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ABSTRACT

The 1990s Sudden Stops in emerging markets were a harbinger for the 2008 global financial crisis. During Sudden Stops, countries lost access to credit, causing abrupt current account reversals, and suffered Great Recessions. This paper reviews a class of models that yields 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 further the constraint causing further deflation. This framework also embodies a pecuniary externality with important implications for macro-prudential policy, because agents do not internalize how current borrowing decisions affect collateral values during future financial crises.

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1 Introduction

From the surface, the debacle of the Mexican economy that began in December 20th of 1994 seemed 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 wordlwide during the 1990s and that we now refer to as Sudden Stops.[1]

The defining characteristic of a Suddent 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 the 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 1997-98, the East Asian crisis engulfed Korea, Malaysia, Indonesia, Thailand, Singapore, Hong Kong and the Philippines, and before the 1990s were over 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.[4] They were also published in leading academic journals.[5] 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 much of modern macroeconomics

[1] The term "Sudden Stop" was first used in this context in a paper by Dornbusch, Goldfajn and Valdés (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 hedge fund Long Term Capital Management. Conditions in capital markets in the United States 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 LTCM amongst its creditors.

[4] See for example the symposia issues of the *Journal of International Economics* (1996, 2000 and 2006), the *Journal of Money, Credit and Banking* (2001), and the *Journal of Economic Theory* (2004), as well as the NBER conference volumes edited by Krugman (2000), Edwards and Frankel (2002), and Dooley and Frankel (2003).

[5] See e.g. Calvo and Mendoza (1996, 2000), Cole and Kehoe (2000), Caballero and Krishnamurty (2001, 2003, 2004), Chang and Velasco (2001), Kaminsky and Reinhart (1999), Martin and Rey (2006), Lorenzoni (2008), Mendoza (2010).

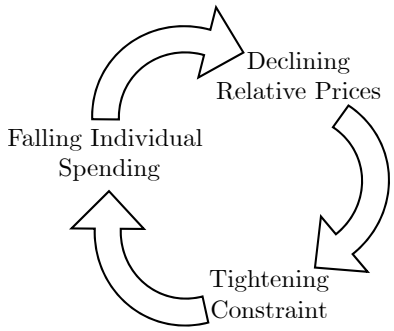

Figure 1: Financial amplification effects

was not paying attention to financial frictions and their potentially catastrophic consequences for the real economy. Moreover, many of the 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 reinassance of the macro/finance field (see e.g. the handbook article by Gertler and Kiyotaki 2010).

In this paper, we first document the key stylized facts that characterize Sudden Stops and then 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 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 Irving Fisher (1933). We start with a simple but general characterization of this Fisherian amplification mechanism and then discuss applications to Sudden Stops models that involve liability dollarization (i.e. debts denominated in different units than incomes and collateral), 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 macro-prudential financial regulation that is at the center of the new efforts to re-construct 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. Since 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, which lowers aggregate demand and leads to declines in real exchange rates, relative prices and asset prices. Since 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, 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 which distinguishes it from the rest of the literature, is the emphasis on studing the models' quantitative predictions using global, nonlinear numerical methods in experiments calibrated to data from actual economies. This is essential in order 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 macro-prudential financial regulation.

It is worth noting that some of the 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-WW-1 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 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 paper. These models can be traced back to the classic article by Fisher (1933), the work of Minsky (1986), the early formal models by Bernanke and Gertler (1989) and Greenwald and Stiglitz (1993) in simple two period settings, and the more general models proposed by Kiyotaki and Moore (1997), as well as quantitative applications of these models using perturbation methods in DSGE environments, as in the work of Carlstrom and Fuerst (1997), Bernanke, Gertler and Gilchrist (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 are 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 are 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 constructs event windows of macroeconomic aggregates centered around those dates in order to study the characteristics of Sudden Stops.

In our empirical description of Sudden Stops we follow the filter used by

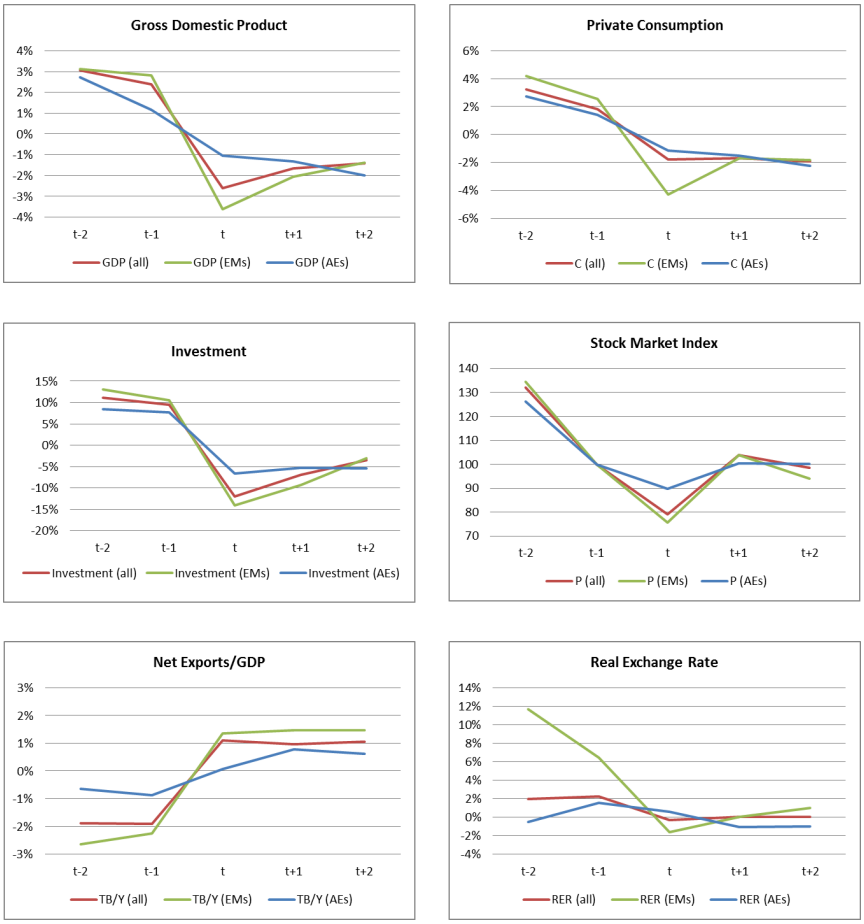

Figure 2: The dynamics of sudden stops

Calvo, Izquierdo and Talvi (2006).[6] 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 EMBI spread is more than two standard deviations above its mean.[7]

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 Sudden Stop events provided by Calvo et al. (2006) who identified 33 Sud-

[6] Other classic articles on this subject include Calvo, Izquierdo and Mejía (2008), Calvo, Izquierdo and Talvi (2006) and Calvo, Izquierdo, and Loo-Kung (2006). Earlier studies include Calvo and Reinhart (1999) and Milesi-Ferretti and Razin (2000).

[7] In some of their work they also apply a third filter to isolate Sudden Stops in which the drop in output was 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.

den Stop events using data for emerging markets (EM) from 1980 to 2004. We extended their analysis by adding emerging markets data from 2005 to 2012 and including advanced economies (AE) data from 1980 to 2012, so as to capture more recent Sudden Stops in both emerging markets (particularly Eastern Europe) and advanced economies (especially around the 2008 crash). See Appendix A for a full description of the data and the identification procedure used. 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 (indeces re-based so that year t-1 equals 100) , where we detrended Y, C and I using the Hodrick-Prescott filter.

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, and asset prices high. The typical Sudden Stop, defined as the median across all events in the data, shows a reversal in the cyclical component of TB/Y of about 3 percentage points at date t. Consumption and GDP fall 2 and nearly 3 percent below trend respectively, and investment drops by 12 percentage points. 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 reach their lowest point also at date t and they are sharply lower than in the pre-Sudden-Stop peak. Two years later they rise somewhat but only recover about 2/5ths of their loses.

The event windows also show a striking contrast in the Sudden Stop dynamics across EMs and AEs. In particular, AEs do not show the inverted-J pattern that EMs display, indicating that the through of the recession is not reached when the Sudden Stop hits. In fact, two years after the Sudden Stop event, output and consumption continue to move deeper below trend and investment remains flat. Almost half of the Sudden Stop events in AEs that we identified in our sample occurred around the 2008/09 crisis and were indeed followed by an extremely slow recovery. In EMs there is also 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 AEs and in the combined sample. This is in line with Mendoza and Terrones (2012) who show that credit boom events display a similar asymmetry: real appreciation followed by collapse in EMs and no noticeable pattern in AEs.

Mendoza (2010) highlights three other important empirical regularities of Sudden Stops: (1) they are infrequent events nested within typical business cycles; (2) they generate negative skewness in macroeconomic aggregates, because we do not observe symmetric episodes of sudden large capital inflows coupled with economic expansions; (3) 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.[8]

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 of Sudden Stops must be to abandon the assumption that credit markets are perfect.[9]

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 that can be observed during sudden stops when debt levels in the economy are high. It also generates regular business cycle dynamics when debt levels in the economy are moderate and the financial constraint is loose.

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 (i) contractionary exchange rate depreciations, (ii) contractionary asset price deflation and (iii) a general equilibrium extension of the latter 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.

3.1 Model Setup

Assume a small open economy in infinite discrete time $t = 1, 2, ...$ 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-

[8] This is due in part to 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) and Meza and Quintin (2007).

[9] An alternative explanation is the possibility of growth shocks as explored by Aguiar and Gopinath (2007), which rely on the existence of persistent growth shocks that can be difficult to identify in the short samples of macro time series of several emerging economies.

separable expected utility function

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

where $\beta < 1$ is the subjective discount factor and $u\left(c_t\right)$ 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. International bonds carry an exogenous, time- and state-invariant price of $1/R$, where R is the gross world real interest rate. As explained below, we require $\beta R < 1$ in order to ensure a well-defined equilibrium. We denote the repayment on the bond holdings of the home agent at the beginning of period t by b_t and the value of bond purchases carried as savings into the ensuing period by b_{t+1}/R. Since 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 risk 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. 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. It proves convenient 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 by assuming the functional form:

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

where $\bar{b}'\left(C_t\right) > 0$, i.e. higher aggregate consumption increases borrowing capacity. In the following two sections, we will examine variants of this setting based on relative price changes that are associated with declines in aggregate consumption: we will describe Fisherian models in which falling consumption leads to real exchange rate depreciations and asset price declines. We will 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 (3) lies at the heart of the Fisherian effects that we want to capture.

The combination of the non-state-contingent debt and the 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 borrowing capacity, and this mismatch drives the financial amplification effects: the liabilities of the agent are non-state-contingent whereas the borrowing limit fluctuates in parallel with aggregate states over the business cycle, for example because of fire sales of goods and assets. In the event of adverse shocks, this implies that the borrowing limit tightens but the level of debt remains the same. Instead of being able to smooth the impact of adverse shocks over time, the representative agents 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.

Impatience Vs. Precaution One of the key trade-offs in this framework is 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.[10] On the other hand, this assumption implies 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 $\bar{b}$ in order to take maximum advantage of this opportunity to trade. In that case, the borrowing constraint would always be binding. Since domestic agents are risk-averse but asset markets are incomplete, however, agents have an incentive to accumulate precautionary savings against stochastic endowment risk. Hence, they raise their bond holdings above the minimum level $\bar{b}$ in order 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, and that the precautionary motive is stronger as βR rises, the more risk-averse agents are, and the greater the volatility and persistence of the uninsurable shocks they face.

It is important to notice that 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 without the collateral constraint, which reduce the probability

[10] 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 implies that $u'(c_t) \to 0$ almost surely, which in turn implies $c_t, b_{t+1} \to \infty$ (see ch. 18 of Ljungqvist and Sargent (2012) for further details).

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 our framework to nest infrequent Sudden Stops within regular business cycles. Still, as we will explain in Section 7, the extra precautionary savings induced by the risk of Sudden Stops are insufficient from a socially-optimal perspective, due to 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 (1) subject to the series of budget constraints (2) and borrowing constraints (3) and the consistency condition $C_t = c_t$.*

We assign the shadow price λ_t to borrowing constraint (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 (4) together with the borrowing constraint (3), and the budget constraint (2).

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

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

Intuitively, the assumption states that a one dollar increase in aggregate consumption relaxes the borrowing constraint by less than one dollar. If this assumption was 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.[11] As we will discuss below in further detail, this assumption is important in models of financial amplification to guarantee uniqueness.

Recursive Formulation We now reformulate the above equilibrium in recursive form, which we will use in our numerical solution algorithms below. First, the stochastic income process can be approximated as a first-order, irreducible Markov process with realization vector $\mathbf{y}$ and transition probabilities $\pi(y_t, y_{t+1})$.[12] The state variables of the representative agent's problem are his holdings of bonds $b \equiv b_t$, his income realization $y \equiv y_t$, and the aggregate bond position of the economy that the agent takes as given B.

[11] We refer the interested reader to appendix A of Jeanne and Korinek (2011) for further details.

[12] 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

$$\begin{aligned} V(b,y;B) &= \max_{b'} \left\{ u\left(y - \frac{b'}{R} + b\right) + \beta \sum_{y'} \pi(y,y') V(b',y';B') \right\} \\ \text{s.t.} \quad \frac{b'}{R} &\geq -\bar{b}(C) \\ \text{where} \quad B' &= H(B,y), \qquad C = y - \frac{B'}{R} + B \end{aligned}$$

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 $\bar{b}(C)$. 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 given 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 will 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 explicit closed-form solutions, except in special cases like the perfect-foresight example we study next. Several global, nonlinear numerical solution methods can be used to solve models in this class. In Appendix A we provide an example based on an endogenous gridpoints method along with a sample calibration and source code.[13]

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 ($y_t = y$) $\beta R = 1$. Given these assumptions, there are two possibilities for how equilibrium is determined, depending on the initial asset position of the representative consumer b_1.

[13] Algorithms that solve recursive formulations of the optimality conditions, instead of solving directly 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.

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 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, which reduces to $w \equiv y/(1-\beta) + b_1$.

Observe that, since the model is fully stationary, bond holdings in all future periods are a strictly increasing function of initial bond holdings: $b_{t+s} = b_1 \forall s$. Hence, a one-dollar increase in initial bond holdings is reflected one-for-one in future bond holdings $db_t/db_1 = 1$, and since 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. Moreover, instead of thinking of shocks to initial net worth, we could do the analysis using wealth neutral shocks to date-1 income, such that y_1 falls and y_{t+s} increases to keep w unchanged. Intertemporal markets would play the same role to keep consumption unchanged (see Mendoza (2005)).

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

$$b_1 \geq -\bar{b}\left(y + (1-\beta) b_1\right)$$

Since $b_{t+s} = b_1 \forall s$, 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 $b_2/R = -\bar{b}\left(C_1\right) > b_1$.

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 $\bar{b}\left(C_1\right)$. Hence the budget constraint yields C_1 as the solution to the implicit equation

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

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 $c_1\left(C_1\right) = ...$ reflects that individual consumption is the minimum of its desired and its feasible level given different levels of aggregate consumption C_1. This equality is represented by the solid line labeled $c_1\left(C_1\right)$ that starts at the intercept $y + b_1$. As long as the financial constraint is binding, it starts at the intercept $y + b_1 + \bar{b}\left(0\right) > 0$ and rises at slope $\bar{b}'\left(\cdot\right)$. When the financial constraint becomes loose, it remains constant at the desired level of consumption $y + (1-\beta) b_1$. By Assumption 1, the slope of the right-hand side in the figure is always less than the slope

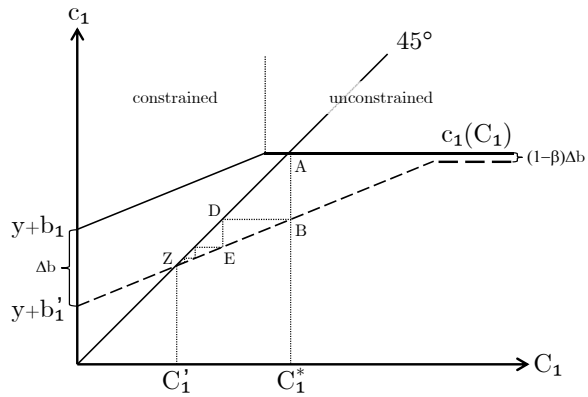

Figure 3: Financial amplification dynamics

of the left-hand side, guaranteeing a unique intersection which indicates the equilibrium.

The 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 at the right side of the Figure, we can see that the desired unconstrained level of consumption falls just by a fraction $(1-\beta)\Delta b$. 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 individual consumption as indicated by the vertical movement from point A to point B. (Observe that the distance between A and B is less than Δb since we started in a situation in which the financial constraint was slack.) In general equilibrium, however, lower individual consumption reduces aggregate consumption from 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 in 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

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

The term $\frac{1}{1-\bar{b}'(C_1)} > 1$ can be interpreted as the coefficient of amplification to initial net worth shocks or output shocks when the financial constraint is binding. The larger $\bar{b}'$, the response of the constraint to changes in aggregate

consumption, the stronger the amplification effects. For $\bar{b}' \to 1$, the amplification coefficient becomes arbitrarily large. As we discussed under Assumption 1, we rule out the case $\bar{b}' \geq 1$ because it would result in multiple equilibria.

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 tradable goods) but backed up by income or assets from the nontraded sector or the economy (see e.g. Calvo 1998 and Eichengreen and Hausmann 2005). Hence, the relevant price between liabilities and the value of collateral is the relative price of nontraded to traded goods.

To introduce liability dollarization, we extend our general model to include traded and a non-traded good. 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 $c = c(c_{T,t}, c_{N,t})$ in which the two goods enter as complements (typically a CES aggregator). Assuming that traded goods are the numeraire and denoting the relative price of non-traded goods by $p_{N,t}$, the budget constraint 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 (2010) 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 non-traded goods, but their debt b_{t+1} is denominated entirely in traded goods in budget constraint (6).

Maximizing the consumer's expected utility subject to the budget constraint (6) and borrowing constraint (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 intra-temporal 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 nontradable goods $c_{N,t} = y_{N,t}$ in the second optimality condition, it follows that the exchange rate is an increasing function of the aggregate consumption of traded goods and the exogenous state variable $y_{N,t}$ so that $p_{N,t} = p_N\left(C_{T,t}; y_{N,t}\right)$. The relationship is increasing because traded and non-traded goods are complements, and therefore for

greater consumption of traded goods, the consumer would also like to increase non-traded consumption. However, since the supply is fixed, the relative price of non-traded goods has to go up instead to clear the market.

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

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

where $\bar{b}$ is increasing in aggregate traded consumption $C_{T,t}$, as in our general model, and depends in addition on the exogenous state variables $y_{T,t}$, $y_{N,t}$. In this case, we need to impose the assumption $\bar{b}'\left(C_{T,t}; \cdot\right) < 1$ to ensure a unique equilibrium.[14] 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

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

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 he is unable to borrow the amount needed to support the unconstrained allocation. For the economy to absorb the available supply of non-traded 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 $\bar{b}$, which forces further cut-backs in consumption, and leads to a feedback loop.[15] Amplification effects introduce considerable volatility not only in the current account and aggregate demand of the emerging economy, but also into the real exchange rate.

4.1 Quantitative Results

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 $c\left(c_T, c_N\right) = \left[a c_{T,t}^{-\mu} + (1-a)\, c_{N,t}^{-\mu}\right]^{-1/\mu}$. We set the expenditure share on traded

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

[15] The balance sheet effect linking constrained borrowing to tradables 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 paper.

β	R	σ	a	μ	κ	Δy	π
.96	1.03	2	1/3	.8	1/3	.03	.05

Table 1: Parameters used in sample calibration of exchange rate model

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 $\frac{1}{1+\mu} = .8$ and a maximum credit-to-output ratio of $\kappa = 1/3$. Finally, we assume a binary output process $y_t \in \left\{y^H, y^L\right\}$ where $y^H = 1$ and $y^L = y^H - \Delta y$ in which output drops by $\Delta y = .03$ from trend with an i.i.d. probability of 5%, which reflects the approximate severity and incidence of sudden stop events in the sample used to determine our stylized facts. The parameters are summarized in Table 1, and the algorithm to numerically solve the model is described in Appendix A.

The policy functions for saving, tradable consumption and the equilibrium nontradable price as functions of b, for high and low values of the income shock, are shown in Figure 4. These policy functions are obtained by solving the model in recursive form. The top two lines depict $p_N\left(b, y^H\right)$ as a solid line and $p_N\left(b, y^L\right)$ as a dashed line. The next two pairs of lines depict $c_T(b, y)$ and $b'(b, y)$ for $y_T = y_N = y \in \left\{y^H, y^L\right\}$. 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, if it lies below this line, the agent decumulates savings.

The Figure can be split into two regions: to the 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 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 the fact that consumers are impatient relative to lenders and run down their wealth.

The left panel of 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 $a * 9\% + (1 - a) * 3\% = 5\%$, roughly

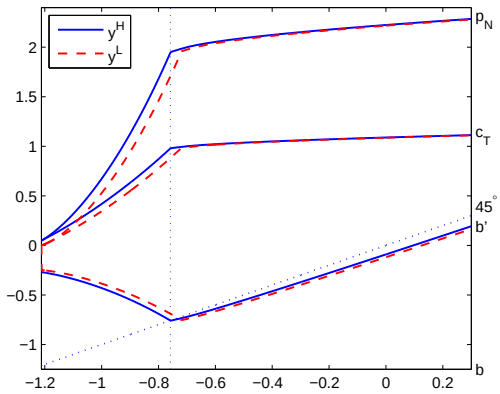

Figure 4: Policy functions of contractionary depreciation model

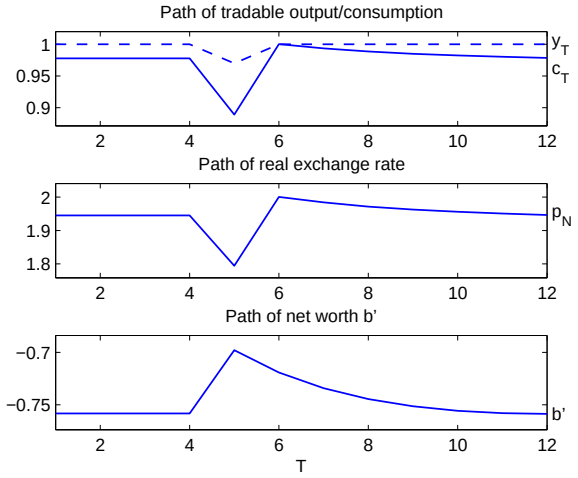

Figure 5: Simulated path of sudden stop

in line with the empirical results documented in section 2. The right panel of the figure depicts the ergodic distribution of the net worth of the consumer, i.e. the distribution of net worth in a stochastic simulation of the economy over 5000 periods.

The Sudden Stops literature has examined in detail several extensions and modifications of this setup. In the policy section we will discuss applications that have been developed to examine normative issues. In terms of positive analysis, Mendoza (2002) considers production of nontradable goods with labor and a borrowing constraint of the form: $b'/R \geq -\kappa\left(wL + \pi\right)$, where wL is wage income collected from endogenous labor supplied to nontradables producers and π are the profits that nontradables producers pay to the representative agent plus a stochastic endowment of tradables. In equilibrium, the constraint reduces to $b'/R \geq -\kappa\left(y_T + p_N y_N(L)\right)$. Durdu, Mendoza, and Terrones (2009) consider a similar setup in which nontradable production requires imported intermediate goods. These models feature a supply-side channel of the Fisherian deflation mechanism, because deflation in the relative price of nontradables reduces the marginal product of labor and intermediate goods, and thus reduces factor demands and output. Hence, in the right-hand-side of the borrowing constraint, both the price and the quantity of the collateral shrinks as the constraint becomes binding.

5 Asset Price Deflation

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

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

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

If the agent absconds with her newly issued debt in period t, we assume that foreign lenders can seize her asset holdings and sell them at the prevailing price in the domestic market to other domestic agents. However, because of bankruptcy frictions, lenders can only extract a fraction ϕ of the value of the tree. Foreseeing this possibility, lenders limit borrowing of each individual consumer to

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

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 uncontingent whereas the value of the asset fluctuates in response to shocks to

the economy. Also, the dependence of the borrowing constraint on aggregate consumption is implicit in that the equilibrium price depends on the aggregate states of the economy.

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

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

Unconstrained Equilibrium When the financial constraint (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 $\frac{\beta u'(c_{t+1})}{u'(c_t)}$, and the typical smoothing behavior prevails.

Constrained Equilibrium 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 $\frac{\beta u'(c_{t+1})}{u'(c_t)}$ falls and assets that pay off tomorrow become less valuable compared to a situation without financial constraints. The stochastic discount factor for trees becomes $\frac{\beta u'(c_{t+1})}{u'(c_t)-\phi\lambda_t}$, with the extra term $-\phi\lambda_t$ in the denominator representing the collateral value of trees (see also Fostel and Geanakoplos, 2008). This term reduces the disutility $u'(c_t)$ of spending one dollar on buying trees by $\phi\lambda_t$ since each dollar of a tree 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 trees cannot be used as collateral.

The asset price is still lower, however, than it would be in an unconstrained equilibrium. To see this, observe that we can use the consumer's Euler equation to re-write the denominator of the marginal rate of substitution as a weighted average of today's and tomorrow's expected marginal utility $u'(c_t) - \phi\lambda_t = (1-\phi)u'(c_t) - \phi\beta RE\left[u'(c_{t+1})\right]$. Since we assumed $\phi < 1$, the denominator will be less than $u'(c_t)$ whenever $\lambda_t > 0$.

Assuming that we know the policy functions of the problem for future periods, 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 $b'(C) = y + b + C$ and employ the known future policy functions to express $p' = p(b', y')$ and $C' = c(b', y')$.[16] Then we can solve for

[16] As we noted in the definition of the recursive equilibrium, the equilibrium policy functions

aggregate consumption C by solving the implicit equation

$$\begin{aligned} C &= c(C) = y + d + b + \bar{b}(C; b, y) \\ &\text{where} \quad \bar{b}(C; b, y) = \phi p(C; b, y) := \phi \frac{\beta E[u'(C')(d' + p')]}{(1-\phi) u'(C) - \phi \beta R E[u'(C')]} \end{aligned} \tag{12}$$

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

For given state variables (b, y), the implicit 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, the process of reaching a new equilibrium can be illustrated by shifting the right-hand side of equation (12), triggering similar dynamics to the ones 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 further reductions in consumption.

Equity Premium and Forward Solution of Asset Prices Following Mendoza and Smith (2006), we can work with the optimality conditions to obtain this expression for the equity premium:

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

where $R^e_{t+1} = \frac{d_{t+1} + p_{t+1}}{p_t}$ 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 the fact 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 trees that pay dividends in the future. This effect is mitigated by $(1-\phi)$ since the agent can borrow against a fraction ϕ of the tree. The two indirect effects are $-Cov\left(\beta u'(c_{t+1}), R^e_{t+1}\right)$ and $\beta E[u'(c_{t+1})]$. The former seems analogous to the standard risk-premium term due to the fact that 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.

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.

β	σ	ϕ	R	α	Δy
.96	2	1/5	1.03	.05	.03

Table 2: Parameters used in sample calibration of asset price model

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

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

A higher equity premium – at 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.

5.1 Quantitative Results

We calibrate the framework in line with Jeanne and Korinek (2010) 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 the tree to be $\phi = 1/4$. We assume that the dividend from the tree is a constant fraction $\alpha = \frac{d_t}{d_t+y_t} = .05$ of total output. This captures the share of total income that derives from pledgeable assets, which represent mostly real estate in emerging economies. Finally, we also continue to assume the same binary i.i.d. output process. We summarize the parameters in table 2. The algorithm to numerically solve the model is described in Appendix A.

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 plots labeled p represent the level of the asset price. To the left of the vertical line that 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 income of the economy by 3% and sets in motion financial amplification effects that leads 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.

Mendoza and 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.

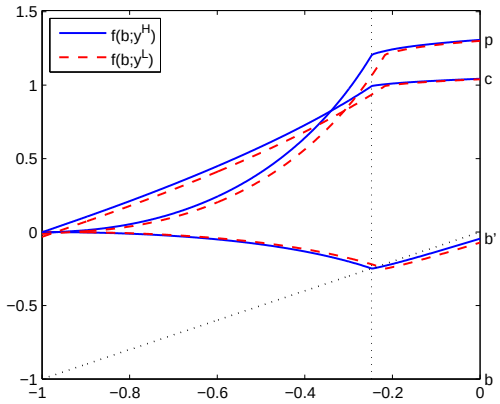

Figure 6: Policy functions of asset price model

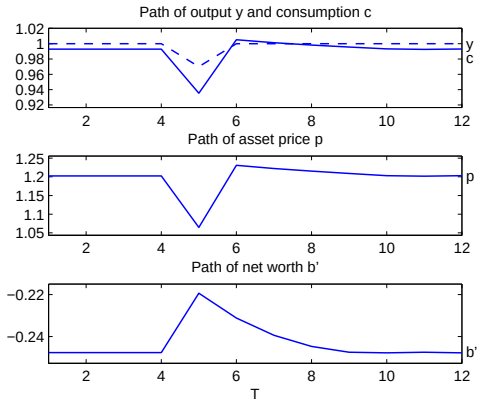

Figure 7: Simulated path of sudden stop

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, require a high price elasticity of foreign asset demand.

The Mendoza-Smith setup also shows 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, the collateral constraint on debt can be circumvented, and without the latter, the foreigners could buy the fire-sold assets at the fundamental price, effectively doing away with the asset price deflation.

Korinek (2011a) develops a quantitative model of a world economy that encompasses two regions that may suffer from binding constraints and crises due 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 and 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. 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 real-business-cycle DSGE models of small open economies applied to both industrial and emerging economies (e.g. Mendoza 1991, 1995, Neumeyer and Perri 2005, Uribe and Yue 2006).The model is similar to other models that study the 1990s emerging markets crises using credit-market frictions (e.g. Choi and Cook 2004, Cook and Devereux 2006ab, Braggion, Christiano and Roldos 2009, Gertler, Gilchrist and Natalucci 2007). 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. On the other hand, it is worth noting 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.

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 accummulable 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 we have studied so far. 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 as 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 demand 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 (see Mendoza 1991 for details, and Durdu et al. 2009 for a comparison of the quantitative implications of this utility function with those of the standard time-separable preferences).

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

The period utility function takes the standard CRRA form $u(\cdot)=(c-G\left(L\right))^{1-\sigma}/(1-\sigma)$, 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 labor supply, which would otherwise deliver a counterfactual increase in labor supply when consumption falls during deep recessions. The time-preference function is defined as $v(.)=\rho\ln(1+c-G\left(L\right))$, where ρ is the semi-elasticity of the rate of time preference with respect to $c-G\left(L\right)$.

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 $i_t = \delta k_t + (k_{t+1} - k_t)\left[1 + \frac{a}{2}\left(\frac{k_{t+1}-k_t}{k_t}\right)\right]$. The left-hand-side of the 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. 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 includes also 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 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. $\partial i_t / \partial \bar{k}_t$, where $\bar{k}_t$ is the aggregate capital stock taken as given by the representative firm-household).

6.2 Financial Amplification in a Business Cycle Model

The Fisherian deflation mechanism operates in this economy in a manner analagous to that of the endowment-economy asset pricing model reviewed earlier: 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 introduces again 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 results 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). Amplification in the sense that when the constraint binds the same size shocks generate much larger recessions and asset price drops that when it does not, and asymmetry in the sense that if the constraint does not bind the responses of the shocks are more tepid and in line with the behavior of a standard RBC model. Both of these properties are very helpful. Amplification because it is behind the model's ability to produce financial crises with realistic features, and asymmetry because it 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 it is reasonably calibrated, can deliver these results is a question that can only be answered with quantitative analaysis.

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 lowers sharply the probability of observing Sudden Stops in the economy's stochastic stationary state, and thus the model can nest together endogenous financial crises with realistic, standard RBC 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 is an updated version of Figure 2 in Mendoza (2010), in which we compare the new Sudden Stop event dynamics documented in Section 2 with the

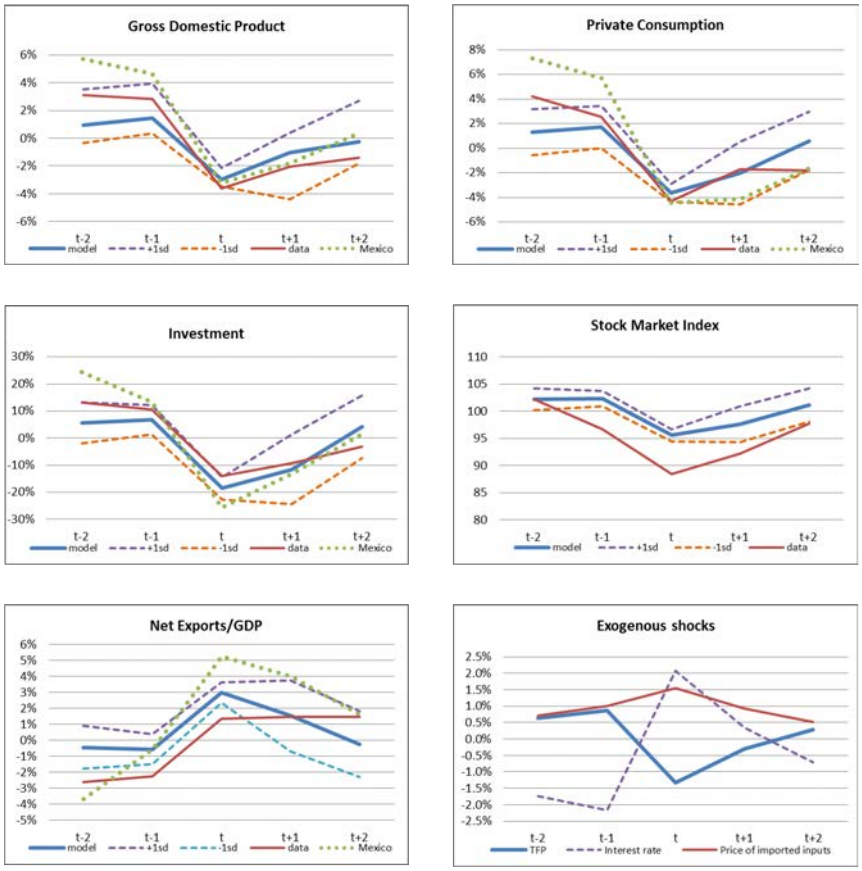

Figure 8: Sudden stop event windows in data and simulations of business cycle model

predicted Sudden Stop event windows produced by the model. The Figure shows the median of Sudden Stop events in the model along with + and - 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 latter 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 and 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

[17] These shocks are introduced into the model as a discrete Markov process that approxi-

frequency of Sudden Stops in the Calvo et al. (2006) dataset, which was 3.3%. This required setting $\kappa = 0.2$.

As Figure 8 shows, the model does a very 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 mimics very closely the declines in GDP, consumption, and investment in the through of the Sudden Stop, but predicts a decline in the price of capital much milder than the one observed in the data. This is because of the standard Tobin-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 both 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 responds 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 we have reviewed has focused on two sets of policies: First, macro-prudential or ex-ante policies, i.e. policies implemented in "good times" in order to mitigate the frequency and severity of sudden stops in the future (e.g. Bianchi and Mendoza 2010, 2013, Jeanne and Korinek 2010b, Bianchi 2011). Second, ex-post policies aimed at dealing with financial amplification once the Fisherian mechanism is in motion (e.g. Benigno et al. 2012ab, Bianchi 2013, Jeanne and Korinek 2013b).

7.1 Macro-Prudential Policies

The fact that the value of collateral is a market price introduces a pecuniary externality into our 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

mates a first-order VAR process estimated with the the data on the three shocks, using the Tauchen-Hussey quadrature method to construct the Markov process.

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 the 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 analyzed earlier 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 in order to relax the future constraints and mitigate the associated financial amplification effects. Such an intervention improves social welfare because of the pecuniary externality.

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

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

The Euler equation of this problem is

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

The difference from the optimality condition (4) of private agents is reflected in the two terms with $\bar{b}'(\cdot)$, which capture that the planner internalizes the effects

[18] A similar pecuniary externality was also described by Caballero and 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, by contrast, the financial constraint depends on prices and so a movement in relative prices directly relaxes the financial constraint.

of aggregate consumption on the borrowing limit. Observe that this term is pre-multiplied by the shadow price on the borrowing constraint, i.e. relaxing the borrowing limit is only relevant when the borrowing constraint is binding.

We distinguish between two cases: 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

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

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 $\lambda' \bar{b}'(C')$. This is achieved by borrowing less at t so as to transfer more consumption into $t+1$. If the constraint is binding with non-zero 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 tomorrow. This result can be proved formally by simply comparing the Euler equation of the planner (14) when $\lambda = 0$ to the Euler equation of private agents (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

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

In order to attain the same allocations as with the planner's Euler equation (14), the optimal tax is:

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

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. The literature has also explored how similar outcomes can be implemented with other instruments such as state-contingent capital requirements or loan-to-value ratios (see e.g. Bianchi 2011).

Pigouvian taxes to lean against the risk of sudden stops can be interpreted as *prudential capital controls*. See Korinek (2011) for a survey of a growing literature on this topic.

Contractionary Depreciations Model The exchange rate 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 $\lambda' \bar{b}'(C'_T; \cdot) = \lambda' \kappa p'_N (C'_T; \cdot)\, y_N$. 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 nontradables 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 the real exchange rate model.

Korinek (2011) 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 formula (15) in order to quantify the magnitude of externalities. He applies this procedure to the externalities during the Indonesian crisis of 1997/98 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 CPI-indexed debt, local currency debt, portfolio investment and FDI, 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 about 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 (2013) 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.

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 (14) can be expressed as $\lambda' \bar{b}' (C'; \cdot) = \lambda \phi p' (C'; \cdot)$. 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 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 delever less.

Bianchi and Mendoza (2010) and Jeanne and Korinek (2010b) conduct a quantitative investigation of the above arguments.[20] They calibrate their models to the sudden stop experienced by the US economy in 2008, and compute taxes on borrowing that are positively correlated with leverage when the con-

[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 of the collateral. The reason is that having lower financial liabilities – no matter in which currency – implies higher aggregate traded consumption next period and a higher price of the non-traded collateral, which relaxes the financial constraint.

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

straint is not binding and go to zero during crashes when the constraint is binding. The optimal prudential intervention not only reduces the incidence and severity of sudden stops but also raises the equilibrium level of asset prices. Bianchi and Mendoza also introduce a supply-side channel for the financial friction by adopting a formulation similar to the setup of Mendoza (2010) of representative firm-households that require working capital (subject to the collateral constraint) to pay a fraction of the wages bill, and they also focus on time inconsistency issues that we discuss briefly below.

Bianchi and Mendoza (2013) show that time inconsistency can be a serious issue in the analysis of macro-prudential 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 $\bar{b} = \phi p(B, y)$. Suppose that the constraint binds in a given period. Then the planner would have an incentive to promise low C' in the next period in order 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 and Mendoza (2010) and Jeanne and Korinek (2010b) conduct 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 and 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 and Mendoza assume that the asset price 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 the second 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. While the loans menu is the same, the planner chooses "more wisely" than private agents 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] Notice it is critical that the pricing functions are assumed to be the same, but the dynamics of asset prices along the equilibrium path are very different.

Since arbitrary assumptions to limit the ability of the planner to influence prices are controversial, and intuitively they mean that regulators would not exploit the full potential of their prudential tools, Bianchi and Mendoza (2013) study instead the design of time-consistent optimal macro-prudential policy.

[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 on a different pricing function than the one of the unregulated economy.

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 while time-consistent macro prudential policy can both improve upon conditionally-efficient setups and tackle the time-inconsistency problem without arbitrary assumptions, the quantitative features of the policies are similar to those obtained assuming the planner values collateral with the pricing function of the competitive equilibrium.

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 using different tools, 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.

Durdu and 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) in order 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, since 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. (2009, 2012ab, 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 costlessly manipulate these prices, then it is always possible to restore the unconstrained equilibrium. Second, even if it is costly to prop up exchange rates or asset prices, it may be desirable to do so in order 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 Stops models that we have studied, which is that the collateral constraints are generally imposed directly on the optimization problems of agents, rather than embedding an optimal contracting problem within the Sudden Stops framework. Hence, while 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 and Korinek (2013b) study a number of the issues brought up by the interaction of ex-ante and ex-post policy measures in our Sudden Stop framework by using a simplified analytic framework of asset price deflation. They find that it is generally desirable to engage in both types of interventions up to the point where 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 time inconsistency problem created by ex-post intervention.

8 Conclusions

This paper documented the empirical regularties of Sudden Stops and reviewed a class of quantitative models that aimed to explain this phenomenon using occassionally binding credit constraints that can trigger non-linear 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 sale goods and/or assets in efforts to meet their financial obligations, but as they do they cause a decline in prices that tightens further the credit constraint forcing further fire sales.

We developed a simple dynamic framework to emphasize the commonalities of different versions of models of sudden stops and financial amplification, and showed how different variants of this setup perform quantitatively. We focused in particular on three models very 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, an a business cycle model that can replicate the dynamics of both regular business cycles and Sudden Stops. Finally, we also discussed prudential policy measures and ex-post crisis interventions that are

supported by this class of models.

Following the crisis of 2008/09, a number of emerging economies have received large capital inflows as investment opportunities in advanced economies were scarce and zero interest policies induced investors to seek for higher returns elsewhere. Given the boom-bust pattern in global capital flows, it is only a question of time when the next episode of Sudden Stops will occur, and the recent increased expectations of higher U.S. 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 for 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 a number of other factors that contribute to such risk-taking, including bounded rationality, herding, or moral hazard. Boz and Mendoza (2013) and Bianchi et al. (2012), for example, make a step in this direction by emphasizing 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 have surveyed. Jeanne and Korinek (2013), for example, develop a framework in which sudden stops reduce trend growth.

A third avenue of research concerns the development of numerical methods that combine the strenghts of global solution methods in describing non-linear 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.

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A Data Appendix and Numerical Appendix

The data appendix to this paper describes how the empirical event analysis of sudden stops was performed. The numerical appendix outlines how the model simulations were implemented and offers source codes of the programs used.

Both are available at `http://www.korinek.com/suddenstops`