the most general level, the relationship captured by the reduced-form constraint in Equation 3 lies at the heart of the Fisherian effects that we want to capture.

Observe that the constraint limits borrowing today to an amount that depends on aggregate demand today (or the collateral prices of today). This can be justified by empirical evidence that lenders base credit availability on current economic conditions or by the observation of the structure of credit contracts with margin requirements or the right to make margin calls. Furthermore, it captures the simplest way of modeling financial amplification effects.[7]

The combination of non-state-contingent debt and a collateral constraint is critical for producing Sudden Stops as an equilibrium outcome in this setup. Taken together, these two financial imperfections imply that there is a mismatch between the denomination of the agent's financial liabilities and his or her borrowing capacity, and this mismatch drives the financial amplification effects: The liabilities of the agent are not state contingent, whereas the borrowing limit fluctuates in parallel with aggregate states over the business cycle (e.g., owing to fire sales of goods and assets). In the event of adverse shocks, this implies that the borrowing limit tightens but that the level of debt remains the same. Instead of being able to smooth the impact of adverse shocks over time, the representative agent experiences a Sudden Stop. In short, the key ingredient of a Fisherian model of financial amplification is a relative price that connects the value of collateral with borrowing ability.

One of the key trade-offs in this Fisherian framework is that between impatience and precaution. The assumption $\beta R < 1$ is necessary because without it agents would find it optimal to accumulate an infinite amount of foreign assets.[8] This assumption also implies, however, that there are gains from intertemporal trade—domestic agents are less patient than foreign creditors, which gives them the incentive to accumulate debt. If domestic agents were risk neutral, they would simply borrow up to the borrowing limit $\overline{b}$ to take maximum advantage of this opportunity to trade. In that case, the borrowing constraint would always be binding. As domestic agents are risk averse, but asset markets are incomplete, agents have an incentive to accumulate precautionary savings against stochastic endowment risk. Hence, they raise their bond holdings above the minimum level $\overline{b}$ to self-insure.

The level of precautionary savings depends on the relative importance of the impatience versus the precautionary motive. Standard results from the theory of optimal savings under incomplete markets imply that impatience grows stronger relative to the precautionary motive the further βR is below one. Moreover, the precautionary motive grows stronger as βR rises, as agents become more risk averse, or as the variability or persistence of uninsurable shocks increases. [Ljungqvist & Sargent (2012, chapters 17 and 18) provide an in-depth discussion of models of precautionary savings.]

[7]Our results generalize, however, to models of financial amplification in which borrowing today affects investment today, which in turn influences asset prices or exchange rates tomorrow and feeds back to borrowing today (see, e.g., Mendoza 2010, Jeanne & Korinek 2013).

[8]If $\beta R \geq 1$, optimal plans when the collateral constraint does not bind imply that $c_t, b_{t+1} \to \infty$ because the Euler equation for bonds forms a supermartingale process, and the convergence of this process requires that $u'(c_t) \to 0$ almost surely, which in turn implies c_t, $b_{t+1} \to \infty$ (see Ljungqvist & Sargent 2012, chapter 18). We note also that in closed-economy models with heterogeneous agents, $\beta R < 1$ is an equilibrium outcome, whereas in small open-economy models, it is an assumption needed to support a well-defined equilibrium.

Importantly, both the precautionary and impatience motives, and the requirement that $\beta R < 1$, are present even without the collateral constraint, as long as asset markets are incomplete. What is key, however, is that the endogenous financial amplification strengthens the precautionary motive because it increases the risk of (very) low consumption when the constraint binds. This leads agents to accumulate larger stocks of precautionary savings than in the situation without the collateral constraint, which reduces the probability of hitting the constraint along the equilibrium path, thereby providing self-insurance against financial crises states. This mechanism will play a key role in allowing Fisherian models to nest infrequent Sudden Stops within regular business cycles. Still, as explained in Section 7, the extra precautionary savings induced by the risk of Sudden Stops are insufficient from a socially optimal perspective because of the pecuniary externality embedded in the collateral constraint.

3.2. Equilibrium

We define the competitive equilibrium of the economy as follows.

> **Definition 1:** Given an initial asset position b_1, a world interest rate R, and a stochastic output process $\{(y_t)_{t=1}^{\infty}\}$, the competitive equilibrium of the economy consists of a set of stochastic allocations $\{(b_{t+1}, c_t)_{t=1}^{\infty}\}$ that maximize the utility of the representative agent (Equation 1) subject to the series of budget constraints (Equation 2) and borrowing constraints (Equation 3) and the consistency condition $C_t = c_t$.

We assign the shadow price λ_t to the borrowing constraint (Equation 3). Observe that the representative agent takes C_t as given. The resulting optimality condition is

$$u'(c_t) = \beta R E\left[u'(c_{t+1})\right] + \lambda_t. \tag{4}$$

The equilibrium is described by the Euler equation (Equation 4) together with the borrowing constraint (Equation 3) and the budget constraint (Equation 2).

The following assumption is a sufficient condition for a well-defined equilibrium.

> **Assumption 1:** The slope of the borrowing limit satisfies $\overline{b}'(C_t) < 1$.

Intuitively, the assumption states that a one-dollar increase in aggregate consumption relaxes the borrowing constraint by less than one dollar. If this assumption is violated for any value of C_t when the constraint is binding, then a coordinated increase in aggregate consumption would become self-financing and the economy would exhibit multiple equilibria (see Jeanne & Korinek 2010a, appendix A, for further details). As discussed below in further detail, this assumption is important in models of financial amplification to guarantee uniqueness.

We now reformulate the above equilibrium in recursive form, which we use in our numerical solution algorithms below. First, the stochastic income process is approximated as a first-order, irreducible Markov process with realization vector $\mathbf{y}$ and transition probabilities $\pi(y_t, y_{t+1})$.[9] The state variables of the representative agent's problem are the agent's holdings of bonds, $b \equiv b_t$; the agent's income realization, $y \equiv y_t$; and the aggregate bond position of the economy that the agent takes as given, B.

[9]The well-known Tauchen-Hussey quadrature algorithm is widely used in quantitative applications for this purpose.

The optimal plans of the representative agent solve the Bellman equation

$$V(b, y; B) = \max_{b'} \left\{ u\left(y - \frac{b'}{R} + b \right) + \beta \sum_{y'} \pi(y, y') V(b', y'; B') \right\},$$

$$\text{s. t.} \frac{b'}{R} \geq -\overline{b}(C),$$

where

$$B' = H(B, y), \quad C = y - \frac{B'}{R} + B.$$

The agent chooses b' taking as given both the aggregate state B and a conjectured law of motion $H(B, y)$. Together, the two pin down aggregate consumption and determine $\overline{b}(C)$. The law of motion $H(B, y)$ determines how the agent's expectations about the aggregate state variable B, aggregate consumption C, and thus the borrowing capacity of the economy will evolve in the future.

For a given $H(B, y)$, the solution to the above problem is provided by a policy function $\hat{b}'(b, y; B)$. In a rational expectations equilibrium, however, we also require that the conjectured law of motion of B must match the actual one implied by the policy function: $H(B, y) = \hat{b}'(B, y; B)$ identically in B.

> **Definition 2 (recursive equilibrium):** The recursive equilibrium is defined by the policy function $\hat{b}'(b, y; B)$ and associated value function $V(b, y; B)$ such that (*a*) they solve the above Bellman equation and (*b*) the rational expectations equilibrium condition holds, $H(B, y) = \hat{b}'(B, y; B)$ identically in B.

To keep the notation simple, we denote the resulting policy function of the recursive equilibrium as $b'(b, y)$, omitting the aggregate state that becomes redundant once condition (*b*) holds. In general, recursive equilibria of this form do not have closed-form solutions, except in special cases such as the perfect-foresight example we study next. Several global, nonlinear numerical solution methods can be used to solve models in this class. **Supplemental Appendix B** provides an example based on an endogenous grid-points method along with a sample calibration and source code.[10]

Supplemental Material

3.3. Amplification: A Deterministic Example

We illustrate the potential for amplification in this class of models by first focusing on a deterministic setup with constant income ($y_t = y$) and $\beta R = 1$. Given these assumptions, there are two possibilities for how equilibrium is determined, depending on the initial asset position of the representative consumer b_1.

3.3.1. Unconstrained equilibrium. For sufficiently high period 1 bond holdings b_1, the borrowing constraint is loose in period 1 and in all following periods. The model collapses to a standard Friedman-style permanent income model of consumption with perfectly smooth

[10]Algorithms that solve recursive formulations of the optimality conditions, instead of directly solving Bellman equations like the one above, have the advantage that they can impose the rational expectations equilibrium condition directly and thus sidestep the need to iterate to convergence on actual and conjectured laws of motion of aggregate states.

consumption, $c_t = y + (1 - \beta)b_1$, where consumption is a fraction $1 - \beta$ of wealth, defined as the present discounted value of income plus initial net worth, $w \equiv y/(1 - \beta) + b_1$.

Because the model is fully stationary, bond holdings in all future periods equal the initial bond holdings: $b_t = b_1 \forall t$. Hence, a one-dollar increase in initial bond holdings is reflected one-for-one in future bond holdings, $db_t/db_1 = 1$, and as w increases by b_1, consumption rises by the fraction $1 - \beta$. In short, the increase in wealth is spread out over the indefinite future, and there is no amplification. Intertemporal markets play a stabilizing role by allowing consumers to smooth the consumption effect of changes in net worth over time.

3.3.2. Constrained equilibrium. The unconstrained equilibrium is feasible if the initial bond holdings satisfy

$$b_1 \geq -\overline{b}\big(y + (1 - \beta)b_1\big).$$

Because $b_t = b_1 \forall t$, this condition guarantees that the same property applies to all the sequence of optimal choices of future bond holdings. Given Assumption 1, there is a unique cut-off value of $\hat{b}_1$ for which this equation is satisfied with equality. Below this threshold, for $b_1 < \hat{b}_1$, the financial constraint is binding in period 1 and new borrowing is given by $b_2/R = -\overline{b}(C_1) > b_1$.

Following Mendoza (2005), instead of looking at alternative initial asset positions b_1 that are high or low relative to the credit constraint, we could also study the implications of constrained versus unconstrained borrowing ability by taking b_1 as given and considering wealth-neutral income shocks (i.e., income shocks such that y_1 falls and y_t increases to keep w unchanged). As long as these shocks are smaller than the threshold value that would trigger the credit constraint, unconstrained intertemporal markets would allow the representative consumer to maintain the perfectly smooth equilibrium consumption path. Otherwise, for shocks at or above the threshold, new borrowing is determined by the credit constraint. Moreover, the setup in Mendoza (2005) spells out the price deflation mechanism that drives the relationship between borrowing capacity and aggregate consumption, which we also make explicit in the examples that follow.

Putting together the unconstrained and constrained cases, borrowing b_2/R is given by whichever is lower—the unconstrained debt $b_2/R = b_1/R$ or the constrained debt level $\overline{b}(C_1)$. Hence, the budget constraint yields C_1 as the solution to the implicit equation

$$C_1 = c_1(C_1) = y + b_1 + \min\left\{\overline{b}(C_1), -b_1/R\right\}.$$

This equation is depicted in **Figure 3**. The first equality corresponds to the consistency condition of the representative agent $c_1 = C_1$ and can be represented by the 45° line in the figure. The second equality starting with $c_1(C_1) = \ldots$ reflects that individual consumption is the minimum of its desired and its feasible level given different levels of aggregate consumption C_1 and is represented by the solid line labeled $c_1(C_1)$. As long as the financial constraint is binding, this equality starts at the intercept $y + b_1 + \overline{b}(0) > 0$ and rises at slope $\overline{b}'(\cdot)$, where the figure assumes that $\overline{b}(0) = 0$. When the financial constraint becomes loose, the line remains constant at the desired level of consumption $y + (1 - \beta)b_1$. By Assumption 1, the slope of the right-hand side of the equation is always less than the slope of the left-hand side, guaranteeing a unique intersection, which indicates the equilibrium.

The solid line labeled $c_1(C_1)$ depicts a situation in which initial net worth and output $y + b_1$ are sufficiently high so that the financial constraint is loose and intersects the 45° line at point A, resulting in the unconstrained level of consumption C_1^*. Suppose that we reduce initial net worth by Δb to $b_1' = b_1 - \Delta b$. This situation is represented by the dashed line. In the unconstrained region on the right side of the figure, the desired unconstrained level of consumption falls by just a fraction,

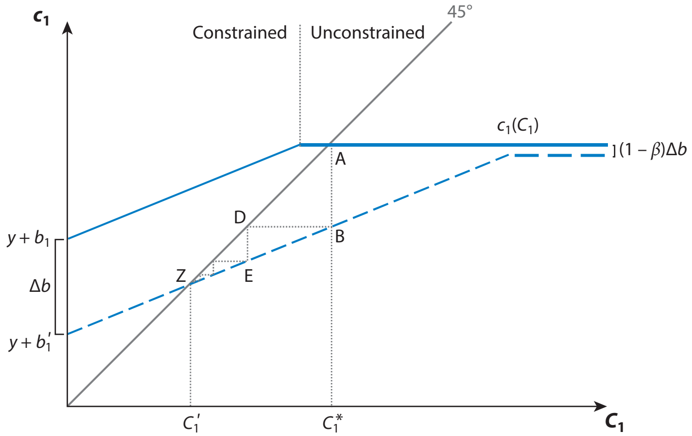

Figure 3

Illustration of financial amplification dynamics.

$(1-\beta)\Delta b$. In the region in which the financial constraint is binding, however, the feasible level of individual consumption $c_1(C_1)$ declines by the full amount Δb. If aggregate consumption remained constant at C_1^*, this would force the representative agent to reduce his or her individual consumption, as indicated by the vertical movement from point A to B. (The distance between A and B is less than Δb because we started in a situation in which the financial constraint was slack.) In general equilibrium, however, lower individual consumption reduces aggregate consumption from point B to D, which tightens the financial constraint further, forcing a reduction in individual consumption to point E and so forth, moving the economy along the zigzag line. Equilibrium is restored at point Z, in which the new individual level of consumption c_1' can be supported by the financial constraint, given an aggregate level of consumption $C_1' = c_1'$. The total decline in consumption is larger than the decline in initial net worth Δb, reflecting amplification effects.

Analytically, a marginal change in initial wealth b_1 (or in output y_1) when the equilibrium is constrained leads to a change in consumption of

$$\frac{dC_1}{db_1} = \frac{dC_1}{dy_1} = \frac{1}{1-\overline{b}'(C_1)} > 1. \tag{5}$$

The term $1/[1-\overline{b}'(C_1)] > 1$ can be interpreted as the coefficient of amplification to initial net worth shocks or output shocks when the financial constraint is binding. The larger is $\overline{b}'$, the response of the constraint to changes in aggregate consumption, the stronger are the amplification effects. For $\overline{b}' \to 1$, the amplification coefficient becomes arbitrarily large. As discussed under Assumption 1, we rule out the case $\overline{b}' \geq 1$ because it would result in multiple equilibria. Keep in mind also that in fully specified models, as the ones we review in the next sections, both $\overline{b}(C_1)$ and $\overline{b}'$ are not arbitrary functions but are equilibrium objects that reflect the endogenous mapping between the market-determined value of collateral and borrowing ability.

4. CONTRACTIONARY DEPRECIATIONS

The first application of our general model focuses on contractionary depreciations under liability dollarization as proposed first in Mendoza (2002) and explored further in Mendoza (2005).

Financial liabilities in emerging markets are often denominated in hard currencies (or traded goods) but are backed up by income or assets from the nontraded sector of the economy (see, e.g., Calvo 1998, Eichengreen & Hausmann 2005). Hence, the relevant price between liabilities and the value of collateral is the relative price of nontraded to traded goods.

We extend our general model to include traded and nontraded goods to capture liability dollarization.[11] The representative agent receives endowments ($y_{T,t}$, $y_{N,t}$) every period and has a period utility function $u(c)$ that depends on the composite good $c = c(c_{T,t}, c_{N,t})$, which is assumed to be homogeneous of degree one [typically a constant elasticity of substitution (CES) aggregator]. We assume that traded goods are the numéraire and denote the relative price of nontraded goods by $p_{N,t}$, which constitutes a measure of the country's real exchange rate. The budget constraint then becomes

$$c_{T,t} + p_{N,t}c_{N,t} + b_{t+1}/R = y_{T,t} + p_{N,t}y_{N,t} + b_t. \tag{6}$$

In case domestic agents abscond with their debts, we follow Mendoza (2005) and Korinek (2011a,b) in assuming that international investors can seize a fraction of the market value of the endowment of consumers, resulting in a financial constraint

$$b_{t+1}/R \geq -\kappa\left(y_{T,t} + p_{N,t}y_{N,t}\right). \tag{7}$$

Observe that the borrowing ability of consumers depends on their total income, which consists of both traded and nontraded goods, but their debt b_{t+1} is denominated entirely in traded goods in the budget constraint (Equation 6).

Maximizing the consumer's expected utility subject to the budget constraint (Equation 6) and borrowing constraint (Equation 7) and denoting the marginal utility of traded consumption goods by $u_T \equiv \partial u/\partial c_T$ and similarly for u_N, we obtain the representative agent's Euler equation and intratemporal optimality condition

$$\begin{aligned} u_T\left(c_{T,t}, c_{N,t}\right) &= \beta R E\left[u_T\left(c_{T,t+1}, c_{N,t+1}\right)\right] + \lambda_t, \\ p_{N,t} &= \frac{u_N\left(c_{T,t}, c_{N,t}\right)}{u_T\left(c_{T,t}, c_{N,t}\right)}. \end{aligned} \tag{8}$$

Substituting the market-clearing condition for nontraded goods $c_{N,t} = y_{N,t}$ in the second optimality condition, it follows that the relative price $p_{N,t}$ is an increasing function of the aggregate consumption of traded goods and a decreasing function of the exogenous state variable $y_{N,t}$ so that $p_{N,t} = p_N(C_{T,t}; y_{N,t})$. With a CES aggregator, the relationship is actually an increasing, strictly convex function of the ratio $C_{T,t}/y_{N,t}$. Hence, an increase in the relative consumption of tradables to nontradables requires an increase in the relative price of nontraded goods to clear the market.

We can rewrite the financial constraint in the form given by our general setup as

$$\overline{b}\left(C_{T,t}; y_{T,t}, y_{N,t}\right) = \kappa\left[y_{T,t} + p_N\left(C_{T,t}; y_{N,t}\right)y_{N,t}\right],$$

where $\overline{b}$ is increasing in aggregate traded consumption $C_{T,t}$, as in our general model, because of the positive effect of tradables consumption on the relative price of nontradables, and depends

[11]In the open-economy macroeconomics literature, traded goods include all goods that can be moved across borders for international trade (e.g., commodities or manufacturing goods); nontraded goods are those that need to be consumed locally (e.g., services such as haircuts).

in addition on the exogenous state variables $y_{T,t}$, $y_{N,t}$. In this case, we need to impose the assumption $\overline{b}'(C_{T,t};\cdot) < 1$ to ensure a unique equilibrium.[12] When the constraint is binding, we obtain financial amplification dynamics that magnify the effects of shocks to the system. As in our general model, for a given pair $(y_{T,t}, y_{N,t})$, we can express traded consumption under a binding financial constraint as the solution to the implicit equation

$$C_{T,t} = c_{T,t}\left(C_{T,t}\right) = y_{T,t} + b_t + \overline{b}\left(C_{T,t}; y_{T,t}, y_{N,t}\right).$$

The graphic representation of this equation is similar to **Figure 3**. And when the representative agent experiences a shock to net worth or endowment income of sufficient magnitude, similar amplification dynamics are set in motion. However, the dynamics now occur through movements in the country's real exchange rate. A negative shock forces the agent to contract consumption of traded goods because the agent is unable to borrow the amount needed to support the unconstrained allocation. For the economy to absorb the available supply of nontraded goods, the real exchange rate p_N has to depreciate. But this reduces the value of the agent's income and collateral, and tightens the financial constraint $\overline{b}$, which forces further cutbacks in consumption and leads to a feedback loop.[13] Amplification effects introduce considerable volatility not only into the current account and aggregate demand of the emerging economy, but also into the real exchange rate.

We illustrate the quantitative potential of this setup by conducting an experiment using the same intertemporal utility function as in the general model and following Mendoza (2005) in specifying the composite good as a CES aggregator $c(c_T, c_N) = \left[ac_T^{-\mu} + (1-a)c_N^{-\mu}\right]^{-1/\mu}$. We set the expenditure share on traded goods to $a = 1/3$, which corresponds closely to the weighted average of the primary and secondary sector in GDP in our sample of emerging economies. As in Mendoza (2005), we assume an elasticity of substitution $1/(1+\mu) = 0.8$ and a maximum credit-to-output ratio of $\kappa = 1/3$. Finally, we assume a binary output process $y_t \in \{y^H, y^L\}$, where $y^H = 1$ and $y^L = y^H - \Delta y$, in which output drops by $\Delta y = 0.03$ from trend with an independent and identical (i.i.d.) probability of 5%, which reflects the approximate severity and incidence of Sudden Stop events in the sample used to study the stylized facts. The parameters are summarized in **Table 1**, and the algorithm to numerically solve the model is described in **Supplemental Appendix B**.

Supplemental Material

Figure 4 shows the policy functions for saving, traded consumption, and the equilibrium price of nontraded goods as functions of b, for high and low values of the income shock. These policy functions are obtained by solving the model in recursive form. The top two lines depict $p_N(b, y^H)$, the solid line, and $p_N(b, y^L)$, the dashed line. The next two pairs of lines depict $c_T(b, y)$ and $b'(b, y)$ for $y_T = y_N \in \{y^H, y^L\}$. We indicate the 45° line by a dotted line. If saving lies above this line [i.e., $b'(b, y) > b$], the agent accumulates savings, and the economy runs a current account surplus. If it lies below this line, the agent decumulates savings, and the economy runs a current account deficit.

The figure can be split into two regions. Left of the vertical line (i.e., for low net worth b), the financial constraint is binding. Within this region, financial amplification occurs, and all variables respond very strongly to changes in net worth. In particular, traded goods consumption rises more

[12]This is satisfied as long as $\kappa p_N'(C_{T,t}) < 1$, which holds for sufficiently low κ. If p_N' is highly convex, then truncating the debt level at some upper level Ω by defining $\overline{b}(C_{T,t};\cdot) = \max\{-\kappa[y_{T,t} + p_N y_{N,t}], -\Omega\}$ can guarantee that the condition $\overline{b}' < 1$ is satisfied globally and that we rule out degenerate equilibria in which agents consume astronomic levels of traded goods to pump up the price of nontraded goods and relax the constraint sufficiently to afford the traded consumption (see Mendoza 2005).

[13]The balance sheet effect linking constrained borrowing to traded goods demand and real depreciation is widely used in the Sudden Stops literature, starting with Calvo (1998). In contrast, the financial amplification of this effect via the Fisherian deflation mechanism is only at work in models of the class we review in this article.

Table 1 Parameters used in the calibration of the exchange rate model

	β	R	σ	a	μ	κ	Δy	π
Value	0.96	1.03	2	1/3	0.8	1/3	0.03	0.05

steeply in net worth than the 45° line. Furthermore, next-period wealth b' is a declining function of current wealth. This captures the fact that more wealth implies a less-binding credit constraint, and therefore a higher exchange rate and greater borrowing capacity, which allows the representative agent to carry a higher level of debt into the following period.

To the right of the threshold, financial constraints are loose, and there are no financial amplification effects. Consumption increases in net worth, but at a rate smaller than one (i.e., c_T is flatter than the 45° line). Within this region, next-period wealth b' is an increasing function of current wealth because consumers are able to smooth their wealth over time. Observe that b' lies mostly below the 45° line within this region, reflecting that consumers are impatient relative to lenders and run down their wealth.

Figure 5 shows the response of an economy that has experienced a long series of good shocks y^H, interrupted by a one-time adverse shock y^L that is followed by good shock y^H again. The shock reduces the endowment income of the economy by only 3% but tightens the financial constraint and sets in motion a process of financial amplification that leads to an 8% decline in the real exchange rate and ultimately a 9% reduction in traded consumption. The overall decline in aggregate consumption is $a \times 9\% + (1 - a) \times 3\% = 5\%$, roughly in line with the empirical results documented in Section 2.

The Sudden Stops literature has examined in detail several extensions and modifications of this setup. In Section 7, we discuss applications that have been developed to examine normative issues.

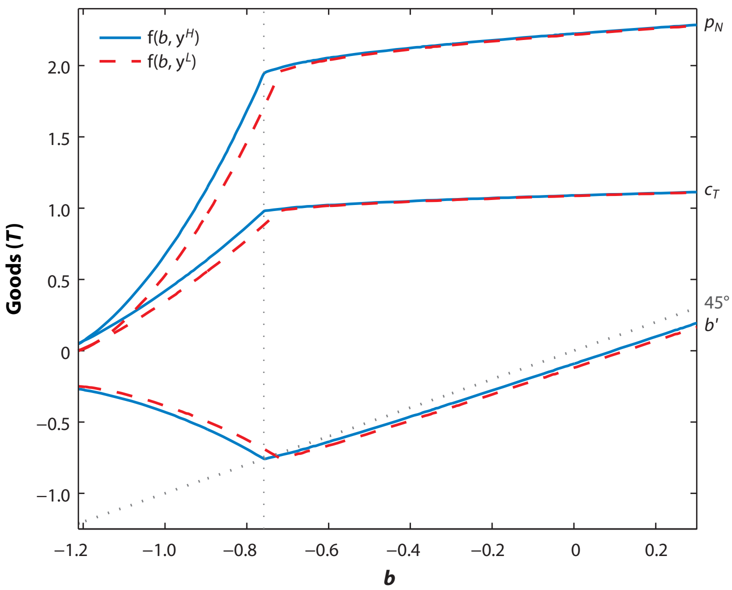

Figure 4

Policy functions in the exchange rate model.

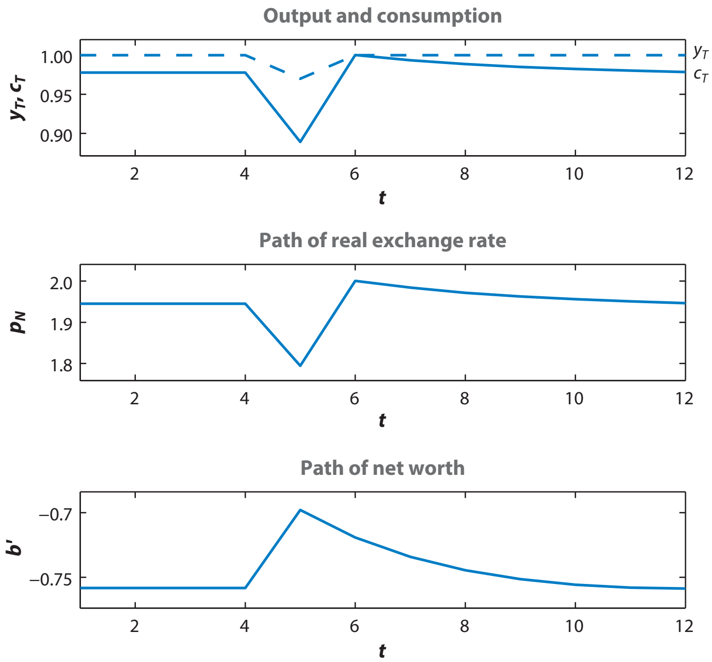

Figure 5

Simulated path of a Sudden Stop in the liability dollarization model.

In terms of positive analysis, Mendoza (2002) considers the production of nontraded goods with labor and a borrowing constraint of the form $b'/R \geq -\kappa(wL + \pi)$, where wL is wage income collected from endogenous labor supplied to nontraded goods producers, and π are the profits that nontraded goods producers pay to the representative agent plus a stochastic endowment of traded goods. In equilibrium, the constraint reduces to $b'/R \geq -\kappa(y_T + p_N y_N(L))$. Durdu et al. (2009) consider a similar setup in which nontraded goods production requires imported intermediate goods.

These models with production feature a supply-side channel of the Fisherian deflation mechanism, which exacerbates the amplification effects because deflation in the relative price of nontraded goods reduces the marginal product of labor and intermediate goods, and thus reduces factor demands and output. Hence, on the right-hand side of the borrowing constraint, both the price and the quantity of the collateral shrink as the constraint becomes binding.

5. ASSET PRICE DEFLATION

We now study models of Sudden Stops driven by asset price collapses similar to those developed by Mendoza & Smith (2006), Bianchi & Mendoza (2010), and Jeanne & Korinek (2010b). This is done by introducing an asset price into the general framework of Section 2.

We follow the setup of Bianchi & Mendoza (2010) and Jeanne & Korinek (2010b) and assume that there is an infinitely lived asset that pays a stochastic dividend d_t every period and that is in fixed unit supply. The asset can be held only by domestic agents and trades in the domestic market at a price p_t. Denoting the asset holdings carried into period t by a_t and the endowment income of the agent by e_t, the budget constraint of the representative domestic agent becomes

$$c_t + p_t a_{t+1} + b_{t+1}/R = e_t + a_t(p_t + d_t) + b_t. \tag{9}$$

If the agent absconds with his or her newly issued debt in period t, we assume that foreign lenders can seize the agent's asset holdings and sell them at the prevailing price in the domestic market to other domestic agents. However, because of bankruptcy frictions, lenders can extract only a fraction ϕ of the value of the tree. Foreseeing this possibility, lenders limit borrowing of each individual consumer to

$$b_{t+1}/R_{t+1} \geq -\overline{b}(\cdot) = -\phi p_t a_{t+1}. \tag{10}$$

Observe that there is once again a mismatch between the denomination of debt and of collateral, as in the previous variants of our general model: Debt is noncontingent, whereas the value of the asset fluctuates in response to shocks to the economy. Also, the dependence of the borrowing constraint on aggregate variables is implicit in that the equilibrium price depends on the aggregate states of the economy.

Maximizing the agent's expected utility (Equation 1) subject to the budget constraint in Equation 9 and the borrowing constraint in Equation 10, we obtain the following Euler and asset pricing equations:

$$\begin{aligned} u'(c_t) &= \beta R E\left[u'(c_{t+1})\right] + \lambda_t, \\ p_t &= \frac{\beta E\left[u'(c_{t+1})\left(d_{t+1} + p_{t+1}\right)\right]}{u'(c_t) - \phi\lambda_t}. \end{aligned} \tag{11}$$

In the following, we assume that both the dividend income and the endowment income of the agent are driven by the same output process y_t. In particular, the dividend from the asset d_t is a constant fraction α of total output (i.e., $d_t = \alpha y_t$). This fraction α captures the share of total income that derives from pledgeable assets, which represent mostly real estate in emerging economies. The remaining fraction of total output accrues to the agent in the form of endowment income, $e_t = (1-\alpha)y_t$, and can be interpreted as the nonpledgeable part of total income.

Consider first the unconstrained equilibrium of this economy. When the financial constraint in Equation 10 is loose, Equation 11 reduces to a standard asset pricing equation, whereby the current asset price corresponds to tomorrow's expected value of the asset (dividend plus future price), discounted at the marginal rate of substitution $\left[\beta u'(c_{t+1})\right]/\left[u'(c_t)\right]$, and the typical smoothing behavior prevails.

The equilibrium is very different when the access to debt is constrained. When the financial constraint is binding, the marginal rate of substitution declines because the valuation of consumption today $u'(c_t)$ increases and the valuation of consumption tomorrow $\beta u'(c_{t+1})$ declines. Hence, the marginal rate of substitution in consumption $\left[\beta u'(c_{t+1})\right]/\left[u'(c_t)\right]$ falls, and assets that pay off tomorrow become less valuable compared to a situation without financial constraints. The stochastic discount factor for assets becomes $\left[\beta u'(c_{t+1})\right]/\left[u'(c_t) - \phi\lambda_t\right]$, with the extra term $-\phi\lambda_t$ in the denominator representing the collateral value of assets (see also Fostel & Geanakoplos 2008). This term reduces the disutility $u'(c_t)$ of spending one dollar on buying assets by $\phi\lambda_t$ because each dollar of the asset relaxes the constraint by ϕ units, providing benefit λ_t. The denominator of the asset pricing equation is therefore lower, and the asset price decline that results from binding constraints is mitigated compared to a situation in which assets cannot be used as collateral.[14]

[14]Because of the collateral value, the expected stochastic discount factor for assets in a constrained equilibrium lies in between the marginal rate of substitution in consumption $\{\beta E[u'(c_{t+1})]\}/[u'(c_t)]$ and the unconstrained value $1/R$. This can be seen by observing that $u'(c_t) - \phi\lambda_t = (1-\phi)u'(c_t) + \phi\beta R E[u'(c_{t+1})]$ and $\phi \in (0, 1)$.

Assuming that we know the policy functions that solve the model in recursive form, we can analytically characterize the constrained equilibrium in a given time period by expressing all equilibrium objects in terms of current aggregate consumption C and solve for this C given the state variables $(b,\ y)$ in a manner similar to our general model. First, we use the budget constraint to express end-of-period wealth as $b'(C)/R = y + b + d - C$ and employ the known policy functions to express $p' = p(b',\ y')$ and $C' = c(b',\ y')$.[15] Then we can solve for aggregate consumption C when the constraint is binding by solving the implicit equation

$$C = c(C) = y + d + b + \overline{b}(C; b, y),$$
$$\overline{b}(C; b, y) = \phi p(C; b, y) := \phi \frac{\beta E\left[u'\left(C'\right)\left(d' + p'\right)\right]}{(1-\phi)u'(C) + \phi\beta R E\left[u'(C')\right]}. \tag{12}$$

As in earlier variants of our general model, the function $\overline{b}(\cdot)$ is increasing in aggregate consumption, as higher C today increases the stochastic discount factor and raises the asset price. We impose the assumption $\overline{b}'(C) < 1$ to rule out multiplicity of equilibrium.

For given state variables $(b,\ y)$, the implicit equation (Equation 12) yields the equilibrium consumption function $c(b,\ y) = C(b,\ y)$ under binding constraints. If the representative agent experiences shocks to y, b, or d, one can illustrate the process of reaching a new equilibrium by shifting the right-hand side of Equation 12, triggering similar dynamics to the ones seen in **Figure 3**. For example, under a binding constraint, an adverse output shock Δy_t will lead to a decline in consumption and/or asset fire sales, which in turn trigger a feedback loop of declining asset prices, tightening financial constraints and leading to further reductions in consumption.

The Fisherian feedback loop at work in this model has important implications for the equity premium and asset pricing behavior. Following Mendoza & Smith (2006), we can work with the optimality conditions to obtain this expression for the equity premium:

$$E\left[R^e_{t+1}\right] - R = \frac{-\mathrm{cov}\left(\beta u'(c_{t+1}), R^e_{t+1}\right) + (1-\phi)\lambda_t}{\beta E\left[u'(c_{t+1})\right]},$$

where $R^e_{t+1} = (d_{t+1} + p_{t+1})/p_t$ is the state-contingent return on equity. This condition shows that the collateral constraint has direct and indirect effects, all of which work to increase the equity premium. The direct effect is represented by the term $(1-\phi)\lambda_t$. This term reflects that a binding financial constraint, $\lambda_t > 0$, drives up the excess return on equity because being constrained now makes it less attractive to hold assets that pay dividends in the future. This effect is mitigated by $(1-\phi)$ because the agent can borrow against a fraction ϕ of the asset. The two indirect effects are $-\mathrm{cov}(\beta u'(c_{t+1}), R^e_{t+1})$ and $\beta E[u'(c_{t+1})]$. The former seems analogous to the standard risk-premium term because equity returns covary negatively with the marginal utility of consumption, but a binding credit constraint makes this covariance more negative because it weakens the ability of agents to smooth consumption. The denominator $\beta E[u'(c_{t+1})]$ is lower for a similar reason, because a binding credit constraint at t forces a postponement of consumption, which lowers the expected marginal utility of future consumption.

Mendoza & Smith (2006) also show that we can obtain the following forward solution for asset prices:

[15]As noted in the definition of the recursive equilibrium, the equilibrium policy functions are expressed as functions of $(b,\ y)$ because B is made redundant by the equilibrium condition that requires $H(B, y) = \hat{b}'(B, y; B)$ identically in B.

$$p_t = E\left\{\sum_{s=t+1}^{\infty}\left[\prod_{r=t+1}^{s}\left(E_t\left[R_r^e\right]\right)^{-1}\right]d_s\right\}.$$

A higher equity premium—at the present or expected at any time in the future along the equilibrium path—reduces the present discounted value of dividends. The possibility of future Sudden Stops therefore reduces the equilibrium level of asset prices, even during good times.

We illustrate the quantitative implications of this setup using calibrated parameter values in line with Jeanne & Korinek (2010b) but adapted to the setting of an emerging economy. We use the same parameters for the utility function as in our earlier calibrations, and we also pick the collateral coefficient of assets to be $\phi = 1/4$. We assume that the dividend from the asset is a fraction $\alpha = 0.5$ of total output y_t and the remainder $(1 - \alpha)y_t$ is endowment income. We continue to assume the same binary i.i.d. output process for y_t as in our earlier calibrations. We summarize the parameters in **Table 2**. The algorithm to numerically solve the model is described in **Supplemental Appendix B**.

Supplemental Material

The policy functions of the calibration are reported in **Figure 6** and are reminiscent of the policy functions in the real exchange rate model of Section 4. Instead of the real exchange rate, however, the two lines labeled p represent the level of the asset price. To the left of the vertical line, which indicates when financial constraints become binding, the asset price is a sharply increasing function of wealth. When the financial constraint is loose, the asset price responds only mildly to changes in wealth.

Figure 7 depicts the response of the economy to a one-time adverse shock y^L. The shock reduces the income of the economy by 3% and sets in motion financial amplification effects that lead to a 12% asset price decline and ultimately a 6% reduction in consumption, roughly twice the initial shock. This is again in line with the empirical results documented in Section 2.

There are several other interesting applications of Sudden Stop models with collateral constraints linked to asset prices in the literature. Mendoza & Smith (2006) analyze asset pricing models of Sudden Stops in which the equity of a small open economy is traded with foreign investors that face asset trading costs. A Sudden Stop emerges when standard TFP shocks driving the dividends process trigger a binding collateral constraint, forcing domestic agents to fire-sale assets. When they do so, asset trading costs imply that foreign traders are willing to buy those assets only at a discount from the fundamental price that would prevail in the absence of asset trading costs. The equilibrium asset price is thus determined by a combination of demand and supply forces. The supply is driven by asset fire sales and the demand by the price elasticity of foreign asset demand, which is inversely related to asset trading costs. When calibrated to data for Mexico, the model does well at tracking observed Sudden Stop dynamics in response to TFP shocks of standard magnitudes. Obtaining large drops in the asset price, however, requires a high price elasticity of foreign asset demand.

The Mendoza-Smith setup also demonstrates that taking models with collateral constraints into environments with multiple assets and multiple agents requires additional financial frictions for the Fisherian mechanism to work. Their setup requires both short-selling constraints on equity and trading costs of foreign assets. Without the former, one could circumvent the collateral constraint on debt, and without the latter, the foreigners could buy the fire-sold assets at the fundamental price, effectively doing away with the asset price deflation.

Table 2 Parameters used in the calibration of the asset pricing model

	β	σ	ϕ	R	α	Δy
Value	0.96	2	1/5	1.03	0.05	0.03

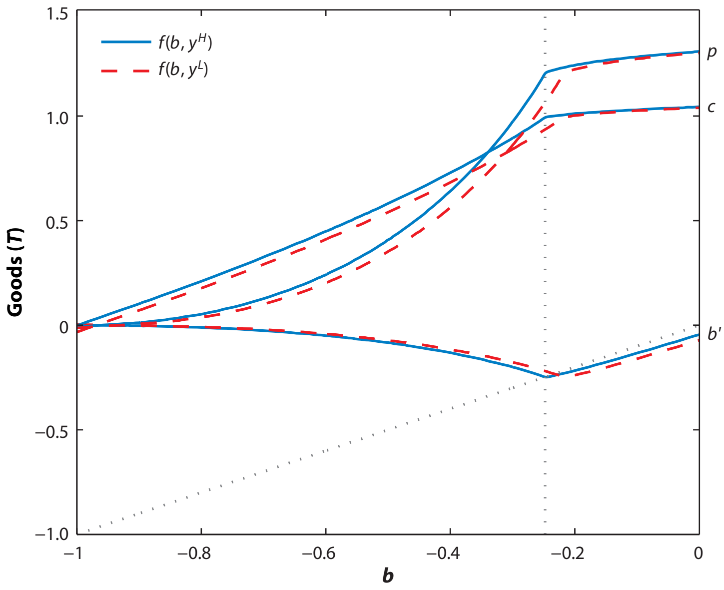

Figure 6

Policy functions of the asset pricing model.

Korinek (2011a) develops a quantitative model of a world economy that encompasses two regions that may suffer from binding constraints and crises owing to asset price deflation. He shows that a crisis in one region leads to lower world interest rates and flows of hot money to the other region, which in turn raises the vulnerability of that region to future crises. This can give rise to the phenomenon of serial financial crises.

Mendoza (2010) and Bianchi & Mendoza (2010, 2013) consider models of Sudden Stops involving asset price deflation in which dividends are endogenous and are affected by the collateral constraint, because working capital financing needed to pay for a fraction of input costs is also affected by the credit constraint. This introduces a channel through which Sudden Stops affect the supply side of the economy and can thus cause output collapses in addition to declines in consumption. We discuss this mechanism in the ensuing section.

6. EQUILIBRIUM BUSINESS CYCLES WITH SUDDEN STOPS

In this section, we extend the analysis to a setup in which the collateral constraints are part of a general equilibrium business cycle model. In the absence of credit constraints, the model reduces to one in the class of widely used RBC DSGE models of small open economies applied to both industrial and emerging economies (e.g., Mendoza 1991, 1995; Neumeyer & Perri 2005; Uribe & Yue 2006). The model is similar to other models that study the 1990s emerging markets crises using credit market frictions (e.g., Choi & Cook 2004; Cook & Devereux 2006a,b; Gertler et al. 2007; Braggion et al. 2009). These models differ from the one we review here in that they use perturbation methods to study the local quantitative implications of credit frictions that are always binding and model Sudden Stops as the result of large, unexpected shocks to external financing or the world real interest rate. Conversely, we note that these models feature nominal rigidities and include a larger set of macroeconomic interactions across sectors than models that are tractable using global solution methods.

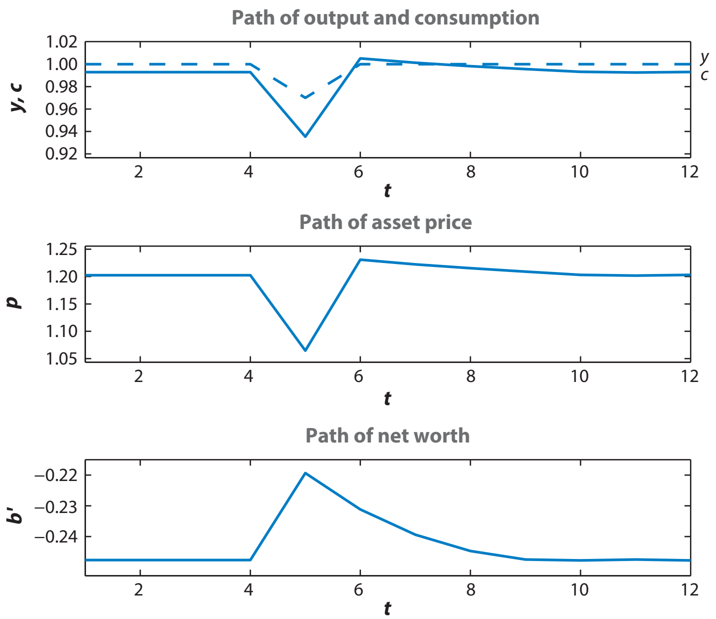

Figure 7

Simulated path of a Sudden Stop in the asset pricing model.

Extending the Fisherian Sudden Stop setup to an equilibrium business cycle environment requires three important modifications. First, we need to introduce a production technology. Mendoza (2010) uses a Cobb-Douglas technology for gross production that depends on capital, labor, and imported intermediate goods. Second, we add endogenous capital accumulation using a Tobin's Q formulation of adjustment costs. Third, we assume that production requires working capital loans that cover a fraction of the cost of variable inputs. This requires additional external financing. Thus, the collateral constraint now limits the total external borrowing on intertemporal bonds and working capital loans to a fraction of the market value of the accumulated physical assets that can be pledged as collateral.

With these modifications, the Fisherian debt-deflation mechanism can trigger strong adverse effects on production and factor markets that are absent from the models studied above. This occurs because the amplification mechanism has two important new features: First, the deflation of the price of capital goods (i.e., Tobin's Q) causes a collapse in investment, which in turn affects future productive capacity and factor demand. Second, the binding collateral constraint causes a sudden, sharp increase in the financing cost of working capital, captured by the shadow value on the constraint, which in turn leads to a decline in current factor demands and production. The first effect induces persistence in the output effects of a financial crisis, and the second causes a contemporaneous output drop when the financial crisis hits.

6.1. A Representative Firm-Household

We follow Mendoza (2010) in assuming a representative firm-household that makes all production and consumption decisions but acts competitively. Preferences are taken from the subclass of small open-economy RBC models that use the Uzawa-Epstein utility function with an endogenous rate of time preference to support the existence of a well-defined long-run distribution of NFA:[16]

$$E_0\left[\sum_{t=0}^{\infty}\exp\left[-\sum_{\tau=0}^{t-1}v\left(c_\tau - G(L_\tau)\right)\right]u\left(c_\tau - G(L_\tau)\right)\right].$$

The period utility function takes the standard CRRA (constant relative risk aversion) form $u(\cdot) = (c - G(L))^{1-\sigma}/(1 - \sigma)$, which depends on the Greenwood-Hercowitz-Huffman composite good defined by consumption minus the disutility of labor, L. The latter is given by a constant elasticity function $G(\cdot) = L^{\omega}/\omega$, where $\omega > 1$ determines the Frisch elasticity of labor supply, $1/(\omega - 1)$. This removes the wealth effect on the labor supply, which would otherwise deliver a counterfactual increase in the labor supply when consumption falls during deep recessions. The time-preference function is defined as $v(\cdot) = \rho \ln(1 + c - G(L))$, where ρ is the semielasticity of the rate of time preference with respect to $c - G(L)$.

The budget constraint of the representative firm-household is

$$c_t + i_t = \varepsilon_t k_t^{\beta} L_t^{\alpha} m_t^{\eta} - p_t m_t - \phi(R_t - 1)(w_t L_t + p_t m_t) - q_t^b b_{t+1} + b_t,$$

where $i_t = \delta k_t + (k_{t+1} - k_t)\left[1 + a/2\left((k_{t+1} - k_t)/k_t\right)\right]$. The left-hand side of the budget constraint adds up consumption and gross investment expenditures. In the definition of the latter, δ denotes the depreciation rate, k_t is the capital stock, and a is an adjustment-cost coefficient for a standard Tobin's Q specification of capital adjustment costs à la Hayashi (1982). The right-hand side is the sum of gross production, represented by a Cobb-Douglas production function that combines capital, labor, and imported inputs m and also includes an exogenous TFP shock ε, minus the cost of imported inputs (purchased at a stochastic exogenous price p), minus the interest payments on foreign working capital loans used to pay for a fraction ϕ of the cost of variable factors, minus the cost of purchasing one-period real international discount bonds at an exogenous, stochastic price q^b, plus the payout on the amount of these bonds purchased the previous period. Notice that there are three underlying real shocks driving economic fluctuations: shocks to TFP, the world relative price of imported inputs, and the world real interest rate.

The Fisherian collateral constraint is

$$q_t^b b_{t+1} - \phi R_t(w_t L_t + p_t m_t) \geq -\kappa q_t k_{t+1}.$$

Hence, total external debt (one-period debt and within-period external working capital financing) cannot exceed the fraction κ of the market value of physical capital that can be pledged as collateral (q_t is the market price of capital, which is also Tobin's Q).

Two endogenous relative prices appear in the above budget and collateral constraints: the wage rate w_t and the price of capital q_t. The assumption that the representative firm-household supports

[16]As explained above, in a small open economy facing noninsurable income shocks and an exogenous world interest rate, precautionary saving leads foreign assets to diverge to infinity under the standard assumption of a constant rate of time preference equal to the interest rate. In the models examined above, we obtain a well-defined stationary distribution of assets by following an alternative approach that sets a constant rate of time preference higher than the interest rate (see Aiyagari 1994). There are also three ad hoc approaches proposed by Schmitt-Grohé & Uribe (2003) for use when solving models by perturbation methods (i.e., the cost of holding assets, a debt-elastic interest rate function, or a rate of time preference that depends on aggregate consumption). However, these are less accurate for studying nonlinear effects and the effects of precautionary savings, which require the use of global methods. Readers are referred to Mendoza (1991) for further details and Durdu et al. (2009) for a comparison of the quantitative implications of the Uzawa-Epstein utility function with those of standard time-separable preferences.

a competitive equilibrium requires that the agent takes these prices as given, so that they satisfy standard optimality conditions: The wage rate equals the marginal disutility of labor, and the price of capital equals the marginal Tobin's Q (i.e., $\partial i_t / \partial \overline{k}_t$, where $\overline{k}_t$ is the aggregate capital stock taken as given by the representative firm-household).

6.2. Financial Amplification in the Business Cycle Model

The Fisherian deflation mechanism operates in this economy in a manner analogous to that of the endowment-economy asset pricing model reviewed above: When the collateral constraint binds, agents fire-sell assets to meet the constraint. This lowers the price of capital, further tightening the constraint, and forces even more asset fire sales. The constraint again introduces direct and indirect effects that increase the expected excess return on assets (i.e., capital) and has a forward-looking effect that results in q_t being affected by the constraint, even in periods in which it does not bind, as long as the constraint is expected to bind with positive probability along the equilibrium path.

There are two new elements to this mechanism that are crucial for integrating Fisherian deflation episodes into a business cycle model: First, the asset fire sales involve sales of productive assets, which result in a collapse of investment when a Sudden Stop occurs. This lowers future factor demands and future output, thus providing a mechanism that gives persistence to the contractionary effects of a financial crisis. Second, the Fisherian deflation impairs access to working capital financing and thus variable inputs for current production plans. When the constraint becomes binding, the effective marginal cost of variable inputs suddenly rises by the factor $(\mu_t/\lambda_t)\phi R_t$, where μ_t and λ_t are the Lagrange multipliers on the borrowing and budget constraints, respectively. This mechanism is critical for the model's ability to generate a sudden output collapse when the economy hits the collateral constraint.

The combination of the above two effects gives this model the ability to produce substantial amplification and asymmetry in the responses of macroeconomic aggregates to the underlying real shocks driving the business cycle (see Mendoza 2010 for quantitative estimates). This is amplification in the sense that, when the constraint binds, the same size shocks generate much larger recessions and asset price drops than when it does not, and asymmetry in the sense that in good times, when the constraint does not bind, the response to the shocks is more tepid and in line with the behavior of a standard RBC model than in bad times when the constraint binds. Both these properties are helpful. Amplification is behind the model's ability to produce financial crises with realistic features, and asymmetry allows the model to produce regular business cycles with standard features if the constraint does not bind. If precautionary saving is strong enough to lower the long-run probability of Sudden Stops to the empirically relevant range, the model will nest infrequent financial crises within regular business cycles and will have an endogenous mechanism driving transitions between both that does not hinge on unusually large, unexpected exogenous shocks. Whether the model, once reasonably calibrated, can deliver these results is a question that can be answered only with quantitative analysis.

6.3. Quantitative Findings

The results reported in Mendoza (2010) provide an informative summary of the strong potential for this model to account for several of the empirical regularities of Sudden Stops documented in Section 2 and illustrate the large amplification and asymmetry in macro responses to shocks that result from the Fisherian deflation mechanism. In addition, the results confirm that precautionary savings incentives in response to these strong amplification effects sharply lower the probability of observing Sudden Stops in the economy's stochastic stationary state, and thus the model can nest endogenous financial crises within realistic, standard business cycle dynamics. The results also shed light on some of the model's limitations, particularly the inability to produce asset price declines of the magnitude observed in the data.

Figure 8, an updated version of figure 2 in Mendoza (2010), compares the new Sudden Stop event dynamics documented in Section 2 with the predicted Sudden Stop event windows produced by the model. The figure shows the median of Sudden Stop events in the model along with plus/minus one–standard error bands, the medians from the Sudden Stop events in the data of emerging economies, and the realizations from Mexico's 1995 Sudden Stop. We show the realizations from the 1995 event because the model was calibrated to Mexican data. In particular, the production function parameters were set to factor shares in Mexico's national accounts. TFP shocks were calibrated to match Solow residuals constructed with Mexican data, the interest rate shocks were set following Uribe & Yue (2006) to match the interest rate Mexico faces in world capital markets (i.e., the EMBI spread), and the shocks to the price of imported inputs were set to match the ratio of the price of Mexico's imported inputs to export prices (see Mendoza 2010 for details).[17] The value of κ was set so as to match the observed frequency of Sudden Stops in the Calvo et al. (2006a) data set, which was 3.3%. This required setting $\kappa = 0.2$.

As **Figure 8** shows, the model does a good job at tracking the actual Sudden Stop dynamics of GDP, consumption, investment, and net exports. Moreover, these Sudden Stops are the result of standard realizations of shocks to TFP, the real interest rate, and the price of imported inputs. Sudden Stops are preceded by periods of economic expansion, and the recoveries that follow are slow paced. The model closely mimics the declines in GDP, consumption, and investment in the trough of the Sudden Stop but predicts a much milder decline in the price of capital than the one observed in the data. This is because of the standard Tobin's Q investment setup of the model, which implies a monotonic relationship between investment and the price of capital in which large investment (price) declines occur only when the price (investment) moves slightly. Hence, without a modification that drives a wedge in this relationship, the model cannot do well at matching the observed large drop in investment and in the price of capital at the same time.

The supply-side channel operating via the collateral constraint on working capital is crucial for these favorable results. Without it the model cannot produce amplification in production and factor demands on impact when the Sudden Stop hits. GDP would respond one period later, as the effect of the collapse of investment lowers future capital and future factor allocations. Moreover, without this mechanism, the optimal amount of precautionary savings (leaving all the other parameters at the values of the baseline calibration) results in a negligible long-run probability of observing Sudden Stops, effectively removing the effect of the collateral constraint from the equilibrium dynamics. The probability of Sudden Stop events declines from 3.32% to 0.07%.

7. POLICY IMPLICATIONS

The normative analysis of Sudden Stop models in the class reviewed here focuses on two sets of policies: (*a*) macroprudential or ex ante policies (i.e., policies implemented in good times to mitigate the frequency and severity of Sudden Stops in the future) (e.g., Bianchi & Mendoza 2010, 2013; Jeanne & Korinek 2010b; Bianchi 2011) and (*b*) ex post policies aimed at dealing with financial amplification once the Fisherian mechanism is in motion (e.g., Benigno et al. 2012a,b;

[17]These shocks are introduced into the model as a discrete Markov process that approximates a first-order vector autoregression process estimated with the data on the three shocks, using the Tauchen-Hussey quadrature method to construct the Markov process.

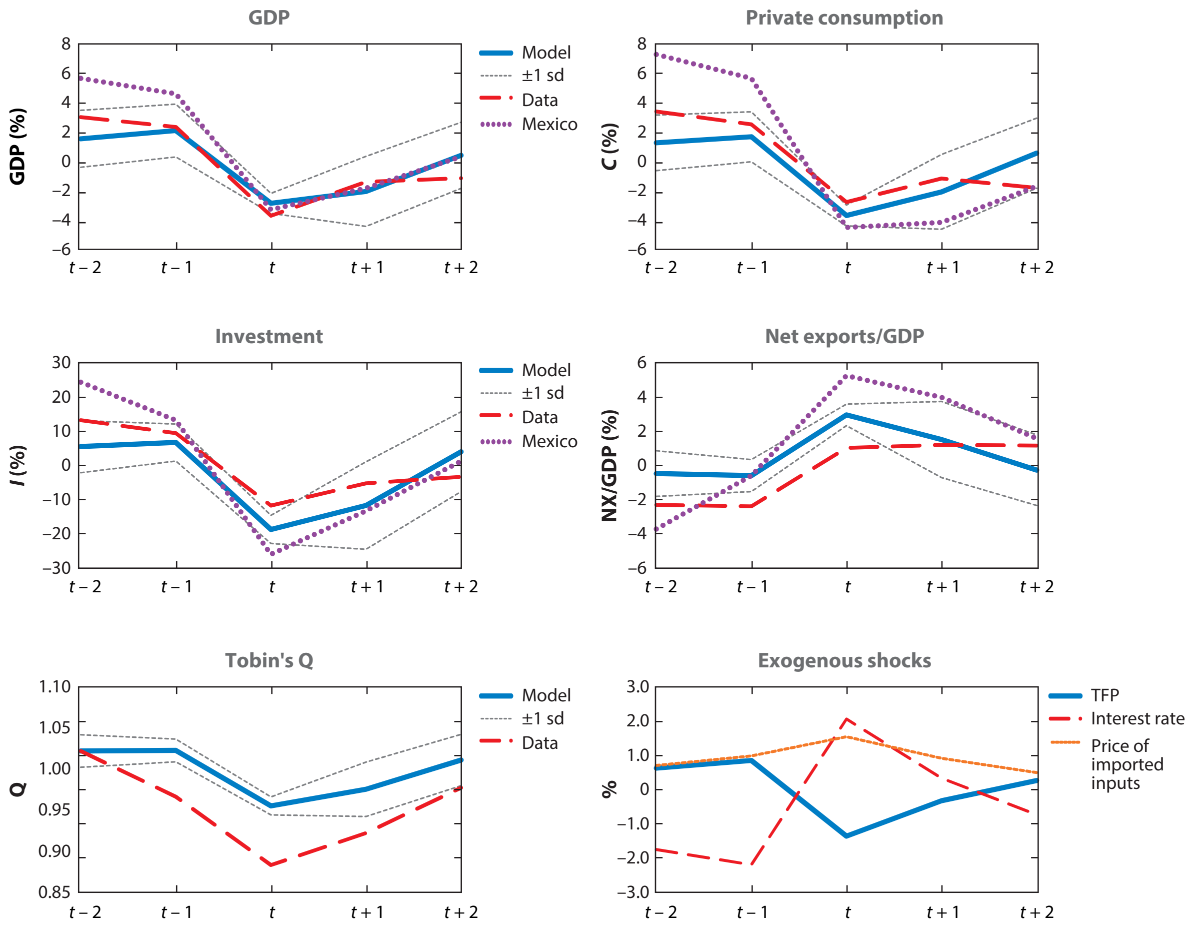

Figure 8

Sudden Stop event windows in data and simulations of the business cycle model. The actual measure used for Tobin's Q is a cross-country median of country estimates, each of which corresponds to the median of firm-level ratios of the market value of equity plus debt outstanding to the book value of equity, computed for listed corporations using the Worldscope database (see Mendoza 2010 for details). Abbreviation: TFP, total factor productivity.

Bianchi 2013; Jeanne & Korinek 2013). In this section, we analyze the macroprudential policy implications of the general model of Sudden Stops presented in Section 3. Then we discuss how these insights relate to the different versions of the model covered in subsequent sections. Finally, we discuss the scope for ex post policies.

7.1. Macroprudential Policies

The fact that the value of collateral is a market price introduces a pecuniary externality into Fisherian Sudden Stop models because agents do not take into account the effect of their individual borrowing plans on the price of collateral, which matters in particular for future states of nature in which the constraint is binding. As a result, they borrow too much relative to what would be optimal taking this externality into account. Alternatively, we can interpret the externality in terms of aggregate demand: Agents do not internalize the effects of their borrowing decisions on future aggregate demand, which is a determinant of future prices. They take on too much debt because they do not realize that this implies less aggregate demand and tighter financial constraints in the future.

This pecuniary externality is the central market failure that justifies macroprudential policy intervention in the described class of models, as first noted in the theoretical work of Korinek (2007).[18] The externality also has a simple interpretation in the theory of the second best: If the planner reduces borrowing in the economy in periods before binding financial constraints occur, this imposes a second-order cost on the economy because it constitutes a small deviation from optimality. When an adverse state of nature occurs next period, the policy relaxes the financial constraint, which has first-order welfare benefits.

The approach followed in the quantitative literature on prudential policies is to compare the features of the competitive equilibria of models similar to the ones we analyze above with the allocations of a social planner. This planner chooses (or regulates) the borrowing and saving allocations of private agents while internalizing the pecuniary externality. In general, the results show that it is optimal for the planner to intervene in a prudential manner: Whenever there is a positive probability that the financial constraint may bind in the ensuing period, the planner reduces borrowing in the present to relax the future constraints and mitigate the associated financial amplification effects. Such an intervention improves social welfare.

7.1.1. A prudential planner.

A simple way to illustrate the implications of the pecuniary externality in the general model of Section 3 is to study a hypothetical prudential social planner who maximizes the welfare of private agents by choosing a decision rule for aggregate bond holdings $B'(B, y)$ to solve the following Bellman equation:

$$\begin{aligned} V(B,y) &= \max_{B'}\left\{u(C)+\beta E\left[V\left(B',y'\right)\right]\right\} \\ \text{s.t.} \quad & C+B'/R = y+B, \\ & B'/R \geq -\overline{b}(C). \end{aligned} \tag{13}$$

Note that we are implicitly assuming that the function $\overline{b}(\cdot)$ is such that it preserves the time consistency of the planner's optimization problem. Later in this section we review the findings of Bianchi & Mendoza (2013) for the case in which this assumption does not hold in models that use assets valued at market prices as collateral.

The Euler equation of the planner's problem is

$$u'(C) = \beta R E\left[u'(C')+\lambda'\overline{b}'(C')\right]+\lambda\left[1-\overline{b}'(C)\right].$$

The difference from the optimality condition (Equation 4) of private agents is reflected in the two terms with $\overline{b}'(\cdot)$, which capture that the planner internalizes the effects of aggregate consumption on the borrowing limit. Observe that this term is premultiplied by the shadow price on the borrowing constraint (i.e., relaxing the borrowing limit is relevant only when the borrowing constraint is binding).

[18]A similar pecuniary externality is also described by Caballero & Krishnamurthy (2003) and Lorenzoni (2008). In their papers, the inefficiency arises because financial markets are incomplete, and a movement in exchange rates or asset prices that is engineered by a social planner generates a redistribution toward constrained agents. In our setup, in contrast, the financial constraint depends explicitly on prices, so a movement in relative prices directly relaxes the financial constraint.

We distinguish between two cases. First, when $\lambda > 0$, the credit constraint is binding at t. In this case, the binding constraint implies that there is effectively no free choice variable at time t, and the planner's allocations coincide with those of the competitive equilibrium.

In the second case, when $\lambda = 0$, the Euler equation reduces to

$$u'(C) = \beta RE\left[u'(C') + \lambda'\overline{b}'(C')\right]. \tag{14}$$

In this case, at date t the planner weighs the marginal utility of consumption today versus the marginal utility of consumption tomorrow plus the marginal benefit of relaxing the constraint tomorrow by increasing consumption tomorrow, captured by the term $\lambda'\overline{b}'(C')$. This is achieved by borrowing less at t so as to transfer more consumption into $t+1$. If the constraint is binding with nonzero probability in some of the states attainable at $t+1$ along the equilibrium path, then this term is positive and captures the uninternalized social benefits of greater aggregate consumption, or higher collateral prices, tomorrow. This result can be proved formally by simply comparing the Euler equation of the planner (Equation 14) when $\lambda = 0$ to the Euler equation of private agents (Equation 4).

The planner can implement the optimal allocations by imposing a tax on borrowing that corresponds to the wedge between the social and private Euler equations. Imposing a tax τ on borrowing b'/R that is rebated lump sum modifies the Euler equation of private agents to

$$(1-\tau)u'(c) = \beta RE\left[u'(c')\right] + \lambda.$$

To attain the same allocations as with the planner's Euler equation (Equation 14), we find that the optimal tax is

$$\tau = \frac{\beta RE\left[\lambda'\overline{b}'(c')\right]}{u'(c)}. \tag{15}$$

The tax captures the effects of higher borrowing on tightening the constraint, which is not internalized by individual agents. It is often referred to as a Pigouvian tax because it offsets an externality. We focus on the tax on debt just because it is a more conventional way of dealing with externalities, but as the work of Bianchi (2011) and Stein (2012) shows, there are a variety of policy instruments that could be used with equivalent results (capital requirements, loan to value ratios, etc.). Conversely, we also acknowledge that in practice, there are a number relevant credit frictions, with collateral constraints or other forms of credit constraints, that vary widely across credit markets and across borrowers within markets (e.g., subprime home mortgages versus low-risk Fannie Mae–backed mortgages), which means that the optimal design of macroprudential policy has intensive informational requirements and a variety of instruments that can be targeted across the cross section of credit market participants.

Pigouvian taxes on foreign borrowing that lean against the risk of Sudden Stops can be interpreted as prudential capital controls. Readers are referred to Korinek (2011b) for a survey of the growing literature on this topic.

7.1.2. Contractionary depreciations model. The liability dollarization model of Section 4 imposes additional structure on the credit constraint that allows us to interpret the externality in terms of Fisherian deflation of the real exchange rate. In particular, the externality term in that model can be rewritten as $\lambda'\overline{b}'(C_T'; \cdot) = \lambda'\kappa p_N'(C_T'; \cdot)y_N'$. In this formulation, it is clear that borrowing less in one period increases aggregate consumption of traded goods in the ensuing period, which in turn increases the price of nontraded goods and hence the value of collateral, relaxing the constraint by a fraction κ of the value of the collateral. Korinek (2010) and Bianchi (2011) quantify the externalities of Sudden Stops in this model.

Korinek (2010) develops a sufficient-statistics approach following the methodology of Chetty (2009), which identifies direct empirical counterparts (i.e., sufficient statistics) to the individual components of the tax equation (Equation 15) to quantify the magnitude of externalities. He applies this procedure to the externalities during the Indonesian crisis of 1997/1998 and finds that each unit of dollar debt that was repaid in the crisis imposed a 30-cent externality. He also quantifies the externalities of other financial liabilities and finds a pecking order, whereby dollar debt imposes the largest externalities, followed by consumer price index debt, local currency debt, portfolio investment, and foreign direct investment, which creates the least externalities.[19]

Bianchi (2011) explores the quantitative implications of the above policy arguments using a model calibrated to the case of Argentina and finds that a tax to internalize the pecuniary externality would average approximately 5% and would increase with crisis risk. In the stochastic steady state of the economy, the optimal tax policy reduces the probability of a Sudden Stop by more than 90%. Gondo Mori (2014) introduces state-contingent assets into this framework and shows that the opportunity to insure reduces the externalities of foreign borrowing but does not make them disappear.

7.1.3. Asset pricing model. We next consider the case for prudential policy in the asset pricing model of Section 5. In that model, the externality term in the Euler equation of the planner (Equation 14) can be expressed as $\lambda'\overline{b}'(C';\cdot) = \lambda'\phi p'(C';\cdot)$. Higher aggregate consumption increases the asset price and relaxes the borrowing constraint. The planner finds it optimal to intervene in a prudential fashion by reducing borrowing in periods when the constraint is loose but when there is a risk of binding constraints and financial amplification in the following period. Lower borrowing increases aggregate demand and asset prices in crisis times, which implies that private agents need to reduce their leverage by less.

Bianchi & Mendoza (2010) and Jeanne & Korinek (2010b) conduct a quantitative investigation of the above arguments.[20] They calibrate their models to the financial crisis experienced by the US economy in 2008 and compute taxes on borrowing that are positively correlated with leverage when the constraint is not binding and that go to zero during crashes when the constraint is binding. Moreover, these taxes also raise the equilibrium level of asset prices. The models differ in that Jeanne & Korinek assume that the credit constraint includes two terms, one set to a fraction of the market value of assets and a constant term, and they model output as an exogenous i.i.d. process set to capture rare disasters. Bianchi & Mendoza consider a collateral constraint that depends only on the market value of assets but limits access to both intertemporal debt and working capital financing, and as a result of this supply-side channel, output in their model is endogenous. In their setting, Sudden Stops result from TFP shocks of standard magnitudes that trigger the credit constraint, and the optimal prudential intervention reduces the incidence and severity of Sudden Stops.

[19]Observe that local currency debt still imposes negative externalities (of about 9 cents per dollar of debt in Korinek's analysis), even though there is no mismatch between the denomination of the debt and that of the collateral. The reason is that having lower financial liabilities, regardless of the currency, implies higher aggregate traded consumption next period and a higher price of the nontraded collateral, which relaxes the financial constraint.

[20]Korinek (2011c) analyzes the externalities created by different types of financial liabilities in a stylized model of fire sales. He finds that the externalities are higher when the mismatch between the payoff profile of liabilities and the assets to be sold is greater. For example, noncontingent debt imposes large externalities, whereas equity finance creates significantly smaller externalities.

Bianchi & Mendoza (2013) show that time inconsistency is an important issue in the analysis of macroprudential policies because the social planner's problem is inherently forward looking. This is of particular importance in the asset pricing model because of the forward-looking nature of asset prices. In our model structure above, the economy's borrowing limit is $\overline{b} = \phi p(B, y)$, and as a result, the planner's problem under commitment is no longer time consistent (i.e., it does not satisfy Bellman's optimality principle). To see why, suppose that the constraint binds in a given period. Then the planner would have an incentive to promise low C' in the next period to prop up the price in the current period and relax the credit constraint. Once the next period arrives, however, sticking to this promise is no longer optimal.

Bianchi & Mendoza (2010) and Jeanne & Korinek (2010b) sidestep this problem by conducting their quantitative experiments with formulations of the planner's problem that make it time consistent by construction. These can be thought of as conditionally efficient policies, in the sense that the social planner's allocations are efficient, conditional on the assumptions that rule out the time-inconsistency problem. Jeanne & Korinek assume that a prudential planner determines the amount of borrowing but that the asset price is determined in private markets (i.e., the asset price is pinned down by the equilibrium condition of decentralized agents). Bianchi & Mendoza assume that the recursive asset pricing function in the collateral constraint of the planner is restricted to be the same as the equilibrium asset pricing function $p(B;\ y)$ of the unregulated decentralized economy.

In Bianchi & Mendoza's (2010) approach, the intuition is that when the planner looks at the menu of feasible debt positions that private agents had available for all (B, y) pairs in the state space in the unregulated competitive equilibrium, the planner's menu is identical, and the planner cannot use policy to alter the equilibrium price for a given (B, y) pair. Whereas the loans menu is the same, the planner chooses more wisely than private agents in how much it borrows because it still internalizes how much asset prices at $t+1$ respond to the debt chosen at t because of the derivative $\partial p'(B',\ y')/\partial B'$.[21] We note that it is critical for maintaining time consistency that the pricing functions are assumed to be the same, but the dynamics of asset prices along the equilibrium path are very different.

Because arbitrary assumptions to limit the planner's ability to influence prices are controversial, and intuitively mean that regulators would not exploit the full potential of their prudential tools, Bianchi & Mendoza (2013) study instead the design of time-consistent optimal macroprudential policy. Their setup is analogous to a Markov perfect equilibrium, in which the social planner chooses optimal plans at t taking as given a policy function that represents the actions that future planners would take, so that at equilibrium the policy is time consistent (i.e., future planners choose optimally the same policy that the current planner assumes they would take). The results suggest that time-consistent macro prudential policy can both improve on conditionally efficient setups and tackle the time-inconsistency problem without arbitrary assumptions.

7.2. Ex Post Policies

We next focus on policy options that can be taken once a Sudden Stop has occurred. The primary policy objective at this point is to break the feedback loop created by amplification effects. Returning to **Figure 1**, this can be done at any step of the process and with the use of different tools

[21]Supporting this optimal policy requires, however, a second instrument to work together with the debt tax: a tax on dividends (which numerically works on average to a small subsidy). Taxing debt alone would result in a different pricing function than the one of the unregulated economy.

(i.e., by supporting aggregate demand, leaning against the decline in aggregate prices, or relaxing financial constraints). Hence, the quantitative literature analyzing these policies has also followed different tracks. More generally, it can be expected that traditional countercyclical macroeconomic policies, if available, will also reduce the severity of financial amplification effects.

Durdu & Mendoza (2006) investigate the use of asset price guarantees to mitigate Sudden Stops in the Mendoza-Smith model of international equity trading. In particular, they explore the effects of implementing Calvo's (2002) proposal to introduce a guarantee on the asset prices of emerging markets (as an asset class) to reduce the risk of Sudden Stops. Foreign investors can sell their equity holdings of an emerging economy either to other agents at the market price or to an international agency at the guaranteed price, with the cost financed with lump-sum taxation on those investors. This reduces the downside risk of holding the emerging economy's assets and neutralizes the Fisherian deflation mechanism. At the same time, it introduces a moral hazard problem that leads to overinvestment in those assets and inflated prices. An unconditional guarantee reduces welfare because the cost of the moral hazard distortion is larger than the benefit of managing Sudden Stops, as the latter are low-probability events. The policy can be welfare improving if the guarantee is provided conditionally on leverage ratios and the state of TFP, which intuitively means that in this environment the policy is welfare improving the more it acts as an ex post policy rather than ex ante policy (i.e., a guarantee present in times of financial vulnerability but absent otherwise).

Benigno et al. (2011, 2012a,b, 2013) analyze the scope for ex post interventions when financial constraints are binding, as well as the implications of these constraints for the desirability of ex ante interventions. They show that, if collateral constraints depend on prices and if a planner can manipulate these prices in a costless manner, then it is always possible to restore the unconstrained equilibrium. Moreover, even if it is costly to prop up exchange rates or asset prices, it may be desirable to do so to relax financial constraints. Such intervention offers an alternative and more direct mechanism to mitigate financial constraints and, if successful, may offer higher welfare gains than ex ante interventions. These policies, however, may also be more difficult to implement in practice because of the time-inconsistency issues raised above, which also emerge in this context. Moreover, these results expose a weakness of the Sudden Stop models we have studied, which is that one generally imposes the collateral constraints directly on the optimization problems of agents, instead of embedding an optimal contracting problem within the Sudden Stops framework. Hence, whereas the results of these studies clearly show that it is technically possible to restore the equilibrium without credit constraints, it is not clear by which market mechanism the planner would fix the actual contractual friction that led lenders to limit credit.

Jeanne & Korinek (2013) study a number of issues brought up by the interaction of ex ante and ex post policy measures in our Sudden Stop framework by using a simplified analytical framework of asset price deflation. They find that it is generally desirable to engage in both types of interventions up to the point at which the marginal cost of each policy measure equals the (expected) marginal benefit of relaxing binding constraints. Ex post measures have the benefit of being more state contingent because they can be imposed conditional on the state of nature that is realized, whereas prudential measures are contingent on the expectation of the state of nature. However, prudential interventions can resolve the moral hazard and time inconsistency problem created by ex post intervention.

8. CONCLUSIONS

This article documents the empirical regularities of Sudden Stops and reviews a class of quantitative models that aimed to explain this phenomenon using occasionally binding credit constraints that can trigger nonlinear financial amplification dynamics in the vein of the classic Fisherian debt-deflation framework. Leverage ratios exhibit regular, procyclical fluctuations driven by the same underlying shocks that drive business cycles, and when those ratios are high enough, they trigger credit constraints. These constraints limit debts not to exceed a fraction of the market value of the assets or incomes pledged as collateral. Hence, when the constraint becomes binding, agents fire-sell goods and/or assets in efforts to meet their financial obligations, but as they do, they cause a decline in prices that further tightens the credit constraint, forcing further fire sales.

We develop a simple dynamic framework to emphasize the commonalities of different versions of models of Sudden Stops and financial amplification and show how different variants of this setup perform quantitatively. We focus, in particular, on three models relevant for Sudden Stop events: a model in which liability dollarization yields a mechanism by which Fisherian deflation induces contractionary real devaluations, a model in which the Fisherian deflation triggers collapses in asset prices, and a business cycle model that can replicate the dynamics of both regular business cycles and Sudden Stops. Finally, we also discuss prudential policy measures and ex post crisis interventions that are supported by this class of models.

Following the crisis of 2008/2009, several emerging economies have received large capital inflows, as investment opportunities in advanced economies were scarce and zero-interest policies induced investors to seek higher returns elsewhere. Given the boom-bust pattern in global capital flows, it is only a question of time as to when the next episode of Sudden Stops will occur, and the recent increased expectations of higher US real interest rates, as the era of unconventional monetary policy winds down, are already raising this prospect. This suggests that further research on the mechanics of Sudden Stops and on policy measures available to reduce crisis risk and alleviate crises is urgently needed.

One important avenue for future research concerns the causes of risk taking that leads to binding constraints. Our analytical framework and most of the works covered in our survey simply assume that emerging market investors are impatient and therefore take on leverage, but there are many other factors that contribute to such risk taking, including bounded rationality, herding, and moral hazard. Boz & Mendoza (2013) and Bianchi et al. (2012), for example, take a step in this direction by emphasizing the role of financial innovation and the need for agents to learn about risk.

Another important direction of research concerns the aftermath of balance sheet crises, which often leads to sustained periods of below-trend growth that are difficult to explain in the set of models that we survey above. Jeanne & Korinek (2014), for example, develop a framework in which Sudden Stops reduce trend growth. Furthermore, balance sheet recessions may also have important redistributive effects (see Korinek & Kreamer 2013). A third avenue of research concerns the development of numerical methods that combine the strengths of global solution methods in describing nonlinear dynamics with the power of perturbation methods in dealing with a large number of variables so as to analyze Sudden Stops in even richer macroeconomic models.

DISCLOSURE STATEMENT

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