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The Impact of Financial Frictions on a Small Open Economy: When Current Account Borrowing Hits a Limit*

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Abstract

The evidence of the last 20 years of recurring output busts and rapid reversals of the current account in emerging markets indicates that domestic agents may not be able to borrow in international capital markets to fully insure themselves against internal and external shocks. This paper models this phenomenon as a form of excess volatility by introducing a financial friction into a stochastic model of a small open economy. The financial friction limits the current account deficit to a fixed fraction of gross domestic product. The paper shows that conditional volatility and asymmetry are significant statistical characteristics of the GDP and current account that reflect the excess volatility and the current account reversals. The economic model can explain the conditional volatility and asymmetry of Mexican GDP and the current account.

JEL Codes: F32, F34, F41, C32

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1 Introduction

The evidence of consumption and output collapses in emerging markets is associated with rapid reversals in the current account and thus suggests limited access to international credit. During the 1980s most Latin American countries were essentially excluded from international capital markets after the Mexican debt crisis of 1981. Economic activity, growth and consumption stalled. Beginning in the late 1980s and continuing through the 1990s there was a strong effort to reintegrate Latin American markets into the world economy. Emerging markets again faced unfavorable problems with external financing in the 1990s. Mexico, in 1994, and Asia, in 1997, experienced rapid reversals in the current account (Milessi-Ferretti and Razin, 1997, 1998; Edwards, 1998).[1] Moreover, for emerging markets the periods of current account reversals (balance-of-payments crises) were also associated with deep recessions. Calvo (1998) has termed this phenomenon the "sudden stop".

From a statistical point of view, the conditional distribution of gross domestic product (GDP) and the current account across several emerging markets deviates significantly from the Normal distribution and exhibits important nonlinearities in that it displays conditional volatility.[2] The statistical properties of these time series characterize economic phenomena studied in the international macroeconomics literature. For example, excess volatility corresponds to time series that display either conditional volatility or high kurtosis, and the sudden current account reversals correspond to time series that display skewness. This paper presents evidence that macroeconomic aggregates for seven emerging markets significantly deviate from Normality and display conditional volatility, particularly GDP, private investment, and the current account. This paper also shows that a small open economy (SOE) model with financial frictions can quantitatively reproduce these

[1] Radelet and Sachs (1998) estimate the net capital outflow in the 1997 Asian financial crisis was upwards of US$ 34 billion.

[2] For the treatment of statistical nonlinearities see Gallant et al. (1993). This notion of nonlinearity is different from the concept of nonlinearity used in the deterministic chaos literature (e.g., Potter (1999) or Brock (2000)).

properties of the times series, using Mexico as a case study.

The model presented here features agents of an SOE who borrow at an internationally set interest rate to smooth consumption. The key assumption of the model is the introduction of a financial friction. Domestic agents face an international financial friction that limits the current account deficit as a percentage of GDP. Specifically, the current account deficit cannot exceed a given fraction of the GDP. One can think of this constraint as arising either from international lenders perceiving a this current account deficit as the maximum sustainable deficit or from a government imposing capital controls to target a maximum current account deficit.

The financial constraint is occasionally binding. This results in simulated time series that exhibit periods of relative stability along with periods of crisis, when the conditional volatility will be high. In the model presented here the constraint is on the flow of assets. Agents cannot self-insure by accumulating buffer stocks of international assets, although the maximum current account deficits are limited. The frequency of crisis in this framework is dependent on how "tight" the constraint is. Periods of crisis can be very frequent if the constraint is tight enough, although the largest deficit will not be as large so the reversal will be smaller. The constraint is more binding when the domestic economy faces a negative shock. Moreover, the constraint limits current account deficits and not surpluses, potentially leading to asymmetries in the time series.

The method used to evaluate the model against the data is the efficient method of moments (EMM) (Gallant and Tauchen, 1996, 2000). EMM is a two-step process that links estimation and simulation techniques. In the first step, we obtain a complete statistical description of the time series of interest. A statistical model of Mexican GDP and current account data is estimated to a family of statistical models using a Seminonparametric (SNP) estimator. The SNP family of statistical models nests a vector autoregression (VAR) but it also includes terms that can capture conditional volatility and a non-Normal conditional distribution, which are the statistical properties of interest. A statistical model that captures the most important statistical properties of the time series is chosen, penalizing larger statistical models. An important result is that a VAR statistical model is not rich enough to capture the nonlinear properties of Mexican output and the current account. There is strong evidence that those two time series exhibit both conditional volatility and a non-Normal joint conditional distribution.

In the second step, the SOE model is simulated for a candidate set of parameters until the statistical properties of the simulated series are as close as possible to the statistical properties of the Mexican data. EMM uses the information from the statistical model of the time series and chooses parameters that make the economic model most closely resemble the statistical model under a minimum chi-squared (i.e., generalized method of moments) criterion. A second important result is that the SOE model can capture the conditional volatility of the GDP and the current account as well as the asymmetry of GDP.

There are several recent alternative theories explaining the role financial frictions play at the domestic and international level in generating excess volatility and sudden stops. Look at the work by Arellano and Mendoza (2002) for a recent literature review. The model studied in Mendoza (2001) is closest to the one presented here. Mendoza considers an SOE that faces a financial constraint that is only occasionally binding. The financial friction arises from income requirements on loans to finance current expenditures. The model predicts periods of relative stability and periods of high volatility, associated with sudden stops. Mendoza refers to periods when the constraint binds and the volatility of the time series is high as periods of "excess volatility". The periods of excess volatility are relatively rare, though, as agents self-insure by accumulating international assets for buffer stock reasons.

2 Data

This section presents evidence of deviations from Normality for seven emerging markets: Argentina, Brazil, Korea, Mexico, Peru, Thailand, and Turkey.[3] The selection of countries is based on data availability. The series that are summarized are the following: private consumption, gross fixed capital formation (GFCF), private investment (not including purchases of consumer durables), government expenditures, and public investment, exports, imports, GDP and the current account as a percentage of GDP. Private investment is derived from combining inventory investment and GFCF.

[3] An appendix shows data sources.

The RBC literature primarily focuses on the business cycle frequencies of the macroeconomic time series, commonly filtering the time series data to remove trending and seasonal effects. A band pass filter (BP) (Christiano and Fitzgerald, 1999; Baxter and King, 1999) is used to filter the data. In this application we use the BP filter by Christiano and Fitzgerald (1999).[4] The BP filter minimizes the mean squared error between the estimated spectral decomposition and the true spectral decomposition of a particular process and works well for standard macroeconomic time series. The filter used is nonlinear and isolates the business cycle properties of the time series between 6 and 32 quarters. This filter assumes that the raw data is close to having a unit root.

Table 1 gives sample statistics for GDP, its components, and the current account for the seven countries. The sample skewness and kurtosis show important deviations from Normality (the Normal distribution has a skewness of 0 and a kurtosis of 3) for most time series. A positive kurtosis indicates that positive changes in a time series tend to be small but relatively more frequent than negative changes. Kurtosis in excess of 3 indicates that there are more frequent "large" changes in the time series than would be predicted by the Normal distribution.

The Jarque-Bera statistic (J-B column) is a statistical test (1987) of the null assumption of Normality based on the sample skewness and kurtosis of the series of interest. It is distributed $\chi^2(2)$. The test is applied to the raw series, not to prewhitened series. If data series were Normally distributed, then we should expect few rejections of the J-B statistic. The J-B statistic does not directly test for the presence of conditional volatility or any other nonlinearity, except for those that lead to asymmetries or thick tails on the time series. However, if a series exhibits conditional volatility, it might produce large estimates for kurtosis, and thus a rejection of the J-B test.

The sudden stop phenomenon is characterized by quick reversals in the current account, sharp drops in output, consumption, and investment, and excess volatility. The excess volatility might show up as conditional volatility and thus may lead to rejections of the J-B statistic, as explained above. The quick reversal in the current account would lead to large rapid improvements in the current account, which would show up as skewness, because one does not observe similar sudden

[4] Filtering in the RBC literature is typically done using the Hodrick-Prescott (HP) filter (Hodrick and Prescott, 1980). The problem with using the HP filter is that it may distort sample second moments of the data in small samples (King and Rebelo, 1993).

large deteriorations in the current account; or it would lead to thick tails because we would have larger changes than those predicted by the Normal distribution. Similarly, drops in output and its components might also lead to skewness and thick tails. The excess volatility would be captured by either thick tails in the distribution, or by significant conditional volatility. So, there are many characteristics of the sudden stop that may lead to rejections of the J-B test. Of course, the sudden stop is not the only reason that one may observe nonlinearities in macroeconomic time series. That is why it is important to study whether a model of the financial frictions can generate the observed nonlinearities.

Overall, investment is the series for which the hypothesis of Normality is most often rejected (four of seven countries).[5] The hypothesis of Normality is rejected for GDP in three countries (Korea, Mexico, and Turkey). GDP is negatively skewed in four countries (Argentina, Korea, Mexico, and Thailand). This negative skewness may be a reflection of the severe recessions that these countries experienced during the sudden stop.

The hypothesis of Normality for the current account (as a percentage of GDP) can be rejected only in one country (Korea); at the same time skewness is positive in six of the seven countries (Brazil being the exception). However, results presented in this paper show that Mexico's current account exhibits significant conditional volatility and asymmetry. This suggests that the J-B test might not be capturing the deviation from nonlinearity in the time series. One possible reason for this result is that the J-B test is designed to detect deviations from Normality on the residuals of a time series after estimating a statistical model. Another possible reason is that the test has low power at this sample size (Urzúa, 1996; Dufour et al., 1998).[6]

Figures 1 and 2 present filtered GDP and current account time series, respectively, for four countries (Korea, Mexico, Peru, and Turkey) with the longest time series. Figures 3 and 4 present histograms for GDP and the current account, respectively. The histograms for Mexico and Korea exhibit a slight negative skewness for GDP and a positive skewness for the current account. From Figure 1, one sees that large falls in Mexican and Korean GDP have been associated with problems

[5] Throughout, the small sample size for national account times series from Argentina, Brazil, and Thailand limits the statistical analysis, but evidence of deviations from Normality in investment is still present.

[6] Valderrama (2002) shows that the current account exhibits important conditional volatility across five OECD countries, including Mexico and Korea.

of access to international credit and reversals in the current account (1982 and 1994 in Mexico, and 1997 in Korea).

Figures 5 and 6 present evidence of conditional volatility for GDP and the current account, respectively. The graphs are generated by squaring the residuals obtained after estimating a three-period VAR on both series; the figures show a three-period moving average (MA(3)) of these squared VAR residuals. The squared residuals give an estimate of the conditional volatility of each series. The graphs of the GDP and of the current account indicate a strong conditional volatility for most time series. In Mexico, for example, Figure 5 presents evidence of periods of relative stability in GDP, particularly the periods of 1986–1993 and 1998–2000, and periods of high instability, 1984–1986 and 1993–1998. Because the graphs are for squared residuals, high numbers could reflect higher than usual growth as well as large recessions.

3 Small Open Economy

This section presents the theoretical model that attempts to explain the features of excess volatility. The model is based on a standard RBC model for an SOE (Mendoza, 1991, 1995) and follows closely the model by Mendoza (2001). Domestic households borrow and lend at an internationally determined market interest rate. International capital markets are incomplete.

The households face a borrowing constraint that limits the size of the current account deficit, as a percentage of GDP. No micro-based theoretical justification for the current account constraint is given. Instead, two observational arguments are made to justify this financial friction. First, this friction may arise in a world of imperfect information and imperfect enforcement of international contracts. Agents may not know the level of a country's indebtedness or the true state of its economy and may have an incentive to monitor the rate of the buildup of foreign debt. One of the most referred-to measures of foreign liability exposure is the current account/GDP ratio. Lenders may have a "critical" level of this ratio above which they are unwilling to finance further debt accumulation (Milessi-Ferretti and Razin, 1996b). The literature on current account sustainability finds that large current account deficits were a factor for the Mexican crisis of 1982, the Mexican crisis of 1994, and the Asia crisis of 1997 (Milessi-Ferretti and Razin, 1996a; Edwards, 2001).[7] This literature emphasizes the importance of financial flows as sources of crises, like this paper does.

A second way to rationalize the current account constraint is to consider a government of an SOE that limits (targets) the current account deficits to a certain fraction of GDP. Indonesia, prior to the financial debacle of 1998, announced a limit of 2% for the current account deficit (McLeod, 1997). In Chile, the Central Bank had a target of 3% for the current account deficit (Williamson, 1997). Many policymakers and government officials have advocated the imposition of limits on current account inflows. Evidence of this is provided by Reinhart and Smith (2002), who state that during the 1990s a number of countries imposed capital controls that "had two distinguishing characteristics: they were *asymmetric* and they were intended to be *temporary*... The asymmetry of the capital controls stemmed from the fact that they were targeted at discouraging capital inflows." The current account restriction used in this paper limits the net inflow of capital and only binds when the current account is "large."

3.1 Structure

Domestic firms choose labor demand, L_t, to maximize profits, π_t, period-by-period:

$$\pi_t = \exp(z_t) AK^{\alpha} L_t^{1-\alpha} - w_t L_t. \tag{3.1}$$

Firms are competitive and take the wage rate, w_t as given. The capital stock, K, is fixed for all firms. Production of total output, $Y_t = \exp(z_t) AK^{\alpha} L_t^{1-\alpha}$, is subject to a productivity shock, z_t; it is realized at the beginning of the period. Given the competitive environment, labor demand will equalize the wage rate and the marginal product of labor.

Households make consumption and labor supply decisions to maximize lifetime utility. They can borrow and lend internationally at an externally determined interest rate. Households face a market imperfection in that they cannot borrow purely based on their lifetime wealth (determined by a no-Ponzi-game condition).

Lifetime utility is given by a Stationary Cardinal Utility (SCU) index (Epstein, 1983) that

[7] Edwards (2001) provides a good survey of the current account sustainability literature.

exhibits a time-varying discount factor. SCU determines a well-defined stationary distribution of international assets in an SOE despite the market incompleteness (Mendoza, 1991).[8] The SCU utility function is:

$$\mathbb{U} = \max_{\{C_t, L_t, B_{t+1}\}} E_0 \left\{ \sum_{t=0}^{\infty} \left[u(C_t, L_t) \exp\left(-\sum_{\tau=0}^{t-1} v(C_\tau, L_\tau) \right) \right] \right\} \tag{3.2a}$$

where:

$$u(C_t, L_t) = \frac{\left(C_t - \frac{L_t^\omega}{\omega}\right)^{(1-\theta)} - 1}{1-\theta} \tag{3.2b}$$

$$v(C_t, L_t) = \beta \ln\left(1 + C_t - \frac{L_t^\omega}{\omega}\right). \tag{3.2c}$$

The instantaneous utility function, $u(C_t, L_t)$, is defined as in Greenwood et al. (1988) (GHH). Instantaneous utility is defined as a composite good made up of consumption goods, C_t, and labor, L_t. The intertemporal elasticity of substitution of labor supply is $1/(\omega - 1)$. Using the GHH instantaneous utility function in a frictionless framework would result in labor demand that would be independent of wealth effects and would depend only on the wage rate. As it is shown below, this is no longer in this model when the financial friction binds. Nevertheless, this form still greatly helps in the computation of the decision rules. θ is the coefficient of relative risk aversion. The time-varying discount factor is given by $v(C_t, L_t)$ and is chosen to ensure that a stationary distribution exists for foreign assets (Mendoza, 1991). β captures the sensitivity of the discount factor to changes in consumption and labor.

Households maximize lifetime utility (3.2) subject to the budget constraint:

$$C_t = \pi_t + w_t L_t + B_t \left(1 + r_t^*\right) - B_{t+1}, \tag{3.3}$$

where B_t is the net holding of international assets ($B_t < 0$ if the domestic household is a net debtor

[8]The SCU index works like Uzawa-type preferences in a stochastic setting. Both types of preferences exhibit a time varying-discount factor. Schmitt-Grohé and Uribe (2001) discuss other ways to induce a steady state for international assets in an SOE framework.

to the rest of the world). The international interest rate, r_t^*, is taken as given by the domestic economy and changes through time owing to an international shock, η_t, $r_t^* = r^* \times \exp(\eta_t)$.

Given that there exists only one international noncontingent bond and there are two shocks, markets are incomplete. Thus, domestic agents are subject to wealth effects coming from shocks to the international interest rate. Marginal utility depends on wealth, and agents accumulate international assets for buffer stock reasons to self-insure against domestic shocks.

The domestic household faces two restrictions on international borrowing. The first is the usual no-Ponzi-game condition, $B_t > \underline{B} > -\infty$. The second is a financial friction that limits the percent of additional net borrowing to an exogenously given fraction of current income, κ:

$$\frac{B_{t+1} - B_t}{\pi_t + w_t L_t} \geq -\kappa. \tag{3.4}$$

If $\kappa > 0$ then the domestic household is limited in the amount of additional borrowing that it can do as a function of the domestic product. The larger the current account, the more borrowing the domestic household can do. If $\kappa = 0$ the household is prevented from reducing its net foreign asset position period by period, but it still has to pay the interest on any outstanding debt.

The financial friction given by (3.4) is the key difference between this model and the model by Mendoza (2001), where there is a restriction that the *level* of debt cannot exceed a certain fraction of current income. That is, the constraint in this paper is on the *flow* of international assets and not on the *stock* of international assets. In contrast with Mendoza's paper, the domestic agents in this economy cannot accumulate additional assets to prevent hitting the constraint.

Models of financial frictions that limit the *stock* of future debt have documented that crisis episodes that occur when the financial constraint binds are rare in the long run because agents accumulate additional assets to avoid hitting the constraint (Mendoza and Smith, 2001; Mendoza, 2001). In this model, this mechanism is dampened: agents cannot use accumulated assets to self-insure against a binding constraint. This happens because the borrowing constraint limits the *flow* of assets. But when the domestic economy faces a large negative shock, the incentive is to liquidate foreign assets rapidly to smooth consumption. The domestic economy is prevented from doing this too rapidly because this would imply a large current account deficit which would violate the flow borrowing constraint. For a given limit on current account borrowing, the larger the volatility of the negative shocks, the more the constraint binds and the less the incentive to self-insure. Thus, in this model if the borrowing constraint is tight enough crises can be more frequent than would occur in a setup where the limit was on the stock of debt.

Define the current account as:

$$CA_t = B_{t+1} - B_t. \tag{3.5}$$

Since all agents are identical and in equilibrium households' income must equal domestic product (GDP), then the restriction says that the current account deficit cannot exceed a given fraction of GDP. The constraint is written so that each household internalizes the current account restriction.[9] In this case κ represents either the critical level of current account sustainability that triggers a crisis or the current account target. [10]

The last step necessary to close out the model is to specify the behavior of the stochastic variables. The two stochastic shocks are assumed to follow a VAR(1) process. That is:

$$\zeta_t \equiv \begin{pmatrix} z_t \\ \eta_t \end{pmatrix} = \begin{pmatrix} \rho_z & 0 \\ 0 & \rho_\eta \end{pmatrix} + \begin{pmatrix} \epsilon_{z_t} \\ \epsilon_{\eta_t} \end{pmatrix} \tag{3.6a}$$

where:

$$\varepsilon_t \equiv \begin{pmatrix} \epsilon_{z_t} \\ \epsilon_{\eta_t} \end{pmatrix} \sim N\left(\mathbf{0}, \begin{bmatrix} \sigma^2_{\epsilon_z} & \sigma_{\epsilon_z,\epsilon_\eta} \\ \sigma_{\epsilon_z,\epsilon_\eta} & \sigma^2_{\epsilon_\eta} \end{bmatrix}\right). \tag{3.6b}$$

[9] The fact that individual households might not internalize the borrowing constraint and "over-borrow" is discussed by Jeske (2000). He finds that under certain conditions, an improvement might be made by restricting domestic agents from borrowing internationally and only allowing the domestic social planner to make decisions on international asset accumulation. For many emerging markets, the domestic government dominates borrowing from international capital markets and few domestic firms are able to borrow internationally, mitigating the coordination problem.

[10] In the calibration of this model, κ is fixed through time. However, this does not imply that any two countries share either the same level of a sustainable current account deficit or the same current account target.

3.2 Equilibrium

Collect the SOE model's parameters in the vector Θ as follows:

$$\Theta = (\sigma_{\epsilon_z}, \sigma_{\epsilon_\eta}, \rho_z, \rho_\eta, \sigma_{\epsilon_z,\epsilon_\eta}, \alpha, A, \omega, \beta, \theta, \kappa).$$

Given the model's parameters, Θ, the capital stock, K, the initial international asset position, B_0, and the evolution of the stochastic variables (3.6), the equilibrium is defined as an infinite sequence of variables $\{B_{t+1}, L_t, C_t\}_{t=0}^{\infty}$ and wages $\{w_t\}_{t=0}^{\infty}$ such that:

1. Firms, taking wages as given, maximize profits (3.1) subject to their production function.
2. The household, taking wages and the international interest rate as given, maximizes lifetime utility (3.2) subject to the budget constraint (3.3) and the borrowing constraint(3.4).
3. The goods market and the labor market clear.

It is straightforward to show that the competitive equilibrium can be obtained as the solution to a domestic central planner that takes the international interest rate as given. The problem of the domestic central planner is time recursive (Epstein, 1983; Mendoza, 1991) and it can be rewritten as a dynamic programming problem:

$$\mathbf{V}(B_t, \zeta_t) = \max_{B_{t+1}} \left\{ u(C_t, L_t) + \exp\left[-\beta \log\left(1 + C_t - \frac{L_t^{\omega}}{\omega}\right)\right] \times E_t\left[\mathbf{V}(B_{t+1}, \zeta_{t+1})\right] \right\} \tag{3.7}$$

subject to the economywide resource constraint,

$$C_t = Y_t + r^* * \exp(\eta_t) B_t - B_{t+1} + B_t \tag{3.8}$$

and the current account restriction,

$$\frac{CA_t}{Y_t} \geq -\kappa. \tag{3.9}$$

Each period, the central planner chooses labor and the foreign asset position to maximize the instantaneous utility plus the discounted value of future utility, subject to the current account borrowing constraint and the budget constraint. The discount rate includes the impatience effect induced by the time-varying discount factor.

3.3 Optimality Conditions

The central planner's optimality conditions are given by:

$$C_t : \qquad 0 = \mathbb{U}_C(t) - \lambda_t \tag{3.10}$$

$$L_t : \qquad 0 = \mathbb{U}_L(t) + \lambda_t F_L(t) + \mu_t \kappa F_L(t) \tag{3.11}$$

$$B_{t+1} : \qquad 0 = -\lambda_t + \mu_t + E\left\{\lambda_{t+1}(1 + r^*_{t+1}) - \mu_{t+1}\right\} \tag{3.12}$$

where λ is the Lagrange multiplier on the resource constraint (3.8) and μ_t is the non-negative Lagrange multiplier on the borrowing constraint (3.9). The marginal utility terms $\mathbb{U}_C$ and $\mathbb{U}_L$ include the marginal effect on the time-varying discount factor.

Combining (3.10) and (3.12) results in the Euler equation for international bond accumulation:

$$\mathbb{U}_C(t) - \mu_t = E_t\left\{\exp\left(-v(t)\right)\mathbb{U}_C(t+1)(1 + r^*_t) - \mu_{t+1}\right\}. \tag{3.13}$$

This condition equates the marginal utility of present consumption, net of the marginal cost of the constraint binding in the present, with the marginal utility of future consumption, in present value terms, net of the marginal utility cost of the constraint becoming binding in the future.

The effect of the constraint becoming binding in the current period (i.e., $\mu_t > 0$) is the unambiguous lowering of consumption, (3.13). The impact of the borrowing constraint is to increase the effective interest rate faced by domestic agents and to increase the marginal benefit of working today. The presence of the financial constraint makes consumption more volatile because it is now forced to respond to changes in the effective interest rate in addition to the usual responses to interest rate and productivity changes. Consumption will have larger falls when the constraint is binding and larger increases when the constraint is relaxed. The high conditional volatility of consumption results only when the constraint is near its limit. Otherwise, consumption will respond to shocks in the usual way. The impact of a binding constraint on the current account is to make it smaller than it would otherwise be (by definition of the constraint).

The effect of the constraint becoming more binding in the future (i.e., $\mu_{t+1} > 0$), in expected terms, is to increase consumption today. The intuition for this is that when the constraint binds, the net benefit of saving today is less, reflecting a fall in the effective interest rate. Thus consumption increases. This leads to an increase in the current account deficit today when there is an expectation of the constraint becoming binding in the future, potentially increasing the current account's volatility.

Combining (3.10) and (3.11) results in the Euler equation for labor:

$$L_t^{\omega-1} = F_L(t)\left[1 + \frac{\mu_t}{\mathbb{U}_C(t)}\kappa\right]. \tag{3.14}$$

This condition equates the marginal benefit from working with the marginal disutility of working. The marginal benefit from working includes the marginal product of labor as well as an additional term that results from the current account restriction. If the constraint does not bind ($\mu_t = 0$) then this equation gives a closed form solution for equilibrium labor, as a function of its marginal product. In this case, the evolution of labor is independent of the time path of consumption. This fact is exploited in the numerical solution method.

If the constraint does bind in the current period ($\mu_t = 0$), then there is an extra benefit from working because it will help to slacken the borrowing constraint, thus increasing labor and output. Suppose that the constraint binds due to a shock in the interest rate. While domestic income decreases, there is a negative wealth effect introduced by the constraint that induces labor effort to increase, increasing output, and potentially increasing output volatility. There is also an additional effect if the constraint binds in the current period. Notice that the marginal utility of consumption enters in the denominator of the second term of equation (3.14). If the constraint binds today, then consumption drops, increasing marginal utility and thus decreasing labor. Basically, if the constraint binds today, the relative price of consumption increases, and there is a substitution effect towards leisure.

The effect of the constraint is to introduce both intratemporal and intertemporal distortions to consumption, labor, and the current account. The effect on the time path and volatility on the current account (saving in this model), output, and consumption depends on parameter values. Later, the model is solved numerically and the effect of the constraint is discussed.

3.4 Solution Method

The competitive equilibrium for the SOE does not have a closed form solution and must be solved numerically. The model is solved by iterating on the value function (3.7) on a grid of the endogenous state variables, B_{t+1}, and the exogenous shocks, ζ_t . In practice, the international asset grid is centered around the deterministic steady state of the problem, and the grid is made up of 501 equidistant points. The grid for the two stochastic shocks are given by the quadrature rule of Tauchen and Hussey (1991) with five points for the productivity shock and four points for the international interest rate shock. For a given guess of the value function on each point of the state variable grid, one finds the optimal state-contingent policy rule using (3.7). The procedure is iterated until there is convergence in the decision rules at each point of the grid over two successive iterations. The solution to the model includes optimal state-contingent decision rules for asset accumulation (the endogenous state), B_{t+1}, labor, L_t, and consumption, C_t, as well as a value function, $\mathbf{V}(B_t, \zeta_t)$. The decision rules, together with the stochastic process for the exogenous state, ζ, imply a transition density function for the endogenous state and the controls, as well as an invariant long-run distribution for the state. In practice, this paper does not calculate the transitional or long-run distribution. Instead the model is simulated to obtain the transition density function of the desired simulated time series.

The value function iteration algorithm is memory and time intensive but it allows the simulated series to properly account for the nonlinearity of the model and the occasionally binding constraint imposed by the restriction on the capital account.[11] Solution methods that result in linear decision rules (by using linear quadratic approximations of the original problem or by linearizing the first order conditions of the problem) cannot handle occasionally binding constraints and will not produce time nonlinear simulated time series.

[11]The algorithm is made faster by storing the resulting value function for each set of parameters and using this as a guess for subsequent simulations.

4 SOE Model Evaluation

The approach followed here to assess the ability of the SOE model proposed in Section 3 to account for the observed statistical regularities of the sudden stop is based on the EMM methodology developed by Gallant and Tauchen (1996, 2000). This method has been previously adopted to study macroeconomic models by Valderrama (2001), and a detailed description of the methodology and further references are given there. Most of the description of the statistical procedure in this section and in the next is taken from there as well.

The EMM methodology consists of two steps. In the first step, the statistical properties of current account and GDP data are characterized using a seminonparametric (SNP) estimator (Gallant and Tauchen, 1998). Successively complex statistical models of the data are estimated until an optimal statistical characterization is achieved using a BIC criterion. The BIC criterion maximizes the quasi-maximum likelihood probability of the statistical model, but also adds a penalty term for statistical models with more parameters. The key to this first step is to take a flexible approach to estimating the statistical model so that, as more observations are available, increasingly richer statistical models are used. This flexibility is necessary because the estimates of the statistical model serve as moments (scores) for the second step of the EMM procedure, the simulation stage. By taking this flexible approach EMM is as efficient as maximum likelihood estimation. The resulting statistical model from the first step is referred to as the score generator (it is also referred to as the auxiliary model). This flexibility is also important because it allows the study of features of the data that would be overlooked by a more rigid statistical structure (e.g., VAR). In particular, a straight VAR approach may miss the conditional volatility and asymmetry present in the Mexican time series that capture the sudden stop.

The SNP estimator used in the first step is flexible enough to capture the rich (nonlinear) statistical features present during the sudden stop. The empirical macroeconomics literature has focused on VARs to summarize the statistical properties of time series data. However, as was shown in data section, nonlinearities are significant features of the sudden stop and these are not easily captured by the VAR framework. The SNP hierarchy nests VAR. The SNP estimator also includes terms to capture richer statistical features for time series, such as periods of low volatility followed by periods of high volatility (i.e., conditional volatility), asymmetric business cycles (i.e., skewness), and "thick tails" (i.e., excess kurtosis).

In the second step of the EMM method, the SOE model is simulated for a candidate set of parameters of the SOE model, Θ. A comparison is made between the statistical properties of the data, characterized by the parameters of the preferred SNP model that serve as moments, and the statistical properties of the simulated data. If the SOE model were the true data generating process for the Mexican data, then each of the sample scores would equal zero and the objective function would also equal zero. The parameters of the economic model are adjusted until the statistical properties of the simulations are as similar as possible to the statistical properties of the observed data. Given that there are more statistical parameters than economic model parameters then the objective function will not be equal to zero in general and the objective function serves as an omnibus test of specification for the model (i.e., it is a test of the over-identifying restrictions). The flexibility in choosing the statistical model in the first step is relevant in the second step because the economic model will have to match the conditional volatility and non-Normality observed in Mexico's GDP and current account time series.

The SOE model is tested against Mexican GDP and the current account data. Mexico is chosen because it is a country with a long, relatively good series that has experienced two clear periods of crisis associated with problems of access to capital markets. EMM will test the economic model against the joint statistical behavior of GDP and the current account. Since the first step of EMM involves a careful statistical description of the time series, this paper considers only two time series to obtain a parsimonious statistical model that captures the nonlinear features of the data. GDP and the current account are chosen because those are the two time series that have received the most amount of attention in the sudden stop literature and capture the most dramatic behavior of the sudden stop.

4.1 Statistical Properties of the Data

Define y_t as the "true" stochastic process of a particular time series to be estimated, the data generating mechanism for GDP and the current account in this case. Define $p(y_t \mid y_{t-1}, y_{t-2}, ...)$

as the conditional distribution function, which fully characterizes the statistical properties of y_t. $p(y_t \mid \cdot)$ is assumed to be Markovian of order L. Vector $x_{t-1} \equiv (y_{t-L}, \ldots, y_{t-1})$ is the lagged values of the time series. SNP approximates $p(y_t \mid x_{t-1})$ with a statistical model. $f(y_t \mid x_{t-1}, \Omega)$ is the transition distribution function of the statistical model, where Ω represents the parameter vector of the statistical model. $\tilde{y}_t$ is a vector of the observed stochastic processes of the GDP and current account quarterly time series. Thus, $f(y_t \mid x_{t-1})$ is estimated using the observed GDP and current account data, $\tilde{y}_t$.

SNP assumes that the conditional mean of the stochastic process, μ_{t-1}, is captured by a VAR. The vector $\Psi = \text{vec}[b_0 \mid B_1 \cdots B_{L_\mu}]$ groups the parameters of the VAR(L_μ). SNP also allows the volatility of the stochastic process for y_t to vary through time (i.e., stochastic volatility). Define $\Sigma_{x_{t-1}} = R_{x_{t-1}} R'_{x_{t-1}}$ as the conditional variance-covariance matrix. SNP nests a GARCH(L_G, L_R) structure to accomplish this; L_G is the lag for the GARCH component and L_R is lag for the ARCH component of the conditional volatility R_{t-1}. The conditional variance parameters are collected on matrices labelled P for the ARCH structure and matrices labelled G for the GARCH structure. The vector ρ_0 collects the intercepts of the variance-covariance terms. In summary, the variance-covariance structure can be written as follows:

$$\text{vech}\left(R_{x_{t-1}}\right) = \rho_o + \sum_{i=1}^{L_r} P_{(i)} \left| y_{t-1-L_r+i} - \mu_{x_{t-2-L_r+i}} \right| + \sum_{i=1}^{L_g} \text{diag}\left(G_{(i)}\right) \text{vech}\left(R_{x_{t-2-L_g+i}}\right). \quad (4.1)$$

The parameters that describe the (conditional) volatility are collected into the following vector $T = \text{vec}[\text{vec}\,\rho_0 \mid \text{vech}\,P_1 \cdots P_{L_r} \mid \text{vech}\,G_1 \cdots G_{L_g}]$. The G and P matrices are assumed to be diagonal, meaning that the conditional variance terms for consumption and investment only depend on their own lagged innovations and not on the other series' lagged innovations.

The SNP estimator also nests a non-Gaussian transition density. SNP assumes that the transition density is a transformation of the normal distribution. A hermite polynomial is used for this purpose:

$$h\left[R_{x_{t-1}}^{-1}(y_t - \mu_{t-1})\right] \propto [P(z,x)]^2\, \phi(t \mid \mu, R)$$

$$P_K(z,x) = \sum_{\alpha=0}^{K_z} \sum_{\beta=0}^{K_x} (a_{\beta\alpha} x^{\beta}) z^{\alpha}.$$

Here, $h[\cdot]$ is the conditional distribution of the normalized innovation z ($z = R_{x_{t-1}}^{-1}(y_t - \mu_{t-1})$), and $\phi(\cdot)$ is a standard Normal probability density function. By increasing the degrees of the polynomial $P(z,x)$, SNP attains increasingly rich statistical structures. If $K_z = 0$ and $K_x = 0$ then the statistical model has a Gaussian error structure. If $K_z > 0$, $K_x = 0$ then the statistical model has a semiparametric error structure. If $K_z > 0$, $K_x > 0$ then conditional distribution is fully non-parametric and depends on lags of the data. The parameters of the hermite polynomial, $a_{\beta\alpha}$, are collected in the matrix $A = [a_{\beta\alpha}]$. The number of parameters grows rapidly as one expands through the hermite polynomial. Thus, SNP allows suppression of interactions between series through the control parameters I_z and I_x so that only the terms with interaction between different series of degree greater than $K_z - I_z$ and $K_x - I_x$ are estimated. The entire SNP parameter vector Ω is given by $\Omega = [A \mid \Psi \mid T]$.[12]

Statistical model selection within the SNP procedure is done by expanding through the SNP hierarchy of candidate statistical models. Gallant and Tauchen (1998) recommend the use of the Schwarz Bayesian Information Criterion (BIC) to help choose amongst different statistical models. Table 2 shows the expansion through the SNP hierarchy. At first, VAR statistical models are considered ($L_g = 0$, $L_r = 0$, $K_z = 0$, $K_x = 0$).[13] After selecting a VAR(3) model (selected by the right arrow $\Rightarrow$), one moves to consider firm ARCH terms ($L_r > 0$), then GARCH terms ($L_g > 0$), and finally we consider nonlinear terms ($K_z > 0$).

The limited nature of the sample size leads to smaller statistical models. For some statistical model specifications, the standard errors of the estimates cannot be estimated even if improvements are made on the likelihood function or the BIC criterion. In these cases, the parameters cannot be

[12] It is the flexibility of the SNP score generator to nest a variety of statistical models that leads EMM to be efficient. Gallant and Nychka (1987) show that as the number of parameters increases with the sample size, SNP is a consistent estimator of the transition density.

[13] $L_p = 1$ due to coding. This SNP control parameter does not do anything until $K_x > 0$.

used for the second step of the EMM procedure and so the particular SNP model is discarded.

It is important to note that the BIC was driven down for the VAR term of order greater than 3. In fact, the BIC was minimized for a VAR of order 11. At that point, however, it was not possible to obtain significant estimates for the nonlinear parameters (ARCH, GARCH, Hermite polynomial), which are features of the Mexican time series we want to explore because these features quantify economic events of interest (crises in this case). Previous experience has shown us that a VAR of order 3 is sufficient to capture movements of the mean and so we proceed from there. We take the model of VAR(3) with ARCH(1) and a hermite polynomial of the 3rd degree with all the interactions suppressed as the most accurate statistical model of the Mexican GDP and current account. The VAR(3) with ARCH(1) and a hermite polynomial of the 4th degree receives a better BIC score but the standard errors on the polynomial terms are all too high, rendering the point estimates statistically insignificant. Given the limited sample size it is difficult to estimate the deviation from Normality, especially the term for the 4th degree of the hermite polynomial, which is usually associated with the excess kurtosis of the conditional distribution time series being estimated.

Table 3 gives the SNP parameter estimates for the statistical model of the Mexican time series. The first column gives the point estimate, the second column gives the standard error for each parameter estimate and the third column gives the associated t-statistic. All terms of the VAR are statistically significant for the statistical model. This should not come as a surprise since this particular data set could accommodate up to a VAR(12) structure. The variance parameters are all significant, including the conditional volatility terms (ARCH(1)) for both GDP (0.3414, t-statistic 7.784) and the current account (0.8057, t-statistic 3.524). This confirms the evidence shown in Section 2 regarding the conditional volatility of GDP and the current account. Finally, the higher order hermite polynomial terms for GDP are significant ($A(y^2)$=1.52745, t-statistic=1.955; and $A(y^3)$=0.43059, t-statistic=2.024). This confirms the evidence also presented in Section 2 regarding the non-Normality of the GDP time series. In particular $A(y^3)$ is related to the asymmetry of GDP. As noted above, it was not possible to obtain a significant estimate for higher order terms that capture the excess kurtosis and other even higher order moments. Thus, the economic model will not have to match those moments when we do the second step of the statistical procedure.

4.2 Simulation

This subsection gives the results for the second step of the EMM procedure. Recall that in the second step the SOE model is simulated and the statistical properties of the simulations are compared to the statistical properties of the Mexican GDP and current account time series. The optimal set of parameters for the SOE model are those that minimize the distance between the two sets of properties. The SNP parameter estimates serve as moments (or scores), and the objective function is distributed χ^2.

Table 4 gives the summary results for the second step of EMM. Two sets of parameters are obtained. The first column gives the estimates of the economic model parameters when all parameters of the SOE model vary to match the properties of the data.[14] This will be referred to as the Benchmark case. In the second column, all of the parameters are allowed to move except the parameter that determines the maximum level of the current account deficit, which is set to 8%.[15] This second set of parameter estimates will be referred to as the Constrained case. This level for the maximum current account deficit is not chosen arbitrarily. Out of the parameter values for which the constraint is binding, holding the other parameters constant at their optimized levels, $\kappa = 8\%$ produced the best objective function. Moreover, this is approximately the largest level of current account deficit that Mexico has ever sustained.

The last two rows of Table 4 give information regarding the overall fit of the SOE model (Benchmark and Constrained cases). The EMM objective function, given in the next to last row, is distributed χ^2 with degrees of freedom equal to the difference between the number of statistical parameters and the number of parameters in the SOE model that are free to vary. The degrees of freedom are given in the last row of the table. Both versions of the SOE model, the Benchmark case and the Constrained case, are rejected statistically.[16] Moreover, the Benchmark case has a better

[14]However, the mean of the international interest rate is never allowed to vary and it is set to a 6.5% annual interest rate. This is because the nonstochastic steady state for the international bonds is very sensitive to small perturbations to the mean international interest rate.

[15]The discount rate parameter β is also fixed to the level found in the Benchmark case due to computational problems in obtaining an estimated value.

[16]It can be argued that an economic model is an oversimplification of the data and can *never* be expected to explain all of its properties. Therefore a model, by design, is expected to fail an overall test of specification. Nevertheless, this paper gives statistical tools to evaluate whether a particular model can reproduce the statistical features of the data that the model is designed to match.

level for the objective function than the constrained case.[17] Nevertheless, as will be shown later, the Constrained case does a better job of capturing the observed nonlinearities than the Benchmark case.

Table 4 also gives two sets of parameters that would be used if the economic model were calibrated in the traditional way. For the first set of parameters, called the Standard calibration, the coefficient of relative risk aversion, θ, is set equal to 1 (logarithmic utility). The logarithmic utility case falls within the range of parameters studied in RBC models and is used to minimize the difference in the simulations arising from different preferences given that the EMM procedure also picked a coefficient of relative risk aversion close to 1. The parameter that sets the capital share of income, α, is set equal to 0.364, as in Mendoza (2001). The parameter that determines the intertemporal elasticity of substitution in labor supply, ω, is set equal to 2. This parameter implies a unitary intertemporal elasticity of substitution. The interest rate is set to produce a yearly interest rate of 6.5%. The parameters that determine the stochastic structure are set again as in Mendoza (2001). The first order autocorrelation parameter for the productivity shock, ρ_z, and the standard deviation parameter, σ_{ϵ_z}, are set to 0.825 and 3.36%, respectively. The first order autocorrelation parameter for the interest rate shock, ρ_η, and the standard deviation parameter, σ_{ϵ_η}, are set to 0.10 and 0.881%, respectively. The correlation parameter between the two shocks, $\sigma_{\epsilon_z,\epsilon_\eta}$, is set to -0.11. In the Standard calibration, the assumption of no financial friction is made and the parameter that determines the level of the friction, κ, is set to infinity.[18] For the second set of parameters, called the Low κ calibration, κ is set to 8%. With this parameter value, the constraint is never binding in a long simulation of the model, but it nevertheless affects the statistical properties of the simulation.

Table 5 gives summary statistics of the Mexican GDP and current account time series. It also reports summary statistics for the simulated data series for the Benchmark estimation, for the Constrained estimation, and for the Standard calibration, with and without a binding constraint.

Table 6 gives the sample moments obtained from the EMM analysis of the Benchmark model and for the Constrained case. Column (1) gives the sample moments for each statistical model

[17] This result follows straight from optimization theory.
[18] $\kappa = 0.9E + 36$ in practice.

parameter for the Benchmark model. Column (2) gives the standard error for the moment, which takes into account the uncertainty from estimating the parameters of the statistical model as well as estimating the parameters of the economic model. Column (3) gives the associated t-statistic. Columns (4)–(6) give the same information for the Constrained case. As pointed out above if the SOE model were the true data generating mechanism of the observed data, each of the sample scores would be equal to zero. For the Constrained case, only one of the scores for the statistical model, out of the eight that capture nonlinearities (ARCH, Hermite polynomial), is statistically different from zero and one is borderline. For the Benchmark case, two of the scores are statistically different from zero and two are borderline.

Looking at the decision rules of the SOE model helps develop intuition as to why the current account restriction produces excess volatility and asymmetry in the current account dynamics. Figures 7 and 8 show the decision rules for the Standard calibration and the Low κ calibration for several shocks. The decision rules are derived from the the calibrated parameters because the only difference between the decision rules is due to the presence of the current account restriction, while the set of parameters obtained in the second step of the EMM procedure all change between the Benchmark and the Constrained results. The figures show the responses of different endogenous variables to two sets of shocks. The first, called the Worst shock, results from the realization of the lowest productivity shock together with the highest interest rate shock. The second, called the Best shock, results from the realization of the highest productivity shock together with the lowest interest rate shock.

Figure 7(a) shows the change in the foreign asset position, given the state (the initial foreign asset position) and the shock. The decision rules are given for the Standard calibration and the Low κ calibration. The first thing to note is that the decision rules in response to the Worst shocks for both calibrations are the same for low asset levels. That is, when the country is poor, the current account restriction is not binding. The second thing to note is that the decision rules for the Best shock are virtually identical for the Standard and Low κ calibrations. Meanwhile, the region of the state space where the constraint changes the decision rules is where agents have a relatively large amount of assets and the agents receive a negative shock. This results from the asymmetry in the constraint, and results in asymmetrical decision rules. This can be seen clearly in Figure 7(b), which graphs the difference in the foreign asset decision rules for the Best and Worst shocks. For the Benchmark calibration, the distance between the two rules is roughly constant. For the Low κ calibration, the distance between the Best and Worst shocks becomes smaller for larger levels of assets. That is, the constraint will be binding more frequently as countries accumulate foreign assets and receive large negative shocks.

The impact of the constraint on the current account/GDP decision is shown on Figure 8. The top panel, Figure 8(a), shows the optimal current account to GDP ratio in response to the Best and Worst shocks for the Standard and Low κ calibrations. The bottom panel, Figure 8(b), shows the difference between the two decision rules. As with the foreign asset position decision rules, the current account/GDP response to shocks is asymmetric as a result of the current account constraint. If the domestic economy has a large positive foreign asset position, a negative shock would induce a very large current account deficit to smooth consumption because the domestic agents could afford it. However, the current account constraint restricts the maximum current account deficit that can be sustained. Thus, as is shown below, one will never observe large current account deficits while one will observe large surpluses due to the asymmetry of the constraint.

Figure 8(b) gives good intuition as to how the model captures the conditional volatility in the current account. Notice that the distance between the Best and Worst shocks for the Standard calibration is largely constant, while the distance is diminishing in the net foreign asset position for the Low κ case. The distance between the two lines gives information between the volatility of the ratio. If the distance is large, the volatility is large, and vice versa. This suggests a higher volatility of the current account/GDP ratio when the economy is poor (low foreign asset position) than when it is high for the Low κ calibration. The volatility of the current account/GDP ratio will not depend on the foreign asset position since the distance between the two decision rules is largely constant.[19]

Figures 9 and 10 show histograms for foreign assets and the current account/GDP ratio, re-

[19] The discreteness and coarseness of the foreign asset grid introduces more conditional volatility than there would otherwise be because agents cannot make marginal adjustments to the foreign asset position. So there will be larger than usual changes in response to larger shocks and no changes for very small shocks.

spectively, produced from the simulations for the Standard calibration and the Low κ calibration. Each simulation has a length of 20,000 periods (quarters) after discarding the first 5,000 periods to remove the impact of initial conditions. The histograms are a good estimate of the model's stationary distribution. Looking at Figure 9 the first thing to note is that the Standard calibration is almost symmetric. However, the Low κ calibration is negatively skewed. This is reflected in the asymmetry of the current account, captured in Figure 10. The distribution of the current account is positively skewed. The asymmetry in the current account distribution is generated by the skewness of the decision rules explained above. The second thing to note is that the Low κ calibration results in a higher mean foreign asset position. The current account restriction results in larger precautionary saving for a given set of parameter values. Third, there is a mass point in Figure 10 at the largest CA deficit allowed by the model, signifying the the constraint is binding often, about 10% of the time.

Intuition as to the failure of the SOE model to reproduce the VAR structure of the Mexican time series can be gained by considering the production structure of the model economy. The production function is linear on the productivity shock, except for the effect of the borrowing constraint. All of the nonlinear effects on output come from the effect of the borrowing constraint on labor through the effective interest rate channel. There are no effects through investment and the capital stock that may produce large collapses in output that are observed in the data. Additionally, in the model, the current account only responds to consumption smoothing effects. If capital were allowed to vary, current account deficit would also be used to finance investment. Thus, there would be more of a correlation of GDP and the current account because deficits today would be associated with higher output in the future. Introducing an investment adjustment cost in addition to the time-varying capital would extend this relationship to more than just two adjacent periods.

Tables 7 and 8 give additional information on the parameter estimates for the Benchmark case and the Constrained case, respectively. Each table includes Wald standard errors obtained from adjusted variance matrix, and criterion difference confidence intervals obtained from inverting the concentrated objective function for each parameter value. The Criterion Difference confidence intervals capture any possible asymmetries in the objective function. All parameters values are statistically significant.

5 Conclusions and Extensions

This paper has extensively documented the statistical properties of emerging markets time series, including the features that result during periods of sudden stops and excess volatility. As this paper has shown, the sudden stop and the excess volatility can be quantified in the time series as skewness and conditional volatility. More importantly, this paper has presented an SOE model with financial frictions that can replicate some of the more salient features of the Mexican time series including those features that capture the sudden stop and the excess volatility. This was accomplished by introducing an asymmetric current account restriction that limits the maximum current account deficit that the SOE can run. Since the restriction is on the flow of assets, the financial constraint can be binding more often than in models where the constraint is on the stock of debt. Moreover, the financial restriction binds when the domestic economy faces negative shocks, which fits the evidence of sudden stops. The goal of the paper was to produce a model that could explain the entire time series behavior of the current account and GDP, so the SOE model presented was chosen to reproduce the cyclical properties of the two series both for periods of crisis and periods of tranquility.

The SOE model proposed here captures some of the properties of the Mexican time series, but not all. In particular, while the model can account for most of the significant nonlinearities, it cannot reproduce the VAR structure of the time series. The oversimplified production structure may be partly to blame, as the current account only responds to consumption smoothing mechanisms and not to finance investment. An extension of the current model where capital is allowed to vary could better generate the GDP current account properties captured by the VAR.

The statistical procedure used here, EMM, can be used to evaluate other alternative candidate models that attempt to explain sudden stops and excess volatility in emerging markets. The procedure gives information about which are features of the data that a candidate model succeeds in explaining and which are the features it cannot explain. Thus, the methodology can go far in distinguishing amongst the many competing models of financial frictions that are available to study emerging markets crises.

References

Arellano, Cristina, and Enrique G. Mendoza (2002) ‘Credit frictions and ’sudden stops’ in small open economies: An equilibrium business cycle framework for emerging markets crises.’ Working Paper 8880, NBER, Cambridge, MA, April

Baxter, Marianne, and Robert G. King (1999) ‘Measuring business cycles: Approximate band-pass filters for economic time series.’ *Review of Economics Studies* 81(4), 575–93

Brock, William A. (2000) ‘Wither nonlinear?’ *Journal of Economic Dynamics and Control* 24(5–7), 663–678

Calvo, Guillermo A. (1998) ‘Capital flows and capital market crises: The simple economics of sudden stops.’ *Journal of Applied Economics* 1(1), 35–54

Christiano, Lawrence J., and Terry J. Fitzgerald (1999) ‘The band pass filter.’ Working Paper 7257: NBER, Cambridge, MA

Dufour, Jean Marie, Abdeljelil Farhat, Lucien Gardiol, and Lynda Khalaf (1998) ‘Simulation-based finite sample normality tests in linear regressions.’ *Econometrics Journal* 1(1), C154–C173. Conference Volume

Edwards, Sebastián (1998) ‘Capital inflows into Latin America: A stop-go story.’ Working Paper No. 6441: NBER, Cambridge, MA

_ (2001) ‘Does the current account matter?’ Unpublished Manuscript

Epstein, Larry G. (1983) ‘Stationary cardinal utility and cardinal growth under uncertainty.’ *Journal of Economic Theory* 31, 133–152

Gallant, A. Ronald, and Douglas W. Nychka (1987) ‘Semi-nonparametric maximum likelihood estimation.’ *Econometrica* 55, 363–390

Gallant, A. Ronald, and George Tauchen (1996) 'Which moments to match.' *Econometric Theory* 12, 657–681

— (1998) 'SNP: A program for nonparametric time series analysis, version 8.7, user's guide.' Working paper, University of North Carolina at Chapel Hill. Available along with code and worked example by anonymous ftp at site ftp.econ.duke.edu in directory pub/arg/snp

— (2000) 'Efficient method of moments.' Working Paper

Gallant, A. Ronald, Peter E. Rossi, and George Tauchen (1993) 'Nonlinear dynamic structures.' *Econometrica* 61, 871–907

Greenwood, Jeremy, Zvi Hercowitz, and Gregory M. Huffman (1988) 'Investment, capacity utilization, and the real business cycle.' *The American Economic Review* 78(3), 402–417. 1988

Hodrick, R., and Edward C. Prescott (1980) 'Post-war U.S. business cycles.' Working paper, Carnegie Mellon University. Reproduced

Jarque, Carlos M., and Anil K. Bera (1987) 'A test for normality of observations and regression residuals.' *International Statistical Review* 55, 163–172

Jeske, Karsten (2000) 'Private international debt with risk of repudiation.' Unpublished Manuscript, Federal Reserve Bank of Atlanta

King, Robert G., and Sergio T. Rebelo (1993) 'Low frequency filtering and real business cycles.' *Journal of Economic Dynamics and Control* 17, 207–231

McLeod, Ross H. (1997) 'Policy conflicts in indonesia.' *ASEAN Economic Bulletin* 14(1), 32–45

Mendoza, Enrique G. (1991) 'Real business cycles in a small open economy.' *The American Economic Review* 91(4), 797–818

— (1995) 'The terms of trade, the real exchange rate, and economic fluctuations.' *International Economic Review* 36(1), 101–137

— (2001) 'Credit, prices, and crashes: Business cycles with a sudden stop.' Unpublished manuscript

Mendoza, Enrique G., and Katherine A. Smith (2001) 'Margin calls, trading costs and sudden stops of capital inflows into emerging markets.' Unpublished Manuscript

Milessi-Ferretti, Gian Maria, and Assaf Razin (1996a) 'Current account sustainability: Selected east asian and latin american experiences.' Working Paper 5791, National Bureau of Economic Research, Cambridge, MA, October

_ (1996b) 'Sustainability of persistent current account deficits.' Working Paper 5467, National Bureau of Economic Research, Cambridge, MA, February

_ (1997) 'Sharp reduction in current account deficits: An empirical analysis.' Working Paper 97/168, IMF, December

_ (1998) 'Current account reversals and currency crises: Empirical regularities.' Working Paper 98/89, IMF

Potter, Simon M. (1999) 'Nonlinear time series modelling: An introduction.' *Journal of Economic Surveys* 13(5), 505–528

Radelet, Steven, and Jeffrey Sachs (1998) 'The east asian financial crisis: Diagnosis, remedies, prospects.' *Brookings Paper* 28(1), 1–74

Reinhart, Carmen M., and R. Todd Smith (2002) 'Temporary controls on capital inflows.' *Journal of International Economics* 57(2), 327–351

Schmitt-Grohé, Stephanie, and Martín Uribe (2001) 'Closing small open economy models.' Unpublished Manuscript

Tauchen, George, and Robert Hussey (1991) 'Quadrature-based methods for obtaining approximate solutions to nonlinear asset pricing models.' *Econometrica* 59, 371–396

Urzúa, Carlos M. (1996) 'On the correct use of omnibus tests for normality.' *Economics Letters* 53(3), 247–271

Valderrama, Diego (2001) 'Statistical nonlinearities in the business cycle: A challenge for the canonical rbc model.' Unpublished manuscript, Duke University

— (2002) 'Nonlinearities in international business cycles.' Unpublished manuscript, Duke University

Williamson, John (1997) 'Mexican policy toward foreign borrowing.' In *Coming Together?: Mexico–United States Relations,* ed. Barry Bosworth, Susan M. Collins, and Nora Claudia Lustig (Washington, D.C.: Brookings Institution) chapter 3, pp. 59–77

A Data Sources

- Argentina (1993Q1–2000Q2)– National Accounts: Argentinean Economics Ministry, Current Account: International Financial Statistics (IFS)
- Brazil (1991Q1–2000Q4)– National Accounts: Brazil Statistical Institute, Current Account: International Financial Statistics (IFS)
- Korea (1976Q1–2000Q4)– National Accounts: OECD Statistical Compendium (OECD), Current Account: International Financial Statistics (IFS)
- Mexico (1980Q1–2000Q4)– National Accounts: Mexican Statistical Institute (INEGI), Current Account: Mexican Statistical Institute (INEGI)
- Peru (1980Q1–1998Q4)– National Accounts: Peruvian Central Bank, Current Account: International Financial Statistics (IFS)
- Thailand (1993Q1–2000Q4)– National Accounts: Bank of Thailand, Current Account: International Financial Statistics (IFS)
- Turkey (1987Q1–1998Q3)– National Accounts: OECD, Current Account: International Financial Statistics (IFS)

Table 1: **Sample Statistics:** Emerging Markets National Accounts

	Mean	Std. Dev.	Skewness	Kurtosis	J-B	P-value
Argentina (1993Q1-2000Q2)						
Private Consumption	8.507	0.038	-0.112	2.027	1.247	0.536
Gov't Consumption	6.859	0.027	1.706	6.977	34.317	0.000
Gross Fixed Capital Form.	7.297	0.089	-0.305	2.227	1.212	0.545
Exports	6.554	0.040	-0.314	2.456	0.864	0.649
Imports	6.750	0.091	-0.152	2.247	0.825	0.662
GDP	8.921	0.035	-0.239	1.838	1.973	0.373
Current Account (% GDP)	-0.038	0.009	0.152	1.889	1.658	0.437
Brazil (1991Q1-2000Q4)						
Private Consumption	6.224	0.023	0.456	2.618	1.627	0.443
Gov't Consumption	5.013	0.019	-0.533	3.105	1.914	0.384
Investment	5.095	0.052	-0.663	2.464	3.412	0.182
Exports	4.278	0.044	-0.640	2.780	2.813	0.245
Imports	3.925	0.080	0.114	2.037	1.631	0.442
GDP	6.740	0.016	0.394	2.781	1.113	0.573
Current Account (% GDP)	-0.020	0.009	-0.232	3.151	0.396	0.820
Korea (1976Q1-2000Q4)						
Private Consumption	13.474	0.029	-0.728	5.703	38.487	0.000
Gov't Consumption	11.941	0.017	0.140	2.556	1.127	0.569
Gross Fixed Capital Form.	12.828	0.077	-0.023	2.173	2.798	0.247
Investment	12.854	0.100	-0.587	4.306	12.601	0.002
Exports	12.618	0.045	-0.274	2.683	1.638	0.441
Imports	12.546	0.073	-0.514	4.205	10.237	0.006
GDP	14.064	0.025	-0.564	3.917	8.633	0.013
Current Account (% GDP)	-0.001	0.031	0.327	3.883	4.924	0.085
Mexico (1980Q1-2000Q4)						
Private Consumption	2.294	0.027	-0.030	3.146	0.087	0.958
Gov't Consumption	0.441	0.035	-0.723	6.394	47.645	0.000
Gross Fixed Capital Form.	0.932	0.098	-0.419	3.713	4.243	0.120
Investment	1.022	0.123	-0.563	3.536	5.438	0.066
Exports	0.820	0.046	-0.094	2.495	1.017	0.601
Imports	0.808	0.142	-0.386	6.030	34.213	0.000
GDP	2.660	0.022	-0.405	4.074	6.336	0.042
Current Account (% GDP)	-0.023	0.020	0.204	2.955	0.588	0.745
Peru (1980Q1-1998Q4)						
Private Consumption	3.383	0.057	-0.063	3.129	0.103	0.950
Gov't Consumption	1.856	0.074	-0.062	3.409	0.578	0.749
Investment	1.661	0.001	-0.772	4.650	16.167	0.000
Exports	2.380	0.048	0.135	2.663	0.590	0.744
Imports	2.267	0.116	-0.166	2.426	1.391	0.499
GDP	3.848	0.057	0.203	2.546	1.176	0.556
Current Account (% GDP)	-0.053	0.019	0.044	2.713	0.285	0.867

Investment is the sum of gross fixed capital formation and change in inventories. All series, except for the current account, are in log per capita terms and then BP filtered. BP filter by Christiano and Fitzgerald (1999) removes the trend and assumes a random walk. Skewness is 0 for a Normal distribution and kurtosis is 3 for the Normal distribution. J-B is the Jarque-Bera statistic (Jarque and Bera, 1987), a Wald test of Normality, distributed $\chi^2(2)$. The 90% $\chi^2(2)$ critical value is 4.61 and the 95% critical value is 5.99.

Table 1 (continued): **Sample Statistics:** Emerging Markets National Accounts

	Mean	Std. Dev.	Skewness	Kurtosis	J-B	P-value
Thailand (1993Q1-2000Q4)						
Private Consumption	8.777	0.042	-0.010	3.055	0.005	0.998
Gov't Consumption	6.939	0.036	0.158	2.656	0.291	0.865
Gross Fixed Capital Form.	8.211	0.146	-0.558	3.119	1.680	0.432
Investment	8.222	0.161	-0.531	2.956	1.507	0.471
Exports	8.676	0.047	0.367	2.548	0.991	0.609
Imports	8.600	0.095	-0.836	2.843	3.761	0.152
GDP	9.387	0.038	-0.523	2.716	1.566	0.457
Current Account (% GDP)	0.002	0.039	0.542	3.109	1.580	0.454
Turkey (1987Q1-2000Q4)						
Private Consumption	12.520	0.044	0.651	3.986	6.226	0.044
Gov't Consumption	10.322	0.076	-0.860	7.788	60.382	0.000
Gross Fixed Capital Form.	11.583	0.093	0.186	3.006	0.324	0.851
Investment	11.518	0.164	1.306	6.949	52.305	0.000
Exports	11.374	0.060	0.266	2.528	1.181	0.554
Imports	11.510	0.109	-0.377	2.935	1.337	0.513
GDP	12.887	0.056	2.318	10.871	194.719	0.000
Current Account (% GDP)	-0.007	0.020	0.594	2.548	3.768	0.152

Investment is the sum of gross fixed capital formation and change in inventories. All series, except for the current account, are in log per capita terms and then BP filtered. BP filter by Christiano and Fitzgerald (1999) removes the trend and assumes a random walk. Skewness is 0 for a Normal distribution and kurtosis is 3 for the Normal distribution. J-B is the Jarque-Bera statistic (Jarque and Bera, 1987), a Wald test of Normality, distributed $\chi^2(2)$. The 90% $\chi^2(2)$ critical value is 4.61 and the 95% critical value is 5.99.

Table 2: **SNP Model Selection**

L_μ	L_G	L_R	L_P	K_z	I_z	K_x	I_x	#P	BIC	
1	0	0	1	0	0	0	0	9	1.262	
2	0	0	1	0	0	0	0	13	-0.252	
$\Rightarrow$ 3	0	0	1	0	0	0	0	17	-1.204	
4	0	0	1	0	0	0	0	21	-2.946	
$\Rightarrow$ 3	0	1	1	0	0	0	0	19	-1.441	
3	0	2	1	0	0	0	0	21	-1.376	
3	1	1	1	0	0	0	0	21	-1.768	(*)
3	0	1	1	2	2	0	0	23	-1.591	
$\Rightarrow$3	0	1	1	3	3	0	0	25	-1.675	
3	0	1	1	4	4	0	0	27	-1.686	
3	0	1	1	5	5	0	0	29	-1.632	
3	0	1	1	4	4	2	2	63	N.A.	(*)
3	0	1	1	4	2	0	0	28	-1.672	
3	0	1	1	4	1	0	0	30	-1.648	

Results of SNP estimation of Mexican GDP and current account time series. BP filter used is the Christiano and Fitzgerald (1999) filter that removes the trend, assumes a random walk. Four lags of filtered data were reserved by the SNP estimator. SNP assumes a diagonal ARCH/GARCH structure where appropriate. BIC is the Schwarz Bayesian Information Criterion. (*) represents values for which standard errors are not available. #P represents the number of parameters of the statistical model.

Table 3: **SNP Parameters**

	Estimate	Standard Error	t-statistic
VAR			
Intercept			
$b(y)$	-0.1106	0.0086	-12.917
$b(ca)$	0.0480	0.0091	5.269
$L_\mu = 3$			
$B(y_t, y_{t-3})$	0.9017	0.0413	21.842
$B(y_t, ca_{t-3})$	-0.1197	0.0629	-1.902
$B(ca_t, y_{t-3})$	0.1830	0.0339	5.400
$B(ca_t, ca_{t-3})$	0.6684	0.0439	15.240
$L_\mu = 2$			
$B(y_t, y_{t-2})$	-2.2595	0.0703	-32.149
$B(y_t, ca_{t-2})$	0.2028	0.0978	2.073
$B(ca_t, y_{t-2})$	-0.1532	0.0535	-2.863
$B(ca_t, ca_{t-2})$	-1.9698	0.0778	-25.334
$L_\mu = 1$			
$B(y_t, y_{t-1})$	2.4013	0.0456	52.649
$B(y_t, ca_{t-1})$	-0.1940	0.0589	-3.292
$B(ca_t, y_{t-1})$	0.0970	0.0321	3.025
$B(ca_t, ca_{t-1})$	2.1191	0.0478	44.381
Variance			
$T(y)$	0.0132	0.0035	3.764
$T(y, ca)$	-0.0592	0.0126	-4.704
$T(ca)$	0.0467	0.0117	4.007
ARCH			
$P(y)$	0.3414	0.0439	7.784
$P(ca)$	0.8057	0.2286	3.524
Hermite			
$A(00)$	1.0000	0.0000	0.000
$A(ca)$	-1.0344	0.9637	-1.073
$A(y)$	-0.1148	0.4697	-0.244
$A(ca^2)$	-0.3080	0.2852	-1.080
$A(y^2)$	1.5275	0.7812	1.955
$A(ca^3)$	0.0544	0.3465	0.157
$A(y^3)$	0.4306	0.2128	2.024

Results of SNP estimation of Mexican GDP and current account time series. BP filter used is the Christiano and Fitzgerald (1999) filter that removes the trend, assumes a random walk. Four lags of filtered data were reserved by the SNP estimator. SNP assumes a diagonal ARCH/GARCH structure where appropriate. Statistical model (VAR(3),ARCH(1), K_x=3).

Table 4: **Summary Results:** EMM Parameter Estimates and Standard Calibration Parameters

	Benchmark	Constrained	Standard Calibration	Low κ Calibration
σ_{ϵ_z}	3.250%	3.250%	3.250%	3.250%
ρ_z	0.82493	0.82500	0.8250	0.8250
σ_{ϵ_η}	0.861%	0.875%	0.360%	0.360%
ρ_η	0.14998	0.14999	0.1500	0.1500
$\sigma_{\epsilon_z,\epsilon_\eta}$	-0.00073	-0.00118	-0.1100	-0.1100
α	0.36574	0.36402	0.3640	0.3640
A	0.98405	0.95030	1.0000	1.0000
ω	1.94074	1.95479	2.0000	2.0000
β	0.00736	0.00736	0.0076	0.0076
θ	1.02165	1.02159	1.0000	1.0000
r^*	1.586%	1.586%	1.586%	1.586%
κ	511%	8.000%	9.00E+33	8%
χ^2	1.17E+06	3.50E+06		
DOF	14	16		

Statistical model (VAR(3),ARCH(1), K_x=3). χ^2 row represents value of EMM objective function, which is distributed χ^2 with degrees of freedom (DOF row) equal to the number of statistical parameters (moments) minus the number of SOE model parameters being estimated. Last two columns represent standard calibration parameters for economic model described in text.

Table 5: **Simulation Statistics**

	Mean	Std. Dev.	Skewness	Kurtosis	J-B	p-value	obs.
GDP							
Data	2.660	2.19%	-0.405	4.074	6.336	0.042	84
Benchmark	3.033	7.57%	0.000	2.377	323.142	6.77E-71	20000
Constrained	3.196	7.59%	0.000	2.379	321.467	1.56E-70	20000
Std. Calibration	2.972	7.72%	-0.006	2.380	320.961	2.01E-70	20000
Low κ Calibration	2.972	7.72%	-0.006	2.380	320.961	2.01E-70	20000
Current Account							
Data	-2.320%	2.00%	0.204	2.955	0.588	0.745	84
Benchmark	-0.312%	4.31%	0.136	2.117	711.671	2.90E-155	20000
Constrained	-0.331%	4.71%	-0.173	2.463	339.969	1.50E-74	20000
Std. Calibration	-0.350%	4.41%	0.180	2.140	724.737	4.22E-158	20000
Low κ Calibration	-0.379%	4.80%	-0.146	2.495	283.590	2.63E-62	20000

Statistical model (VAR(3),ARCH(1), K_x=3). J-B is the Jarque-Bera (1987) statistic, a Wald test of Normality, distributed $\chi^2(2)$. The 90% $\chi^2(2)$ critical value is 4.61 and the 95% critical value is 5.99. Each simulation has 20,000 periods, after dropping the initial 5,000 to eliminate the impact of starting conditions.

Table 6: **EMM Mean Scores**

	(1)	(2)	(3)	(4)	(5)	(6)
	Benchmark			Constrained		
	Mean Score	S.E.	t-stat	Mean Score	S.E.	t-stat
VAR						
Intercept						
$b(y)$	5949.93	60572.77	0.098	2025.02	60572.74	0.03
$b(ca)$	1157.01	15255.49	0.076	1791.28	15255.53	0.12
$L_\mu = 3$						
$B(y_t, y_{t-3})$	159593.83	48845.12	3.267	61987.33	48847.70	1.27
$B(y_t, ca_{t-3})$	25694.62	24818.72	1.035	17216.72	24818.10	0.69
$B(ca_t, y_{t-3})$	59062.11	8478.35	6.966	92400.25	9057.79	10.20
$B(ca_t, ca_{t-3})$	-4500.10	1674.33	-2.688	-45292.55	2260.89	-20.03
$L_\mu = 2$						
$B(y_t, y_{t-2})$	45946.94	21455.35	2.142	51299.73	21457.06	2.39
$B(y_t, ca_{t-2})$	28101.90	8869.47	3.168	33064.51	8869.52	3.73
$B(ca_t, y_{t-2})$	-267709.23	9005.08	-29.729	43953.81	9332.78	4.71
$B(ca_t, ca_{t-2})$	-3049.22	492.70	-6.189	321.12	2250.53	0.14
$L_\mu = 1$						
$B(y_t, y_{t-1})$	14419.72	32245.73	0.447	26171.11	32248.46	0.81
$B(y_t, ca_{t-1})$	27101.51	6842.95	3.961	44328.24	6843.89	6.48
$B(ca_t, y_{t-1})$	-365178.04	9308.63	-39.23	-23327.81	9439.70	-2.47
$B(ca_t, ca_{t-1})$	-3470.40	1745.70	-1.988	18594.35	2254.19	8.25
Variance						
$T(y)$	-151368.30	175228.93	-0.864	-56101.07	175235.00	-0.32
$T(y, ca)$	-10752.32	30368.82	-0.354	-6807.34	30368.65	-0.22
$T(ca)$	-4614.92	19344.38	-0.239	-14114.57	19344.58	-0.73
ARCH						
$P(y)$	-8298.54	4477.30	-1.853	-4854.59	4477.45	-1.08
$P(ca)$	-1181.86	1596.29	-0.74	-1285.09	1596.28	-0.81
Hermite						
$A(00)$						
$A(ca)$	2.72	1.81	1.498	-3.65	1.95	-1.87
$A(y)$	6.11	1.02	5.987	3.73	1.22	3.07
$A(ca^2)$	6.07	7.75	0.783	3.94	8.30	0.47
$A(y^2)$	-3.45	1.91	-1.807	1.86	2.78	0.67
$A(ca^3)$	21.10	54.41	0.388	14.96	54.76	0.27
$A(y^3)$	16.42	6.95	2.362	-9.82	9.93	-0.99

Statistical model (VAR(3),ARCH(1), K_x=3). Mean scores are the average scores for each of the parameters of the respective statistical model from a simulation of 20,000 periods, after dropping the initial 5,000 periods to eliminate the impact of starting values. Standard errors (S.E.) and t-statistics are adjusted for uncertainty arising from estimating economic model's parameters.

Table 7: **Benchmark Case Estimates**

	Estimate	Wald S.E.	t-ratio	95% Confidence Interval	
σ_{ϵ_z}	0.03250	1.972E-05	1647.94	0.03250	0.03250
ρ_z	0.82493	2.319E-03	355.79	0.82493	0.82493
σ_{ϵ_η}	0.00861	3.205E-05	268.66	0.00861	0.00861
ρ_η	0.14998	5.946E-04	252.26	0.14998	0.14998
$\sigma_{\epsilon_z,\epsilon_\eta}$	-0.00073	6.865E-05	-1.06	-0.00073	-0.00073
α	0.36574	1.460E-05	25055.06	0.36574	0.36574
A	0.98405	2.530E-04	3889.89	0.98405	0.98405
ω	0.19407	6.480E-05	29933.03	1.94070	1.94077
β	0.00736	2.768E-05	265.97	0.00736	0.00736
θ	1.02165	7.651E-03	133.54	1.02165	1.02165
r^*	1.586%				
κ	5.10548	6.413E-03	796.11	5.10548	5.10548

Parameter estimates based on 30113300 SNP scores (VAR(3), ARCH(1), K_x=3). EMM objective function: 0.117E7. EMM objective function distributed χ^2 with 14 degrees of freedom. The 99% critical value is 36.2.

Table 8: **Constrained Case Estimates**

	Estimate	Wald S.E.	t-ratio	95% Confidence Interval	
σ_{ϵ_z}	3.250%	1.189E-04	2733.70	3.250%	3.252%
ρ_z	0.82500	7.899E-05	10443.84	0.82500	0.82500
σ_{ϵ_η}	0.875%	5.462E-04	1601.17	0.875%	0.875%
ρ_η	0.14999	1.879E-04	798.38	0.14999	0.14999
$\sigma_{\epsilon_z,\epsilon_\eta}$	-0.00118	2.532E-04	-4.67	-0.00118	-0.00118
α	0.36402	5.570E-06	65394.97	0.36402	0.36406
A	0.95030	8.350E-06	11380.78	0.95030	0.95030
ω	1.95479	3.460E-06	56547.64	1.95475	1.95479
β	0.00736				
θ	1.02159	2.172E-04	470.31	1.01607	1.02159
r^*	1.586%				
κ	8.000%				

Parameter estimates based on 30113300 SNP scores (VAR(3), ARCH(1), K_x=3). EMM objective function: 0.350E7. EMM objective function distributed χ^2 with 16 degrees of freedom. The 99% critical value is 36.2.

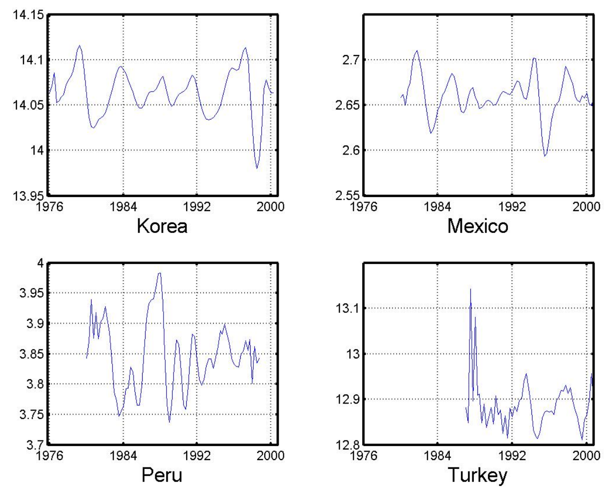


Figure 1: Gross Domestic Product

BP filtered GDP (Christiano and Fitzgerald, 1999). Raw data is in real log per-capita millions of local currency.

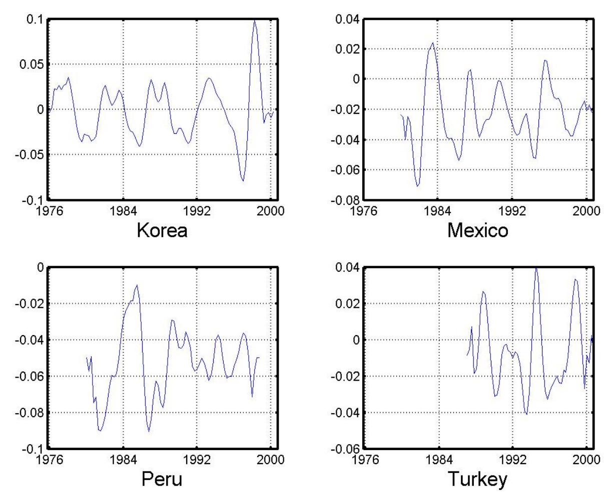


Figure 2: Current Account

BP filtered current account as a percentage of GDP. (Christiano and Fitzgerald, 1999).

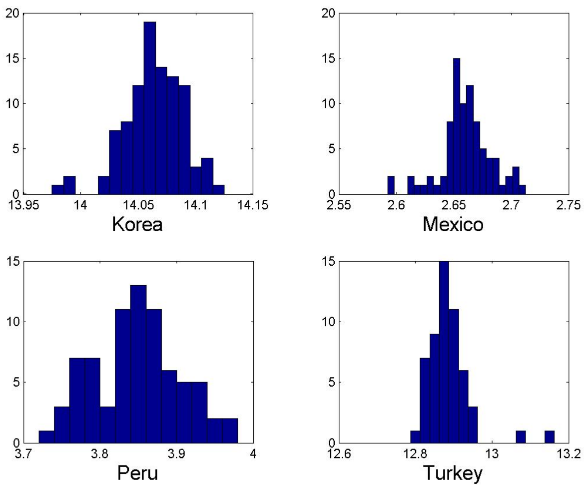


Figure 3: Histogram: Gross Domestic Product

BP filtered GDP (Christiano and Fitzgerald, 1999). Raw data is in real log per-capita millions of local currency.

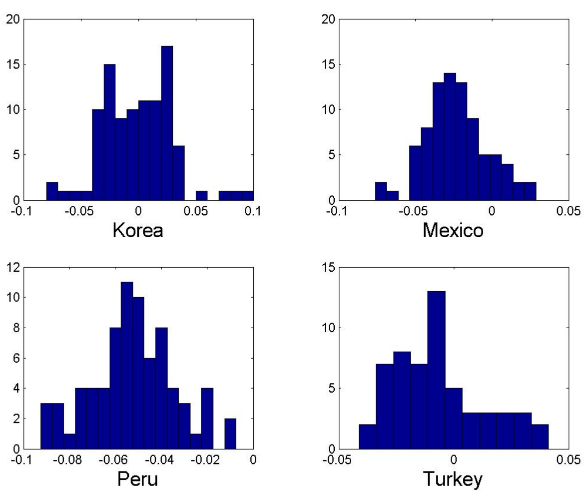


Figure 4: Histogram: Current Account

BP filtered current account as a percentage of GDP. (Christiano and Fitzgerald, 1999).

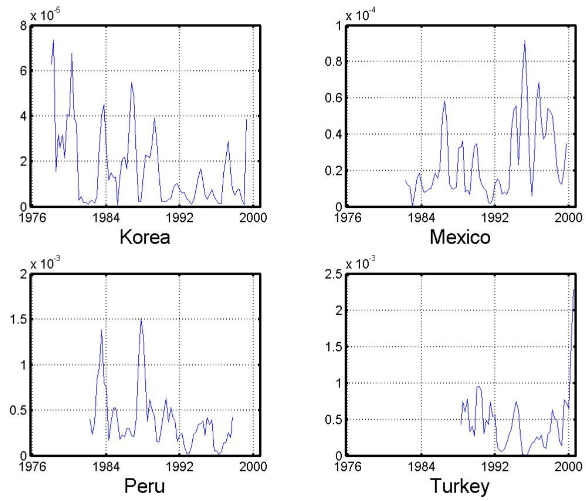


Figure 5: Conditional Volatility: Gross Domestic Product

Residuals obtained from a VAR(3) for BP filtered GDP and current account series. BP filter used is by Christiano and Fitzgerald (1999). Graph of three-period Moving Average of squared residuals as estimates of GDP conditional volatility.

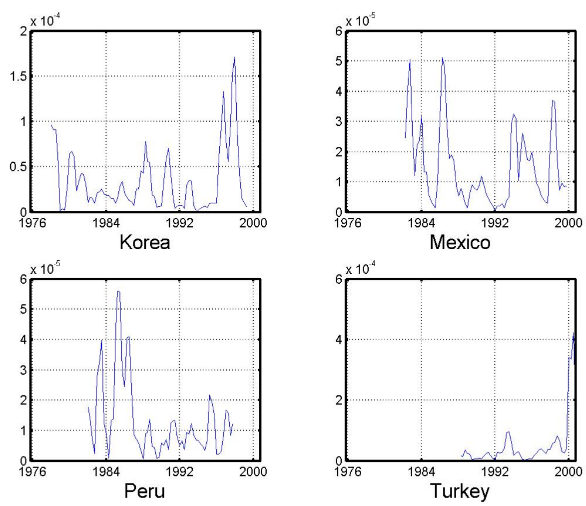
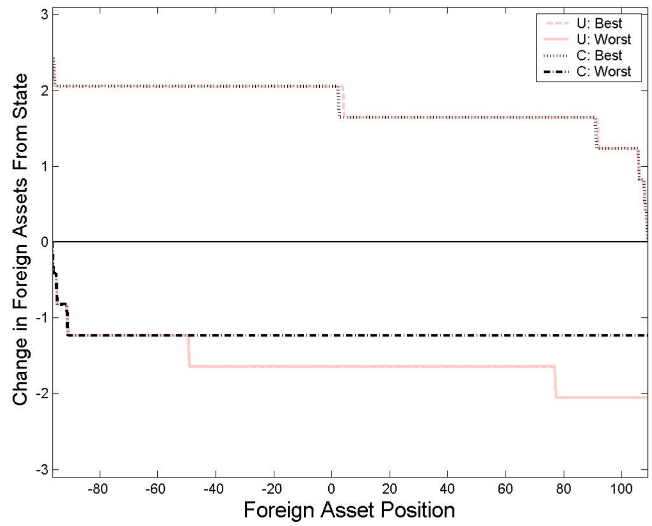
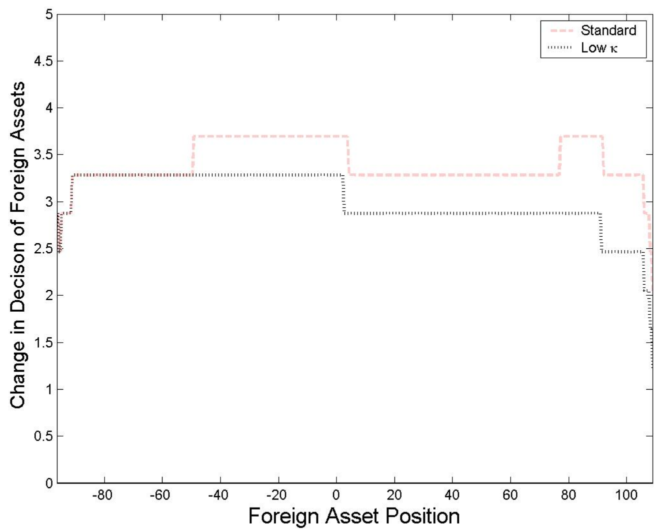


Figure 6: Conditional Volatility: Current Account

Residuals obtained from a VAR(3) for BP filtered GDP and current account series. BP filter used is by Christiano and Fitzgerald (1999). Graph of three-period Moving Average of squared residuals as estimates of the current account conditional volatility.



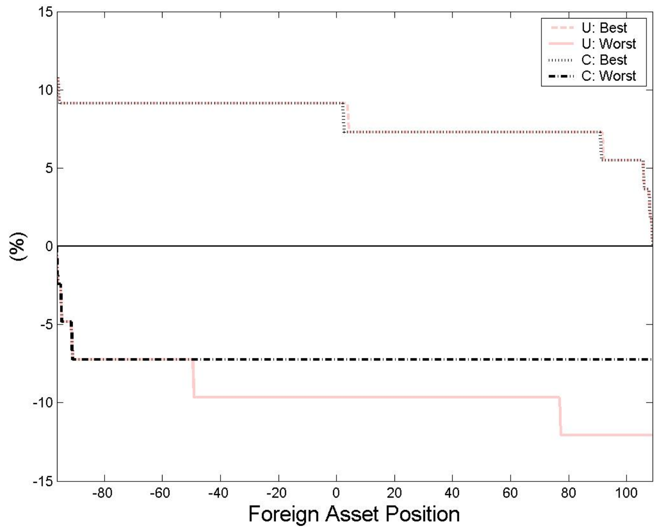
(a) Impact Effect



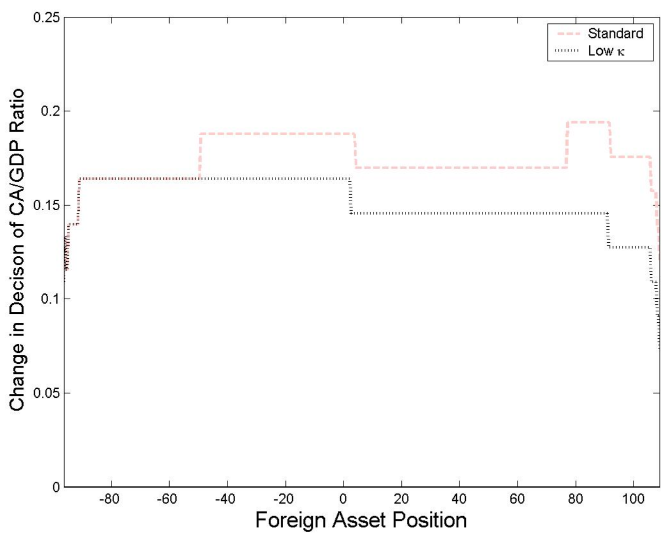
(b) Difference

Figure 7: Decision Rules: Foreign Assets

Foreign asset position decision rule in response to two shocks, Best and Worst. The Worst shock is a low productivity, high interest rate shock while the Best shock is a high productivity, low interest rate shock. The top panel shows decision rules as the change from the given foreign asset position shown on the horizontal axis for a given shock. U refers to the Benchmark calibration, C refers to the Low κ calibration. The bottom panel shows the distance between of the foreign asset position decision for the Best shock and the foreign asset position decision for the Worst Shock



(a) Impact Effect



(b) Difference

Figure 8: Decision Rules: CA/GDP Ratio

Current account/GDP decision rule in response to two shocks, Best and Worst. The Worst shock is a low productivity, high interest rate shock while the Best shock is a high productivity, low interest rate shock. The top panel shows the desired current account/GDP ratio at each given foreign asset position shown on the horizontal axis for a given shock. U refers to the Benchmark calibration, C refers to the Low κ calibration. The bottom panel shows the distance between of the foreign asset position decision for the Best shock and the foreign asset position decision for the Worst Shock

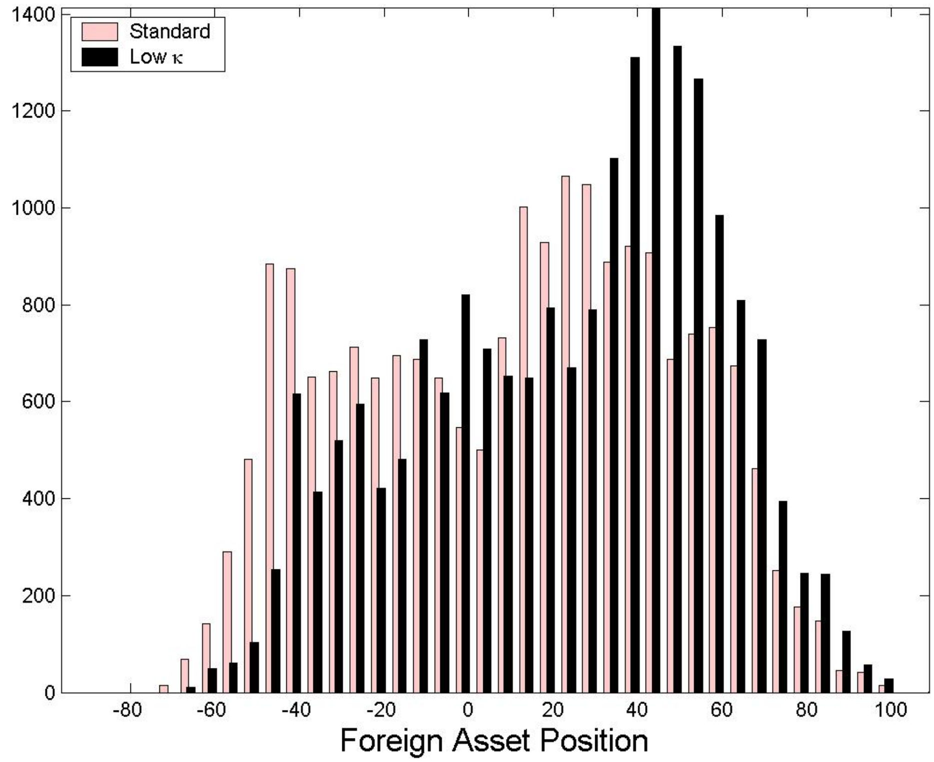


Figure 9: Histograms: Foreign Asset Position

Histogram produced by simulating the SOE model for the Standard calibration and the Low κ calibration. The length of the simulation is 20,000 periods, after discarding the first 5,000 periods to remove the impact of initial conditions.

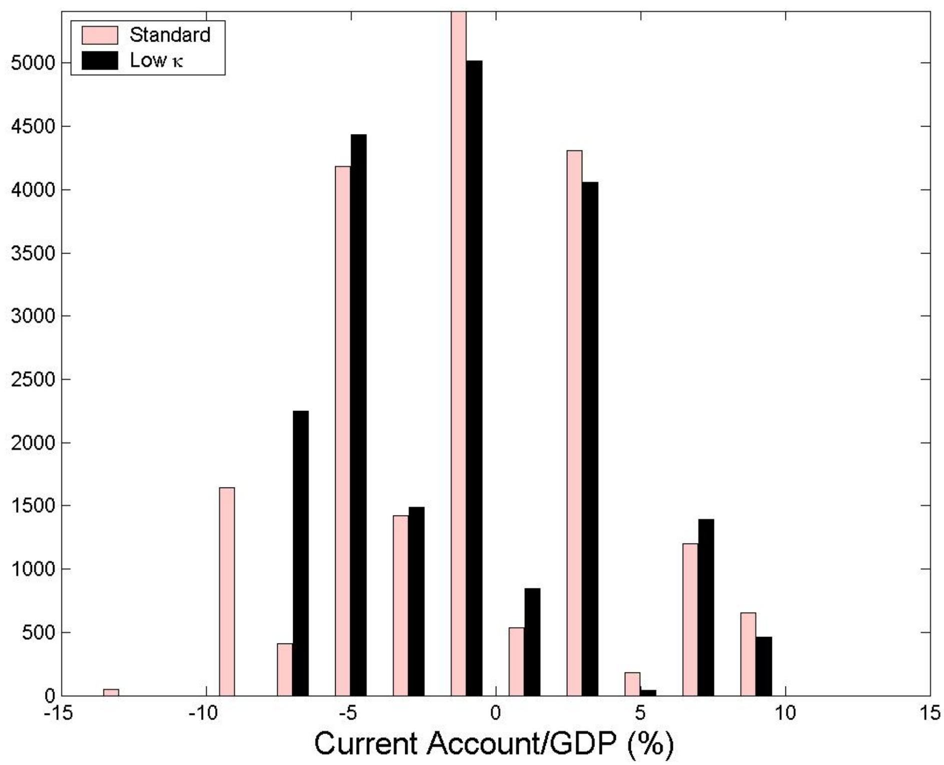


Figure 10: Histograms: Current Account/GDP (%)

Histogram produced by simulating the SOE model for the Standard calibration and the Low κ calibration. The length of the simulation is 20,000 periods, after discarding the first 5,000 periods to remove the impact of initial conditions.