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ABSTRACT

Using a sample of 32 developed and developing countries we analyze the empirical characteristics of sudden stops in capital flows and the relevance of balance sheet effects in the likelihood of their materialization. We find that large real exchange rate (RER) fluctuations coming hand in hand with Sudden Stops are basically an emerging market (EM) phenomenon. Sudden Stops seem to come in bunches, grouping together countries that are different in many respects. However, countries are similar in that they remain vulnerable to large RER fluctuations – be it because they could be forced to large adjustments in the absorption of tradable goods, and/or because the size of dollar liabilities in the banking system (i.e., domestic liability dollarization, or DLD) is high. Openness, understood as a large supply of tradable goods that reduces leverage over the current account deficit, coupled with DLD, are key determinants of the probability of Sudden Stops. The relationship between Openness and DLD in the determination of the probability of Sudden Stops is highly non-linear, implying that the interaction of high current account leverage and high dollarization may be a dangerous cocktail.

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I. Introduction

The sequence of financial crises that started with the so-called Tequila crisis in Mexico in 1994/5 strongly suggests that these phenomena cannot simply be rationalized in terms of advanced-country business cycle models. More is at stake here. In particular, these episodes are associated with a sharp contraction of international capital flows, or *Sudden Stop,* which may by itself have triggered the ensuing disruption. Sudden Stops are associated with large depreciations and major financial disruptions, leading to significantly lower rates of return, investment and growth. This is the point of view that will be elaborated and subject to empirical analysis in the present paper.

For starters, we would like to say a few words on alternative explanations about deep financial crisis in Emerging Market economies (EMs), and give an intuitive presentation of the approach pursued in this paper. A popular explanation for these crises used to be and, in some quarters, still is "lack of fiscal discipline." As the argument goes, crisis-prone EMs have a tendency to run high fiscal deficits, which eventually result in an unsustainable level of the public debt. Thus, there comes the time when lenders stop lending, forcing a major domestic adjustment. This explanation is very appealing for the 1980s Debt Crisis in Latin America, but finds little support in Asia. For example, at the inception of its 1997 crisis, Korea's public debt hovered around only 10 percent of GDP. Moreover, debt levels in EMs are comparable to if not significantly lower than in advanced countries (e.g., Japan).

Ardent believers in the fiscal view may not be entirely convinced by these observations, because during a financial crisis, the country as a whole, and the government in particular, lose access to international capital markets. Thus, lenders behave as if they have smelled "something rotten in the State of Denmark." However, loss of access need not be the result of over-indebtedness *in the context of a good equilibrium*, but rather the *result* of a bad equilibrium *triggered by a Sudden Stop*. This Inverse Fiscal View finds support in the fact that Sudden Stop episodes tend to occur around the same time, and for countries exhibiting a variety of fiscal situations (indeed, the "bunching" of Sudden Stops is an important characteristic that we identify in the empirical section). The most outstanding such episode was associated with the Russian August 1998 crisis, in which practically all EMs suffered serious Sudden Stops and an increase in country risk premiums.[1]

The fiscal view started to be questioned during the 1997 Asian crises because these countries' fiscal stances were much stronger than those in Latin America.[2] Even the IMF (1999) recognized that it made a mistake in calling for strong fiscal adjustment in that part of the world. As a result, attention shifted to other variables. It did not take long for professional opinion to identify *soft pegs* as the likely culprit. The Soft Peg view is that crisis countries engaged in unsustainable exchange rate pegs, which they were reluctant to abandon in a timely fashion, and only did so when hit by a balance-of-payments crisis. This is an eminently sensible argument, but it falls short of providing an explanation for the ensuing *real* meltdown (collapse in output and employment, for instance). Thus, our criticism follows the same lines that we have just utilized to question the relevance of the fiscal view, and need not be repeated.

[1] This view, incidentally, should not be taken as saying that public debt is not an important factor but, rather, that by and of itself, public debt is not enough to explain the devastation surrounding Sudden Stops in the last decade. Moreover, the fiscal view does not offer a clear explanation of why fiscal adjustment (which typically does not exceed 4 percent of GDP) should result in major economic disruption.

[2] However, in their explanation of the Asian crisis, Burnside, Eichenbaum and Rebelo (2001) emphasize the importance of *prospective* fiscal deficits related to implicit bailout guarantees due to a fragile banking sector. This approach highlights a fundamental element of crisis that will prove to be a key determinant in our empirical findings, yet we emphasize the valuation effects on contingent liabilities in the event that a Sudden Stop materializes, and do not necessarily consider crises to be inevitable or fully expected events, as would be the case in the Burnside-Eichenbaum-Rebelo framework.

The view that will be spelled out in this paper is that EMs suffer from structural weaknesses that make them vulnerable—much more than advanced economies—to shocks. In particular, we will zero in on shocks that are reflected in large changes in the real exchange rate (RER), i.e., the relative price of tradables with respect to nontradables. The RER is a fundamental relative price that cuts across the fabric of the whole economy, and involves a large variety of non-tradable goods. Large variety, in turn, militates against the existence of effective state-contingent markets (e.g., futures markets) like those found in commodities markets. There is, of course, nothing special about EMs in this respect. However, what could make the variability of the RER deadly in EMs is the fact that many of them suffer from *Domestic Liability Dollarization* (DLD), i.e., a high incidence of foreign-exchange denominated obligations with the domestic banking system.[3] Hence, a rise in the RER (i.e., real currency depreciation) makes it more difficult to repay loans for firms producing nontradables. This effect is particularly relevant because it may trigger substantial uncertainty about the solvency of the banking system as loans become non-performing, sometimes leading to bank runs in expectation of bank bankruptcies, which, in turn, almost inevitably affect the payments system and cause disruption in transactions and output.[4] Whether or not this effect is large depends, of course, on the size of the RER change, the stock of foreign-exchange denominated loans, and the ability of firms to switch production into tradables along their production possibilities frontier (which is likely to be difficult, particularly in the short run). Thus, one could conjecture that real devaluations are

[3] For evidence about this phenomenon, see Eichengreen, Hausmann, and Panizza (2003), where Liability Dollarization is a salient component of a phenomenon labeled *Original Sin*. In what follows we focus on *domestic* liability dollarization.
[4] In contrast to DLD, foreign liability dollarization (i.e., foreign-exchange obligations with foreign creditors), does not directly affect the domestic payments system, and those obligations are typically contracted by either firms engaged in tradable activities, or non-tradable firms whose revenues are indexed to the dollar, a characteristic that makes them less susceptible to RER fluctuations.

particularly dangerous after a period in which there have been significant capital inflows (like the period from 1990 to 1996 in EMs). The next section will present a simple model that helps to endogenize the RER. It should be intuitive, however, that a Sudden Stop, being a sizable cut in credit, will bring about a fall in aggregate demand and, consequently, a possibly large increase in the RER. Thus, a Sudden Stop may sow the seeds of a self-fulfilling crisis. This is the main line that will be pursued in the paper. However, it will be argued that equilibrium-multiplicity is not required in order to rationalize the existence of Sudden Stops. Thus, for example, Sudden Stops might be displayed in models in which the equilibrium set does not vary continuously with respect to fundamentals (Calvo (2003)).

Our empirical findings support the view that potential RER fluctuations coupled with DLD are key determinants of the probability of experiencing Sudden Stops, thus highlighting the relevance of potential balance-sheet effects in explaining the likelihood of a crisis. As will be discussed later, we argue that potential changes in the RER are linked to the size of the current account deficit prevailing before the materialization of a Sudden Stop. Thus, our approach focuses on the impact of dollarization on the likelihood of a Sudden Stop, rather than on the consequences of dollarization and Sudden Stops on relevant variables such as economic growth, as in Edwards (2003), for example.

Recent empirical literature has focused on alternative measures of crisis, whether currency crises (Frankel and Rose (1996),[5] Kaminsky and Reinhart (1999),[6] Edwards

[5] Using a panel of 105 countries for the period 1970-1991, they conclude that the current account has no significance in explaining currency crises.

[6] Kaminsky and Reinhart (1999) implicitly introduce a link between current account performance and currency crises by incorporating the growth rate of imports and exports in their analysis. They select the latter as a relevant early warning indicator of currency crises based on noise-to-signal ratio properties of the series.

(2001),[7] Arteta (2003), Razin and Rubinstein (2004)[8]) or current account reversals (Milesi-Ferretti and Razin (2000), Edwards (2003)). However, we believe that to the extent that many of the recent crises were originated by credit shocks in international markets, as argued in Calvo (1999), measures of crisis should be more closely linked to large and unexpected capital account movements rather than to measures that focus on large nominal currency fluctuations or current account reversals. Besides, current account and exchange rate behavior may be more affected by policy choices than Sudden Stops. Moreover, Sudden Stops may imply quite different timings for the onset of a crisis compared to exchange rate crises or current account reversals.[9]

Our strategy concentrates on the valuation effects of *domestic* dollarized liabilities (or, more specifically, on liabilities in terms of tradable goods), so our interest lies in real rather than nominal exchange rate fluctuations. Furthermore, we do not focus on the current account itself, but rather on the percentage fall in the absorption of tradable goods, which, as will be argued later, may represent a summary statistic for the rise in the RER following a Sudden Stop. Moreover, we highlight DLD, a phenomenon not considered in previous empirical studies of crises, with the exception of Arteta (2003), who explores the significance of Liability Dollarization in explaining the probability of a currency crisis. Interestingly, he finds no significant role for Liability Dollarization. This result is not incompatible with our findings, given that we do not focus on currency crises, and, as stated earlier, the timing of currency crises may be quite different from that of Sudden Stops.

[7] This analysis does find that under some definitions of currency crisis, and particularly excluding African countries, current account deficits are a significant determinant of the probability of experiencing currency crises.

[8] They focus on large RER swings to define a crisis.

[9] According to our definition, for example, Argentina's Sudden Stop starts in May of 1999, whereas the currency crisis only hits in February of 2002.

Additionally, our measure of dollarization is different in that it includes not only deposits but foreign borrowing as well, something that is particularly relevant for EMs when trying to proxy for credit awarded in foreign currency.[10]

The paper is organized as follows: Section II describes a model that identifies the variables that determine the change in the RER, which is at the heart of our crisis framework. Section III develops an empirical definition and characterization of Sudden Stops. Section IV focuses on an empirical analysis of the determinants of Sudden Stops, following a panel Probit approach. Section V concludes with a description of our main findings and future lines of research.

II. Basic Models

The link between shocks to the current account and financial variables has been explored in the literature and can be traced back to work by Rodríguez (1980) and Dornbusch and Fischer (1980).[11] In these studies, which rely on a two-asset portfolio model (the assets are domestic and foreign currency), the path of the nominal exchange rate depends on fluctuations in the trade balance. Given that the accumulation of foreign assets is determined by trade balance performance, the current exchange rate depends on both the path of money supply and the path of the trade balance. Shocks to the latter with sufficient persistence can therefore have effects on the spot exchange rate.[12] However, the motivation

[10] Our sample of countries is also different from that of Arteta (2003).

[11] The literature on current account behavior goes much further back in time, focusing mainly on the price elasticity aspects of devaluation on the trade balance. An excellent summary of the different views on the current account can be found in Edwards (2001).

[12] Calvo and Rodríguez (1977) construct a similar model that includes non-tradable goods to analyze RER determination under monetary policy shocks. Although shocks akin to Sudden Stops are not discussed there, they can be accommodated as an upward shift in the rate of accumulation of foreign assets (the equivalent of the current account balance as a share of foreign assets analyzed in Rodríguez (1980)), leading to a rise in the RER.

of these models is anchored in the persistence of structural trade deficits as an explanation for exchange rate movements. We focus instead on shocks to the *financing* of the current account.[13] Consider the following demand function for nontradables:

$$h = a + b\ rer + d\ z, \quad (1)$$

where $h = \log H$, $z = \log Z$, $rer = \log RER$, H and Z are the demand for nontradables (or home goods) and tradables, and a, b, and d are parameters.[14] Let the current account deficit be denoted by CAD. By definition,

$$CAD = Z - Y + S, \quad (2)$$

where Y is output of tradables and S are factor payments, remittances abroad, etc. Now consider a Sudden Stop episode. Typically, prior to these episodes the CAD is positive, and as a result of the Sudden Stop it goes down to zero, or even runs into negative territory (this is documented in Calvo and Reinhart (2000) for EMs, and in Calvo, Izquierdo and Talvi (2002) for Latin American countries following the Russian 1998 crisis). Moreover, it is worth noting that these are not common events. As shown in Appendix Table 1, as a general rule, changes in the trade balance display substantial persistence when the latter is approximated by an AR(1) process, both for EMs and developed economies.[15]

Abstracting from remittances, and momentarily keeping international reserves constant, it can be argued that a country could not be forced to a Sudden Stop larger than

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[13] More recent models, such as Izquierdo (1999), Caballero (2001), or Arellano and Mendoza (2002), have revisited the issue of shocks to current account financing by looking at collateral constraints. Shocks to collateral requirements, or to the terms of trade, can lead to substantial overshooting of the RER, as the value of assets used as collateral may overshoot downwards due to inefficient production levels when credit constraints bind following an external shock.

[14] This equation could be derived from first principles if H and X are identified with consumption of nontradables and tradables, the intertemporal utility function is separable, and the utility function is iso-elastic in H and X.

[15] Monthly, seasonally adjusted data on imports and exports were used to calculate the trade balance for the set of countries included in Appendix Table 1 (these countries will be used later on in our empirical analysis, see section IV). Changes in the trade balance are approximated by a first-order autoregressive (AR(1)) process. On average, the estimated coefficient yields 0.38 for EMs, and 0.5 for developed countries.

the initial trade balance (or initial *CAD* if it is too costly not to pay interest on outstanding debt). Reserves loses could momentarily cushion the blow, but as the Sudden Stop phenomenon lingers on, international reserves will be depleted. Actually, that is the general rule in Sudden Stop episodes that are accompanied by a balance-of-payments crisis (which will be the focus of our empirical analysis). Thus, as a first approximation, we will center on the case in which the *CAD* is driven down to zero.[16] In that case, given Y and S,

$$-\Delta Z = CAD; \quad (3)$$

thus,

$$-\Delta Z / Z = CAD / Z. \quad (4)$$

Taking first differences in equation (1), approximating the relative change in Z by its first difference in logs, and assuming that the supply of nontradables is constant, we obtain in equilibrium (i.e., setting H = supply of nontradables, assumed a constant, for simplicity)

$$\Delta rer = \frac{d}{b}\frac{CAD}{Z}. \quad (5)$$

In words, equation (5) states that the relative change in the real exchange rate is proportional to the prevailing CAD prior to the Sudden Stop, relative to the absorption of tradables. This equation is not intended to model the *actual* change in the equilibrium real exchange rate but, rather, *that part of the total change that is likely to be very difficult for the country to prevent.* A debtor country could stop paying its debt, but, as a general rule, it cannot force *new money* from its creditors. That is the assumption behind equation (5). We

[16] Therefore, when we compute changes in *CAD*, the latter will be equivalent to (minus) the *CAD* prevailing in the previous period, i.e., $\Delta CAD_t = CAD_t - CAD_{t-1} = -CAD_{t-1}$. For convenience, we drop the time subscript in the equations that follow.

are now ready to complete the framework that will help to rationalize Sudden Stops as defined in the empirical section, containing a largely *unexpected* component.

Consider a scenario in which a shock is spread from one country to other regions because of prevailing rules in capital market transactions (such as margin calls) that are unrelated to country fundamentals. Such a possibility is discussed in Calvo (1999), where it is argued that a liquidity shock to informed investors due to adverse developments in one country[17] may trigger sales of assets from other countries in their portfolio in order to restore liquidity. Now add to this framework a set of uninformed investors who face a signal-extraction problem in that they cannot observe whether sales of the informed are motivated by lower returns on projects or by the informed facing margin calls. In this context, uninformed investors may easily interpret the informed investors staying out of the market for EM securities or massive asset sales as an indication of lower returns and decide to get rid of their holdings as well, even though the cause for informed investors' sales was indeed due to margin calls.[18] When this occurs, a set of countries with no ties to the country at the epicenter of the crisis will be exposed to a large and unexpected liquidity shock making their equilibrium real exchange rate rise according to equation (5). Thus, if the relative change in RER is large and the economy is liability-dollarized, then massive bankruptcy will likely ensue, and the economy will land on a bad equilibrium characterized by a Sudden Stop with output contraction and low debt repayment capacity.

The latter can be rationalized in different ways. For example, although they do not deal with bankruptcies, models such as Izquierdo (1999) or Arellano and Mendoza (2002) help rationalize the effects of changes in the RER on output via credit contraction, where

[17] Say, a margin call due to the fall in the price of asset holdings from a particular country.

[18] This can occur when the variance of returns to projects is sufficiently high relative to the variance of the liquidity shock of informed investors.

the relevant price is that of non-tradable collateral relative to the tradable good being produced. Aghion, Bacchetta, and Banerjee (2001) exploit the fact that with incomplete pass-through from exchange rates to domestic prices, currency depreciation leads to a fall in net worth due to the increase in the debt burden of domestic firms indebted in foreign currency, thus reducing investment by constrained firms as well as output levels in future periods. The associated fall in future money demand and consequent future currency depreciation, coupled with arbitrage in the foreign exchange rate market, imply that currency depreciation must take place in the current period as well, opening the door for expectational shocks that could push an economy into a bad (low output) equilibrium. Therefore, given the damaging effect of RER fluctuations on balance sheets, output and repayment capacity, it can be argued that the probability of a Sudden Stop *cum* output contraction will be an increasing function of *CAD/Z*, and the degree of Liability Dollarization, among possibly other variables. This is the central conjecture that will be put to a test in the next sections.

The simple theory outlined above stresses the possibility that a current account deficit (a proxy of *unavoidable* current account adjustment when the country is tested by the capital market) combined with Liability Dollarization will bring about objective conditions that generate a Sudden Stop. Notice that in this context the stock of debt is, in principle, not central, unless one can argue that it changes the size of the current account *unavoidable* adjustment when the country is tested. This point is worth keeping in mind because our empirical results suggest that total debt is not a key factor behind Sudden Stop. On the other hand, once a Sudden Stop occurs, *how long* financial turmoil will last should quite sensibly be expected to depend on total debt, a phenomenon that appears to be supported in part by the data.

A Note on Models

Sudden Stops could be rationalized in terms of models displaying a unique equilibrium. It may suffice that the equilibrium outcome be a discontinuous function of fundamentals. This feature could actually be derived in conventional models in the presence of externalities, where if more than one equilibrium were to be displayed, uniqueness is recovered by assuming, for example, that the best equilibrium will be chosen (a *Panglossian* assumption[19]). This is a natural assumption in the present context if one is prepared to assume that the IMF and other multilateral financial institutions perform a good job in helping countries to avoid crises that would be preventable at very little cost.

In Calvo (2003) there exists a critical level of government debt beyond which the economy plunges into a bad equilibrium. The transition from the good to the bad equilibrium displays Sudden Stop features. Although the model assumes perfect foresight, it could be used to depict a situation in which the economy is hit by a totally unexpected shock that pushes it into the bad equilibrium. Thus, this model does not rely on equilibrium multiplicity, but it nonetheless provides some insight on a possible cause of a Sudden Stop, namely, public sector indebtedness. Calvo (2003) is a non-monetary model, where public debt is denominated in terms of tradables. Thus, Liability Dollarization is actually assumed for the entire debt, implying that the higher the degree of Liability Dollarization (measured by the public debt/output ratio), the higher the probability that a given negative shock will

[19] "All is the best possible," says Master Pangloss in Voltaire's *Candide*.

generate a Sudden Stop, helping to rationalize the empirical results discussed later on in the paper.[20]

Before closing this section, a word about *transitory* or *non-credible* policy models (see Calvo (1996)). Those models would be able to rationalize a large cut in capital inflows (even unexpected cuts, as in Calvo and Drazen (1998)), and would be in line with Burnside, Eichenbaum and Rebelo (2001). However, we are not keen about this as a stand-alone interpretation because of the high degree of bunching displayed by Sudden Stop crises. In these models, the Sudden Stop would be driven by policies that suffer a sudden reversal because they are unsustainable. Thus, bunching implies that many countries find themselves in this predicament at about the same time, and that policies are pushed to their sustainability limit in regions as different as Latin America and Asia.

III. Sudden Stops and Large Real Currency Depreciations

We start our empirical analysis with the identification and characterization of Sudden Stops. Specifically, we explore: 1) How EMs compare in terms of the frequency of Sudden Stops relative to developed countries; 2) Whether large real currency depreciations are inevitably associated with unexpected reversals in capital inflows, or this is mostly a characteristic of EMs; 3) Whether Sudden Stops precede large real currency depreciations, or vice versa; 4) Whether Sudden Stops occur simultaneously for a large set of countries, probably signaling disruptions in world capital markets and contagion, or they are indeed isolated events.

[20] Uniqueness could also be obtained along the lines suggested by Morris and Shin (1998). Consider the limit case in which informational noise (e in their notation) goes to zero, and let currency devaluation after crisis be an increasing function of the degree of Liability Dollarization. Then, it can be shown that the likelihood of a crisis as a result of deterioration in *fundamentals* (q in their notation) would be higher, the higher the degree of Liability Dollarization.

Given our discussion in the previous section, and following Calvo (1998b), we look for measures of a Sudden Stop that reflect *large* and *unexpected* falls in capital inflows that have costly consequences in terms of disruptions in economic activity, a central element in the characterization of this type of event given its impact on repayment capacity.

In order to make the concept of Sudden Stop operational, we first define a Sudden Stop as a phase that meets the following conditions:

- It contains at least one observation where the year-on-year fall in capital flows lies at least two standard deviations below its sample mean (this addresses the "unexpected" requirement of a Sudden Stop).[21]
- The Sudden Stop phase ends once the annual change in capital flows exceeds one standard deviation below its sample mean. This will generally introduce persistence, a common fact of Sudden Stops.
- Moreover, for the sake of symmetry, the start of a Sudden Stop phase is determined by the first time the annual change in capital flows falls one standard deviation below the mean.[22]

Notice that there is an important difference between this concept of crisis and the one used in other studies focusing on measures such as a fixed current account deficit threshold as a share of GDP in that, in line with the theoretical arguments outlined in the previous section, our definition accounts for the volatility of capital flow fluctuations of each particular country at each point in time in deciding whether an event is "large and

[21] Both the first and second moments of the series are calculated each period using an expanding window with a minimum of 24 (months of) observations and a start date fixed at January 1990. This intends to capture a learning process or updating of the behavior of the series.

[22] As a result, a Sudden Stop phase starts with a fall in capital flows exceeding one standard deviation, followed by a fall of two standard deviations. The process lasts until the change in capital flows is bigger than minus one standard deviation.

unexpected". If anything, our concept of crisis will tend to include episodes that would otherwise not qualify for crisis when using measures such as a fixed current account deficit threshold. This is so because the latter would exclude many crisis episodes in developed countries simply because their volatility is smaller.

To maximize the chances of detecting Sudden Stops, we work with monthly data, since lower frequency data may hide the origin of these episodes. Given that capital account information is typically not available at this frequency, we construct a capital flow proxy by netting out the trade balance from changes in foreign reserves[23] (both net factor income and current transfers are thus included in our measure of capital flows, but since they represent mostly interest payments on long-term debt, they should not vary so substantially as to introduce significant spurious volatility into our capital flows measure). Changes in this measure of capital flows are measured on a yearly basis to avoid seasonal fluctuations. We work with a sample of 32 countries, 15 EMs and 17 developed economies for the period 1990-2001 (see the Data Appendix for details)[24]

We also construct a Sudden Stop measure that builds upon the one previously described by adding a criterion of costly disruption in economic activity, defined as a contraction in output.[25] We do this because, in many cases, a fall in capital flows may just be the natural consequence of a positive shock that works as alternative financing, namely,

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[23] See the Data Appendix for definitions and sources of these variables. All series are measured in constant 1995 US dollars.

[24] The first two years of observations are lost, given that such information is used to construct initial standard deviations.

[25] Alternatively, one could replace this absolute criterion with some relative measure of output fall that takes into account the economy's track record. To address this issue, we defined a "relatively large output fall" as one displaying an output fall exceeding two standard deviations below the mean change in (the log of) output. Interestingly, however, due to the high volatility in output growth in EMs (even for periods of positive growth), this criterion turned out to be much more stringent than the absolute output fall, as it would require falls in output of such a large magnitude to highlight a crisis that it would ignore most of the crisis episodes in our sample of countries.

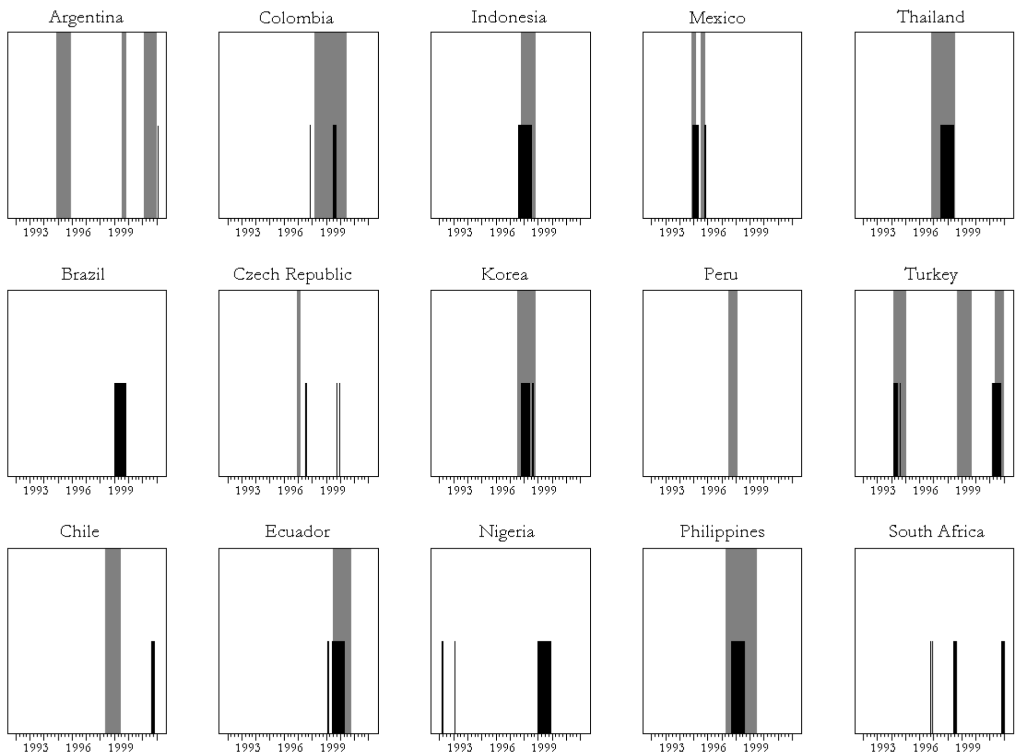
a terms-of-trade shock. Thus, we would be including a phenomenon that could be dismissed as a crisis event, and is therefore not relevant for our analysis. As a matter of fact, when comparing Sudden Stop episodes picked up by our first criterion, but not by our second criterion, we find that 61% of the time these episodes coincide with an increase in the terms of trade[26] (see Appendix Table 2). For this reason, we decided to work with our second definition of Sudden Stop.

Results are presented in Figures 1 and 2, for EMs and developed countries, respectively, showing the binary variable describing periods of Sudden Stop, together with a binary variable indicating periods of a large rise in the RER (see the Data Appendix for details). For EMs, Sudden Stop signals are mostly lit around the Tequila (1994), East Asian (1997), and Russian (1998) crises. Sudden Stops in developed countries are centered on the ERM (1993) crisis. These results imply that there are periods of Sudden Stop "bunching," suggesting contagion effects across countries. This is clearly shown in Figure 3, which measures the number of Sudden Stop episodes taking place simultaneously, both for our EM and developed country samples. Bunching is particularly striking around the time of the Russian crisis of August 1998. Within a window stretching one year before and after the Russian crisis, countries like Argentina, Chile, Colombia, Ecuador, Indonesia, Korea, Peru, Thailand, Turkey, and the Philippines were all in a Sudden Stop phase. Out of this sample, five countries, namely, Argentina, Chile, Colombia, Ecuador and Turkey, entered a period of Sudden Stop either in 1998 or 1999. Countries in this group were quite

[26] Also, when using the first criterion, Probit estimations of the type described in section IV yield the result that an increase in the terms of trade would lead to an increase in the probability of experiencing a Sudden Stop, something that is clearly picking up the mechanical negative correlation between capital flow changes and terms of trade growth. Estimations performed with our alternative measure, including costly disruption of economic activity, predict exactly the opposite, i.e., terms of trade growth impacts negatively on the probability of a Sudden Stop.

heterogeneous in terms of their fiscal stance and other macroeconomic measures, making it hard to argue that there was a common flaw in fundamentals driving these episodes, other than the fact that they are all EMs.[27] This suggests that all these episodes were not necessarily crises just waiting to happen, although there may be factors that made them more prone to crisis, an issue that we will analyze in the following section.

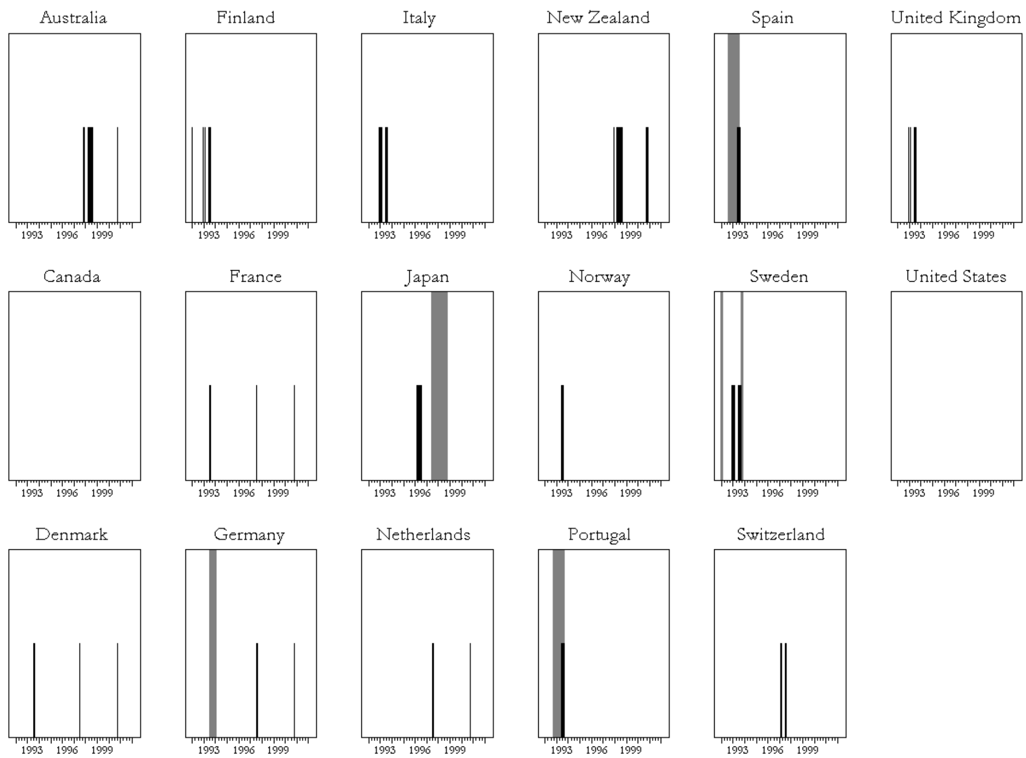
Figure 1
Real Exchange Rate Depreciation Dummy (20%) vs. Sudden Stop Dummy, 1992-2001
Emerging Markets



Note: Tall grey areas indicate Sudden Stop periods. Short black areas indicate intervals of large RER depreciation.

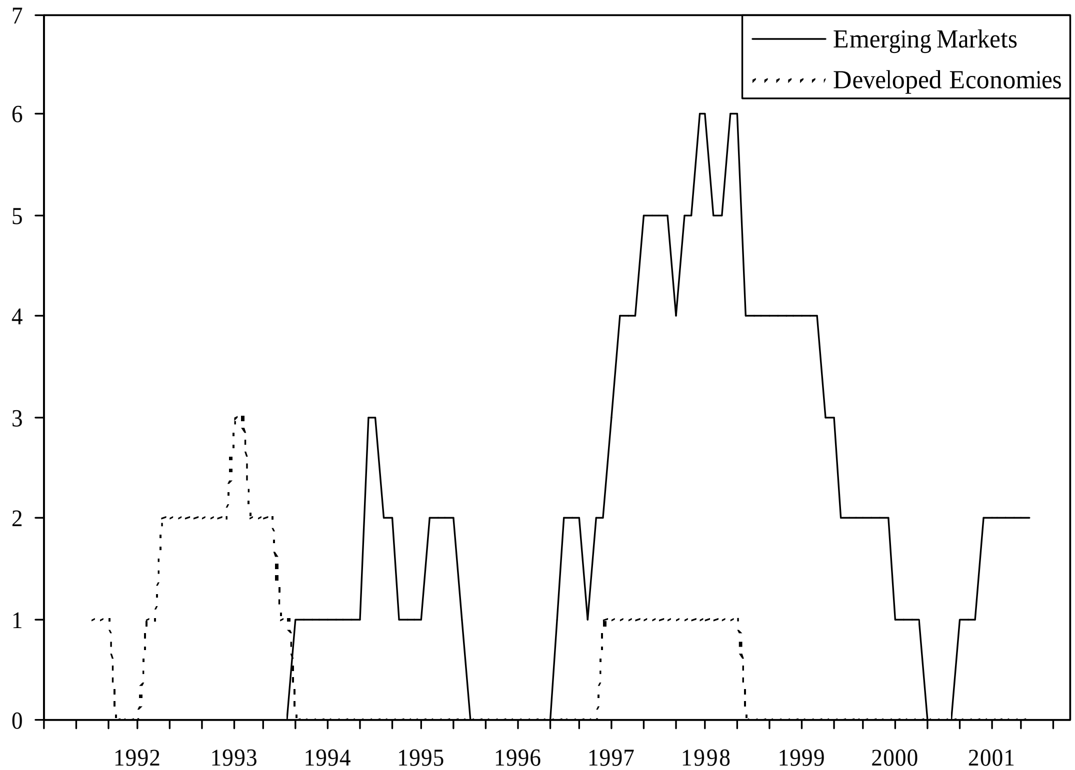
[27] For a detailed treatment of the Latin American episodes see Calvo, Izquierdo and Talvi (2002).

Figure 2
Real Exchange Rate Depreciation Dummy (20%) vs. Sudden Stop Dummy, 1992-2001
Developed Economies



Note: Tall grey areas indicate Sudden Stop periods. Short black areas indicate intervals of large RER depreciation.

Figure 3
The Bunching of Sudden Stops Events
Emerging Markets vs. Developed Economies



Note: The sample of countries includes 15 EMs and 17 developed countries.

Next, we discuss a set of relevant statistics regarding Sudden Stops that we summarize in Table 1. It is particularly interesting to note that for EMs only 37 percent of all depreciation episodes *were not* associated with a Sudden Stop. This figure is even smaller (25 percent) once we exclude South Africa, which captures three out of the seven episodes of depreciation without Sudden Stops in EMs. South Africa is a particularly interesting case, given that it was identified in previous work by Calvo and Reinhart (2000) as one of the few EMs without "fear of floating", resembling in this respect the behavior of developed economies. Results change dramatically for developed countries, where 83 percent of all depreciation episodes were not associated with a Sudden Stop. This is a clear indication that, unlike the case of EMs, capital markets for developed countries are more likely to remain open during currency crises. Within the developed-country sample, newcomers to the European Union (Portugal and Spain) experienced half of the Sudden Stop episodes. This evidence suggests that Sudden Stops are typically events associated with EMs, and sometimes even with countries that have recently graduated into the group of highly developed economies.

The next question that we address is whether, in episodes in which large real currency depreciation lies in the neighborhood[28] of a Sudden Stop, capital flow reversal comes first, or depreciation comes first. Our sample does not provide a clear-cut answer, but there is some evidence that capital flow reversals may precede high real depreciation, as indicated by the fact that 63 percent of the time capital reversals come first. This figure increases slightly (to 67 percent) for EMs (see Table 1).[29]

Table 1
Sudden Stop Statistics

In % of total

	Emerging Markets	Developed Economies
Devaluations <u>associated</u> with Sudden Stop	63	17
Of which: First Sudden Stop, then devaluation	42	9
First devaluation, then Sudden Stop	21	9
Devaluations <u>not associated</u> with Sudden Stop	37	83

Note: The total number of large devaluations is 19 in emerging markets and 23 in developed economies.

[28] Defined as a one-year-window before and after a Sudden Stop.
[29] Granger-causality-type tests of the effects of a Sudden Stop on depreciation and vice versa (using a Probit model to measure the joint significance of depreciation lags on the probability of a Sudden Stop, and another Probit to measure the joint significance of Sudden Stop lags on depreciation) do not provide a conclusive answer.

Another element of the characterization of Sudden Stop episodes that we are interested in is the behavior of key macroeconomic variables at the time of a Sudden Stop. In particular, we focus our attention on the performance of real interest rates, foreign reserves and the current account balance. Appendix Table 3 shows the average behavior of real money market interest rates from trough to peak in a two-year window centered at the beginning of a Sudden Stop episode, both for EMs and developed countries, as well as for the whole sample. Clearly, real interest rates rise sharply in the neighborhood of a Sudden Stop (on average, 3900 basis points), particularly so for EMs (on average, 4670 basis points). Thus, we conjecture that Sudden Stops are mainly capturing supply-side shifts in capital markets.

Let us now examine the behavior of foreign reserves in the neighborhood of Sudden Stops. We do this in order to check to what extent countries have used reserves to smooth out the effect of a Sudden Stop on the current account deficit. Even though this is in principle a losing strategy if Sudden Stop events are highly persistent (reserves will typically not be enough to sustain a current account deficit for a long time), many countries have engaged in reserve loss strategies to sustain exchange rates and avoid abrupt current account adjustment, perhaps in the hope that Sudden Stops would be reversed. Indeed, as discussed in Calvo (2003), under a Sudden Stop, a Central Bank may have incentives to hand its reserves to credit constrained non-tradable corporate sectors via credit expansion (a strategy that requires keeping a quasi-fixed exchange rate). As shown in Appendix Table 3, there is a substantial reserve loss from peak to trough within the Sudden Stop phase (on average, 35.7 percent) for every country in our sample.

We also keep track of current account balance behavior in times of Sudden Stops. The important point to notice here is that Sudden Stops bring along abrupt current account adjustment, reflecting the disruption in international credit markets. This is presented in Appendix Table 3. As expected, the toll of capital reversals and current account adjustment is much more substantial in EMs than in developed countries. The average increase from trough to peak in the current account balance[30] is of 6.1 percent of GDP in EMs, while it is only 1.1 in developed economies. These results are akin to those found in Calvo and Reinhart (2000).

IV. Determinants of Sudden Stops: Empirical Analysis

Having examined the empirical characteristics of Sudden Stops, we now turn to a search for Sudden Stop determinants. The theories discussed in Section II suggest a set of factors that exacerbate an economy's vulnerability to Sudden Stops: The degree of domestic liability dollarization (both in the private and public sectors), as well as the sensitivity of the RER to capital flow reversals, which is related to the degree of openness (measured by the size of the supply of tradable goods relative to demand of tradable goods). The latter becomes clear once we examine equation (5), which shows that the size of the increase in the RER[31] depends on the percentage fall in the absorption of tradables needed to close the current account gap (CAD/Z). As a matter of fact, the less leveraged the absorption of tradable goods is, the smaller will be the effect on the RER. To see this, rewrite CAD/Z as:

$$\frac{CAD}{Z} = \frac{Z - Y + S}{Z} = 1 - \frac{Y - S}{Z} = 1 - w \,, \quad (6)$$

[30] In a two-year interval centered at the beginning of a Sudden Stop.
[31] An increase means a real depreciation of the currency.

where w is defined as $w = (Y - S)/Z$. It is evident that the more open an economy is, (defining openness as a higher value of the supply of tradables (Y)), the smaller will be the financing from abroad (or leverage) of the absorption of tradables, $(Z - Y + S)/Z$. Following Calvo, Izquierdo and Talvi (2002), we rely on 1-*w* for our estimations, given that it represents a key summary variable to assess the impact of a Sudden Stop on relative prices, since it measures the leveraged portion of the absorption of tradables. Thus, higher values of 1-*w* mean that a country relies less on its own financing of the absorption of tradables, and is therefore more vulnerable to RER depreciations stemming from closure of the current account gap.

In order to construct a measure of 1-*w* for each of the 32 countries in our sample, we need to obtain a value for the absorption of tradable goods (*Z*), which is composed of imports plus a fraction of the supply of tradable goods. We do this by proxying tradable output by the sum of agriculture plus industrial output, i.e., we exclude services from total output (for these and all other variables used in this section, see the Data Appendix for details on definitions and sources). Next, we obtain the fraction of tradable output consumed domestically by subtracting exports from tradable output, and add imports to the latter in order to get a measure of *Z*. Having computed values for *Z*, and using CAD data, we get values for 1-*w* as indicated by equation (6).

We use as a benchmark a panel Probit model[32][33] that estimates the probability of falling into a Sudden Stop regime as a function of lagged values of 1-*w* and DLD,

[32] We use random effects to control for heterogeneity across panel members.
[33] The use of a Probit model and the construction of a dichotomous Sudden Stop variable are due to our belief that large and unexpected capital flow reversals have non-linear effects, as they trigger substantial balance-sheet fluctuations that may lead to serious credit constraints or plain bankruptcies. An alternative, which is not explored in this paper, would be to use regime-switching models.

controlling for time effects using yearly dummies. In order to reduce endogeneity issues, and given that many of the variables used in our estimations come at an annual frequency, we switch to yearly data.[34] DLD is defined as BIS reporting banks' local asset positions in foreign currency as a share of GDP. Such data is not available for EMs, so we construct a proxy by adding up dollar deposits and bank foreign borrowing as a share of GDP. Under the assumption that banks are matched by currency in their assets and liabilities, then this measure should be a good proxy for liability dollarization[35]. Following related literature on determinants of crises, we also include a set of macroeconomic control variables, which we describe later. We lag variables[36] to avoid endogeneity problems. We are particularly interested in lagged *w* because it proxies for the potential change in relative prices that could occur were the country to face a Sudden Stop, something that would not be conveyed by contemporaneous *w* once the current account gap is closed and relative prices have adjusted.

Regression results, presented in Appendix Table 4, indicate that both 1-*w* and DLD are significant at the 1% level in almost every specification, underscoring the relevance of *w* as an indicator of potential Sudden Stops, taken here as a signal of the potential change in relative prices that could materialize at the time of a Sudden Stop. These results withstand the inclusion of a set of other control variables, such as the ratio of foreign reserves to CAD (a measure of the ability to finance CAD, at least initially), private sector credit growth, total public debt, FDI and the public sector balance (all expressed as shares of GDP), and

[34] Thus, lagged observations are one year apart from contemporaneous observations.
[35] Data on dollar deposits is mainly that in Honohan and Shi (2003), see the Data Appendix for a full description.
[36] Except for terms-of-trade growth, which is included contemporaneously.

terms of trade growth, as well as two different measures of exchange rate flexibility, and an EM dummy.

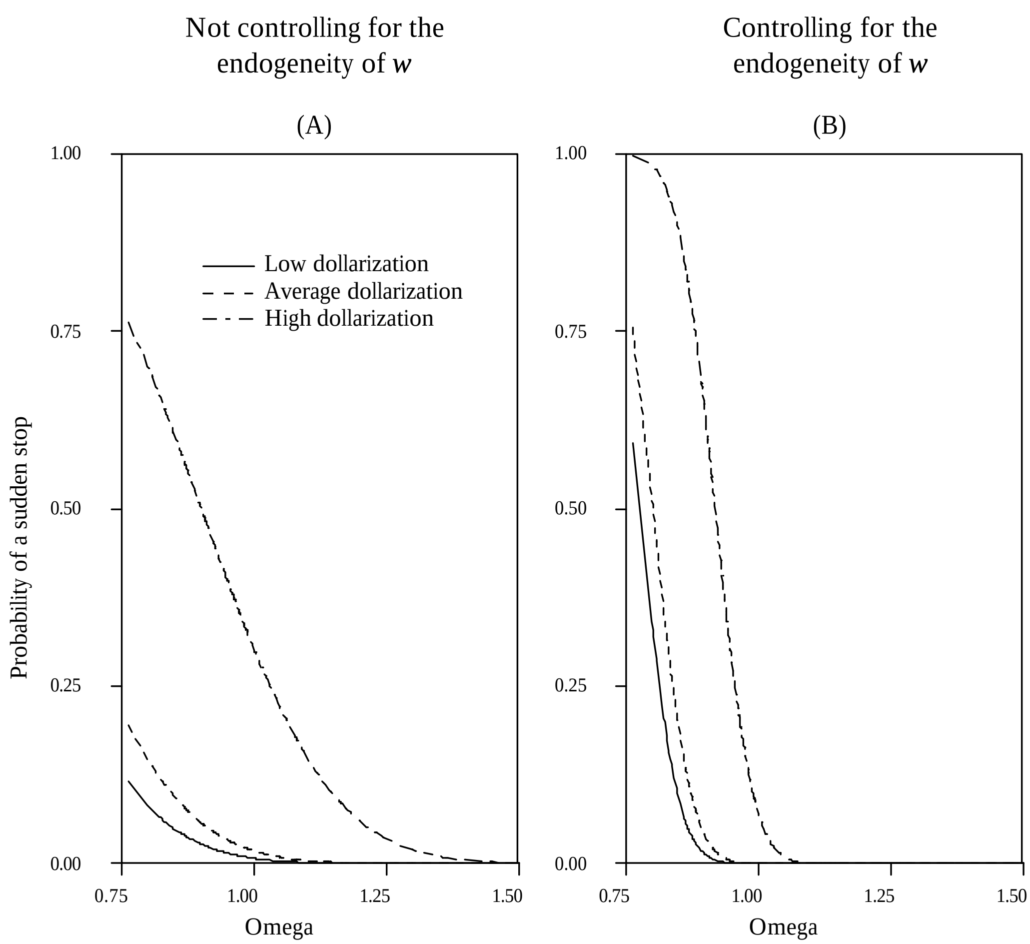
Having accounted for the relevance of w and DLD in explaining the likelihood of a Sudden Stop, we now focus on their interaction, which is particularly amenable to Probit models. We find that the effects of w on the probability of a Sudden Stop crucially depend on the degree of DLD. Low values of w (high leverage of CAD) imply a higher probability of Sudden Stop, but this is particularly so for dollarized economies. Consider, for example, the effects of varying w on the probability of a Sudden Stop, keeping all other variables constant at their means, except for DLD, which could be low (5^{th} percentile in our sample), average, or high (95^{th} percentile). This is represented in Figure 4 (panel A).[37] For small values of w, there are substantial differences in the probability of a Sudden Stop depending on whether DLD is low or high. Take, for example, any two countries with a value of w of 0.76 (the lowest measure of w in our sample), and assume that the first country is highly dollarized (medium-dash line), whereas the second country is not (solid line). The probability of a Sudden Stop in the highly dollarized country exceeds that of the lowly dollarized country by about 0.65. Now evaluate this difference for the same two countries when w is equal to 1 (i.e., when $CAD = 0$). The difference in the probability of a Sudden Stop is now only about 0.30, about half the difference at the lower w level. The high non-linearity described by the data implies that low w and high dollarization can be a very dangerous cocktail, as potential balance sheet effects become highly relevant in determining the probability of a Sudden Stop.

[37] We use model (1) in Table 4 of the Appendix to construct this figure.

The effects of DLD on the probability of a Sudden Stop are particularly important for EMs. As of end-2001, 78 percent of EMs in our sample lay above the dollarization median, whereas 76 percent of developed countries lay below the dollarization median. This helps in rationalizing why the EM dummy included in our estimations turned out not to be significant, as dollarization seems to capture appropriately a key difference between these groups.

Figure 4

Probability of a Sudden Stop for Different Values of *w* and Domestic Liability Dollarization in the Average Country



We now turn to the remaining set of variables used as controls in our regressions. First, we focus on two measures of exchange rate regime flexibility that were used alternatively in the estimations presented in Appendix Tables 4 and 5. These measures are those constructed by Levy-Yeyati and Sturzenegger (2002), who classify the flexibility of exchange rate regimes based on exchange rate volatility, exchange-rate-changes volatility, and foreign reserves volatility. The first, narrower measure, classifies regimes into floating regimes, intermediate regimes, and fixed regimes, while the second measure extends this classification to 5 categories. This first pass suggests that neither of these two measures of exchange rate flexibility turns out to be significant for the whole sample, although results are different for the EM group when we estimate later on a linear probability model that controls for endogeneity due to unobserved common factors.[38] Although this finding may seem puzzling, it can be explained by the fact that the loss of access to international credit is a real phenomenon with real effects such as output contraction, which in principle does not rely on the behavior of nominal variables. Indeed, the framework presented in Section II does not rely on any particular nominal setup to explain the change in relative prices following a Sudden Stop, which would materialize under both flexible and fixed exchange rate regimes. As a matter of fact, models that provide a full-fledged version of the effects of Sudden Stops on output such as Izquierdo (1999), Arellano and Mendoza (2002), and Calvo (2003) are concerned with real effects that are independent of nominal arrangements. Of course, this does not rule out very different short-term dynamics, which are likely to be dependent on nominal arrangements, as was evidenced by the very dissimilar behavior of several Latin American economies after the Sudden Stop triggered by the Russian crisis of 1998. Even though all countries hit by Sudden Stops eventually experienced substantial

[38] See the section on robustness checks and Appendix Table 9.

real currency depreciation and output loss, the dynamics were very different for countries like Colombia, for example, which quickly depreciated its currency and withstood the real shock sooner, and Argentina, which took much longer to correct the resulting RER misalignment[39] Other macroeconomic variables that we added for control, including the ratio of foreign reserves to CAD, credit growth, FDI, government balance, terms of trade growth, and public sector debt, do not turn out to be significant at the 5 percent level.[40] This is consistent with other empirical work on the determinants of crises that do not find a strong relationship between most of these variables and the probability of a crisis. Of particular interest to us was public sector debt, because one would expect that highly indebted countries would be more susceptible to capital flow reversals, as suggested by Calvo (2003) (see Section II for a discussion). We tried four different versions of total public sector debt: its share to GDP, the debt-to-revenue ratio[41], the debt-to-GDP ratio scaled by its de-trended standard deviation, as well as the debt-to-GDP ratio interacted with an EM dummy. The last three transformations attempt to capture the fact that developed countries are able to sustain higher levels of debt relative to GDP because they have a higher tax base to support the debt-servicing burden, or because the demand for public bonds is less volatile, or simply because other factors (including their reputation in terms of willingness or ability to pay) fare better than for EMs. Despite all these plausible considerations, public debt in any of these variations turns out not to be statistically significant at the 10 percent level. We also worked with the external debt-to-exports ratio to capture the ability to support the external debt-servicing burden as an explanatory

[39] See Calvo, Izquierdo and Talvi (2002) for a more detailed discussion.
[40] At least when not controlling for potential endogeneity of ω. We address this issue later on (see page 30).
[41] For space reasons, only this variable is reported in our estimations. Other estimations are available upon request.

variable, with similar results. Finally, in the same vein as our DLD variable, we included a proxy of public dollar-denominated debt as a share of GDP to account for potential balance sheet effects in the public sector. This variable also turns out not to be significant at the 10 percent confidence level. To control for the fact that instead of public debt, it may be total foreign debt that is responsible for determining the likelihood of Sudden Stop, we also constructed a proxy for total debt by adding up current account balances from 1982 onwards.[42] This figure was later normalized by either GDP or government revenues. These measures did not turn out significant either. These results suggest that public debt or total foreign debt stocks are not clear factors that determine the likelihood of a Sudden Stop. The fact that w as well as domestic DLD remain significant, while debt measures do not, suggests that valuation effects, coupled with the materialization of contingent liabilities resulting from public sector takeover of private debts with the financial system may be key in explaining the likelihood of a Sudden Stop.[43] This assertion is particularly relevant for cases like Korea, where public sector debt represented only 10 percent of GDP prior to its 1997 Sudden Stop, before quadrupling once the financial sector bailout was added to the fiscal burden.

Robustness Checks

Using the EM Sample. In order to address the fact that all efforts to account for debt as a determinant of the likelihood of a Sudden Stop were unsuccessful, and that this failure could be due in part to problems in accounting for differences between EMs and developed

[42] We chose 1982 as the starting date because several EMs defaulted on their obligations prior to 1982. Thus, it would be incorrect to add current account balances prior to this date, since they were not necessarily paid off.

[43] Models such as Calvo (2003) should therefore be extended to include a financial sector as well as debt in both tradable and non-tradable goods.

countries regarding the size of debt levels deemed sustainable by capital markets, we repeat our estimations, this time only for the EM group. Interestingly, we confirm the same results reached with the full dataset (see Appendix Table 5). Both w and domestic DLD remain significant at the 5% level, whereas the ratio of total debt to fiscal revenues does not (as well as all other measures of public debt mentioned above), even after controlling for the same set of macroeconomic variables used in previous estimations, thus indicating the robustness of w and DLD to the choice of panel members.

Further Addressing Endogeneity. One issue we have not yet fully covered is that there may be room for endogeneity between w_{t-1} and the latent variable behind Sudden Stops (capital flows) due to unobserved and persistent characteristics common to both variables. Such would be the case of variables proxying credibility or political factors. To tackle this potential endogeneity problem, we carried out a Rivers-Vuong test to the estimations previously presented in Appendix Tables 4 and 5.[44] Based on the results of this test (see Appendix Tables 6 and 7), we cannot reject the presence of endogeneity since the residuals obtained in the first stage of this method appear to be significant.[45] Therefore, in order to assess the significance of all variables included in the estimations in the presence of endogeneity, we need to construct appropriate measures of the standard deviation of their coefficient estimators, as standard test statistics are no longer valid. In order to do this, and

[44] Probit models can be reduced to latent variable models. For this particular case where endogeneity in w is suspected, a system of two equations can be defined, one representing the latent variable behind the Sudden Stop variable (which is assumed to be a linear function of all variables in the Probit, including w), the other representing w, which is considered to be a linear function of all other variables included in the Probit estimation, as well as a lag in w. Residuals from this second regression are included in the Probit regression to determine their significance. If the latter are significant, endogeneity cannot be rejected. For further details, see Rivers and Vuong (1988), or Wooldridge (2002).

[45] In the first stage, we used all the other explanatory variables in the corresponding equation and the second lag of w as instruments of the potentially endogenous variable (w_{t-1}).

given the presence of random effects, we rely on a non-parametric hierarchical two-step bootstrap methodology. Random effects introduce an intra-group correlation structure among observations. This is accounted for by first randomly sampling countries with replacements, and, in a second stage, randomly sampling without replacement within the countries sampled in the first stage. According to Davison and Hinkley (1997), this procedure closely mimics the intra-group correlation structure of the data mentioned above (see the Technical Appendix for a detailed explanation). Confidence intervals are computed using the percentile method at a 5 percent significance level, based on 500 replications.

Using bootstrapped confidence intervals, we confirm that both 1-*w* and domestic liability dollarization remain significant at the 5 percent level even after controlling for endogeneity. Results for the whole sample of countries are reported in Appendix Table 6. It is worth considering that, in particular, the coefficient accompanying 1-*w* increases substantially compared to results shown in Appendix Table 4, indicating that the relevance of 1-*w* increases once controlling for endogeneity.[46] This can be seen graphically by replicating panel (A) of Figure 4 with the new estimates, to show that the non-linear effect of *w* on the probability of a Sudden Stop increases compared to previous estimates that do not control for endogeneity (panel B of Figure 4).

Further Addressing Endogeneity for EMS. Results for 1-*w* and domestic liability dollarization remain significant at the 5 percent level when we apply a Rivers-Voung correction to the EM country sample. One additional interesting result emerges after

[46] None of the previous point estimates of the coefficient accompanying 1-*w* in Appendix Table 4 fall within the confidence interval shown in Appendix Table 6.

controlling for endogeneity: Terms of trade growth becomes a significant variable throughout our set of estimations (see Appendix Table 7), with a negative coefficient indicating that falls in terms of trade growth increase the likelihood of a Sudden Stop. This result is consistent with the case made by Caballero and Panageas (2003) that in countries where commodities are relevant, a fall in commodity prices may be accompanied by a Sudden Stop, thus amplifying the original shock.

Linear Probability Model Estimation. To check the robustness of our results, we also estimate a linear probability model. Despite its limitations,[47] this approach lets us control for endogeneity using standard two stages least squares[48] techniques, and it is amenable to the introduction of fixed effects to capture country-specific differences.[49] The obtained results (see Appendix Tables 8 and 9) show that previous results remain valid: both 1-*w* and the degree of DLD are significant determinants of the probability of a Sudden Stop at the 5% confidence level in most specifications, both for our full sample, as well as for EMs only. For the EM group, terms-of-trade growth does show up as a significant variable at the 10 percent significance level. Interestingly, the coefficient accompanying exchange rate regime measures does come up positive and significant at the 5 percent level, implying that, controlling for dollarization, fixed exchange rate regimes may increase the likelihood of a Sudden Stop. However, these results are not robust to the Rivers-Voung specification shown earlier (see Appendix Tables 8 and 9).

[47] Such as the fact that probability is not necessarily constrained to the [0,1] interval.
[48] As in the Rivers-Vuong estimation, we use all other variables previously included in the Probit as well as the second lag of *w* as instruments of the potentially endogenous variable (w_{t-1}).
[49] A control that cannot be applied to the panel Probit estimation without a significant loss in observations.

Another relevant robustness check is that an interaction term between 1-*w* and DLD comes up significant in the linear estimation, both for the whole sample as well as for EMs only, confirming results shown with Probit analysis indicating that the combination of dollarization and low values of *w* can be dangerous in terms of amplifying the probability of a Sudden Stop.

V. Conclusions

Focusing on the characteristics and determinants of large capital flow reversals for a set of EMs and developed countries, we obtained a few key suggestive empirical findings that open up several areas of research. We summarize them as follows:

- Large RER fluctuations coming hand in hand with Sudden Stops are basically an EM phenomenon. In contrast, developed countries can sustain large depreciations while keeping their capital account open.
- Sudden Stops seem to come in bunches, grouping together countries that are different in many respects, such as fiscal stance, monetary and exchange rate arrangements. However, countries are similar in that they remain vulnerable to large RER fluctuations—be it because they could be forced to large adjustments in the absorption of tradable goods, and/or because the size of their dollar liabilities in the banking system is high.
- This particular type of bunching suggests that when analyzing Sudden Stops, careful consideration should be given to financial vulnerabilities to external shocks, rather than

to arguments relying only on unsustainable domestic policies that may exhibit sharp reversals.

- Sudden stops are accompanied by large interest rate upswings, reserve losses and large current account adjustment, suggesting that these phenomena are associated with shifts in the supply of capital flows.
- Openness, understood as a large supply of tradable goods relative to absorption of tradable goods, and Domestic Liability Dollarization, are key determinants of the probability of a Sudden Stop.
- Both Openness and the structure of Balance Sheets are the result of *domestic* policies. Countries may be tested by foreign creditors, but vulnerability to Sudden Stops is purely due to domestic factors, such as tariff and competitiveness policies affecting the supply of tradable goods, and badly managed fiscal and monetary policies that result in Domestic Liability Dollarization.
- The effect of Openness and Liability Dollarization on the probability of a Sudden Stop could be highly non-linear. In particular, high current account leverage and high Domestic Liability Dollarization could be a dangerous cocktail.

Although our work has established the empirical relevance of balance-sheet effects on the likelihood of Sudden Stops, it does not cover another topic that represents an important extension of research, namely, the consequences of Sudden Stops and balance sheet effects on economic growth, particularly in dollarized economies[50]. We leave this significant topic for future analysis.

[50] Relevant work in this direction has recently been conducted by Edwards (2003).

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Appendix Table 1

AR(1) Coefficients of Changes in the Trade Balance (in absolute value)

Emerging Markets		Developed Economies	
Argentina	0.170	Australia	0.506
Brazil	0.305	Canada	0.487
Chile	0.373	Denmark	0.540
Colombia	0.386	Finland	0.487
Czech Rep.	0.585	France	0.479
Ecuador	0.431	Germany	0.477
Indonesia	0.413	Italy	0.536
Korea	0.445	Japan	0.454
Mexico	0.230	Netherlands	0.481
Nigeria	0.302	Norway	0.502
Peru	0.374	New Zealand	0.500
Philippines	0.383	Portugal	0.475
South Africa	0.558	Spain	0.518
Thailand	0.431	Sweden	0.541
Turkey	0.340	Switzerland	0.505
		United Kingdom	0.473
		United States	0.456
Min.	0.170	Min.	0.454
Max.	0.585	Max.	0.541
Average	0.382	Average	0.495

Appendix Table 2

Costless Capital Flow Reversals Statistics

In % of Total

	Emerging Markets	Developed Economies
Associated with and Increase in Terms of Trade	62	60
Not Associated with and Increase in Terms of Trade	38	40

Note: The total number of costless capital flow reversals is 26 in emerging markets and 30 in developed economies.

Appendix Table 3

Trough to Peak Differences in a Two-year Window Centered Around the Beginning of a Sudden Stop, Selected Variables

	Current Account Balance (% of GDP)	Real Foreign Reserves (% change)	Real Interest Rates (%)
Argentina-94	1.40	-40.95	20.36
Argentina-99	1.75	-14.17	0.97
Argentina-01	13.43	-48.61	48.05
Chile-98*	4.57	-22.30	24.15
Colombia-98	6.24	-18.29	36.28
Czech Republic-97	4.94	-33.44	13.97
Ecuador-99*	15.63	-72.90	10.37
Germany-93	-0.43	-43.03	1.05
Indonesia-97	7.41	-24.48	102.16
Japan-97	1.62	-10.68	3.88
Korea-97	17.15	-41.14	21.49
Mexico-94	5.25	-85.16	56.07
Peru-97*	0.58	-6.58	11.03
Philippines-97	6.85	-31.54	20.20
Portugal-92	1.19	-40.53	11.71
Spain-92	2.48	-44.12	3.69
Sweden-92	0.57	-35.52	68.79
Thailand-96	5.82	-37.22	17.34
Turkey-94	2.44	-53.06	132.08
Turkey-98	0.41	-10.94	23.31
Turkey-01	4.04	-34.89	209.02
Emerging Markets	6.12	-35.98	46.68
Developed Economies	1.09	-34.78	17.82
Overall sample	4.92	-35.69	39.81

* Due to lack of data on money market rates, lending rates were used instead.

Appendix Table 4

Panel PROBIT

All Countries – Dependent Variable: Sudden Stop Indicator

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1- ν	5.193	4.812	4.915	4.745	4.825	4.818	6.099
	(1.836)***	(1.834)***	(1.841)***	(1.842)***	(1.849)***	(1.848)***	(2.402)**
DLD	7.924	7.009	6.948	6.961	7.106	7.104	7.513
	(2.183)***	(2.255)***	(2.267)***	(2.275)***	(2.292)***	(2.290)***	(3.090)**
EM Dummy		0.460	0.463	0.473	0.444	0.443	0.174
		(0.403)	(0.405)	(0.396)	(0.398)	(0.398)	(0.586)
TOT Growth			-1.383	-1.369	-1.380	-1.371	-1.857
			(2.220)	(2.212)	(2.216)	(2.218)	(2.299)
Total Debt over Revenues				0.014	0.009	0.009	0.026
				(0.115)	(0.116)	(0.116)	(0.131)
Ex. Regime 3					0.028		
					(0.165)		
Ex. Regime 5						0.019	0.001
						(0.109)	(0.130)
Reserves over CAD							-0.003
							(0.006)
M2 over Reserves							-0.036
							(0.031)
Credit Growth							-1.919
							(1.341)
FDI/GDP							-1.372
							(9.096)
Public Balance/GDP							2.382
							(6.386)
Constant	-3.393	-3.550	-3.558	-3.563	-3.599	-3.610	-3.154
	(0.762)***	(0.790)***	(0.788)***	(0.812)***	(0.876)***	(0.896)***	(1.132)***
Observations	302	302	302	298	296	296	294

All regressions include time dummies

Standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Appendix Table 5

Panel PROBIT

Emerging Markets – Dependent Variable: Sudden Stop Indicator

	(1)	(2)	(3)	(4)	(5)	(6)
1- ν	4.709	4.979	4.546	5.102	4.994	5.690
	(2.127)**	(2.148)**	(2.089)**	(2.226)**	(2.180)**	(2.240)**
DLD	4.719	4.638	4.604	5.006	4.911	4.073
	(1.949)**	(1.970)**	(1.917)**	(2.141)**	(2.125)**	(1.623)**
TOT Growth		-1.801	-1.759	-1.639	-1.568	-2.514
		(2.253)	(2.250)	(2.246)	(2.249)	(2.336)
Total Debt over Revenues			-0.098	-0.118	-0.105	-0.087
			(0.137)	(0.149)	(0.146)	(0.130)
Ex. Regime 3				0.359		
				(0.239)		
Ex. Regime 5					0.222	0.134
					(0.155)	(0.125)
Reserves over CAD						0.014
						(0.010)
M2 over Reserves						-0.068
						(0.059)
Credit Growth						-1.067
						(1.155)
FDI/GDP						-18.102
						(10.227)*
Public Balance/GDP						-3.027
						(5.009)
Constant	-2.630	-2.651	-2.424	-3.155	-3.234	-2.117
	(0.726)***	(0.721)***	(0.755)***	(0.969)***	(1.019)***	(0.834)**
Observations	138	138	134	134	134	132

All regressions include time dummies

Standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Appendix Table 6

Panel PROBIT – Rivers & Vuong Approach

All Countries – Dependent Variable: Sudden Stop Indicator

Estimates and Bootstrapped Confidence Intervals

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Residuals	-12.654**	-12.590**	-14.154**	-14.100**	-14.053**	-13.912**	-18.700**
	[-25.5, -3.8]	[-30.1, -4.5]	[-34.5, -3.8]	[-354, -4.5]	[-40.1, -4.7]	[-44.3, -4.5]	[-72.1, -5.3]
1- v	17.909**	17.722**	19.597**	19.040**	19.014**	18.743**	24.471**
	[9.8, 35.6]	[9.2, 40.3]	[9.6, 48.8]	[8.1, 45.8]	[9.7, 57.2]	[9.7, 57.0]	[10.0, 100.9]
DLD	10.569**	10.831**	10.665**	10.651**	10.766**	10.672**	12.070**
	[6.2, 20.8]	[6.0, 23.9]	[5.6, 28.6]	[5.8, 25.1]	[6.3, 26.7]	[6.2, 27.6]	[6.5, 50.8]
EM Dummy		-0.054	-0.081	-0.141	-0.170	-0.157	-1.622
		[-1.4, 2.3]	[-1.7, 2.1]	[-1.4, 2.5]	[-1.8, 2.5]	[-1.8, 3.0]	[-5.7, 2.5]
TOT Growth			-4.436	-4.612	-4.581	-4.581	-4.369
			[-15.3, 2.4]	[-16.4, 1.8]	[-16.8, 2.4]	[-16.8, 1.9]	[-13.1, 5.4]
Total Debt over Revenues				-0.111	-0.118	-0.121	-0.121
				[-1.1, 0.3]	[-1.2, 0.4]	[-1.4, 0.4]	[-1.5, 0.7]
Ex. Regime 3					0.022		
					[-0.5, 0.9]		
Ex. Regime 5						0.035	-0.091
						[-0.4, 0.7]	[-0.5, 1.0]
Reserves over CAD							-0.004
							[-0.01, 0.03]
M2 over Reserves							-0.132**
							[-0.6, -0.03]
Credit Growth							-1.539
							[-13.5, 1.7]
FDI/GDP							-5.532
							[-55.3, 24.5]
Public Balance/GDP							25.875
							[-2.6, 80.1]
Constant	-4.055**	-4.065**	-4.229**	-3.872**	-3.857**	-3.893**	-1.514
	[-7.1, -2.8]	[-8.2, -2.9]	[-9.0, -2.8]	[-8.8, -2.7]	[-10.6, -2.7]	[-11.4, -2.8]	[-13.5, 0.6]
Observations	302	302	302	298	296	296	294

** Significant at the 5 percent level using bootstrapped confidence interv als constructed by the percentile method, shown in brackets.

Note: Larger models, including several variables, show wide confidence intervals. Instability in the random effects estimator may arise when the dimension of the problem is increased and the number of individual observations is low (Guilkey and Murphy (1993)). These facts point towards keeping the dimension of the model relatively low. Yet, even for the more problematic cases, both 1-*w* and DLD remain significant at the 5 percent level.

Appendix Table 7
Panel PROBIT – Rivers & Vuong Approach
Emerging Economies – Dependent Variable: Sudden Stop Indicator
Estimates and Bootstrapped Confidence Intervals

	(1)	(2)	(3)	(4)	(5)	(6)
Residuals	-19.480**	-22.569**	-24.485**	-27.164**	-28.273**	-22.988**
	[-71.3, -8.3]	[-97.1, -9.3]	[-103.6, -11.1]	[-144.8, -11.7]	[-173.2, -16.0]	[-422.5, -14.8]
1- v	23.790**	27.131**	28.433**	31.704**	32.777**	23.984**
	[13.5, 92.2]	[16.4, 119.6]	[17.8, 144.5]	[19.3, 181.6]	[19.8, 201.2]	[18.5, 5548.5]
DLD	10.149**	9.816**	9.725**	10.822**	11.001**	6.877**
	[7.1, 30.7]	[6.2, 39.0]	[6.3, 44.0]	[6.7, 52.6]	[6.8, 62.7]	[4.8, 1393.9]
TOT Growth		-7.077**	-7.621**	-8.502**	-8.663**	-7.512**
		[-31.5, -1.0]	[-36.6, -1.4]	[-43.1, -2.0]	[-54.6, -3.1]	[-1500.5, -1.0]
Total Debt over Revenues			-0.258	-0.301	-0.300	-0.303
			[-1.7, 0.1]	[-2.0, 0.1]	[-2.3, 0.2]	[-47.2, 0.1]
Ex. Regime 3				0.305		
				[-0.2, 2.1]		
Ex. Regime 5					0.210	0.029
					[-0.2, 1.4]	[-0.4, 30.9]
Reserves over CAD						0.009**
						[0.004, 1.6]
M2 over Reserves						-0.018
						[-2.3, 1.5]
Credit Growth						-2.000
						[-513.0, 0.1]
FDI/GDP						-14.165
						[-183.3, 535.8]
Public Balance/GDP						-6.453
						[-936.2, 64.5]
Constant	-3.563**	-3.735**	-3.282**	-4.122**	-4.365	-2.159
	[-11.5, -2.8]	[-14.1, -2.9]	[-15.6, -2.4]	[-23.6, -2.7]	[-27.4, -2.8]	[-512.9, -1.0]
Observations	138	138	134	134	134	132

** Significant at the 5 percent level using bootstrapped confidence intervals constructed by percentile method, shown in brackets.

Note: Larger models, including several variables, show wide confidence intervals. Instability in the random effects estimator may arise when the dimension of the problem is increased and the number of individual observations is low (Guilkey and Murphy (1993)). These facts point towards keeping the dimension of the model relatively low. Yet, even for the more problematic cases, both 1-*w* and DLD remain significant at the 5 percent level.

Appendix Table 8

Linear Probability Model with Fixed Effects

Two-Stage Estimation

All Countries – Dependent Variable: Sudden Stop Indicator

	(1)	(2)	(3)	(4)	(5)	(6)
(1- v)	1.148	1.260	1.290	1.376	1.374	1.385
	(0.457)**	(0.481)***	(0.507)**	(0.532)**	(0.535)**	(0.543)**
DLD	1.722	1.674	1.628	1.818	1.818	2.009
	(0.424)***	(0.428)***	(0.454)***	(0.450)***	(0.450)***	(0.465)***
(1- v)*DLD	4.486	4.459	4.211	4.366	4.322	4.610
	(1.773)**	(1.773)**	(1.807)**	(1.813)**	(1.815)**	(1.871)**
TOT Growth		-0.541	-0.568	-0.615	-0.615	-0.500
		(0.365)	(0.371)	(0.378)	(0.380)	(0.373)
Total Debt over Revenues			-0.027	-0.032	-0.032	-0.027
			(0.026)	(0.026)	(0.026)	(0.028)
Ex. Regime 3				0.017		
				(0.030)		
Ex. Regime 5					0.012	0.013
					(0.020)	(0.021)
Reserves over CAD						-0.001
						(0.001)
M2 over Reserves						-0.007
						(0.003)**
Credit Growth						-0.196
						(0.103)*
FDI/GDP						0.534
						(0.883)
Public Balance/GDP						1.458
						(0.812)*
Constant	-0.113	-0.110	-0.048	-0.079	-0.086	0.017
	(0.059)*	(0.059)*	(0.084)	(0.097)	(0.102)	(0.117)
Observations	302	302	298	296	296	294
R-squared	0.23	0.23	0.24	0.25	0.25	0.27

All regressions include time dummies
Standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Appendix Table 9
Linear Probability Model with Fixed Effects
Two-Stage Estimation
Emerging Markets – Dependent Variable: Sudden Stop Indicator

	(1)	(2)	(3)	(4)	(5)	(6)
(1- ν)	2.396	2.736	2.877	2.794	2.731	2.076
	(1.011)**	(1.111)**	(1.203)**	(1.250)**	(1.267)**	(1.331)
DLD	1.837	1.885	1.712	1.749	1.735	1.272
	(0.663)***	(0.666)***	(0.724)**	(0.717)**	(0.720)**	(0.732)*
(1- ν)* DLD	4.351	4.359	4.379	4.607	4.529	6.645
	(2.508)*	(2.511)*	(2.621)*	(2.579)*	(2.583)*	(2.831)**
TOT Growth		-1.110	-1.178	-1.125	-1.106	-0.805
		(0.600)*	(0.628)*	(0.633)*	(0.639)*	(0.682)
Total Debt over Revenues			-0.025	-0.024	-0.023	0.002
			(0.046)	(0.046)	(0.046)	(0.051)
Ex. Regime 3				0.100		
				(0.055)*		
Ex. Regime 5					0.058	0.088
					(0.037)	(0.037)**
Reserves over CAD						-0.000
						(0.001)
M2 over Reserves						0.003
						(0.008)
Credit Growth						-0.864
						(0.305)***
FDI/GDP						2.385
						(2.676)
Public Balance/GDP						1.210
						(1.837)
Constant	-0.313	-0.350	-0.290	-0.457	-0.458	-0.500
	(0.137)**	(0.144)**	(0.153)*	(0.170)***	(0.175)**	(0.188)***
Observations	138	138	134	134	134	132
R-squared	0.34	0.35	0.35	0.38	0.38	0.42

All regressions include time dummies
Standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Data Appendix

Our sample of EMs are those countries tracked by JP Morgan's Emerging Market Outlook (which includes the subset of countries used in the calculation of the EMBI+ index), i.e., EMs that significantly participate in world capital markets. Countries with missing information on their monthly trade balance, or which do not report quarterly capital account information (a measure we used to check the accuracy of our monthly proxy in mimicking quarterly fluctuations) were dropped from the sample. The complete list of EMs included therefore consists of Argentina, Brazil, Chile, Colombia, Czech Republic, Ecuador, Indonesia, Korea, Mexico, Nigeria, Peru, Philippines, Thailand, Turkey, and South Africa. Our choice of developed countries is dictated by OECD membership, and it includes Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and USA. Data is collected on an annual basis unless otherwise stated.

Variable	Definitions and Sources
Capital Flows Proxy	Trade balance minus changes in international reserves (monthly). All figures are expressed in 1995 US dollars. Source: IMF IFS.
Absorption of tradable goods (Z)	Imports plus tradable output domestically consumed, proxied by the sum of agricultural and industrial output minus exports. More specifically, we construct the share of tradable output in total output as the ratio of agriculture plus industrial output to total GDP at constant prices. Next, we multiply this share by total dollar GDP to obtain the dollar value of tradable output. We do this in order to avoid excessive fluctuations in output composition due to valuation effects that are present in sectoral data at current prices. Source: World Bank, World Development Indicators.
CAD	Current account deficit. Source: IMF's World Economic Outlook (WEO) database.
Financial Dollarization	For developed economies: BIS reporting banks' local asset positions in foreign currency as a share of GDP (since data for Australia and New Zealand is not available from this source, we used data from their respective Central Banks). For emerging economies: dollar deposits obtained from Honohan and Shi (2002) (and complemented with data from Central Banks for the cases of Colombia, Korea, Brazil) plus bank foreign borrowing (IMFIFS banking institutions line 26c) as a share of GDP.
Total Public Debt	Data on public debt for developed economies was obtained from OECD. Data on public debt for EMs was obtained from the World Bank's World Development Indicators database (WDI). (for a few cases, data from Central Banks and JP Morgan was used when not available from WDI). Data refers to gross central government debt.
External Public Debt	Data on external debt for developed economies was obtained from OECD (for a few cases, it was complemented with data from IMF IFS). Data on external debt for EMs was obtained from WDI

	(for a few cases, data from Central Banks was used when not available in WDI).
TOT growth	Annual rate of change of terms of trade on goods and services. Source: IMF's WEO database.
Ex. Regime 3	3-way exchange regime classification: 1 = float; 2 = intermediate (dirty, dirty/crawling peg); 3 = fix. Source: Levy-Yeyati and Sturzenegger (2002)
Ex. Regime 5	5-way exchange regime classification: 1 = inconclusive; 2 = float; 3 = dirty; 4 = dirty/crawling peg; 5 = fix. Source: Levy-Yeyati and Sturzenegger (2002)
Credit growth	Annual rate of change on the credit to private sector to GDP ratio. Source: IMF IFS.
Deposit rates	Source: IMF IFS.
FDI	Net foreign direct investment. Source: IMF's WEO database.
Fiscal Revenue	General Government Revenues. Source: IMF's WEO database.
GDP	Gross domestic product. Source: IMF's WEO database.
Lending rates	Source: IMF IFS.
M2	Money plus quasi-money. Source IMF IFS.
Money market rates	Source: IMF IFS.
Public Balance	General government balance to GDP ratio. Source: IMF's WEO database.
Large RER depreciation dummy	Dummy variable that takes the value of 1 when a large rise on RER (vis-à-vis US dollar) occurs and 0, otherwise. We define a rise in the RER (i.e., real depreciation of the currency) to be large when it exceeds two standard deviations of the sample mean prevailing before the rise. We also impose that the rise be of at least 20 percent, in order to ensure we capture episodes of substantial depreciation. This is particularly important for some developed countries where two standard deviation changes may not be big enough in size so as to make balance sheet effects play a relevant role.
Reserves	International reserves. Source: IMF IFS.

Technical Appendix

Inference with Random-Effects Probits under Endogeneity

Walter Sosa Escudero[51]

This note is concerned with estimation and inference in a random effects Probit specification allowing for possibly endogenous explanatory variables. The standard random effects Probit model with exogenous explanatory variables is:

$$y^*_{it} = x'_{it}\, b + m_i + e_{it}\,,\ \ i=1,2,\ldots,n;\ \ t=1,2,\ldots,T$$

where x_{it} is a k vector of exogenous explanatory variables, ß is a k vector of coefficients, μ_i is IN(0, s^2_m), and e_{it} is IN(0, s^2_e). The observed binary random variable y_{it} is related to the model through:

$$y_{it} = 1[\,y^*_{it} > 0]$$

Maximum likelihood estimation (MLE) of this model is extensively studied in Heckman (1981) and reviewed in Hsiao (2003). The likelihood function for this problem is given by:

$$L = \prod_{i=1}^{N} \int_{-\infty}^{+\infty} \prod_{t=1}^{T} \Phi \left\{ \left[\left(x'_{it}\ ß/s_e \right) + \tilde{\mu}_i \left(\frac{r}{1-r} \right)^{1/2} \right] \left[2y_{it} - 1 \right] \right\} f(\tilde{\mu}_i)\, d\,\tilde{\mu}_i$$

where $r \equiv s^2_m / s^2_e$. The evaluation of the integral in the previous expression is not trivial and it is usually carried out through Hermite integration or simulation.

Guilkey and Murphy (1993) conducted an extensive Monte Carlo experiment to study the small sample behavior of alternative estimation strategies of the random effects Probit model. The most important results that are relevant for this study are summarized below:

1. Standard probit and MLE of the random effects Probit provide consistent estimation of ß.
2. The standard Probit estimator of the standard errors of the estimators is markedly downward biased, leading to incorrect inferences, in the sense of suggesting significant coefficients when in fact they are not.
3. The random effects MLE based estimator provides more accurate estimators of the standard errors but the gain in performance is relatively mild when compared to that of the standard Probit.

[51] Universidad de San Andres, Victoria, Argentina. Email: wsosa@udesa.edu.ar, Phone: 54-11-4725-7024. Martin Cicowiez provided excellent computing support.

4. For small individual observations (*N* around 25), the numerical accuracy problems involved in the evaluation of the integral shown above severely affect the performance of the procedure, invalidating the use of standard asymptotic approximations.

The possibility of allowing for endogenous explanatory variables has been studied in the context of the standard Probit model:

$$y_j^* = z_j g + x_j' b + u_j, \quad j=1,2,\ldots,J$$

where u_j is $IN(0,\ s_u^2)$, and x_j, ß and y_j^* are defined as in the previous model, and z_j is a possibly endogenous explanatory variable. Rivers and Vuong (1988) provided a simple estimation strategy for the case where:

$$z_j = \tilde{x}_j' d + v_j$$

and $(u_j,\ v_j)$ have a bivariate normal distribution independent of $\tilde{x}_j$. $\tilde{x}_j$ is a vector of exogenous explanatory variables in the reduced-form model for z_j, which in this context is endogenous if and only if u_j and v_j are correlated. Rivers and Vuong (1988) propose a consistent estimation[52] based on a two-step approach:

- *Step 1:* Run the OLS regression of z_j on $\tilde{x}_j$ and save residuals $\hat{v}_j$.

- *Step 2:* Run a standard Probit regression of y_j on x_j, z_j and $\hat{v}_j$.

Details of the procedure can be checked in the original reference and in Wooldridge (2002). The main intuition behind the result comes from the fact that under bivariate normality of *u* and *v*, we can write $u_j = qv_j + h_j$ where h_j is independent of $\tilde{x}_j$ and v_j. Then, replacing in the definition of y_j^*:

$$y_j^* = z_j g + x_j' b + qv_j + h_j$$

If v_j were observable, consistent estimation could proceed by a standard Probit regression of y_j on z_j, x_j and v_j, since, by construction, all explanatory variables are exogenous with respect to h_j. The first stage of the Rivers-Vuong procedure replaces v_j by a consistent estimate obtained from OLS regression in a first stage.

The performance of the Rivers and Vuong (1998) procedure in the context of the random effects specification has not been explored, and though it deserves a more detailed exploration

[52] It is important to remark that, as it is usual in binary choice index models, not all the parameters are identified, hence appropriate normalizations must be adopted. See Rivers and Vuong (1998) for details on this subject.

than the one offered here, some insights can be discussed. A simple extension in the panel context, as described in the first equation of this appendix, is to allow for endogenous explanatory variables by allowing for correlation between the observation specific error term of the index model (e_{it}) and the error term of the reduced form of the possibly endogenous explanatory variable (v_{it}). In this context, the index model can be written as:

$$y_{it}^{*} = z_{it}g + x_{it}'b + qv_{it} + m_{i} + h_{it}$$

and, again, if v_{it} were observable, the model should be unaltered albeit for some redefinition of relevant parameters. In this case, the Rivers-Vuong procedure is replacing an exogenous explanatory variable (v_{it}) with a consistent estimate obtained from a first stage regression.

An important problem is how to perform reliable inference with the proposed method. As discussed previously, Guilkey and Murphy (1993) suggest that the numerical accuracy problem related to the evaluation of the likelihood function of the random effects Probit makes asymptotic approximations very unreliable. A natural possibility is to consider a bootstrap approach. The nature of such procedure in this context is complicated due to the fact that, by construction, observations are not independent due to the presence of random effect. In this note we follow Davidson and Hinkley (1997) and use a non-parametric hierarchical two-step bootstrap strategy, where in a first stage, individuals are randomly sampled with replacements, and, in a second stage, observations are randomly sampled without replacement within the individuals sampled in the first stage. According to Davison and Hinkley (1997, pp. 100-102), this procedure closely mimics the intra-group correlation structure of the data, due to the presence of the individual random effect.

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