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Margin Calls, Trading Costs, and Asset Prices in Emerging Markets: The Financial Mechanics of the 'Sudden Stop' Phenomenon[*]

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"Sudden Stops" experienced during emerging markets crises are characterized by large reversals of capital inflows and the current account, deep recessions, and collapses in asset prices. This paper proposes an open-economy equilibrium asset-pricing model in which financial frictions cause Sudden Stops. Margin requirements impose a collateral constraint on foreign borrowing by domestic agents and trading costs distort asset trading by foreign securities firms. At equilibrium, margin constraints may or may not bind depending on portfolio decisions and equilibrium asset prices. If margin constraints do not bind, productivity shocks cause a moderate fall in consumption and a widening current account deficit. If debt is high relative to asset holdings, the same productivity shocks trigger margin calls forcing domestic agents to fire-sell equity to foreign traders. This sets off a Fisherian asset-price deflation and subsequent rounds of margin calls. A current account reversal and a collapse in consumption occur when equity sales cannot prevent a sharp rise in net foreign assets.

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1. Introduction

A significant fraction of the literature dealing with the waves of economic and financial crises affecting emerging economies since the 1990s focuses on an intriguing phenomenon that is now commonly referred to as a "Sudden Stop." This phenomenon is defined by three key features: sudden, sharp reversals in capital inflows and current account deficits, large downward adjustments in domestic absorption and production, and collapses in asset prices and in the relative prices of nontradable goods relative to tradables.

Calvo and Reinhart (1999) examine the features of Sudden Stops and compare them with previous crisis episodes in emerging markets. Their findings show that while the empirical regularities of Sudden Stops resemble a typical "contractionary devaluation," the changes in capital flows and the collapses in the real sector of the economy exceed those observed in previous balance-of-payments crises of developing nations. Mendoza (2002) shows that in the case of Mexico the Sudden Stop of 1995 resulted in a recession and a collapse in domestic relative prices that largely exceeded the recession phase of a regular Mexican business cycle.

The collapses in equity prices, current account reversals and deep recessions that occur when a Sudden Stop takes place are striking. Table 1 summarizes these stylized facts using quarterly data from the IMF for four well-known cases: Mexico 1994, Argentina 1995, Korea 1997 and Russia 1998. In the Mexican crisis, equity prices deflated by the CPI fell by 29 percent, the current account rose by 5.2 percentage points of GDP, industrial output fell nearly 10 percent and consumption declined by 6.5 percent. Argentina's 1995 crisis resulted in collapses in real equity prices and industrial output similar to Mexico's, a current account reversal of 4 percentage points of GDP, and a decline in consumption of 4 percent. The Korean and Russian crises stand out for their large current account reversals (11 and 9.5 percentage points of GDP in Korea and Russia respectively). Real asset prices fell by about 10 percent in Korea. The IMF's *IFS* CD-ROM does not report a CPI for Russia, but measured in U.S. dollars the Russian equity price collapse was about 60 percent. The Korean and Russia crises were also episodes of widespread contagion across emerging markets. In South East Asia in 1997, equity prices fell at the same time as in Korea even in emerging markets in which there was no devaluation of the currency, as in Hong Kong where equity prices fell by 20 percent. Sudden Stops also induced higher asset price volatility. The volatility of weekly emerging-market dollar returns doubled from 2 to 4 percent during the 1997 East Asian crisis and the 1998 Russian crisis.[1]

The large and sudden reversals of capital inflows and current accounts that define a Sudden Stop ultimately reflect an emerging economy's loss of access to international capital markets. Hence, there is growing consensus in the view that financial-market imperfections are important for explaining Sudden Stops.[2] The theoretical literature has made significant progress in showing how a variety of financial frictions can potentially account for different aspects of a Sudden Stop. In contrast, the quantitative predictions of this class of models are largely unknown. In particular, there is little quantitative evidence showing whether the effects of financial frictions in the models can be large enough to account for the observed features of Sudden Stops. Moreover, the loss of access to world capital markets itself is often modeled as an exogenous shock rather than as an endogenous outcome of financial frictions. Hence, it is yet unknown whether models of financial frictions can produce endogenous Sudden Stops caused by the standard underlying sources of business cycles in emerging markets, *without* recurring to exogenous shocks that impose the loss of access to world capital markets by assumption. This paper attempts to address these issues by studying the quantitative predictions of an open-economy equilibrium asset-pricing model with financial frictions in which Sudden Stops emerge endogenously.

The model considers two financial frictions commonly emphasized in studies of emerging markets crises (see the survey by Arellano and Mendoza (2003)): (1) collateral constraints, in the form of

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

[2] An incomplete list of the many interesting papers that follow this approach includes Auernheimer and Garcia (2000), Aghion, Baccheta and Banerjee (2000), Caballero and Krishnamurty (1999), Calvo (1998), Calvo and Mendoza (2000a), Cespedes, Chang and Velasco (2001), Choi and Cook (2002), Gopinath (2002), Martin and Rey (2002), Mendoza (2002), and Paasche (2001).

a margin requirement that limits the ability of an emerging economy to use domestic equity to leverage foreign debt, and (2) asset trading costs, intended to capture the effects of informational or institutional frictions affecting the ability of foreign traders to trade the equity of emerging economies. These frictions interact with the economic forces at work in equilibrium stochastic asset pricing models (uncertainty, risk aversion and incomplete insurance markets) to conform an environment in which Sudden Stops occur as an endogenous response to productivity shocks of the same magnitude that drive regular business cycles in a frictionless real-business-cycle model of small open economy.

The transmission mechanism that causes Sudden Stops in the model operates as follows. When the economy is in a state of nature with a "sufficiently high" level of debt relative to equity holdings, an adverse productivity shock of standard magnitude has an effect that it does not have in other states: it triggers margin calls. How high debt needs to be for this effect to occur is an endogenous outcome of the analysis. The margin calls force domestic residents to fire-sell assets to foreign traders,[3] which are slow to adjust their portfolios because of trading costs. As a result, asset prices fall. This price fall triggers a new round of margin calls setting off a *Fisherian* asset-price deflation as domestic agents engage in further fire sales of assets to comply with increasingly tight margin requirements.[4] If fire sales of equity cannot prevent a large adjustment in total net foreign assets, the margin calls result in large reversals of capital inflows and the current account and in a collapse in consumption. That is, a Sudden Stop takes place. Interestingly, echoing a result in Aiyagari and Gertler (1999), current equity prices fall whenever agents expect margin calls in the future with some probability, even if there is no margin call at present.

The analysis of the above financial transmission mechanism as a feature of the competitive equilibrium of a dynamic, stochastic general equilibrium model of asset pricing with risk averse agents and incomplete markets is a challenging task. Equilibrium equity prices are forward looking objects that

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[3] This is a "fire sale" in the sense that domestic agents rush to meet margin calls by adjusting their equity position below the position they would optimally hold in the absence of margin calls.

[4] The idea of the Fisherian deflation was developed in Fisher (1933). Keynes (1932) proposed a similar idea.

represent the present value of the stream of dividends discounted with equilibrium stochastic sequences of intertemporal marginal rates of substitution. These stochastic discount factors vary depending on whether margin calls take place or not, and this in turn depends on the current equilibrium price of equity. Thus, equilibrium dynamics feature a nonlinear feedback between equity prices, stochastic discount factors, and margin constraints. The paper develops a numerical solution method to explore these nonlinear dynamics using the recursive representation of the models' competitive equilibrium.

The quantitative results show that the model can produce Sudden Stops as an endogenous response to standard productivity shocks when the economy's external debt is large relative to its equity holdings. Sudden Stops can occur when debt ratios exceed 47 percent of GDP and equity holdings are less than 90 percent of total domestic equity. The model accounts for current account reversals and large declines in consumption even though the foreign traders' demand for equity is parameterized with a very high price elasticity. Asset price collapses and risk premia are nearly 60 percent larger than in a variant of the model without financial frictions, but the high price elasticity of the foreign traders restricts the price collapses to be small relative to observed crashes in emerging markets. Analysis of the equilibrium dynamics suggests that Sudden Stops are more likely for highly-indebted economies that first gain access to global capital markets, but they become rare events in the stochastic stationary state because the precautionary-savings motive leads agents to manage debt and equity holdings so as to minimize the risk of the abrupt consumption adjustments implied by Sudden Stops.

The transmission mechanism triggering Sudden Stops in this paper differs from the "financial accelerators" examined in the literature on emerging markets crises, particularly those based on the closed-economy models of credit cycles of Kiyotaki and Moore (1997) and Bernanke, Gertler and Girlchrist (1998). The model of this paper differs in that it introduces elements of equilibrium asset-pricing theory in the presence of non-insurable risk, collateral constraints and asset trading costs that drive the effects that financial frictions have on the economy. Most models of Sudden Stops with collateral constraints feature borrowing constraints that are always binding at equilibrium or that appear suddenly as an unanticipated, exogenous shock. In contrast, in the model examined here collateral constraints become endogenously binding in states of nature in which debt is sufficiently high (relative to equity holdings) to trigger margin calls once the state of productivity is realized. Thus, collateral constraints are “occasionally” binding and agents formulate optimal plans factoring in the possibility of observing these states. Moreover, in contrast with models that adopt the Bernanke-Gertler setup of costly monitoring, in which the external financing premium is unaffected by aggregate risk and is a smooth function of the net worth-debt ratio of the economy, the equilibrium dynamics of the model studied here are influenced by non-insurable risk and the risk premium jumps when margin calls occur.

The asset-pricing features of the model proposed in this paper are similar to those studied in the closed-economy equilibrium asset pricing literature, particularly in Aiyagari (1993), Lucas (1994), Heaton and Lucas (1996), Krusell and Smith (1997) and Aiyagari and Gertler (1999). These authors examined the asset-pricing implications of borrowing constraints, trading costs and short-selling constraints aiming to explain financial facts of U.S. capital markets, particularly the equity premium puzzle. In terms of explaining the equity premium, the quantitative results of these studies were mixed. Yet, the financial frictions they proposed can still be important for explaining Sudden Stops because empirical regularities like the equity premium relate to long-run features of the data and moments of the limiting distribution of a model economy (on which the literature found that financial frictions produce small effects). In contrast, Sudden Stops are features of equilibrium dynamics when “occasionally binding” financial frictions become binding even if in the limiting distribution they remain rare events.

The rest of the paper proceeds as follows. Section 2 presents the structure of the model, defines the competitive equilibrium in recursive form, and discusses the transmission mechanism driving Sudden Stops. Section 3 reviews key properties of the deterministic version of the model. Section 4 develops the numerical solution method and reports simulation results. Section 5 concludes.

2. An Open-Economy Equilibrium Asset Pricing Model with Financial Frictions

The model can be summarized as an equilibrium asset-pricing model with heterogeneous agents and financial frictions. One set of agents is modeled as a representative-agent small open economy subject to non-diversifiable productivity shocks. The residents of this economy are risk averse and trade bonds and equity with the rest of the world. They face a margin requirement that limits their ability to borrow and a standard short-selling constraint on their equity holdings. The second set of agents is represented by the rest of the world, which is in turn made of two entities: a set of foreign securities firms specialized in trading equity of the small open economy and a trivial global credit market of non-state-contingent, one-period bonds that determines the world's real interest rate via the standard small-open-economy assumption. The foreign traders face higher costs than domestic residents in trading the small open economy's equity because of institutional features or informational frictions that are not explicitly modeled (see Frankel and Schmukler (1996) and Calvo and Mendoza (2001)).[5]

Margin requirements and trading costs are modeled in a manner similar to that proposed by Aiyagari and Gertler (1999). They examined a closed-economy setting in which households face portfolio adjustment costs, securities firms face margin requirements, and income, consumption, and the risk-free real interest rate are driven by exogenous random processes.[6] In contrast, in the small-open-economy model examined here domestic households face margin requirements, foreign traders are subject to trading costs, and consumption and income are endogenous.

2.1 Domestic Firms

There is a large number of identical firms in the small open economy which produce a single tradable good using a variable labor input (L_t) and a fixed supply of capital (K). Firms produce this good using a constant-returns-to-scale (CRS) technology $exp(\varepsilon_t)F(K,L_t)$, where ε_t is a Markov productivity

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[5] Note that this can be the case regardless of the location in which trading takes place. For instance, emerging-markets securities traded in New York (i.e., ADR's) may still be traded in an environment in which trading orders placed by residents of emerging markets reflect better information or smaller effective trading costs than those placed by nonresidents.

[6] Coen-Pirani (2000) shows that in a closed-economy, heterogeneous-agents variation of the Aiyagari-Gertler model, in which agents differ in their degree of risk aversion, margin requirements lower the risk-free rate and increase its volatility but do not alter equity prices.

shock. The markets for the final good and labor are competitive, so firms choose labor demand in order to maximize profits:

$$\exp(\varepsilon_t)F(K,L_t)-w_tL_t. \tag{1}$$

The assumption that the stock of capital is an exogenous constant is adopted for simplicity. This assumption and the assumptions about the structure of preferences introduced below yield equilibrium sequences of labor, wages and dividends that are determined separately from those of consumption, portfolio choices and asset prices. The drawback is that, by construction, the model's financial frictions cannot alter the manner in which productivity shocks affect output, factor payments and the labor market. Their responses to productivity shocks are exactly the same with or without financial frictions.

Labor demand for $t=0,\ldots,\infty$ is given by the standard marginal productivity condition:

$$\exp(\varepsilon_t)F_L(K,L_t)=w_t \tag{2}$$

Dividend payments for $t=0,\ldots,\infty$ are thus given by:

$$d_t=\exp(\varepsilon_t)F_K(K,L_t) \tag{3}$$

Productivity shocks follow a two-point, symmetric Markov chain. This specification minimizes the size of the exogenous state space E without restricting the variance and first-order autocorrelation of the shocks. The shocks take high (H) or low (L) values, so $E=\{\varepsilon_H,\varepsilon_L\}$. Symmetry implies that $\varepsilon_L=-\varepsilon_H$, and that the long-run probabilities of each state satisfy $\Pi(\varepsilon_L)=\Pi(\varepsilon_H)=1/2$. The transition probabilities are set by the "simple persistence" rule (see Backus, Gregory and Zin (1989)):

$$\begin{aligned}&\pi_{\varepsilon_i\varepsilon_j}=(1-\vartheta)\Pi(\varepsilon_j)+\vartheta\mathrm{I}_{\varepsilon_i\varepsilon_j},\\&\mathrm{I}_{\varepsilon_i\varepsilon_j}=1\ \mathit{if}\ i=j\ \mathit{and}\ 0\ \mathit{otherwise},\ \mathit{for}\, i,j=L,H.\end{aligned} \tag{4}$$

Under these assumptions, the shocks have zero mean, their variance is $(\varepsilon_H)^2$, and their serial autocorrelation coefficient is given by ϑ.

2.2 Households

A large number of identical, infinitely-lived households inhabit the small open economy. Their preferences are represented by Esptein's (1983) Stationary Cardinal Utility (SCU) function with an endogenous subjective rate of time preference:

$$U = E\left[\sum_{t=0}^{\infty} \exp\left\{-\sum_{\tau=0}^{t-1} v(C_\tau - G(L_\tau)\right\} u(C_t - G(L_t))\right] \qquad \textbf{(5)}$$

With these preferences, the lifetime marginal utility of date-t consumption includes an "impatience effect," by which a change in C_t alters the subjective discount rate that applies to the entire future utility stream. The period utility function *u* is a standard continuously differentiable, concave utility function that satisfies $u(\cdot)<0$, $u'(\cdot)>0$, $u'(0)=\infty$, and $ln(-u(\cdot))$ convex. The time-preference function *v* must satisfy $v(\cdot)>0$, $v'(\cdot)>0$, $v''(\cdot)<0$, and $u'(\cdot)exp(v(\cdot))$ nonincreasing. These conditions are easy to satisfy with standard functional forms such as a Constant Relative Risk Aversion (CRRA) period utility function and a logarithmic time-preference function. The argument of the *u* and *v* functions is the composite commodity *C-G(L)* defined by Greenwood, Hercowitz and Huffman (1988), or GHH. *G(L)* is a concave, continuously differentiable function that measures the disutility of labor. The GHH composite good neutralizes the wealth effect on labor supply by making the marginal rate of substitution between consumption and labor supply depend on the latter only.

Intertemporal preferences with endogenous impatience have a long history in the analysis of small open economies (see, for example, Obstfeld (1982) and Mendoza (1991)). These preferences play a central role in stochastic models because in these models the precautionary savings motive implies that the standard assumption of setting a fixed rate of time preference equal to the world's interest rate fails to produce a well-defined stochastic stationary equilibrium (as foreign asset holdings still diverge to infinity under this assumption). Preferences with a fixed rate of impatience can support a well-defined stochastic steady state only if the rate of interest is set lower than the rate of time preference arbitrarily. In this case, however, the mean foreign asset position is largely determined by the assumed difference between those two rates. Other alternatives address this stationarity problem by assuming ad-hoc functional forms relating the world interest rate to foreign debt or the rate of time preference to average consumption, but these are serious departures from microfoundations and whether they can yield solutions equivalent to preferable alternatives can only be determined case by case. In contrast, Epstein (1983) showed that a Von Neumann-Morgenstern intertemporal utility function satisfies standard preference axioms for choice under uncertainty (generalized to include an axiom requiring preferences over random future consumption to be independent of non-random current consumption) *if and only if* the utility function is the SCU function. Moreover, the conditions linking u and v imply quantitatively small impatience effects, so that these effects do not play an important role in the quantitative analysis of the model.

Households maximize SCU subject to the following period budget constraint:

$$C_t = \alpha_t K d_t + w_t L_t + q_t(\alpha_t - \alpha_{t+1})K - b_{t+1} + b_t R \qquad \textbf{(6)}$$

where α_t and α_{t+1} are beginning- and end-of-period shares of the domestic capital stock owned by domestic households, b_t and b_{t+1} are holdings of one-period international bonds, q_t is the price of equity, and R is the world's gross real interest rate (which is kept deterministic for simplicity).

In addition to the budget constraint, households face a *margin requirement* according to which they cannot borrow more than a fraction κ of the value of assets offered as collateral:

$$b_{t+1} \geq -\kappa q_t \alpha_{t+1} K, \qquad 0 \leq \kappa \leq 1 \qquad \textbf{(7)}$$

This is an "ex ante" collateral constraint that differs in three key respects from "ex post" collateral constraints (which limit debt not to exceed the discounted one-period-ahead liquidation value of the collateral, as with the Kiyotaki-Moore constraint). First, with a margin clause custody of the collateral is surrendered to the lender at the time the debt contract is entered. Second, margin calls are automatically triggered by declines in the market value of the collateral, giving lenders the option to liquidate the collateral if borrowers fail to meet margin calls. Third, the borrowing limit depends on current equity prices, rather than on expected prices for one period in the future. These properties imply that margin constraints are not affected by some of the strategic issues often raised in connection with other collateral constraints, related to whether countries have efficient institutions to enforce the repossession and liquidation of assets in cases of default and to whether this is even optimal for lenders once they reach a default state. It is also worth noting that margin clauses are widely used in international capital markets and take different forms, ranging from explicit margin clauses imposed by lenders or regulatory agencies to implicit margin clauses like those implied by the investment banks' use of value-at-risk models to set collateral and capital requirements.

Households also face a constraint setting a minimum equity position $\alpha_t \geq \chi$ for $-\infty < \chi < 1$ and $t=1,...,\infty$. This constraint is a short-selling constraint if $\chi \leq 0$, while $0 < \chi < 1$ can be interpreted as a portfolio requirement. The latter is worth considering because α is the share of the domestic capital stock owned by domestic agents, which is known to display "home bias" in the data. The constraint $\alpha_t \geq \chi$ is needed to ensure that the state space of portfolio holdings is compact and that the margin requirement is not irrelevant. If unlimited short selling of equity were possible, domestic agents could always undo the effect of the margin constraint. The lower bound on equity also serves to support well-behaved equilibria as in other general-equilibrium, incomplete-markets models of asset trading because of the potential for the portfolio $\alpha_t + b_t$ to become unbounded otherwise.

The first-order conditions of the optimization problem of domestic residents are:

$$U_{C_t}(\cdot) = \lambda_t \tag{8}$$

$$G'(L_t) = w_t \tag{9}$$

$$q_t\left(\lambda_t - \eta_t \kappa\right) = E_t\left[\lambda_{t+1}(d_{t+1} + q_{t+1})\right] + \upsilon_t \tag{10}$$

$$\lambda_t - \eta_t = E_t\left[\lambda_{t+1} R\right] \tag{11}$$

$U_{Ct}(\cdot)$ denotes the lifetime marginal utility of date-t consumption, and λ_t, η_t, and υ_t are the nonnegative multipliers on the budget constraint, the margin constraint, and the constraint on the lower bound on equity respectively. In addition to conditions (8)-(11), the first-order conditions include the three constraints and the Kuhn-Tucker conditions associated with each constraint.

The above first-order conditions have straightforward interpretation, with the caveat of the impatience effects on marginal utility. The optimal labor supply condition in (9) shows the effect of the

GHH composite good: the marginal disutility of labor is set equal to the real wage without any intertemporal effects. Conditions (10) and (11) are Euler equations for the accumulation of equity and foreign bonds. Given the return on equity is $R^q_{t+1} \equiv (d_{t+1}+q_{t+1})/q_t$, these conditions can be combined to derive the following expression for the expected risk premium on domestic equity:

$$E_t\left[R^q_{t+1}\right] - R = \frac{\eta_t(1-\kappa) - \frac{\upsilon_t}{q_t} - COV_t(\lambda_{t+1}, R^q_{t+1})}{E_t[\lambda_{t+1}]} \qquad \textbf{(12)}$$

If the margin and short-selling constraints never bind (i.e., $\eta_t = \upsilon_t = 0$ for all t), this expression yields the standard result for the equity premium of a frictionless asset-pricing model. In contrast, a binding margin requirement at date t (i.e., $\eta_t > 0$) induces an "excess" equity premium because of the pressure that the margin call exerts on households to fire-sell equity, depressing the current equity price. This *"direct effect"* of the margin constraint on the equity premium is limited to the fraction $(1-\kappa)$ of the shadow value η_t because a binding margin requirement increases the marginal benefit of increasing equity holdings by the fraction κ, since increased equity holdings help households to relax the borrowing constraint. A binding short-selling constraint (i.e., $\upsilon_t > 0$) increases the marginal gain of increasing equity holdings and has no effect on the marginal benefit of saving in foreign assets, hence it reduces the equity premium. The rest of this Section derives analytical results for the effects of margin calls and trading costs on asset prices assuming internal solutions for equity holdings (i.e., $\upsilon_t = 0$).

In addition to the direct effect, binding margin constraints have an *"indirect effect."* This effect follows from the fact that the conditional covariance between λ_{t+1} and R^q_{t+1} in the right-hand-side of (12) is likely to be more negative when margin calls are possible than with a perfect credit market.[7] This occurs in turn because the risk of a binding borrowing limit at $t+1$ hampers the ability of households to smooth consumption, leading to precautionary savings, increased consumption volatility and a lower

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[7] This is the Heaton-Lucas "indirect effect of trading costs" on asset prices, which occurs "to the extent that the increase in consumption volatility increases the covariance between individual consumption and the net return on stock" (Heaton and Lucas (1996), p. 465).

covariance between consumption and equity returns (i.e., λ_{t+1} rises while R^q_{t+1} falls). The intuition is that equity is a bad hedge against the risk of margin calls because the more negative the covariance between these two variables, the more likely it is that margin calls coincide with low ex-post equity returns. Households will thus demand a larger equity premium to reflect this unhedged risk. Note also that, as in Aiyagari and Gertler (1999), equation (12) predicts that excess equity returns may exist whenever it is possible for a margin call to occur in the future, *even if the margin requirement is not binding at present*.

To analyze further the effects of margin calls on equity prices, consider the following forward solution of the Euler equation for equity holdings (equation (10)):

$$q_t = E_t\left(\sum_{i=0}^{\infty}\left[\prod_{j=0}^{i}\left(\frac{\lambda_{t+j}}{E_{t+j}\left[\lambda_{t+1+j}R\right]+\eta_{t+j}(1-\kappa)}\right)\right]M_{t+1+i}d_{t+1+i}\right) \tag{13}$$

where $M_{t+1+i}\equiv\lambda_{t+1+i}/\lambda_t$ for $i=0,\ldots,\infty$, is the stochastic intertemporal marginal rate of substitution between C_{t+1+i} and C_t. If the margin requirement never binds, this expression collapses again to the standard asset-pricing formula. In the case that margin calls are possible *at any date*, the rates at which future dividends are discounted in the valuation of asset prices by domestic agents are altered by the direct and indirect effects mentioned above. The net effect on the price of equity is easier to interpret by solving forward the expression $E_t[R^q_{t+1}]=E_t[(d_{t+1}+q_{t+1})/q_t]$ to obtain:

$$q_t = E_t\left(\sum_{i=0}^{\infty}\left[\prod_{j=0}^{i}\left(E_t\left[R^q_{t+1+j}\right]\right)^{-1}\right]d_{t+1+i}\right) \tag{14}$$

where the sequence of $E_t[R^q_{t+1+j}]$ is given by (12). Hence, *if* the direct and indirect effects of margin calls lead to excess equity returns, a margin requirement that is binding at present or is expected to bind in the future implies that some or all of the expected returns used to discount the future stream of dividends in the above asset-pricing formula increase, and thus the current price of equity bid by households falls.

It is important to note that *at equilibrium* the direct and indirect effects of margin calls on the small open economy's equity price are magnified by the interaction between domestic agents and foreign securities firms in the equity market. An exogenous real shock triggers an initial margin call. Domestic agents then try to liquidate equity to meet the call, which puts downward pressure on the equilibrium equity price because domestic agents trade with foreign traders who incur trading costs and are thus slow to adjust their portfolios. The resulting fall in equity prices tightens the margin constraint, which leads to further equity sales and further tightening of the margin constraint. Thus, the mechanism that magnifies the impact of the direct and indirect effects of margin calls on asset prices is the Fisherian deflation (domestic agents fire-sale equity trying to maintain the balance between the value of their debts and the value of their assets required by the collateral constraint). This deflation occurs within the date-t equity trading period.

2.3 Foreign Securities Firms

Foreign securities firms specialize in holding equity of the small open economy. These firms maximize the present discounted value of dividends paid to their global shareholders, facing trading costs that are quadratic in the size of trades (as in Aiyagari and Gertler (1999)) and in a fixed recurrent cost.[8] These trading costs represent the disadvantaged position from which foreign traders operate relative to domestic agents when trading domestic equity. This disadvantage may result from informational frictions (i.e., domestic residents may be better informed on economic and political variables relevant for determining the earnings prospects of local firms),[9] or because of country-specific institutional features or government policies that favor domestic residents. The recurrent cost represents fixed costs for

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[8] Trading costs are generally modeled as quadratic in the *value* of the trade (see Heaton and Lucas (1996)). The Aiyagari-Gertler specification, in which the equity price enters in linear form, yields a more tractable recursive specification of the trader's optimal behavior.

[9] Foreign traders may be less informed simply because they cannot access or process country-specific information as easily as domestic agents or because they optimally choose not to do so. Calvo and Mendoza (2000b) provide two arguments for why the latter can be the case. First, with limited short-selling, a foreign investor's utility gain of paying information costs falls as the number of emerging markets in which to invest grows. Second, if portfolio manager's face performance-based incentives with marginal punishments larger than rewards, there is a range of multiple optimal portfolios in which managers simply mimic each other's behavior.

participating in an emerging equity market that are also intended to reflect informational and operational costs that foreign traders incur to be able to trade emerging-market instruments, even if they do not actually trade in a given period.

Foreign securities firms choose α^*_{t+1} for $t=0,...,\infty$ so as to maximize:

$$D = E_0\left[\sum_{t=0}^{\infty} M_t^*\left(\alpha_t^* K(d_t+q_t) - q_t\alpha_{t+1}^* K - q_t\left(\frac{a}{2}\right)\left(\left(\alpha_{t+1}^* - \alpha_t^* + \theta\right)K\right)^2\right)\right], \quad \theta, a \geq 0 \qquad \textbf{(15)}$$

where $M_0^* \equiv 1$ and M_t^* for $t=1,...,\infty$ are the exogenous marginal rates of substitution between date-t consumption and date-0 consumption for the world's representative consumer. For simplicity, these marginal rates of substitution are set equal to the world real interest rate, so $M_t^* \equiv R^t$. Trading costs are given by the term $q_t(a/2)[(\alpha^*_{t+1} - \alpha^*_t + \theta)K]^2$. The recurrent entry cost is θ and the parameter a is an adjustment cost coefficient that determines the price elasticity of the foreign trader's demand for equity.

At an interior solution, the first-order conditions for the above optimization problem imply that the foreign traders' demand for equity follows a partial adjustment rule of the form:

$$\left(\alpha_{t+1}^* - \alpha_t^*\right)K = a^{-1}\left(\frac{q_t^f}{q_t} - 1\right) - \theta \qquad \textbf{(16)}$$

where q^f_t is the "fundamentals" price of equity defined as:

$$q_t^f \equiv E_t\left(\sum_{i=0}^{\infty} M_{t+1+i}^* d_{t+1+i}\right) \qquad \textbf{(17)}$$

According to (16), foreign traders increase their demand for equity by a factor $1/a$ of the percent deviation of the date-t fundamentals price above the actual price (i.e., $1/a$ is the price elasticity of their demand for equity). If foreign traders did not incur trading costs, their demand for equity would be infinitely elastic and domestic agents could liquidate the shares needed to meet margin calls at an infinitesimal discount of the fundamentals price.

The foreign traders' assessment of the equity values at which they are willing to hold a particular position on the emerging economy's assets can be compared with the assessment made by domestic residents by comparing equations (13) and (16). One key element in this comparison are the sequences of foreign and domestic stochastic discount factors M^*_{t+1+i} and M_{t+1+i} for $i=0,..\infty$. In a perfect foresight equilibrium both sequences would equal the reciprocal of the world's real interest rate (compounded i periods). Under uncertainty, however, this is not the case even with an exogenous, risk-free world interest rate. The domestic stochastic discount factors are endogenous and reflect the direct and indirect effects of margin calls. The foreign traders' discount factors are exogenous and are set so that foreign securities firms discount returns at the discount rate of the world's representative consumer.

2.5 *Equilibrium*

Given the probabilistic process of productivity shocks and the initial conditions $(b_0, \alpha_0, \alpha_0^*)$, a competitive equilibrium is defined by sequences of state-contingent allocations $[C_t, L_t, b_{t+1}, \alpha_{t+1}, \alpha^*_{t+1}]_{t=0}^{\infty}$ and prices $[w_t, d_t, q_t, R^q_t]$ such that: (a) domestic firms maximize dividends subject to the CRS production technology, taking factor and goods prices as given, (b) households maximize SCU subject to the budget constraint, the margin constraint, and the short-selling constraint, taking as given factor prices, goods prices, the world interest rate and the price of equity, (c) foreign securities firms maximize the expected present value of dividends net of trading costs, taking as given equity prices, and (d) the market-clearing conditions for equity, labor, and goods markets hold.

The competitive equilibrium is solved for by reformulating it in recursive form and applying a recursive numerical solution method. To represent the equilibrium in recursive form, define b as the endogenous state variable for the representative household of the small open economy, α and B as the aggregate endogenous states taken as given by the representative household, and ε as the exogenous state. The state space of equity positions spans the discrete interval $[\chi, \alpha^{max}]$ with NA elements and the state space of individual and aggregate debt positions spans the discrete interval $[b^{min}, b^{max}]$ with NB elements. The state space of the aggregate endogenous states is thus given by the set $Z = \left[\chi, \alpha^{\max}\right] \times \left[b^{\min}, b^{\max}\right]$ of NAxNB elements. Note also that *equilibrium* wages, dividends and factor payments depend only on ε, and are given by the functions *w(ε)*, *d(ε)* and *L(ε)* that solve jointly equations (2), (3) and (9).

Assume a nonnegative equity pricing function $q(\alpha,B,\varepsilon): E\times Z\to R^{+}$ that is taken as given by foreign traders and the residents of the small open economy. For any initial state *(α,B,ε)* the pricing function satisfies $q(\alpha,B,\varepsilon)\in\left[q^{\min}(\alpha,\varepsilon),q^{\max}(\alpha,\varepsilon)\right]$, where $q^{\min}(\alpha,\varepsilon)=q^{f}(\varepsilon)\big/\left[1+a\left(\alpha-\chi+\theta\right)\right]$ and $q^{\max}(\alpha,\varepsilon)=q^{f}(\varepsilon)\big/\left[1+a\left(\alpha-\alpha^{\max}+\theta\right)\right]$ are the maximum and minimum equity prices along the foreign traders' demand curve for an initial state with equity holdings α and productivity shock ε. These bounds of the pricing function follow from the fact that when equity holdings of the small open economy hit either χ or α^{max}, the foreign traders' price prevails because they are at the "short side" of the market.

Imposing market clearing in the equity market, the conjectured pricing function and the foreign trader's demand function imply the following transition equation for equilibrium asset holdings:

$$\hat{\alpha}'(\alpha,B,\varepsilon)=\alpha-\frac{1}{a}*\left(\frac{q^{f}(\varepsilon)}{q(\alpha,B,\varepsilon)}-1\right)+\theta \tag{18}$$

Taking as given this asset transition equation, the conjectured pricing function, and a conjectured law of motion for aggregate bond holdings *B'=H(α,B,ε)*, the optimization problem of the representative household can be represented by the following dynamic programming problem:

$$V(b;\alpha,B,\varepsilon)=$$

$$\max_{b'}\left\{\frac{\left[c-\dfrac{n(\varepsilon)^{\delta}}{\delta}\right]^{1-\sigma}-1}{1-\sigma}+\exp\left(-\beta\left[Ln\left(1+c-\frac{n(\varepsilon)^{\delta}}{\delta}\right)\right]\right)E\left[V\left(b';\hat{\alpha}'(\alpha,B,\varepsilon),H(\alpha,B,\varepsilon),\varepsilon'\right)\right]\right\}$$

subject to: **(19)**

$$c=\alpha kd(\varepsilon)+w(\varepsilon)n(\varepsilon)+q(\alpha,B,\varepsilon)k\left[\alpha-\hat{\alpha}'(\alpha,B,\varepsilon)\right]-b'+bR$$

$$b'\geq-\kappa q(\alpha,B,\varepsilon)\hat{\alpha}'(\alpha,B,\varepsilon)k$$

The solutions of this problem yield the representative household's optimal consumption and bond accumulation choices for *any* given asset pricing function, law of motion of aggregate bonds and asset transition equation. The optimal consumption and labor plans applied to the asset pricing condition (13) yield then a domestic asset pricing function $\tilde{q}(\alpha,b,\varepsilon)$, which shows the asset prices at which residents of the small open economy would agree to the trades implicit in the conjectured pricing and asset transition equations in a competitive asset market.

In the model's recursive competitive equilibrium, the representative household's optimal plans satisfy $b'(B;\alpha,B,\varepsilon)=H(\alpha,B,\varepsilon)$ and $\tilde{q}(\alpha,B,\varepsilon)=q(\alpha,B,\varepsilon)$ identically in B. When these conditions hold, the optimal rules determining equity holdings, bond holdings, consumption, labor, wages, dividends, foreign equity holdings and the equity pricing function are such that: (a) given equity prices, wages and dividends, the allocations of c, b', α' and L solve the maximization problems of households and firms in the small open economy, (b) given equity prices and dividends, the allocation of α'^* solves the maximization problem of foreign traders, and (c) the market-clearing conditions for equity, goods and labor markets hold.

3. Perfect Foresight Implications

The model's deterministic equilibrium delivers interesting predictions regarding the effects of margin requirements and trading costs on asset prices and portfolio choice. It also provides the conditions used to calibrate the model for the numerical analysis in the next Section. Under perfect foresight, the emerging economy's equity premium and asset pricing equations (12) and (13) reduce to:

$$R^q_{t+1} - R = \frac{\eta_t(1-\kappa)}{\lambda_{t+1}} \tag{20}$$

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

As these expressions show, there is an equity premium under perfect foresight only if the margin requirement binds at date *t* and this premium reflects only the direct effect of margin calls.

The above results are useful to show that the margin constraint has asset-pricing effects similar to those of the collateral constraint in Kiyotaki and Moore (1997), or KM. The KM constraint would require $Rb_{t+1} \geq -q_{t+1}\alpha_{t+1}K$. This constraint yields the following forward solution for equity prices (using η now for the multiplier on the KM constraint):

$$q_t = \sum_{i=0}^{\infty} \left[1 - \frac{\eta_{t+i}}{\lambda_{t+i}}\right]^{-1} R^{-i} d_{t+1+i}. \qquad \textbf{(22)}$$

Thus, the KM constraint is similar to a margin requirement in that (a) if the constraint binds the equity price is lower than the fundamentals price because of the higher effective real interest rate that households face with a binding borrowing constraint,[10] and (b) if the constraint can be binding in the future, the current equity price is lower than the fundamentals price. The differences in the product terms of (21) and (22) indicate, however, that the *quantitative* implications of the two constraints differ. In turn, those product terms differ because a margin requirement binding at *t* alters the discount rates domestic agents apply to dividends and capital gains at $t+1$, while a binding KM constraint alters only the discount rate applied to dividends.

Consider next the implications of margin requirements and trading costs for the deterministic steady state. The definition of the fundamentals price in (17) implies that the long-run fundamentals equity price equals the present value of steady-state dividends discounted at the world interest rate. The foreign traders' demand function implies then that at steady-state the equity price satisfies $\bar{q} = \bar{q}^f / (1 + a\theta) \leq \bar{q}^f$ and therefore the return on equity satisfies $\bar{R}^q = 1 + (\bar{d} / \bar{q}) \geq \bar{R}$.

It follows from the above results that, if $a > 0$, a *necessary* condition for the steady-state equity price to equal its fundamentals level, and for the equity premium to vanish in the long run, is that $\theta = 0$.

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[10] Note that the Euler equation for bonds (eq. (10)) implies that $0 \leq 1 - \eta_t / \lambda_t \leq 1$.

However, this is necessary but not sufficient because for this equity price to satisfy the domestic agents' Euler equations for equity and bonds it must be the case that the margin constraint does not bind. If this is the case, the asset pricing condition (21) implies that domestic agents agree to an equilibrium price $\bar{q} = \bar{q}^f = \bar{d}/(\bar{R} - 1)$. In this case, there is a unique level of steady-state consumption independent of initial conditions determined by the condition $\exp(v(\bar{C})) = \bar{R}$. The stock of saving, $\bar{S} \equiv \bar{b} + \bar{q}\bar{\alpha}$, also has a unique steady state because savings and consumption are related by the budget constraint $\bar{C} = \bar{w}\bar{L} + \bar{S}(\bar{R} - 1)$. The steady-state portfolio composition is undetermined, however, because any equity position that satisfies $\chi \leq \bar{\alpha} \leq \bar{S}/((1-\kappa)\bar{q}^f)$ can be supported as a steady state with the corresponding bond position set to obtain the unique level of steady-state saving. A steady-state equilibrium does not exist for either smaller equity holdings, because the short-selling constraint would not hold, or larger equity holdings, because this would make the margin constraint bind.

In the case in which $\theta>0$, the foreign traders' problem yields a steady-state equity price lower than the fundamentals price and a long-run equity premium equal to $\theta a(R-1)$. This outcome can be supported as a steady state on the households' side only because the endogenous rate of time preference allows the rate of impatience to increase to match the equity premium. This would not be possible with a constant rate of time preference. The domestic steady-state equity position is now $\bar{\alpha} = \bar{S}/((1-\kappa)\bar{q})$. Domestic agents hold more equity than in the case with $\theta=0$ because the margin constraint increases long-run saving and because the equity price falls below q^f. The long-run composition of the portfolio is now uniquely determined and is independent of initial conditions.

These results show that recurrent trading costs *and* preferences with endogenous impatience are both necessary for the model to support binding margin constraints at a deterministic stationary state. The results also suggest that trading costs and credit constraints that bind at steady state can offer a potential explanation for a long-run "home bias" in portfolio holdings. For a given coefficient κ, recurrent trading costs and binding margin constraints increase home bias by increasing domestic saving and lowering equity prices. These saving and price effects are stronger the higher are θ or a because higher values of these parameters imply a lower long-run equity price, a larger premium on domestic equity, and higher steady-state saving.

4. Numerical Analysis of the Stochastic Competitive Equilibrium

This Section develops an algorithm for computing the recursive competitive equilibrium and presents numerical results to assess the model's ability to account for the main features of Sudden Stops.

4.1 Solution Method

The algorithm proposed below is designed keeping in mind four key features of the model: incomplete markets of contingent claims, two-dimensional portfolio choice in a two-agent competitive equilibrium setting, forward-looking asset prices, and occasionally binding margin constraints. The algorithm combines features of the solution methods proposed by Lucas (1994), Heaton and Lucas (1996), Judd et al. (2000), and Krusell and Smith (1997).

As in Lucas (1994) and Heaton and Lucas (1996), equilibrium asset prices are determined by an iterative procedure analogous to a "Tatonnment" process. The Heaton-Lucas algorithm iterates on the quantities of assets that different agents wish to trade, seeking to converge to a market-clearing outcome. The method used here is similar but it iterates on prices instead of quantities. The algorithm iterates on the pricing functions described in Section 2 until they satisfy a convergence criterion. In the model of this paper, this procedure is more efficient than iterating on the quantities because it takes advantage of the closed-form solution of the foreign traders' demand function. The algorithm differs from the Heaton-Lucas algorithm in that optimal portfolios are not forced to be drawn from the nodes that make up discrete grids of bonds and equity. Instead, following Judd et al. (2000), optimal portfolios are chosen from a continuous approximation to the endogenous state space Z. This avoids the extra transactions costs added implicitly by requiring portfolio decision rules to correspond exactly to grid points. Since policy functions exhibit kinks because of the borrowing and short-selling constraints, the approximation to a continuous state space is based on interpolations of the value function (as in Krusell and Smith

(1997)) instead of approximations of the policy functions. The value function is interpolated using bi-linear interpolation over the nodes of the discrete grids that define Z so as to ensure continuity of the interpolants. The value function is examined to ensure that bi-linear interpolation preserves concavity.

The algorithm proceeds in the following steps:

1. Select functional forms and parameter values for the problems of households, domestic firms and foreign securities firms, and for the Markov process of productivity shocks.
2. Specify the value of the lower bound on equity and construct discrete grids containing the interpolation nodes for the endogenous state space: $Z=[\chi, \alpha^{max}]\text{x}[b^{min}, b^{max}]$. The space of initial states is therefore defined by all triples (α, B, ε) in the discrete set $Z\text{x}E$.
3. Propose an initial conjectured pricing function $q(\alpha, B, \varepsilon)$ -- the fundamentals equity price is generally used as the initial conjecture.
4. Combine the conjectured pricing function with the foreign traders' demand function and the equity market-clearing condition to create the asset transition equation (equation (18)).
5. Solve the dynamic programming problem (19) via value-function iteration. The maximization step approximates the value function in the right-hand-side of (19) using bi-linear interpolation so that the approximate decision rule $b'(b; \alpha, B, \varepsilon)$ can be chosen off grid nodes. This decision rule is determined by solving for the bond position that satisfies the first-order condition of the dynamic programming problem using the bi-linear approximation to the value function within the interpolation nodes included in $Z\text{x}E$. The conjectured bond transition equation $H(\alpha, B, \varepsilon)$ can be approximated in two ways. A direct approach defines an initial H function and iterates on solutions of (19) until it satisfies the condition $b'(B; \alpha, B, \varepsilon)=H(\alpha, B, \varepsilon)$. An indirect approach solves (19) assuming that $b=B$ always. For general solutions of (19), this introduces a distortion by which the Euler equation on bonds incorporates effects of changes in bonds on asset prices. However, at the recursive equilibrium this distortion is negligible because Step 8. below requires asset prices to satisfy the competitive equilibrium's Euler equation for equity holdings.
6. Check the margin constraint for each $b'(b; \alpha, B, \varepsilon)$ at each pass of the maximization step. The constraint is assumed to be nonbinding first, but if the resulting $b'(b; \alpha, B, \varepsilon)$ violates the constraint, the constraint is imposed with equality. That is, when the constraint binds the decision rule for bonds is the closed form $b'(b; \alpha, B, \varepsilon) = -\kappa q(\alpha, B, \varepsilon)\hat{\alpha}'(\alpha, B, \varepsilon)$.
7. Value function iterations continue until convergence is attained.
8. Use the equilibrium decision rule $b'(B; \alpha, B, \varepsilon)$ to compute optimal consumption plans, the multipliers on the margin constraint, and the domestic equity pricing function given by equation (13). If the domestic and conjectured equity pricing functions satisfy the stopping rule $\sup\left(\frac{|q(\alpha, B, \varepsilon) - \tilde{q}(\alpha, B, \varepsilon)|}{1+q(\alpha, B, \varepsilon)}\right) \leq \xi$ for some small ξ, a recursive equilibrium for the model has been found. If the rule fails, update the conjectured pricing function and return to Step 4. Updates of the pricing function for iteration $i+1$ follow this Gauss-Siedel algorithm:

   $q^{i+1}(\alpha, B, \varepsilon) = \omega(\alpha, B, \varepsilon)\left[\tilde{q}^{i}(\alpha, B, \varepsilon) - q^{i}(\alpha, B, \varepsilon)\right] + q^{i}(\alpha, B, \varepsilon)$. $\omega^{i}(\alpha, B, \varepsilon)$ is a coefficient set to

   dampen unstable price iterations ($\omega<1$) or accelerate convergence of stable ones ($\omega>1$) using an adaptive successive overrelaxation (ASOR) procedure that combines data from iterations i and $i-1$. This is necessary because iterations on pricing functions do not follow a contraction mapping and work instead by searching for a fixed point on the "Tatonnement" process. Without ASOR, this process may not converge due to the well-known problem of unstable "hog cycles."

4.2 Functional Forms and Baseline Calibration

The functional forms adopted to represent preferences and technology are as follows::

$$F(K, L_t) = K^{1-\gamma} L_t^{\gamma}, \qquad 0 \leq \gamma \leq 1 \tag{23}$$

$$u(C_t - G(L_t)) = \frac{[C_t - G(L_t)]^{1-\sigma} - 1}{1-\sigma}, \quad \sigma > 1 \tag{24}$$

$$v(C_t - G(L_t)) = \beta[Ln(1 + C_t - G(L_t))], \qquad 0 < \beta \leq \sigma \tag{25}$$

$$G(L_t) = \frac{L_t^{\delta}}{\delta}, \qquad \delta > 1 \tag{26}$$

The parameter γ is the share of output allocated to labor payments, σ is the coefficient of relative risk aversion, β is the elasticity of the rate of time preference with respect to $1+C_t-G(L_t)$ and δ determines the wage elasticity of labor supply (which is equal to $1/(\delta-1)$). The condition $0<\beta\leq\sigma$ is required to satisfy the conditions identified by Epstein (1983) to ensure that SCU yields well-behaved dynamics.

The algorithm needs values for the vector of parameters $J = [\gamma, \sigma, \beta, \delta, R, \varepsilon_H, \vartheta,, \kappa, \chi, a, \theta]$. In addition, the algorithm requires an upper bound for the grid of equity holdings α^{max}, boundaries for the grid of foreign bonds (b^{min}, b^{max}), and the interior nodes of the discrete grids of bonds and equity. The values of several parameters are set using the calibration technique typical of real business cycle (RBC) theory that relates parameter values to observed empirical regularities. Setting values for the financial frictions parameters $(\kappa, \chi, a, \theta)$ is more difficult. Margin requirements and short-selling constraints at work in international capital markets are a combination of government regulations and private contractual practices. Similarly, actual trading costs are a mixture of pecuniary costs and economic costs that is difficult to measure. Hence, the numerical analysis starts from a *baseline calibration* in which an RBC-like calibration exercise sets the values of the parameters $(\gamma, \sigma, \beta, \delta, R, \varepsilon_H, \vartheta)$, while the values of $(\kappa, \chi, a, \theta)$ are set so that the margin constraint is not binding in all of ZxE. The value of κ is then lowered to trigger margin calls in a subset of the state space.

The RBC calibration exercise sets parameter values so that the deterministic stationary state of the model replicates empirical regularities taken from Mexican macroeconomic time series. The average share of payments to labor in GDP at current prices for the period 1988-96 from Mexico's *System of National Accounts* yields a value $\gamma=0.341$. Mexico's average GDP shares of consumption, net exports, investment and government expenditures at current prices for the period 1970-95 from the World Bank's *Development Indicators* are 0.684, 0.007, 0.217, and 0.092 respectively. For the model to mimic the consumption- and net exports-GDP ratios in a deterministic stationary state, it is necessary to introduce adjustments to allow for investment and government expenditures. The calibration assumes that government expenditures are financed with a constant consumption tax set at $\tau = 0.092/0.684 = 0.135$, which is very close to Mexico's actual value-added tax rate. This tax washes out from the Euler equations but it does distort labor supply. Still, keeping the tax rate state- and time-invariant implies that its effects on the stochastic dynamics are minimal. To control for investment expenditures, the calibration adds an autonomous level of private expenditures equal to the share of steady-state output absorbed by private investment.

Without loss of generality, the capital stock is set at $K = 1$. Lacking precise information on the wage elasticity of labor supply, the calibration assumes unitary elasticity, so $\delta=2$. Given the parameters γ, K, τ and δ, the steady-state allocations of labor and output and the associated wage and dividend rates are computed using the production function in (23) and the optimality conditions (2), (3) and (9), adjusted for the presence of the consumption tax.

The coefficient of relative risk aversion and the gross real interest rate are set to standard RBC values $\sigma=1.1$ and $R = (1.065)^{1/4}$. The real interest rate and the dividend rate determine the steady-state fundamentals asset price $q^f = d/(R-1) = 32.4$. Similarly, steady-state consumption is calculated using steady-state output and the requirement that the consumption-GDP ratio matches the average from Mexican data (0.684). Given C, L and δ, the value of β is derived from the steady-state Euler equation for bonds, which implies $\beta = Ln(R) / Ln(1+C- L^{\delta}/\delta) = 0.04518$.

The Markov process of productivity shocks is set so that the standard deviation and first-order autocorrelation of these shocks matches the standard deviation and first-order autocorrelation of the quarterly cyclical component of Mexico's tradables GDP reported in Mendoza (2002). In terms of the simple persistence rule defined in (4), this implies $\varepsilon_H = 0.0336$ and $\vartheta = 0.553$.

The values of the parameters governing financial frictions (κ, χ, θ, a) are set as follows. Recall first that in the baseline calibration the margin constraint must not bind at any point in the state space, including the deterministic stationary equilibrium. The results from Section 3 showed that this requires setting $\theta = 0$. The value of a is then set so as to yield a high price elasticity for the foreign traders' demand curve. The elasticity is set at 200, which implies $a=0.005$. This ensures that trading costs have a negligible effect on the equilibrium of the baseline calibration. Thus, the results for the baseline calibration are intended to approximate a version of the model without financial frictions (i.e., no margin requirements on domestic agents and negligible trading costs paid by foreign traders). Given the values of a and θ and setting $\alpha^{max}=1$, the results of Section 3 imply that values of κ such that $\kappa \geq 1-(S/q^f)= 0.011$ support a deterministic steady state with nonbinding margin requirements.[11] Finally, the value of χ is set at 0.5, so that foreign ownership of the domestic capital stock is not allowed to exceed 50 percent.

The emerging economy's steady-state net foreign asset position, $[\alpha-1]q^fK+b$, can now be computed given $K=1$, $q^f=32.4$, and Mexico's average trade balance-GDP ratio of 0.007. Steady state net foreign assets are about -43.7 percent of output, which is in line with the calculations for Mexico reported by Lane and Milesi-Ferretti (2002). However, in this deterministic stationary state debt positions in bonds (i.e., $b < 0$) exist only for values of α between 0.99 and 1. The reason is that lower equity positions imply that foreign equity holdings take a larger share of the negative overall net foreign asset position of the emerging economy, hence increasing its steady-state bond holdings. In terms of the data, however, the fact that emerging countries' debt bears a large risk premium suggests that their debt instruments are more keen to equity than to riskless debt, so the relevant figure to match with the model

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[11] Since in this case there is a unique steady state for saving $S = \alpha q^fK+b$ but the composition of the portfolio is undetermined (any $\chi \leq \alpha \leq \alpha^{max}$ and $b = S-\alpha q^fK$ is consistent with the steady state), the range for κ is set so as to support a steady state at α^{max}. This value of κ would therefore support a steady state with nonbinding margin requirements for any $\chi \leq \alpha \leq \alpha^{max}$.

is the net foreign asset position rather than the portfolio composition in terms of equity and debt.

Before reviewing the simulation results, note that because of the precautionary savings effect and the direct and indirect effects of margin calls at work in the stochastic model, the deterministic stationary state used for the calibration may differ widely from the first moments of the limiting distributions of bonds and equity. Hence, the deterministic steady state is useful for imposing some discipline in the manner in which parameter values are selected but it is not necessarily a good predictor of the mean values of α and b in the stochastic steady state.

4.3 Simulation Results

The quantitative analysis compares the equilibrium of the nearly-frictionless baseline calibration with the case in which the parameters of financial frictions are reset to trigger margin calls. In both cases, the grid of bond holdings has 130 evenly-spaced nodes spanning the interval [-3.06,6.54]. The equity grid has 76 evenly-spaced nodes spanning the interval [0.5,1.0].

Given the setting of the financial frictions parameters in the baseline calibration ($a=0.005, \theta=0$ and $\chi=0.5$), a value of κ set at $\kappa=0.92$ is sufficient to make the margin constraint non-binding over the entire state space ZxE in the simulation of the nearly-frictionless baseline case. The accuracy of this simulation is evaluated by computing the error in the pricing functions, defined as the absolute value of differences between the conjectured and domestic pricing functions as a percent of the former (see Judd et al. (2000)). After 250 iterations on the pricing functions, the average error was 0.007 percent and the largest error was 1 percent. This compares favorably with average errors of up to 0.4 percent in Heaton and Lucas (1996).

The simulation for the case that introduces occasional margin calls lowers κ to 0.009, which is slightly below the threshold value at which the margin constraint begins to bind in the deterministic steady state (which is 0.011). In this case, the emerging economy cannot borrow more than 0.9 percent of the market value of its equity holdings. However, since the price of equity is relatively high (fluctuating around the 32.4 level of the deterministic steady state), this low κ still allows the economy to sustain high levels of debt (of up to37 percent of GDP).

Figures 1 and 2 are three-dimensional plots of the bond and equity equilibrium decision rules of the small open economy in the low productivity state. The *"x"* and *"y"* axes are measured in integers that represent grid points in the bond and equity grids and the vertical axis is the value of the corresponding equilibrium decision rule $b'(\alpha,B,\varepsilon_L)$ or $\alpha'(\alpha,B,\varepsilon_L)$. The figures include plots for the baseline case with frictionless capital markets and for the case with occasionally binding margin requirements and asset trading costs. Figures 3, 4 and 5 show the corresponding three-dimensional plots for equity prices, the premium on the emerging market's equity relative to the world interest rate, and the "real" debt-equity ratio (i.e., the ratio $-b'(\alpha,B,\varepsilon_L)/\alpha'(\alpha,B,\varepsilon_L)$). All the plots for the case with financial frictions show triangular areas around the coordinates $(\alpha=\chi,\ b=b^{min})$, which correspond to $(0,\ 0)$ in the *"x"* and *"y"* axes, that should be disregarded because for such low values of α and b the non-negativity constraint on $C\text{-}G(L)$ and the margin constraint cannot be jointly satisfied. The plots are forced to show values for this area that correspond to the lowest (α,b) pair for which a feasible value for the variable being plotted exists.

Figures 1 to 5 illustrate striking differences across economies with and without financial frictions. In the absence of margin calls and with very low trading costs, the model produces standard results from equilibrium asset pricing models. Portfolio decision rules $b'(\alpha,B,\varepsilon)$ and $\alpha'(\alpha,B,\varepsilon)$ are smooth, increasing functions of α and B. There is little volatility in equity prices and negligible equity premia, and the debt-equity ratio is a well-behaved function of the state variables that increases smoothly as B falls. All these results are turned around in the economy with financial frictions.

For the region of the state space in which the debt-equity ratio exceeds 29 percent (i.e., the Sudden Stop or SS region), the state of low productivity triggers margin calls. As explained in Section 2, the productivity shock triggers an initial margin call that leads domestic agents to fire-sale equity to foreign traders, and since the demand for equity of the latter is less than perfectly elastic, the price of equity falls. This leads to subsequent rounds of margin calls and a Fisherian asset-price deflation in which asset prices fall while at the same time domestic agents are reducing their debt exposure and equity holdings. This behavior is clearly observed in the SS region of the equity decision rule under financial frictions shown in Figure 2. This region of the surface plot can be broken into three areas. First, if the emerging economy is at the minimum equity position χ when a margin call hits, domestic agents cannot sell equity and hence their debt position remains constant and the price of equity cannot fall (see also Figs. 1 and 3). Second, for relatively low levels of initial equity holdings but above χ, the emerging economy fire-sales all the equity it can, yielding the largest equity price collapses and debt position corrections. Third, for relatively high initial equity holdings, the emerging economy meets margin calls without reducing its equity holdings to χ, so the asset price collapse and the correction in the debt position are large but less severe than in the second area.[12]

The asset price collapses in the SS region deviate sharply from the smooth price adjustments observed in the economy without margin requirements. Still, the price collapses themselves are quantitatively small because of the high price elasticity of the foreign traders' demand curve assumed in the calibration. For the same reason, equity premia are small compared to observed equity premia, even though they are much larger than those produced by the economy with frictionless capital markets. These excess returns display the same pattern of the asset price collapses. They are the largest in the area of the SS region in which domestic agents liquidate the largest amount of equity to meet margin calls.

The behavior of consumption and the current account in the SS region can also differ markedly from the frictionless baseline depending on the above described patterns of asset trading and asset prices. If the economy has a relatively high initial equity position, consumption and the current account can remain at levels not so distant from those obtained in the absence of financial frictions. In this case, the active asset trading and large asset price shifts that take place reflect the domestic agent's relatively

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[12] This change in portfolio composition also reflects the relative cost of using equity or bonds to smooth consumption. In the absence of margin requirements, equity trading costs lead to intensive trading in bonds (which can be traded at no cost). In contrast, binding margin requirements produce a state-contingent pattern of asset trading. If debt is low, bonds are again traded more actively than equity, but if the economy is highly leveraged the trade-off can change abruptly in favor of equity.

successful efforts at minimizing the impact of the margin calls and the Fisherian asset-price deflation on consumption. However, if the initial equity position is low, consumption in the economy with margin requirements can be more than 7 percent below that in the economy without margin requirements and the current account-GDP ratio can be up to 3 percentage points higher.

The above comparisons of prices and allocations across simulations for economies with and without financial frictions can be interpreted as reflecting the model's ability to generate Sudden Stops caused by an unexpected, once-and-for-all regime change in world capital markets (i.e., a sudden fall in the value of κ). This is analogous to the thought experiment in Paasche (2001) and Christiano et al. (2002), in which a borrowing constraint is suddenly imposed on a small open economy, with the difference that in the experiment conducted here whether the change in κ triggers or not a Sudden Stop is an endogenous outcome that depends on the debt-equity ratio of the economy when the regime switch takes place. The magnitude of the Sudden Stop also varies with the initial state as this determines the size of the fire sale of assets and deflation of asset prices. Still, accounts of Sudden Stops like these are incomplete inasmuch as they start from the assumption of an exogenous regime change in international capital markets.

The model and the simulation results can be used to conduct a more interesting experiment in which Sudden Stops emerge endogenously, without assuming an exogenous regime change in international capital markets. To examine this possibility, consider now only the solutions for the simulation with financial frictions and compare the impact effects on consumption and the current account-GDP ratio of a shift from the high to the low state of productivity. Figures 7 and 8 plot these impact effects for the subset of coordinates (α, b) that captures the SS region of the state space. The productivity shocks are always the same 3.3 percent standard-deviation shocks from the baseline case regardless of the debt and equity possitions.

Figure 7 shows that, in the SS region a "normal" productivity shock triggers margin calls that result in impact effects equivalent to collapses in consumption that can reach 9.2 percent and reversals in the current account-GDP ratio as large as1.6 percentage points of GDP. Note that, as explained above, there is a segment of the SS region in which domestic agents can manage to fire-sale assets and adjust their debt position in a manner such that consumption remains relatively smooth *(if* they hold enough equity when the margin calls hit). Margin calls result in large drops in consumption and current account reversals when equity holdings are too small relative to the debt position. In states in which the impact effect on consumption is moderate, equity price collapses and sales of equity by domestic agents are much larger than to those observed in states in which consumption falls sharply.

The impact effects of productivity shocks are very different in the economy without financial frictions. In this case, the impact effects of the productivity shock as functions of the initial state result in consumption declines ranging between 1.8 and 2.8 percent and *widening* current account deficits ranging from 2.5 to 5 percentage points of GDP. Clearly, the model with perfect credit-market access and costless asset trading cannot explain large current account reversals and consumption collapses.

The magnification effects by which margin constraints and trading costs magnify the effects of real shocks on consumption, the current account and asset prices in the SS region are summarized in Table 2. The table reports impact effects for combinations of initial debt and equity positions within the SS region in economies with and without financial frictions and coefficients that measure the magnitude of the increase in these responses across the two economies.

In line with the intuition developed above, Table 2 shows that when a country has a high external debt (65 percent of output) and a low position in domestic assets (50 percent of total equity), the model with financial frictions reproduces two important features of a Sudden Stop: a collapse of private consumption (of -11.5 percent) and a reversal of the current account (1.8 percentage points of GDP). The consumption effect is 4 times larger than without financial frictions and the current account moves in the opposite direction by over 4 percentage points of GDP. However, since domestic asset holdings start virtually at the short-selling limit, asset prices cannot move. On the other hand, with the same initial debt-to-GDP ratio but initial domestic asset holdings of 90 percent of total equity, the collapse in asset prices in the economy with financial frictions is about 60 percent larger than in the frictionless economy. Finally, if we increase asset holdings beyond 90 percent and reduce external debt below 47 percent of GDP, the economy moves out of the SS region and the magnification effects of financial frictions disappear. Thus, combinations of equity and debt positions within the ranges used in Table 2 can yield outcomes in which consumption, the current account and asset prices experience magnification effects within the ranges of those shown in the Table. For these combinations, the model can produce jointly consumption collapses and asset price collapses (the magnification effects on consumption will be less than a factor of 4 and those on asset prices will be less than 60 percent).

Judging by the figures from actual Sudden Stops in Table 1, the results in Table 2 show that the model does well at producing current account reversals and consumption collapses. Interestingly, the data show that the two countries with large asset price collapses (Argentina and Mexico) experienced smaller current account reversals, while Korea displayed the smallest asset price collapse but a very large current account reversal. This is in line with the model's prediction that, when margin constraints bind, smaller price adjustments coincide with larger current account reversals. Still, the model misses two features of Sudden Stops. One feature are the large output collapses. This is because, by construction, there is no magnification effect on output in the model, since output, dividends and labor allocations are unaffected by financial frictions. Altering this result would require more complex models that endogenize physical investment (as proposed by Arellano and Mendoza (2003)) or introduce alternative financial frictions such as constrained financing of working capital. Solving these models can be significantly more difficult, however, because output and the dividend stream would no longer be separated from consumption and portfolio choices.

The second feature of actual Sudden Stops that Table 2 misses is the large collapse in asset prices. As noted before, the simulated asset price collapses are restricted to be small because of the high elasticity of the foreign traders' demand curve implied by the calibrated value of a (with $a = 0.005$ the elasticity is 200).[13] Larger values of a increase the magnification effect on asset prices and allow the model to produce asset price collapses similar to those observed in the data. For example, with a set to 0.5 (so that the elasticity is 2), asset price collapses can be as large as 20 percent. However, lacking empirical evidence to determine a realistic value for a, the calibration was designed to illustrate the model's potential to account for Sudden Stops even with a very high price elasticity of the foreign traders' demand curve.

The limiting distributions plotted in Figure 6 indicate that the endogenous Sudden Stops described above are rare events, since states in which α and B are at levels such that a productivity shock can trigger a Sudden Stop have a low long-run probability of occurrence. This result follows from the aversion of domestic agents to a volatile consumption profile, which drives them to undertake precautionary savings, require a risk premium on equity in most states, and fire-sale assets to meet margin calls. Even without margin calls, the model is prone to have domestic agents sell equity at equilibrium in any state in which they demand an equity premium because (with $\theta=0$) foreign traders always buy equity at prices that reflect a positive excess return on equity (which are prices below q^f_t). Domestic agents then seek to self-insure by building up a large enough bond position. These trends show in the high probability of low equity and high bond positions in the ergodic distribution of the economy without margin requirements.

The fire-sales of assets that take place in the economy with margin calls exacerbate the above effects and result in an ergodic distribution for equity that is more biased towards low equity positions and an ergodic bond distribution with zero probability of very high debt levels. The highest debt positions (i.e., b less than the 36th point in the bonds grid, or $b<-0.454$) are ruled out by a version of Aiyagari's (1994) natural debt limit: since there is a non-zero long-run probability of visiting states with low equity holdings (including $\alpha=\chi$), domestic agents must hold a minimum amount of bonds such that they are not exposed to the possibility of $C-G(L)$ becoming non-positive at any time.

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[13] Recall that for any initial state (α,ε) the lower bound of asset prices is pin down by $q^{min}(\alpha,\varepsilon)$.

These findings provide an interesting interpretation of the dynamics of emerging economies after the relatively recent creation of emerging equity markets in the late 1980s, which took place in an environment of high external debts. The simulation results suggest that during the early periods of this financial globalization emerging economies would be highly vulnerable to suffer endogenous Sudden Stops in response to the "normal" real impulses that drive their business cycles via productivity, terms-of-trade or interest-rate shocks. Economies that go through these early periods with favorable realizations of the state of nature can reach the area of debt-equity ratios in which Sudden Stops are very unlikely. In these early periods the model also predicts high excess returns on emerging markets equity.

The simulation results are robust to the addition of a small recurrent trading cost on foreign traders set at $\theta=0.001$. The only significant difference is in the shapes of the ergodic distributions of equity and bonds (see Figure 6). The recurrent trading cost implies at equilibrium that domestic agents will hit the lower bound in equity holdings more often in the long run and this translates into stronger precautionary savings incentives affecting bond holdings. However, these effects do not translate into significant differences in the equilibrium prices and allocations reviewed for the simulations with $\theta=0$.

5. Conclusions

This paper explores whether the key stylized facts of the Sudden Stop phenomenon can be rationalized as the outcome of a stochastic, general-equilibrium asset pricing model of a small open economy with financial frictions. The underlying source of uncertainty in the model are standard productivity shocks that domestic agents cannot hedge against because asset markets are assumed to be incomplete. Two sets of financial frictions are considered. First, domestic residents face a collateral constraint in international debt markets in the form of a margin requirement. Second, foreign traders face trading costs that reflect institutional or informational frictions they encounter in trading the equity of the small open economy.

Margin calls have direct and indirect effects working to depress equity prices and to increase the premium on the emerging economy's equity. The direct effect is driven by fire-sales of equity in which domestic agents engage to meet margin calls. The indirect effect is induced by the larger consumption volatility and negative covariance between consumption and equity returns that results from the reduced ability to smooth consumption in the presence of current or expected margin calls.

When domestic agents rush to sell equity to meet margin calls they deal with foreign traders that have a less-than-infinitely-elastic demand for equity because of trading costs. As a result, equity prices drop below their fundamentals level and the equity premium rises. These results require both the margin constraint on domestic agents *and* the trading costs on foreign firms. The collateral constraint on the small open economy is necessary but not sufficient to induce asset price collapses and Sudden Stops.

The initial margin call triggers a Fisherian asset-price deflation as the fall in equity prices leads to subsequent rounds of margin calls. If the domestic economy is not highly leveraged (i.e., if it has a low debt-equity ratio), the asset-price deflation and large portfolio re-allocations take place without impairing too much the domestic agent's ability to smooth consumption. In contrast, if foreign debt is high relative to equity holdings, asset prices fall less and portfolio shifts are smaller but the emerging economy suffers a collapse in consumption and a large reversal in the current account deficit.

The paper proposes a numerical solution method that solves the competitive equilibrium of the model in recursive form. Numerical simulations illustrate the potential for the interaction of margin calls and trading costs to trigger Sudden Stops in two ways. First, as a result of unexpected, permanent changes in exogenous world credit market conditions that tighten margin constraints. Second, as an endogenous outcome induced by negative productivity shocks of standard magnitude in the Sudden Stop region of the state space, in which equity holdings are small relative to external debt and thus adverse productivity shocks trigger margin calls. The analysis is simplified by considering productivity shocks as the only underlying source of economic fluctuations, but Sudden Stops can be triggered by a variety of real foreign and domestic shocks that could be added to the model (such as policy shocks or shocks to the terms of trade or the world interest rate). The central implication of this paper is that these real shocks need not be unusually large to cause a Sudden Stop and that the loss of access to world capital markets need not result from an exogenous shock. Adverse real shocks of standard magnitude that hit highly-leveraged economies trigger Sudden Stops and these Sudden Stops are driven by an endogenous Fisherian deflation of asset prices.

The model's ergodic distribution shows that Sudden Stops are dramatic but rare events which economies can outgrow as they build up their net foreign asset position. This is an interesting finding in light of the fact that emerging equity markets were created only a decade ago and in an environment in which emerging economies were highly indebted. The model predicts that in this early stages emerging economies were vulnerable to Sudden Stops even in the absence of systemic shocks to world capital markets, and that in these same early stages emerging economies will command large excess returns.

The focus of the numerical analysis conducted here was on accounting for the current account reversals, consumption recessions, and asset price collapses observed in Sudden Stops. The model's occasionally binding collateral constraint and its explicit link between asset prices and macroeconomic dynamics can be important for understanding other aspects of Sudden Stops. First, as argued in Mendoza (2002), these features may provide a means to account for Sudden Stops as rare but violent episodes that are nested within regular business cycles. Second, to the extent that foreign shocks like a world-interest-rate shock can trigger margin calls, models of this class embody a financial transmission mechanism for the international spillover or "contagion" of capital markets crises.[14] Third, since occasionally binding credit constraints can lead to distorted asset prices even in states in which the constraints do not bind (as long as they may become binding in the future), they can offer an explanation for the higher volatility of emerging-markets asset prices relative to industrial-country prices even if actual Sudden Stops are rare.

Further research in models of the class examined here can go on several directions. One is to

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[14] The contagion episode after the Russian default in 1998 offers an interesting example. During this episode, margin calls were triggered across emerging markets by rising estimates of potential losses produced by the value-at-risk models of investment banks that leveraged hedge funds like Long Term Capital Management. As volatility increased and asset prices fell, value-at-risk estimates worsened mandating even larger margin calls. Similarly, in the model, a foreign real shock that triggers an initial margin call leads to a fall in equity prices that induces even larger margin calls.

incorporate other sources of uncertainty affecting emerging economies that can trigger Sudden Stops such as policy shocks or shocks to the terms of trade or the world interest rate. A second route is to endogenize physical capital accumulation to explore the investment transmission channel of Sudden Stops. A third route is to introduce the "liability dollarization" feature of foreign debt contracts of emerging economies (for which debt is largely denominated in units of tradable goods but leveraged in part on the income and assets of the domestic nontradables sector).

Recent research is filling some of these gaps. Cavallo, Perri, Roubini and Kisselev (2002) adopt the model of this paper to a two-sector environment and study the interaction of margin constraints and 'over-reaction' in real exchange rates. Arellano and Mendoza (2003) sketched a model with capital accumulation and capital adjustment costs that links a margin constraint to a Tobin's-q valuation of physical capital. Finally, in work in progress Mendoza examines the potential benefits of ex ante official asset price guarantees targeted at offsetting the effects of the margin calls and trading costs identified in this paper. The goal is to determine how best to trade off these benefits against the moral hazard incentives that the official provision of price guarantees would create.

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Table 1. Sudden Stops in Four Emerging Economies

	Real Equity Prices (percent change)	Current Account-GDP Ratio (percentage points change)	Industrial Production (percent change)	Private Consumption (percent change)
Argentina (94.4-95.1)	-27.82	4.05	-9.26	-4.12
Korea (97.4-98.1)	-9.79	10.97	-7.20	-9.48
Mexico (94.4-95.1)	-28.72	5.24	-9.52	-6.44
Russia (98.3-98.4)	-59.37	9.46	-5.20	-3.12

Note: Real equity prices are deflated by the CPI, except Russian equity prices which are in U.S. dollar terms. The change in the current account-GDP ratio for Argentina corresponds to the second quarter of 1995. Industrial production for Korea and Russia and private consumtpion for Argentina, Korea, and Russia are annual rates.

Table 2. Sudden Stops in the Model Economy

(impact effects of an adverse two-standard deviation shock to productivity)

Initial State				
Equity holdings (percent)	Debt-GDP ratio (percent)	Equity Prices (percent change)	Current Account-GDP Ratio (percentage points change)	Private Consumption (percent change)
		Economy with Margin Constraints & Trading Costs		
50.68	-65.00	-0.153	1.766	-11.465
89.87	-65.00	-0.243	-5.064	-2.246
89.87	-46.69	-0.154	-5.242	-2.058
		Frictionless economy		
50.68	-65.00	-0.160	-2.602	-2.899
89.87	-65.00	-0.154	-5.221	-2.071
89.87	-46.69	-0.154	-5.242	-2.059
		Magnification effects due to financial frictions 1/		
50.68	-65.00	0.959	4.368	3.955
89.87	-65.00	1.581	0.157	1.084
89.87	-46.69	1.003	0.000	1.000

1/ Magnification effects for equity prices and consumption are ratios of the impact effects in the economy with financial frictions relative to the frictionless economy. The magnification effect for the current account-output ratio is the difference between the impact effect in the economy with financial frictions and the frictionless economy.

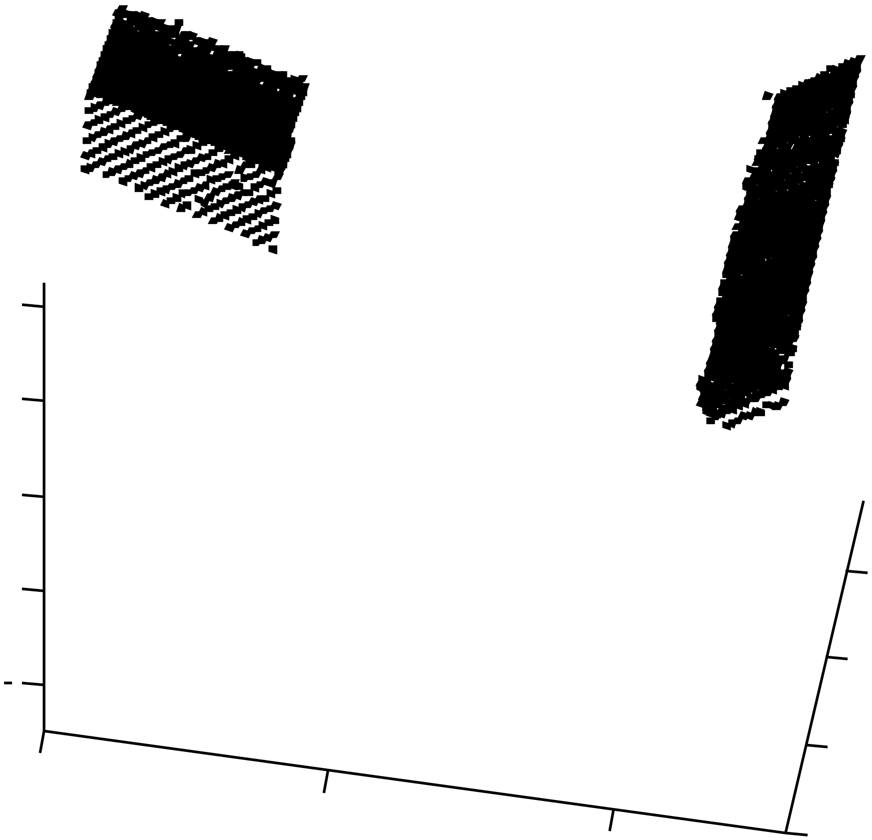
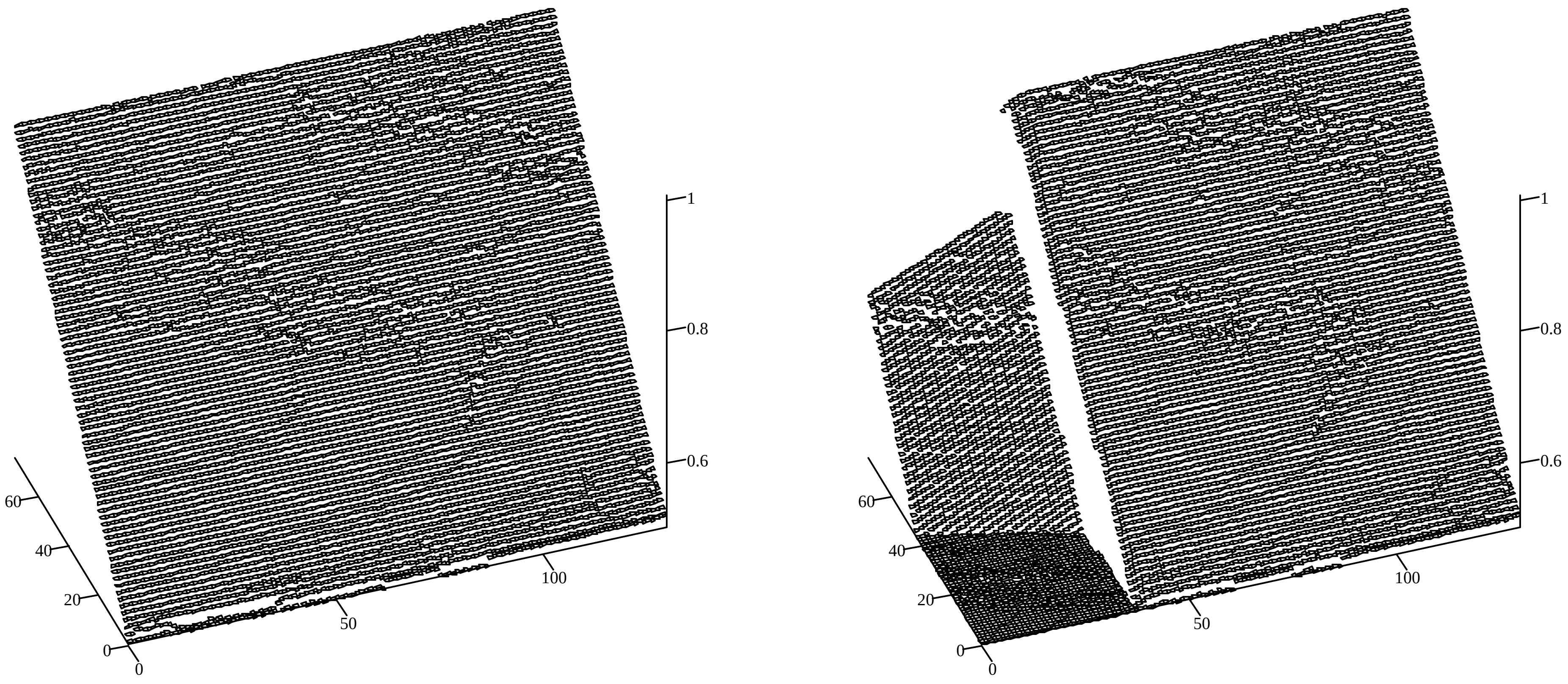


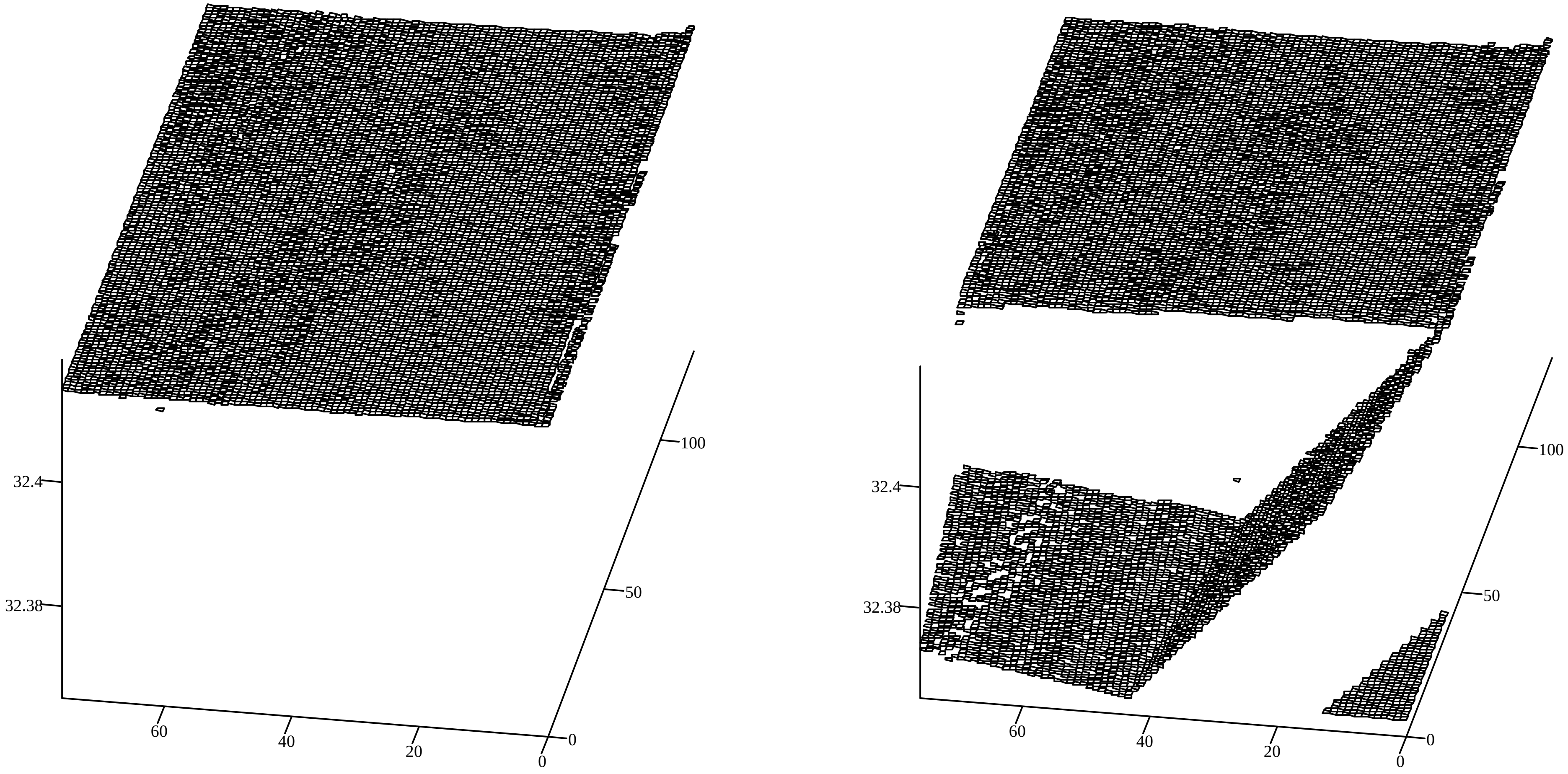
Figure 2. Equity Decision Rule of the Emerging Economy with and without Margin Requirements in the Low Productivity State
(as functions of the (α,b) pairs in the discretized state space Z)



AP1
Without Margin Requirements

AP1b
With Margin Requirements

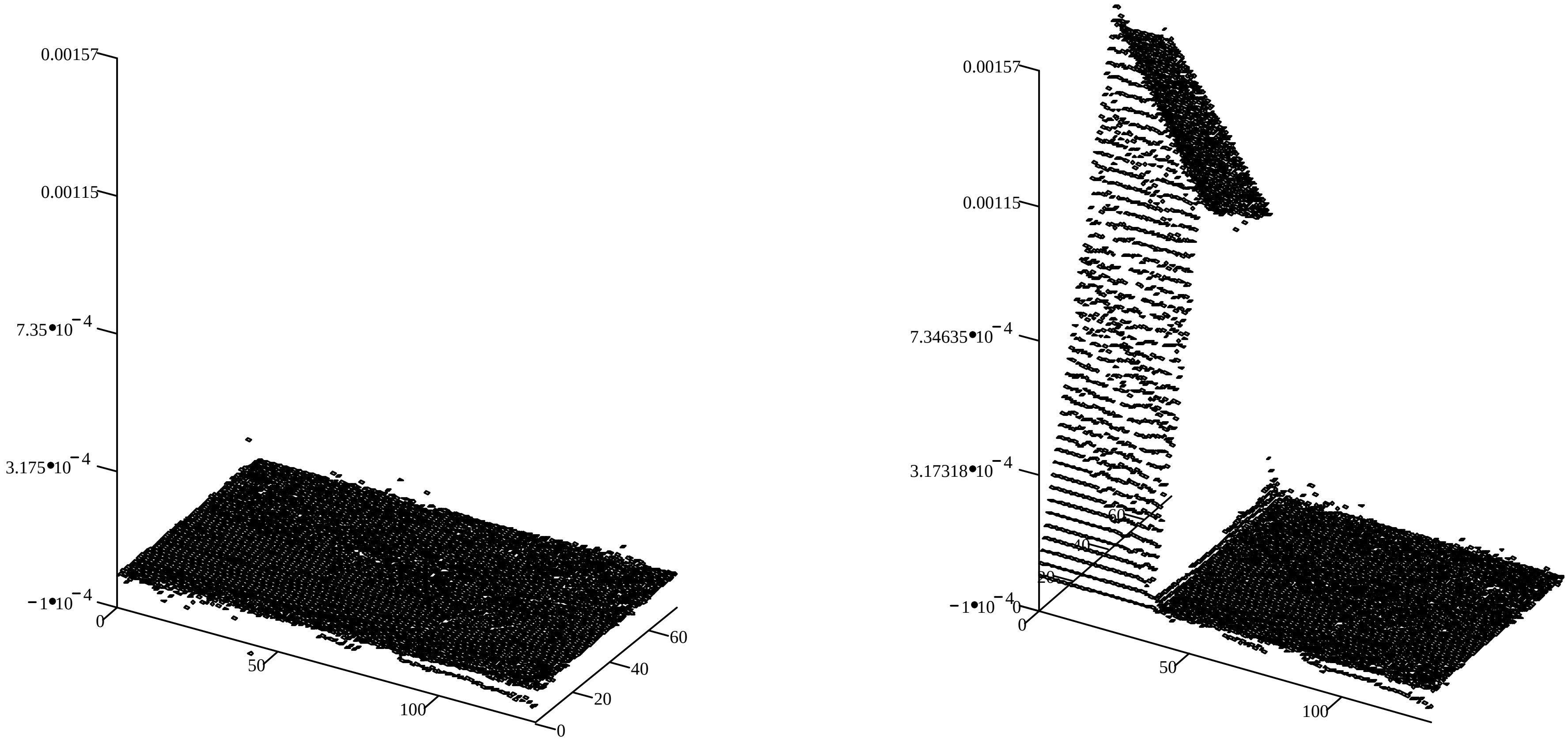
Figure 3. Equity Prices for Emerging Economy with and without Margin Requirements in the Low Productivity State
(as functions of the (α,b) pairs in the discretized state space Z)



Q1
Without Margin Requirements

Q1b
With Margin Requirements

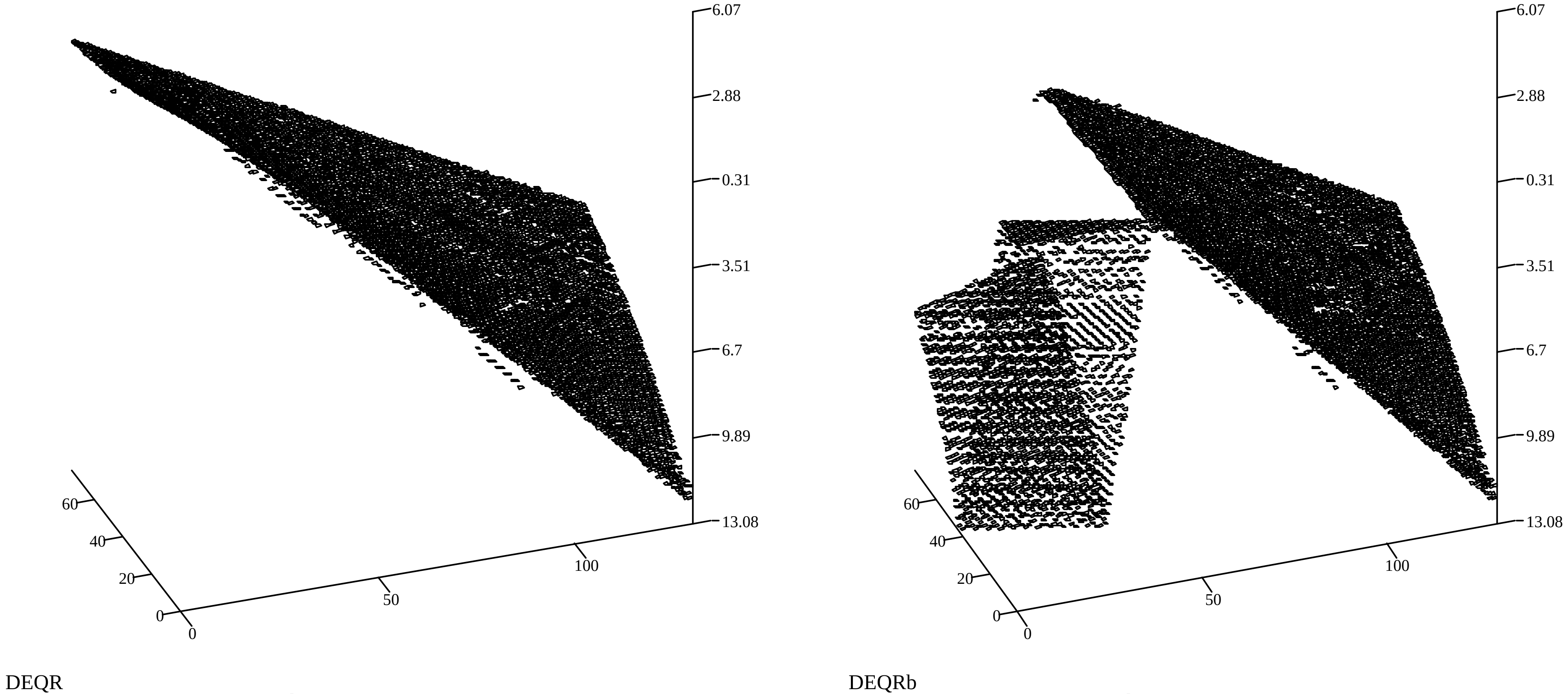
Figure 4. Premium on the Emerging Economy's Assets with and without Margin Requirements in the Low Productivity State
(as functions of the (α,b) pairs in the discretized state space Z)



EQP1
Without Margin Requirements

EQP1b
With Margin Requirements

Figure 5. Debt Equity Ratios for Economies with and without Margin Requirements in the Low Productivity State
(as functions of the (α,b) pairs in the discretized state space Z)



Without Margin Requirements

With Margin Requirements

Figure 6. Ergodic Cumulative Distribution Functions of Bonds and Equity Holdings in Economies with and without Margin Requirements

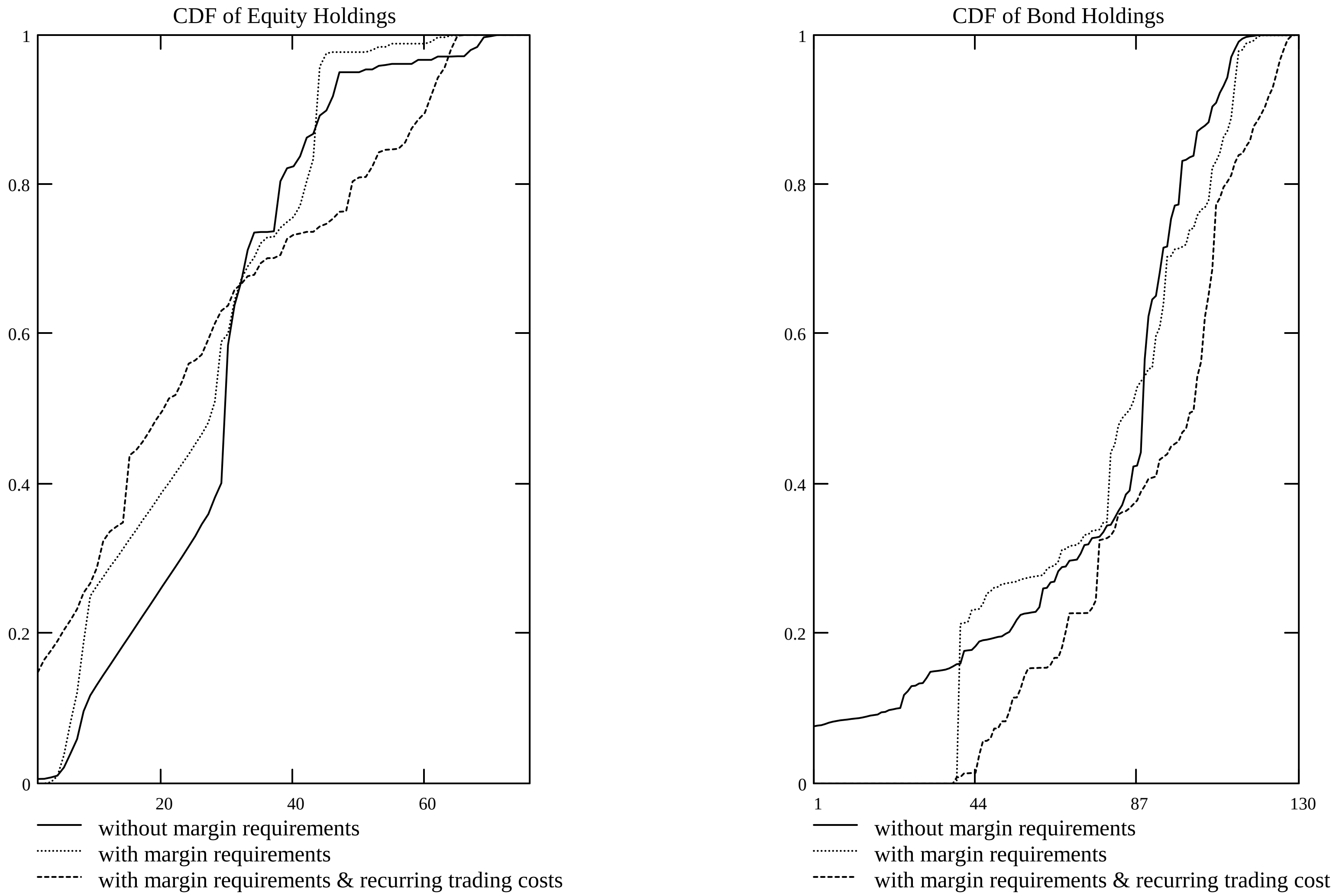
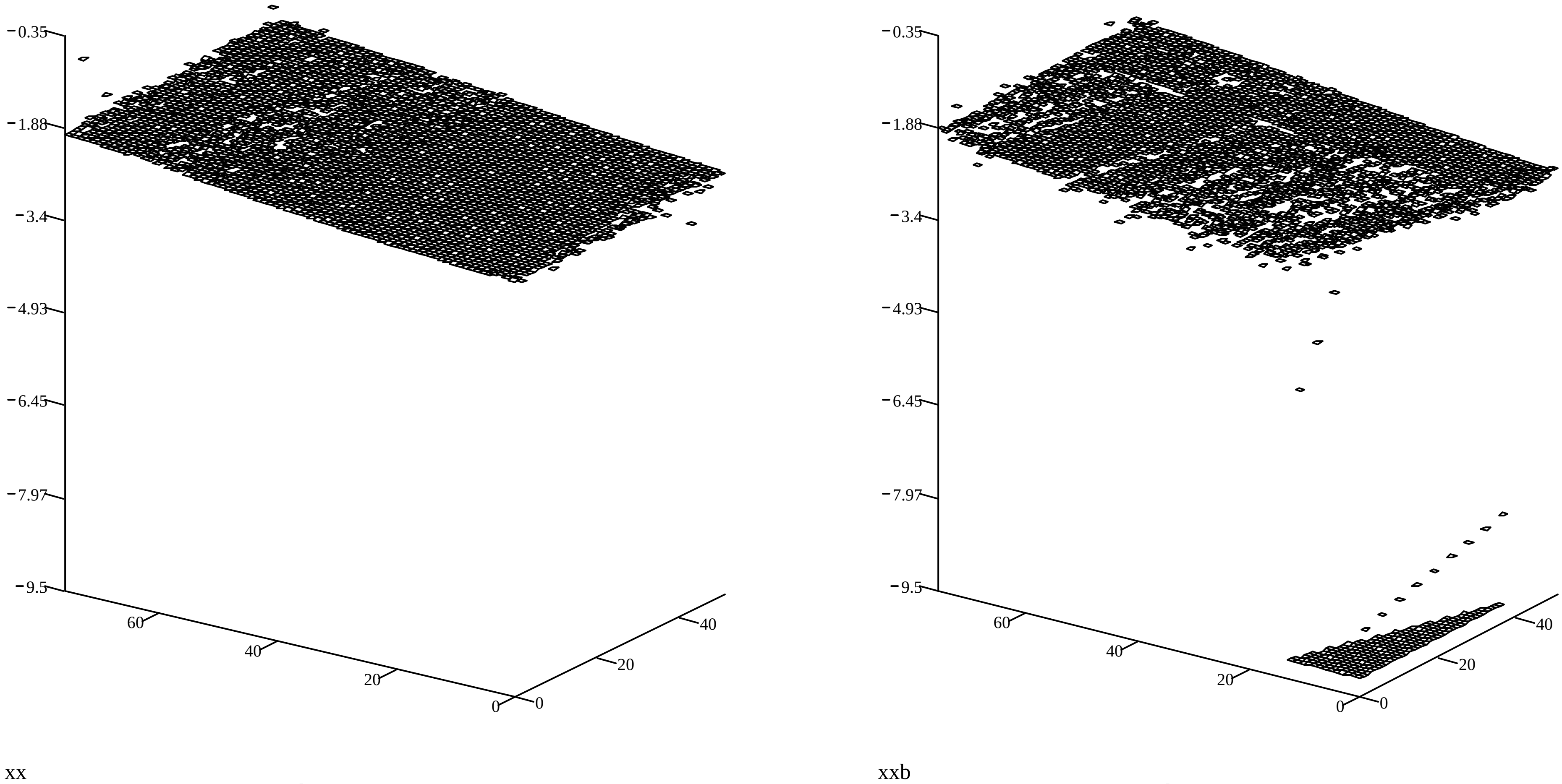


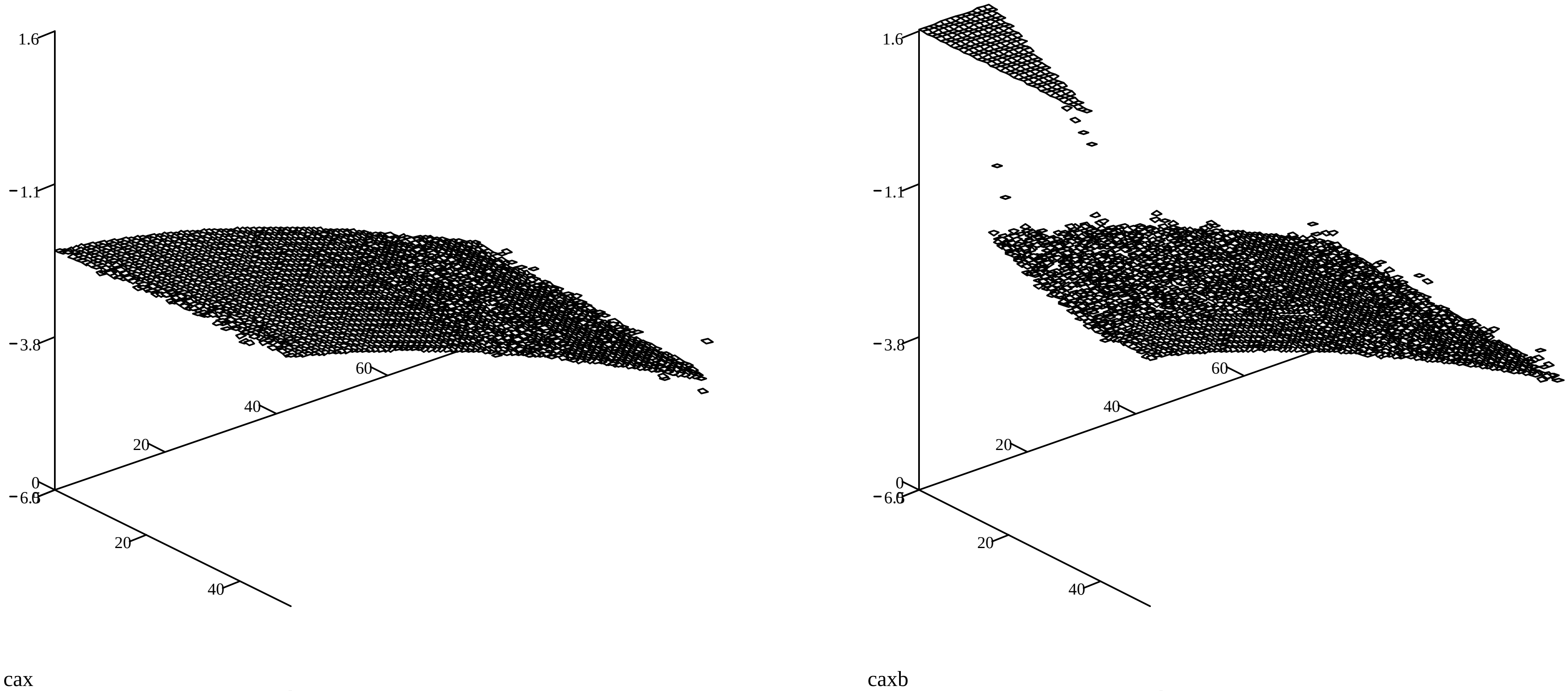
Figure 7. Impact Effect of a Productivity Shock on Consumption in the Margin Calls Region
(as functions of the (α,b) pairs in the subset of the state space with margin calls)



Without Margin Requirements

With Margin Requirements

Figure 8. Impact Effect of a Productivity Shock on the Current Account-Output Ratio in the Margin Calls Region
(as functions of the (α,b) pairs in the subset of the state space with margin calls)



Without Margin Requirements

With Margin Requirements