Essays on Balance of Payments Crises

by

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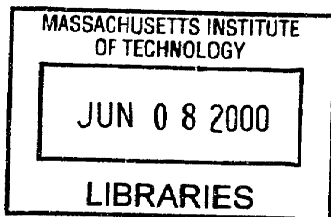   Ricardo Caballero
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Abstract

This thesis studies four different aspects of balance of payments crises. Chapter 1 provides a dynamic asymmetric-information model of the timing of crises. It focuses on investors' learning process and its interaction with interest rate policy. The model shows that the presence of private information delays the onset of BOP crises, giving rise to large drops in asset prices when crises finally take place. It also shows that raising interest rates can be an effective defense against speculative attacks: the optimal policy consists of raising interest rates sharply as fundamentals become very weak. However, this policy is time inconsistent, suggesting a role for commitment devices such as currency boards or IMF pressure.

Chapter 2 studies the relationship between macroeconomic fundamentals and asset prices during crises. Key findings are that fundamentals can account for a significant part of the cross-sectional variance of stock returns during crises, and that credit market conditions play a crucial role during crises.

Chapter 3 studies the behavior of spreads on emerging-market sovereign bonds of different maturities, focusing on the supply side of funds. Spreads on long-term bonds are shown to be too volatile to be reconciled with investors' being risk-neutral and financially unconstrained. An explanation for this volatility is proposed, based on the fact that investors holding long-term bonds are subject to substantial *price risk*. A study of the expected returns and volatility of holding bonds of different maturities after drops in bond prices provides empirical support.

Chapter 4 examines the degree of real exchange rate misalignment in seven Latin American countries and in the U.S. between 1960 and 1998. In all cases there is a long-run relationship among the CPI-based real exchange rate, stock of net foreign assets and relative price of nontradable goods. The results suggest that in 1998 the real exchange rate in Peru was in equilibrium, in Chile slightly undervalued, in Venezuela overvalued by about 8% and in the US overvalued by about 16%. In Argentina, Brazil, Colombia and Mexico, the exchange rate was overvalued by over 20%.

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Introduction

This thesis focuses on four different aspects of balance of payments crises: the effect of interest rate policy on the timing of crises, the relationship between macroeconomic fundamentals and asset prices during crises, the behavior of the spreads on sovereign bonds of different maturities, and the degree of real exchange rate misalignment.

Chapter 1 provides a simple dynamic framework for understanding the timing of balance of payments crises. It presents an asymmetric information model that focuses on investors' learning process and its crucial interaction with interest rate policy. The model incorporates two basic ingredients: (i) investors have private information; and (ii) investors interact in a dynamic setting, weighing the high returns they receive while holding domestic assets against the incentives to pull out before crises take place. The model shows that the presence of private information delays the onset of BOP crises, giving rise to large drops in asset prices when crises finally take place. It also shows that, even though there is a positive relationship between domestic interest rates and the speed at which investors can learn from each other, high interest rates are an effective defense against speculative attacks. The effect of interest rates on the timing of crises increases with the degree of private information. Finally, I characterize the optimal interest rate policy for the monetary authority: the optimal policy is to raise interest rates sharply as fundamentals become very weak. However, this policy is time inconsistent, suggesting a role for commitment devices such as currency boards or IMF pressure.

Emerging market crises are characterized by high volatility in both asset prices and macroeconomic fundamentals. Chapter 2 (co-authored with Mark Aguiar) address two issues related to this observation. Can the movements in asset prices be associated with innovations to fundamentals? If so, which fundamentals play important roles during the crises? To answer these questions, we propose an empirical methodology that makes use

of the information provided by the cross-sectional behavior of stock returns during crises. It consists of two stages. In the first, we use a standard multi-factor model to measure the sensitivity of stocks to macroeconomic variables. Given the poor data available for the countries under study, we use data on U.S. stock returns. In the second stage, we run a cross-sectional regression of crisis returns on factor sensitivities. Under the assumption that the U.S. sensitivities are a good proxi for those in the affected countries, we obtain a set of "effective" fundamentals. We apply this methodology to study the effects of the Mexican, Asian, Russian and Brazilian crises on Mexico and Argentina. We find that fundamentals can account for a significant part of the cross-sectional variance observed during crises. In addition, our results suggest that credit market problems played a crucial role in the crises, especially during the Mexican crisis.

Chapter 3 (co-authored with Guido Lorenzoni) studies the behavior of spreads on emerging market sovereign bonds of different maturities. We first show that spreads on long-term bonds are too volatile to be reconciled with an environment in which investors are risk-neutral and do not face financial constraints. (More specifically, we reject the expectations hypothesis.) We then propose an explanation for this observation, based on the fact that the price of long-term bonds is very sensitive to news about countries' long-term prospects and, as a result, investors are subject to significant *price-risk* when holding long-term debt. During times of financial turmoil, investors are less willing to hold this price-risk because they are more likely to become financially constrained, exacerbating the drop in long-term bond prices. Finally, we present empirical evidence consistent with this mechanism. After drops in bond prices, the risk-premium on emerging market bonds rises sharply. Moreover, the rise in the risk premium seems to reflect an increase in the effective risk aversion of investors, since the increase in demanded excess returns cannot be accounted for by changes in the volatility of returns. The chapter also argues that countries can save substantially on financing costs by adapting their debt maturity to the liquidity needs of investors.

Chapter 4 (co-authored with Norman Loayza and Humberto Lopez) examines the degree of misalignment of the real exchange rate in Argentina, Brazil, Chile, Colombia, Mexico, Peru, Venezuela and the US over the period 1960-1998. We follow a model in which the equilibrium real exchange rate is the value consistent with both a balance of payments position where any current account imbalance is compensated by a sustainable flow of international capital (external equilibrium) and the efficient use of domestic resources (in-

ternal equilibrium). Using cointegration analysis, we find that for all the countries above there is a long-run relationship between the CPI-based real exchange rate, the stock of net foreign assets and the relative price of nontradable goods. We use an unobserved components model to estimate the equilibrium value of the real exchange rate and the degree of misalignment. Our results suggest that in 1998 the real exchange rate in Peru was in equilibrium, in Chile close to equilibrium but with some room for a further appreciation. In Venezuela, the exchange rate was overvalued by about 8% and in the US by about 16%. Finally, in Argentina, Brazil, Colombia and Mexico, the exchange rate was overvalued by more than 20%.

Chapter 1

The Timing of Balance of Payments Crises

1.1 Introduction

During the 1990's the world witnessed a large number of balance-of-payments (BOP) crises, including the EMS crisis in 1992, the Mexican crisis in early 1995, the Asian crisis in 1997, and the recent crises in Russia and Brazil. The large, and rapidly growing, literature on BOP crises has provided many insights into the causes behind these crises. A consensus now exists about the importance of institutions (e.g. bank supervision, corporate governance), debt management, and consistency in the setting of monetary and fiscal policy. Despite this progress, however, economists still have a limited understanding of the dynamics and timing of crises.

The main difficulty in studying the timing of BOP crises stems from the need to account for two seemingly contradictory characteristics. On the one hand, BOP crises are usually "large," in that they involve massive asset reallocations, wild swings in asset prices, and heavy output losses. On the other hand, BOP crises are often triggered by shocks that seem too small to account for these effects. This chapter proposes a simple dynamic framework for studying the timing of BOP crises that accounts for these two characteristics. It emphasizes the dynamics of investors' learning process and its crucial interaction with interest rate policy.

This chapter models BOP crises as the equilibrium outcome of a game between a mon-

etary authority, which attempts to keep a fixed exchange rate, and a set of investors that at each point in time decide how much of their capital to invest in the country. The model relies on two basic ingredients: (i) investors have private information; and (ii) investors interact in a dynamic setting, weighing the high returns they receive while holding domestic assets against the incentives to pull out before the crisis takes place. The crisis is triggered by some investors selling their domestic assets and starting a run on the central bank's reserves, with other investors following suit until reserves are exhausted. Investors have private information regarding the level of the exchange rate in case the peg is abandoned. The run up to the crisis is characterized by a slow learning process, in which the high returns on domestic assets more than compensate for the risk of capital losses due to devaluation. During the crisis most of the remaining uncertainty regarding investors' private information is resolved. Furthermore, when the peg is abandoned the exchange rate experiences a discrete devaluation. As a result, investors' strategies incorporate an incentive to take their capital out before the crisis takes place.[1] Although the timing of the crisis is unpredictable based on public information, the model has a unique equilibrium, in which the timing depends on investors' private information.

Two versions of the model are presented. The first, in which the return on domestic assets is taken as exogenous, emphasizes investors' learning process and its implications for the timing of BOP crises. This version provides insights into the behavior of asset prices during crises, as well as into the effects of interest rates and asymmetric information on the timing of crises. First, it shows that even in a model with a single equilibrium, "large shocks" are not necessary in order for crises to involve large drops in asset prices. Large movements in asset prices at the time the peg is abandoned are possible as a result of the large amount of private information that is revealed during crises. Furthermore, an asymmetry exists in that revaluations never take place.

Second, it shows that the presence of private information delays the crisis, in the sense that the peg lasts longer for all realizations of investors' private information. This result follows from two features of BOP crises that are captured by the model. As the crisis progresses, investors become more informed because they can infer the private information

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[1]This contrasts with so-called first generation models of BOP crises, in which the timing of crises is determined by the condition that the exchange rate be continuous. In fact, in the model presented in this chapter crises would also involve a continuous exchange rate if private information were not present.

of the investors who take their capital out. The investors who would leave last then know the value of the new exchange rate and, thus, would have an incentive to wait if they expected a revaluation. As a result, arbitrage can rule out negative but not positive devaluations.[2] In addition, the high returns on domestic assets in episodes of BOP crises create an incentive to wait past the point when the expected devaluation is zero. Without private information, however, investors cannot "coordinate" into staying past this point and leave when the size of the devaluation is zero. The delay of BOP crises in the presence of private information can account for the observation that crises often occur long after problems in the affected countries are recognized. It also implies that when the peg is finally abandoned the currency always depreciates.

Third, the fixed exchange rate lasts longer when domestic interest rates are high. This result follows from the fact that, conditional on other investors' actions, each investor has greater incentives to leave his capital in the country when interest rates are high. In addition, an indirect channel exists due to the presence of complementarities in investors' actions: if each investor stays longer the expected losses from devaluation decrease, further increasing the incentives not to pull out. However, in a setup in which the exchange rate is continuous at the time of the crisis it is unlikely that an increase in interest rates would postpone the abandonment of the peg.[3,4] It is the existence of positive devaluations as a result of private information that allows interest rates to delay the crisis. The model thus provides a rationale for interest rate defenses.[5]

To better understand the effect of interest rate policy on the timing of BOP crises, the behavior of the monetary authority is endogenized in the second version of the model. I assume that the monetary authority controls the return on domestic assets in order to minimize a loss function, which incorporates a cost of raising interest rates and a cost

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[2]In other words, if investors start leaving "too soon," they can recognize their mistake before reserves are exhausted, which gives rise to probing attacks. If, on the other hand, they start leaving "too late" there is a devaluation.

[3]Calvo (1995) presents such an argument. He argues that high interest rates could induce capital inflows in the run up to the crisis, but these would be compensated by a larger portfolio reallocation when the peg is abandoned. He also argues that, since the fiscal deficit (or expected future deficits) likely increases when interest rates are raised to defend a peg, it is possible that the "defense" actually hastens the end of the peg.

[4]This chapter concentrates on the effect of interest rates before the peg is abandoned. Lahiri and Végh (1999) and Salant and Henderson (1978) show that, even if no private information exists, the value of interest rates *after* the peg is abandoned affects the desired portfolio reallocation and, as a result, the timing of the crisis. Drazen (1999) argues that interest rates can affect the timing of crises by providing information about the government's objectives.

[5]Stiglitz (1998) argues that only unrealistically high interest rates would be effective in defending a peg. In this chapter this is not the case.

of having to abandon the peg. I also assume that there is an exogenous probability of "turnaround" in which case the peg survives and no further interest rate costs need to be incurred. The model has a number of implications for interest rate policy during BOP crises.

First, the optimal interest rate policy is to raise interest rates sharply when fundamentals become very weak, rather than raising interest rates by a smaller amount for a longer period of time. This result follows from the fact that raising interest rates when fundamentals are very weak is both "more effective" and "cheaper." For any interest rate path, the effect of increasing the interest rate at some point increases the equilibrium probability that the crisis will occur at that point.[6] Correspondingly, the amount of learning that takes place at that point increases, thereby "shifting back" the crisis distribution function for all previous times. As a result, high interest rates are more effective in postponing the devaluation if they are expected to take place when fundamentals are weaker. In addition, it is possible that interest rate costs will not need to be incurred if the crisis or the turnaround take place earlier.

Second, a problem of time inconsistency arises. The monetary authority would be better off if it could commit to raising interest rates as fundamentals deteriorate. This result follows from the fact that the benefits of high interest rates at a point in time are partly "sunk" when that time is reached. This time inconsistency problem suggests a role for international organizations such as the IMF, or for commitment devices such as currency boards.

Third, empirical studies on the effectiveness of interest rate defenses should be careful in interpreting episodes in which interest rates are sharply raised but the peg is abandoned. In the model presented in this chapter, although interest rates are an effective instrument for defending against speculative attacks, crises are more likely while interest rates are high, even conditioning on the level of fundamentals. Finally, these results are stronger in cases of liquidity crises than in cases of solvency crises.[7]

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[6]This corresponds approximately to uncovered interest parity.

[7]In the context of this chapter, a "liquidity crisis" is a crisis in which the probability that the peg survives increases when the attack is postponed.

Related Literature

The large shifts in asset holdings during crises initially led observers to associate such episodes with investor irrationality. The so called first-generation approach to BOP crises, initiated by Salant and Henderson (1978), Krugman (1979), and Flood and Garber (1984), provided an alternative explanation. If crises mark a switch in regimes, with inflation higher after the fixed exchange rate is abandoned, the desired holdings of domestic currency should likely fall during crises. As a result, a "run" on the central banks's reserves could be interpreted as a rational portfolio reallocation. These models, though, also have the unrealistic implications that the timing of crises should be predictable and that crises should not involve large changes in asset prices. Flood and Garber (1984) and Dornbusch (1987) develop stochastic models of BOP crises that address these shortcomings by assuming the existence of large shocks.[8]

A different approach to explain the unpredictability of crises and the drops in asset prices is to assume the existence of multiple equilibria. Starting with Obstfeld (1984), second-generation models introduce the possibility that crises be self-fulfilling: if investors expect a crisis, they will act in a way such that a crisis occurs. However, these models have little to say about the *timing* of BOP crises, as a wide range of results can be obtained by assuming different expectational dynamics. Furthermore, as Morris and Shin (1998) show in a generic second-generation model, the existence of multiple equilibria might not be very robust, as adding even a small amount of noise to investors' perceptions about a country's fundamental eliminates the multiplicity of equilibria.

The model presented in this chapter is complementary to a number of asset-pricing models that present alternative amplification mechanisms for the effects of shocks on asset prices (Gennotte and Leland 1990, Romer 1993, Caballero and Krishnamurthy 1999, Hong and Stein 1999, and Yuan 1999). These models emphasize asymmetric information, liquidity, and financial constraints considerations.

There are models in the social learning literature that share many ingredients with the one presented here. (Caplin and Leahy (1994), Gul and Lundholm (1995), and Chamley (1998) present models with "informationally-driven" crises or clustering.) Although these models provide the basic intuition for why small shocks can give rise to large crises in the

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[8]Rigobon (1999) presents an alternative argument: "small shocks," if unexpected, can give rise to large reassessments about a country's fundamental.

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presence of private information, they do not provide an adequate framework for under-standing the *timing* of BOP crises. The most important difference between the model in this chapter and those in the social learning literature is given by the trade offs investors face in choosing their actions. In social learning models, which are usually concerned with industry dynamics or problems that give rise to similar "reduced-form" models, investors have an incentive to wait to observe other agents actions and face a cost of waiting. In episodes of BOP crises, on the other hand, investors have an incentive to move first (take their capital out of the country before the crisis takes place) and receive a flow benefit of waiting in the form of high returns on domestic assets. In addition, in episodes of BOP crises investors care about other investors' actions not only because they reveal their pri-vate information, but also because in case of a crisis those who leave first have a higher probability of doing so before the devaluation takes place.[9] Finally, during BOP crises there is a "terminal condition," given by zero reserves at the central bank, which will play an important role in this chapter but does not have a counterpart in social learning models.

Although there are no systematic studies of whether asymmetric information exists in the context of BOP crises, suggestive evidence exists. Evans and Lyons (1999) find a strong positive correlation between order flow[10] and price movements in the US$/DM exchange rate market, which is consistent with investors' trades revealing price-relevant private infor-mation. Garber (1998) argues that the existence of derivatives "obscures true risk positions and undermine the usefulness of balance-of-payments capital account categories." For ex-ample, according to IMF's International Capital Markets (1995), published 8 months after the Mexican devaluation, most of the Tesobonos outstanding at the time of the devaluation were held by foreigners (page 62). However, according to Garber, all of the US$ 16 billion worth of Tesobonos held by foreigners were involved in swaps with Mexican banks, so that all the risk was actually held by domestic banks. Furthermore, international investors do not share information on these types of trades, for they are considered proprietary. There exists an account of the events that led to the collapse in Mexico's bond market in which the crisis was triggered by investors' realization of the size of the total Tesobono swaps.[11]

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[9]In social learning models that incorporate non-informational externalities, such as Chamley (1998), com-plementarities give agents an incentive to move *simultaneously*. These models do not capture the incentive to pull out first.

[10]Evans and Lyons define order flow as "a measure of buying/selling pressure. It is the net of buyer-initiated orders and seller-initiated orders."

[11]Another piece of evidence that suggests that investors learned about the situation of the Mexican banking

Johnson, Boone, Breach, and Friedman (1999) find that measures of corporate governance have a significant explanatory power for the size of devaluations and drops in local stock markets in a cross-section of countries during the Asian crisis. Under the assumption that investors have private information regarding the extent of corporate governance problems in the firms they invest, it is plausible that private information played a role in the crisis. Other "evidence" includes the fact that, in many cases, crises are triggered when an identifiable group of investors "pulls out," such as when domestic investors refused to roll over Russia's debt in August 1997.

The chapter is organized as follows. Section 1.2 describes the model under the assumption that the interest rate on domestic assets is exogenous. Section 1.3 solves and analyzes this simpler model. Section 1.4 focuses on interest rate policy by endogenizing the behavior of the monetary authority. Section 1.5 describes the robustness of the results under alternative assumptions. Section 1.6 concludes and suggests some speculative applications of the theory presented in this paper for contagion, asset-market bubbles, and banking crises.

1.2   The Model

To simplify the analysis, the model is based on a linear first-generation-type framework, with the additional assumption that investors have private information regarding the level of the exchange rate in case the peg is abandoned. Time is continuous and there are two kinds of players; a monetary authority, which attempts to keep a fixed exchange rate, and a set of investors, who at each point in time decide how much of their capital to invest in domestic assets. The state of the economy is summarized by a fundamental that deteriorates monotonically. While the peg lasts, investors receive a return on domestic assets which is higher than the international rate of return. If there is a speculative attack, the investors who are able to convert their holdings of domestic currency into foreign currency before reserves are exhausted do not suffer any capital losses. Others suffer losses equal to the size of the devaluation. The interplay between the benefit of being able to pull out before others and the high returns on domestic assets provides the main forces affecting the behavior of investors.

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system during the crisis is given by the fact that, in January 1995, the stock prices of the banks fell much more than that of other companies, even though banks' stock prices closely followed the stock market index throughout 1994.

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Monetary Authority

The monetary authority follows a simple rule: buy and sell foreign currency at the fixed exchange rate while reserves last.[12] Without loss of generality, the exchange rate is fixed at 1. Once reserves are exhausted, the currency is floated.

Investors

Investors are risk-neutral. They initially have some capital invested in the country, for which they receive a riskless, constant, and exogenous return $r > 0$, unless a crisis occurs. At each point in time, investors decide how much of their capital to invest in the country, and how much to invest abroad. The international rate of return is 0. There are no transaction costs associated with capital movements. I also assume that investors have a maximum amount of capital (equal to their initial holdings for simplicity) and that there are no other investors who could invest in the country.[13]

Investors are heterogeneous and have private information regarding their idiosyncratic characteristics. The specific dimension of heterogeneity is not crucial for the qualitative predictions of the model but, for concreteness, I assume that investors differ in the amount of investments in domestic liquid assets. In the context of this model, liquid assets (e.g. short-term local-currency bank deposits) are assets which can be sold instantaneously and at a price which is fixed in local currency, while illiquid assets cannot be sold at any price.[14]

There are two groups of atomistic investors of mass 1 each. All investors within each group have the same amount of liquid assets or "type," denoted a_i for $i = 1, 2$.

Assumption 1 *Each investor knows his own type (and that of the rest of his group), but does not know the type of the other group. The a_i's are distributed with density function $g(\cdot)$ and support $[a_m, a_M]$. $g(\cdot)$ has no atoms and is common knowledge.*

The proportion of liquid assets invested in the country by investor $j \in [0, 1]$ of group $i \in \{1, 2\}$ at time t is denoted by $x(i, j, t)$.

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[12]In section 1.4 the behavior of the monetary authority is endogenized, allowing it to set interest rates in order to delay, and possibly avoid, the crisis.

[13]This assumption can be justified by assuming that investors are capital-constrained "specialists." In section 1.5 I will argue that if a pool of uninformed investors existed who could bring their capital to take advantage of the high returns, the results would be stronger.

[14]At least in principle, it is possible to determine the amount of foreign investment by looking at capital flows. However, information regarding the types of investments and off-balance sheet operations is much scarcer, e.g. Garber (1998).

Environment

Time is continuous. Investors observe capital movements by all other investors.[15] The state of the economy at time t is summarized by a fundamental $f(t)$, which affects both the level of reserves and the value of the exchange rate if the government were to abandon the peg (i.e. the "shadow" exchange rate).[16]

Assumption 2 *Reserves at time t are given by*

$$R(t) = f(t) - \sum_{i=1,2} a_i \int_0^1 (1 - x(i,j,t)) \, dj.$$

Assumption 3 *The shadow exchange rate at time t is given by*

$$E_s(t) = 1 + f(t) + e_0 - a_1 - a_2 \tag{1.1}$$

where $e_0 \in (0, a_m)$ is a constant.

As a result, the size of the devaluation, which is given by $a_1 + a_2 - f(t) - e_0$, is increasing in the amount of liquid assets.[17]

The fundamental $f(t)$ deteriorates monotonically at speed μ. Time is defined such that $f(0) = 2a_m - e_0$. I assume that the game starts at a time $\underline{t} < 0$ early enough such that there is an initial period when a devaluation cannot occur.

Assumption 4 *The fundamental $f(t)$ follows*

$$f(t) = (2a_m - e_0) - \mu t$$

In addition, $f(\underline{t}) > 2a_M - e_0$ (i.e. $\underline{t} < -2\frac{(a_M - a_m)}{\mu}$).

Since $f(t)$ falls at speed μ, the peg cannot last forever. Let $\bar{t}$ be the time at which the peg is abandoned, which is given by

$$\bar{t} = \sup \left\{ t : \forall \tau \in (\underline{t}, t) \, R(\tau) > 0 \right\}, \tag{1.2}$$

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[15]It does not make any difference if I assume investors only observe net flows.

[16]For example, the fundamental could be domestic credit, as in Krugman (1979) and Flood and Garber (1984).

[17]Equation 1.1 implies that the size of the devaluation is increasing in the amount of liquid assets that cannot be covered by existing reserves, which equals $a_1 + a_2 - f(t)$.

i.e. when reserves at the central bank reach zero. If investors decide to pull out and reserves are not enough to cover all liquid assets, reserves are paid out according to a sequential servicing constraint. The investors who initiated the attack are able to exchange their domestic currency before others, and reserves are assigned randomly if they are not sufficient to cover a group that moves simultaneously.

A few technical assumptions are needed to rule out some forms of unrealistic behavior. Some of these assumptions will only be used in the appendix, where a formal treatment of the game is presented.

Technical Assumption 1 *The game is the limit, as $\epsilon \to 0$, of the game in which the strategies $x(i, j, t)$ can be conditioned on flows only up to time $t - \epsilon$.*

Technical Assumption 2 *Strategies must be "well-behaved." For all flow histories, $x^-(i, j, t) \equiv \lim_{\tau \to t^-} x(i, j, \tau)$ exists, $x^+(i, j, t) \equiv \lim_{\tau \to t^+} x(i, j, \tau)$ exists, and $x(i, j, t) = x^-(i, j, t)$.*

In equilibrium, investor i in group j chooses strategy $x(i, j, t)$, taking strategies $x(i', j', t)$ as given, to maximize

$$
E\left[\int_{\underline{t}}^{\bar{t}} x(i, j, t) r \, dt - x^+(i, j, \bar{t})(1 - E_s(\bar{t})) - \right.
$$
$$
\left. (x(i, j, \bar{t}) - x^+(i, j, \bar{t})) \left(\frac{A(\bar{t}) - R(\bar{t})}{A(\bar{t})} \right) (1 - E_s(\bar{t})) \right]
$$

where $\bar{t}$ is given by equation 1.2, and $A(t)$ is the amount of *desired outflows* at time t

$$
A(t) = \sum_{i=1,2} a_i \int_0^1 (x(i, j, t) - x^+(i, j, t)) \, dj.
$$

The first term in the maximization problem accounts for the returns on liquid capital while the peg survives. The second term accounts for the devaluation losses from the capital that the investor did not attempt to take out at $\bar{t}$. The third term accounts for the devaluation losses from the capital that the investor attempted to take out, which incorporates the fact that this capital can be taken out with probability $\frac{R(\bar{t})}{A(\bar{t})}$.[18]

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[18]Returns on illiquid assets are not included in the maximization problem because these assets cannot be sold.

Technical Assumption 3 *The model is the limit of a model with transaction costs as these costs tend to zero.*

Technical Assumption 4 *Investors within each group have access to a "correlating device" that allows them to follow "mixed-like" strategies. The two groups have independent correlating signals that cannot be observed by investors in the other group (as in mixed strategies). In addition, strategies must be individual best responses since there are no commitment devices (as in correlated equilibria).*[19]

1.3 Analysis

As a benchmark, it is helpful to start by analyzing the model when there is no private information:

Proposition 1 *If a_1 and a_2 are common knowledge there is a unique Nash equilibrium. Investors stay in the country until time*

$$\bar{t} = -\frac{(a_1 - a_m) + (a_2 - a_m)}{\mu},$$

which satisfies $E_s(\bar{t}) = 1$. At that point they all try to leave, the peg is abandoned, and the size of the devaluation is zero.

Proof: It is trivial to show that the proposed solution is an equilibrium. To prove uniqueness note that, since $f(t)$ falls at speed μ, the peg must be abandoned, at the latest, when $f(t) = 0$. In pure strategies, investors cannot stay past $\bar{t}$ in equilibrium, since the crisis would involve a predictable depreciation. Mixed-strategy equilibria are not possible either, because they must involve randomizations over exit times up to the time when the crisis is inevitable. As a result, the "crisis hazard rate" would approach infinity at a point at which $E_s(t) < 1$, which cannot occur in equilibrium. □

This example shows that, in the model presented in this chapter, the timing of crises is *independent of the interest rate r* when there is no private information.[20] The rest of this

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[19]Alternatively, I could assume that investors' types have infinite dimensions, with the first dimension being the liquidity of their investments, and the other dimensions being characteristics that are not pay-off relevant but on which investors can condition their actions.

[20]Salant and Henderson (1978) and Lahiri and Végh (1999) show that raising interest rates can delay the timing of BOP crises by increasing the demand for domestic assets after the devaluation thereby "shifting

section studies the dynamics of crises and the effect of interest rates on their timing when private information is present.

For a formal analysis of the model, the reader should see the appendix. Here, I take the following proposition as a starting point, and present a more heuristic approach.

Proposition 2 *There is a unique and symmetric Nash equilibrium. The equilibrium is symmetric both between the two groups and between different investors in a single group. Symmetry within groups means that investors "move together," i.e. for all $j, j' \in [0,1]$ and $i \in \{0,1\}$, and for all histories of capital flows, $x(i,j,t) = x(i,j',t)$. In addition, investors always want to have either all their capital in the country, or all out, i.e. $x(i,j,t) \in \{0,1\}$.*

Proof: See appendix.

The analysis is greatly simplified by two features of the model. First, since investors are atomistic, they do not act strategically, i.e. they take the actions of other investors as given, as opposed to only their strategies. Together with the absence of transaction costs, this implies that the investors' maximization problem can be solved *pointwise.*

The equilibrium of the game is composed of several "stages." In the first stage, investors' types are private information and their strategies can be summarized by a function $\bar{f}(a)$, which indicates at which value of the fundamental they would leave, conditional on their type. The first stage ends when a group of investors starts taking their capital out, thereby revealing their type. The other group then either leaves or stays, depending on their type. If the amount of their investments in liquid assets is high enough, investors in the second group leave, exhausting the government's reserves and ending the game; otherwise, they stay, the first group returns, and the second stage begins. In the second stage, the type of the group that initiated the first attack (type 2 without loss of generality) is thus known, but the type of the other group is only known to be below some value $\underline{a}$, consistent with not having pulled

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up" the shadow exchange rate schedule. On the other hand, raising interest rates also has negative effects on the shadow exchange rate by accelerating the accumulation of government liabilities through higher debt service costs, bailouts of banks in distress, or a fall in revenue due to lower activity. Lahiri and Végh present a framework that combines these two effects. However, in these papers only *post*-devaluation interest rates have an effect on the timing of crises. As Calvo (1995) argues, raising interest rates before the devaluation likely has only negative effects on the shadow exchange rate, which prompts the question of why interest rate defenses often include raising interest rates *prior* to the devaluation. ⁻: 's chapter provides a possible answer, focusing on the effects of interest rates on investors' learning p. ⸱s rather than on the shadow exchange rate. Drazen (1999) provides an alternative explanation based on the idea that interest rates can act as a signal about the government's objectives.

out. The equilibrium in this stage is characterized by a function $\bar{f}_1(a_1; a_2)$, which indicates at which value of the fundamental investors in group 1 would leave conditional on their type and that of group 2, and a hazard rate $\bar{h}(f; \underline{a}, a_2)$, which indicates the probability of group 2's leaving when the fundamental is f, conditional on their type and the maximum possible group 2's type. If group 1 leaves first, group 2 follows, reserves are depleted, and the game ends. If the attack is again initiated by group 2, investors in group 1 follow if the amount of their investments in liquid assets is high enough, or stay and stage 3 begins. Each stage thereafter is identical to stage 2, and the same functions $\bar{f}_1(\cdot)$ and $\bar{h}(\cdot)$ apply. In general, the functions $\bar{f}(\cdot)$, $\bar{f}_1(\cdot)$, and $\bar{h}(\cdot)$ would depend on the information investors acquire *during* each stage. However, it is not necessary to include this information separately because it is uniquely determined by the value of f.

Since investors' solve their maximization problem pointwise, each stage of the equilibrium can be solved independently. I start by describing the first stage, where most of the insights become clear, and briefly analyze the rest of the game later.

With some abuse of notation, let us define $a(t) = \bar{f}^{-1}(f(t))$, where $\bar{f}^{-1}$ denotes the inverse of $\bar{f}$.[21] $a(t)$ is then the "marginal type" or type that would leave exactly at time t. For t such that $f(t) > \bar{f}(a_M)$, we define $a(t) = a_M$, since $\bar{f}^{-1}(f(t))$ is not defined. Similarly, for t such that $f(t) < \bar{f}(a_m)$, we define $a(t) = a_m$. We can solve for $a(t)$ by noting that, in equilibrium, the marginal type must be indifferent between staying or leaving when the crisis hazard rate is positive.

Proposition 3 *In the unique and symmetric Nash equilibrium of the game, the equilibrium in the first stage is characterized by the "marginal type" function $a(t)$. Investors take all their capital out of the country when $a(t)$ reaches their type. $a(t)$ satisfies the differential equation*

$$r = \frac{g(a(t))}{G(a(t))}(-\dot{a}(t))\left(\frac{2a(t) - f(t)}{a(t)}\right)(2a(t) - f(t) - e_0) \tag{1.3}$$

and the boundary condition

$$a(0) = a_m.$$

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[21]That such inverse exists follows from the fact that if $\bar{f}(a)$ where not strictly increasing, there would be a point in time with positive mass in the crisis probability distribution, which cannot occur in equilibrium since returns are only of order dt.

Proof: Even though the equilibrium is symmetric, the intuition is more clear if we start by assuming it is not. Let us define $a_1(t)$ and $a_2(t)$ as the marginal type functions for groups 1 and 2 respectively. In equilibrium, the marginal investor must be indifferent between staying or leaving. The returns outside the country are 0, while the returns inside the country consist of the sum of r and the expected losses from devaluation.

The expected losses from devaluation arise because when an investor in group 1 is in the country, there is a positive hazard rate for group 2's pulling out, in which case the investor would suffer devaluation losses with positive probability.[22] The hazard rate for group 2's pulling out is given by

$$\gamma_2(t) = \frac{g(a_2(t))}{G(a_2(t))}(-\dot{a}_2(t))$$

where $G(\cdot)$ is the cumulative distribution of $g(\cdot)$, and $\frac{g(a_2(t))}{G(a_2(t))}$ is the density of a_2 at $a_2(t)$, conditional on $a_2 \leq a_2(t)$. The probability of an investor in group 1 not being able to take his capital out conditional on group 2 pulling out is given by $\left(\frac{a_1(t)+a_2(t)-f(t)}{a_1(t)}\right)$, since after investors in group 2 take their capital out only $f(t) - a_2(t)$ reserves are left. Finally, the new exchange rate would be given by equation 1.1. As a result, $a_1(t)$ and $a_2(t)$ must satisfy[23]

$$
\begin{aligned}
r &= \frac{g(a_1(t))}{G(a_1(t))}(-\dot{a}_1(t))\left(\frac{a_1(t)+a_2(t)-f(t)}{a_2(t)}\right)(a_1(t)+a_2(t)-f(t)-e_0) \\
r &= \frac{g(a_2(t))}{G(a_2(t))}(-\dot{a}_2(t))\left(\frac{a_2(t)+a_1(t)-f(t)}{a_1(t)}\right)(a_2(t)+a_1(t)-f(t)-e_0).
\end{aligned}
$$

Since the solution is symmetric, these equations are equivalent to equation 1.3, $a_1(t) = a_2(t) \equiv a(t)$, and $\gamma_1(t) = \gamma_2(t) \equiv \gamma(t)$. Finally, let τ be such that $a(\tau) = a_m$. Then, since $\gamma(t) \to \infty$ as $t \to \tau$, it must be the case that $E_s(\tau) = 1$; otherwise, some investors could

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[22]To make this step rigorous, TA1 is needed. Otherwise, there could be other equilibria in which a group leaves even though r is higher than the expected devaluation losses due to attacks initiated by the other group. If one group left at such a time, and the reaction time were zero, the other group would follow *immediately* with positive probability. An investor would then have no incentive to deviate from this strategy, because no time elapses between the time at which he is supposed to leave and the possible crisis time. A more formal treatment of this point can be found in the appendix.

[23]Actually, if there are no transaction costs these differential equations must be satisfied only if $\dot{a}_1(t) < 0$ and $\dot{a}_2(t) < 0$. However, this problem does not arise under TA3. In the appendix I show that if $\dot{a}_i(t) = 0$ for some t, then $a_i(t') = a_M$ for all $t' \leq t$.

suffer predictable capital losses by staying too long or miss predictable capital gains by leaving too early. This is equivalent to $a(0) = a_m$.[24] $\square$

Figure 1-1 shows the marginal type $a(t)$ for different interest rates r.[25] It is clear that, for any values of a_1 and a_2, the first attack occurs later the higher r is. The intuition behind this result is that, although "learning" (which is related to $\dot{a}(t)$) can be faster when interest rates are high, the moment at which this learning starts is determined by the terminal condition. As a result, faster learning implies that more of it can take place closer to $t = 0$.
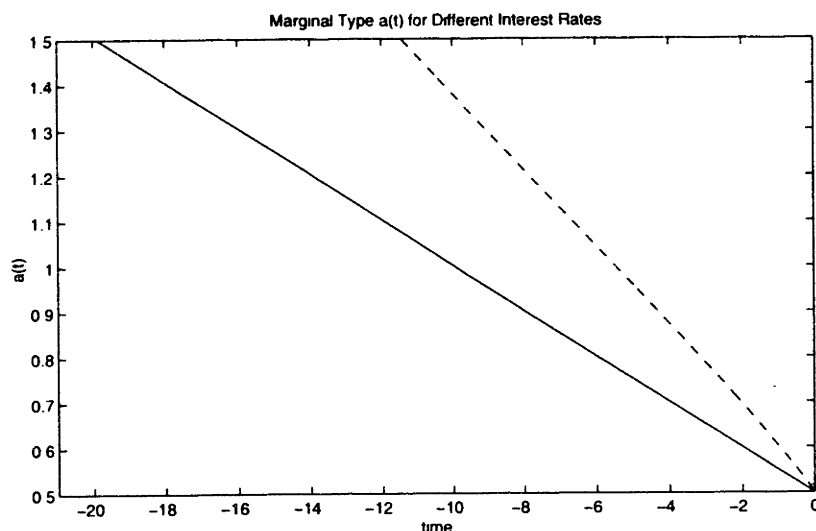
Figure 1-1: Marginal type a(t) for different interest rates. $a_m = 0.5$, $a_M = 1.5$, $g(a)$ is uniform, $\mu = 0.1$, and $e_0 = 0.2$. Solid line: $r = 0$. Dashed line: $r = 0.05$. Dotted line: $r = 0.2$.

Let t_1 be the time at which the first stage ends, i.e. $a(t_1) = \max\{a_1, a_2\}$. After the initial attack either the peg is abandoned or the second stage of the game begins. Without loss of generality, let us assume $a_2 > a_1$, so group 2 is the first to leave.

Proposition 4 *If $E_s(t_1) = 1 + f(t_1) + e_0 - a_1 - a(t_1) < 1$, investors in group 1 also leave and the peg is abandoned immediately. Otherwise, investors in group 2 return and*

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[24]For equation 1.3 to be valid, $\left(\frac{2a(t)-f(t)}{a(t)}\right) \in (0,1)$ is needed. This is satisfied at $t = 0$ iff $e_0 \in (0, a_m)$, which I assumed in A3. For earlier times, it is also satisfied if I assume $e_0 < a_m - (a_M - a_m)$. However, A3 is enough unless r is extremely high. In addition, even if the constrain were not satisfied by the solution described in the proposition, the qualitative behavior of the model would not change: the path of $a(t)$ would be less "steep" than the one proposed, but the effects of interest rates and the information structure on the timing of the crisis would be the same.

[25]Equation 1.3 can only be solved analytically for $r = 0$, in which case $a(t) = a_m - \frac{\mu}{2}t$. For $r > 0$, it can be shown that $a(t; r_1) < a(t; r_2)$ for all t if $r_1 < r_2$. In addition, $\dot{a}(0) = -\frac{\mu}{2} - \frac{r}{2}\frac{a_m}{e_0}$, which is useful for the numerical simulation.

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the second stage begins. The equilibrium is characterized by a marginal type function $a^1(t)$,
which denotes the type of investors in group 1 that would take their capital out at time t,
and $h(t)$, which denotes the hazard rate of investors in group 2's pulling out. The function
$a^1(t)$ satisfies the differential equation

$$r = \frac{g(a^1(t))}{G(a^1(t))}(-\dot{a}^1(t))\left(\frac{a^1(t)+a_2-f(t)}{a_2}\right)\left(a^1(t)+a_2-f(t)-e_0\right) \qquad (1.4)$$

and the boundary condition

$$a^1\left(-\frac{a_2-a_m}{\mu}\right) = a_m. \qquad (1.5)$$

The hazard rate $h(t)$ solves

$$r = h(t)\left(\frac{a^1(t)+a_2-f(t)}{a^1(t)}\right)\left(a^1(t)+a_2-f(t)-e_0\right) \qquad (1.6)$$

for $a^1(t) \leq f(t_1) + e_0 - a(t_1)$ and equals zero otherwise.

Proof: See appendix.

To understand the second stage of the game, consider the case when r is small. In this case, investors pull out in the first stage even when the expected devaluation losses are small, i.e. when t is such that $2a(t) - f(t) - e_0$ is close to zero. As a result, unless a_1 and a_2 are very similar, the first attack occurs *earlier* in the case with private information. However, there is a low probability that the group that did not initiate the attack has a type close enough to $a(t)$ so that the shadow exchange rate $E_s(t) < 1$, which implies that the currency will likely not be devalued in the first attack. Figure 1-2 shows this point graphically. Assuming group 2 attacks first, the solid line displays the learning process by investors in group 2, and marks the maximum possible type a_1. The dashed line is the marginal type $a(t)$ when no attack has taken place, and the dotted line is the marginal type $a^1(t)$ for group 1, conditional on group 2's type being known.[26] The marginal type $a(t)$ falls until it reaches $\max\{a_1, a_2\}$ at some time t_1. At that point, the peg is abandoned if the other type is such that the shadow exchange rate $E_s(t_1)$ is lower than 1. If the second group does not follow, the second stage begins, with an initial period of time when a crisis cannot

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[26]The path $a^1(t)$ depends on which value a_2 takes.

take place. When the maximum type consistent with the peg having survived intersects the marginal type function $a^1(t)$, investors start learning again. At some point, either $a^1(t)$ reaches the type of investors that did not initiate the first attack, which triggers a successful attack, or the group that initiated the first attack pulls out again. (Not described in the figure.) A sequence of "probing" attacks can ensue, until one takes place when $E_s(t) < 1$, in which case the attack is successful. However, the size of the devaluation is small since investors do not take high risks for small r.[27]
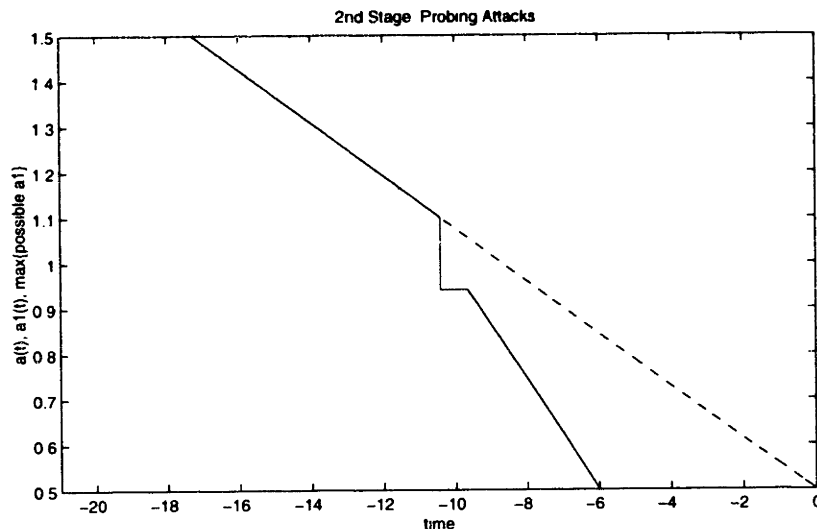
Figure 1-2: Second Stage: Probing Attacks. $a_m = 0.5$, $a_M = 1.5$, $a_1 = 1.1$, $a_2 < a_1$, $g(a)$ is uniform, $r = 0.005$, $\mu = 0.1$, and $e_0 = 0.2$. Dashed line: $a(t)$. Dotted line: $a^1(t)$. Solid line: $\max\{a_1 : a_1$ is consistent with group 1 not having left$\}$.

The model provides a number of results regarding the effects of asymmetric information and interest rates on the timing of BOP crises, and the behavior of asset prices during such episodes. First, once we account for the presence of private information, interest rates have a significant effect on the timing of crises, in contrast with the case presented at the beginning of this section.

Second, for any interest rate r, the presence of private information delays the crisis, in the sense that the peg lasts longer for all realizations of investors' private information. The presence of private information has two main effects. On the one hand, it introduces "noise," so that investors do not know precisely when the other investors are going to start leaving. As a result, investors can "coordinate" into staying in the country for a longer

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[27]An empirical prediction of the model is that, when a country defends its peg very strongly, attacks should be less frequent but more likely to be successful. In addition, the devaluation should be larger.

period of time and receiving the high returns.[28] This effect is illustrated in figure 1-1, as high interest rates "push back" the distribution of initial attack times.

On the other hand, private information makes investors "too optimistic" when the types are high (large amount of investments in liquid assets), and "too pessimistic" when the types are low (small amount of investments in liquid assets). The first (second) effect tends to make the first attack take place later (sooner) than under symmetric information. Although this seems to imply that the peg should last less under asymmetric information when types are low, this is not the case because there is an asymmetric arbitrage. When one group leaves, the second group learns whether $E_s(t_1) < 1$, and would not leave unless this would cause the exchange rate to devalue. Namely, the second group can "correct" the mistake introduced by the first group's leaving too early, but it cannot correct the mistake if the first group left too late.

Third, in the context of BOP crises, private information gives rise to discontinuous drops in asset prices and, hence, complementarities in investors actions. The asymmetry in the movement of the exchange rate is due to the high returns inside the country, the fact that investors learn as the crisis progresses, and the existence of an agent (the monetary authority) which is willing to buy domestic currency even if a depreciation is expected. In addition, the model shows that a simple change in a conventional first-generation model can give rise to crises with characteristics similar to those of multiple-equilibria models.

Fourth, the model also sheds light onto the positive relationship between the rate of return and the speed at which learning occurs.[29] The reason is that the faster investors learn, the higher the crisis-hazard rate is and, thus, the higher the risk premium demanded by investors. However, in equilibrium an increase in the interest rate implies that the learning process starts *later*, as less time is needed to do the same amount of learning. As a result, it is the expectation of high interest rates in the future, with a correspondingly high learning speed, that makes investors stay now. Namely, high interest rates at a point in time push back the marginal type functions for all *earlier* times. This indicates the possibility of time inconsistency in the setting of interest rate policy.

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[28]The term coordination can be misleading, since investors are better off in the asymmetric information case only if μ is not large compared to r. If μ is not too large, though, one can think of the symmetric information case as a problem of coordination failure, since investors would like to commit to staying longer.

[29]Stock (1987) shows that, empirically, the business cycle evolves on an "economic time scale" rather than on a "calendar time scale." Interestingly, he also found that the most important determinant of the economic time scale is the short-term interest rate, which has an accelerating effect.

To better understand the role of interest rates in the learning process, and in order to obtain implications for optimal interest rate policies during BOP crises, the next section endogenizes the behavior of the monetary authority. In addition, I will also show that the results presented in this section are not due to the assumption that crises are inevitable. In fact, they are strengthened if we introduce the possibility that there is a turnaround and fundamentals stop worsening.

1.4 Interest Rate Policy

The model in the previous section revealed the existence of a significant relationship between interest rates, the speed at which investors learn from each other, and the timing of BOP crises. This section focuses on the implications of these results for optimal interest rate policy during crises. I also include the possibility that crises be avoided if pegs last long enough. As a result, the model sheds light on how the results presented in this chapter depend on whether crises are "solvency" or "liquidity" crises.[30]

Interest rate policy is endogenized by introducing an objective function for the monetary authority.

Assumption 5 *The monetary authority minimizes the loss function*

$$L = E\left[1_{[\text{peg is abandoned}]}\bar{D} + 1_{[\text{deviate}]}\Phi + \int_{\underline{t}}^{\bar{t}} c(r(t))\,dt\right]$$

where $\bar{D} > 0$ is the cost associated with abandoning the peg, $\Phi > 0$ is the cost associated with deviating from a pre-announced interest rate policy, and $c(\cdot) \geq 0$ is the flow cost associated with raising interest rates. In addition, $c(0) = 0$, $c'(\cdot) > 0$, and $c''(\cdot) > 0$.

Without further changes, the equilibrium of the model would be trivial, since the crisis would take place regardless of interest rate policy. As a result, the monetary authority would set $r = 0$, and the peg would be abandoned as soon as the shadow exchange rate $E_s(t) = 1$.[31]

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[30]The model presented in the previous section was one of solvency crises, since crises occurred with probability 1. In this section, crises are less likely if the monetary authority delays the learning process by increasing interest rates.

[31]Note that I assume a zero discount rate. This is not an unreasonable assumption, since episodes of BOP crises usually only last a few months. However, the monetary authority might be interested in postponing

However, most crises have some liquidity component associated with them. For example, governments can implement policies to take a country out of an unsustainable path (such as increasing taxes or cutting government spending). In addition, the situation in international capital markets can improve and allow the country to find new sources of financing, or a positive terms-of-trade shock can take place. Usually, though, these developments take time and are not in the hands of the monetary authority. To capture such features of crises. I modify the model slightly to allow for the possibility of a turnaround in the economy.

Assumption 6 *With hazard rate ρ (or "turnaround" hazard rate), the game ends, the peg survives, and the monetary authority is spared all further interest rate costs.*

To solve the model, we first note that, although the equilibrium in the previous section was obtained for constant r, a similar equilibrium exists when r is not constant. The only difference is that r is replaced by $r(t)$ in equation 1.3. Let

$$t_0 \equiv \sup \left\{ t : a(t) = a_M \right\}$$

be the time at which the learning process starts. It is clear that the monetary authority does not need to set $r > 0$ for $t < t_0$. In addition, the monetary authority will not announce an interest rate policy that is not credible. Then, for $t < t_0$, the loss function is given by

$$L[t, \{r(s)\}] = \int_{t_0}^{0} \left[c(r(s)) + 2\frac{g(a(s))}{G(a(s))}(-\dot{a}(s))D(s, a(s)) \right] G(a(s))^2 e^{-\rho(s-t)} ds$$

where $D(s, a)$ equals the expected losses, as of time s, conditional on the first attack being initiated at time s by a group with type a. Interest rate costs incurred *before* time s are *not* included in $D(s, a)$.[32] The other terms in the expression are the hazard rate of having an initial attack at time s, conditional on not having had a previous attack or a turnaround before time s, which equals $2\gamma(s) = 2\frac{g(a(s))}{G(a(s))}(-\dot{a}(s))$, the interest rate flow cost at time s, conditional on the same event, $c(r(s))$, and the probability that neither a turnaround nor

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the crisis for political reasons, which might imply a higher discount rate. In any case, the "turnaround" hazard introduced below can also account for a discount rate, without affecting the equilibrium of the game.

[32] $D(s, a) = \bar{D}$ if the peg is abandoned at time s. If the type of the group that did not initiate the attack is low enough such that the peg is not immediately abandoned, $D(s, a) < \bar{D}$.

an attack take place before time s, $G(a(s))^2 e^{-\rho(s-t)}$.[33]

In order to determine $D(s, a(s))$, one would need to solve a similar minimization problem. However, this introduces some additional difficulties because $D(s, a(s))$ is defined recursively.[34] To keep the problem simple, I assume that $r = 0$ after an initial attack.[35] The function $D(s, a(s))$ is then given by

$$
D(s, a(s)) \;=\; \bar{D}\left[\frac{G(a(s)) - G(f(s) + e_0 - a(s))}{G(a(s))} + \right.
$$
$$
\left. \int_s^{-\frac{a(s)-a_m}{\mu}} \mu \frac{g((f_m - \mu\tau) + e_0 - a(\tau))}{G(a(s))} e^{-\rho(\tau-s)} d\tau \right]
$$

The first term is the probability that the second group has a type such that the shadow exchange rate $E_s(s) < 0$, i.e. the probability that the devaluation occurs immediately. The second term takes into account the fact that, if the second group has a type such that the devaluation occurs later, the probability that the turnaround takes place is higher. Note that, since I assume $r = 0$, there are no further interest rate costs.

To simplify notation, let

$$
k(s, a(s)) \equiv \frac{G(a(s))}{g(a(s))} \left(\frac{a(s)}{2a(s) - f(s)} \right) \left(\frac{1}{2a(s) - f(s) - e_0} \right)
$$

Then, from proposition 3, $a(s)$ is given by

$$
\dot{a}(s) \;=\; -r(s)k(s, a(s)) \tag{1.7}
$$
$$
a(0) \;=\; a_m
$$

I first ignore issues of time inconsistency by assuming $\Phi = \infty$. The monetary authority's problem is then to choose t_0 and $\{r(s)\}_{t=t_0}^{t=0}$ to minimize

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[33]Note that ρ enters in the loss function $L[t, \{r(s)\}]$ in the same way a discount rate would. As a result, ρ can be taken as the sum of the turnaround hazard rate and a discount rate.

[34]Minimization of $D(s, a(s))$ involves an initial period with $r = 0$, followed by an increasing path for r.

[35]This assumption does not affect the qualitative results of the model because the peg is abandoned after the first attack with high probability. The reason for this is that the optimal interest rate policy involves postponing the learning process and, as a result, after the first attack takes place the type of the group that did not initiate the attack is likely large enough such that $E_s < 1$. On the other hand, the "unconstrained" $D(s, a(s))$ is steeper than the one assumed here, so the incentives to postpone the learning would be slightly lower without this assumption.

$$L[t, \{r(s)\}] = \int_{t_0}^{0} \left[c(r(s)) + 2\frac{g(a(s))}{G(a(s))} r(s) k(s, a(s)) D(s, a(s)) \right] \times$$
$$G(a(s))^2 e^{-\rho(s-t)} ds$$

subject to equation of motion 1.7, $a(t_0) = a_M$, and $a(0) = a_m$.

Proposition 5 *The solution to the monetary authority's problem when $\Phi = \infty$ is characterized by*

$$\dot{a}(s) = -r(s) k(s, a(s))$$
$$\dot{r}(s) = \frac{1}{c''(r(s))} \left\{ [\rho D(s, a(s)) - D_t(s, a(s))] 2\frac{g(a(s))}{G(a(s))} k(s, a(s)) + \right.$$
$$c'(r(s)) \left[\rho + r(s) 2\frac{g(a(s))}{G(a(s))} k(s, a(s)) \right] -$$
$$\left. c(r(s)) 2\frac{g(a(s))}{G(a(s))} k(s, a(s)) + c'(r(s)) \frac{k_t(s, a(s))}{k(s, a(s))} \right\}$$
$$r(t_0) = 0$$
$$a(t_0) = a_M$$
$$a(0) = a_m$$

(1.8)

where a subscript t denotes the partial derivative with respect to time.

Proof: See appendix.

The solution is more intuitive than it looks. The $\dot{a}(s)$ equation has been described above. The equation for $\dot{r}(s)$ is composed of four terms and a scaling factor. The first term captures the fact that it is desirable to postpone the expected cost D so that the peg has more chances of survival, and also if D is expected to fall. The second term is associated with the fact that the monetary authority would like to postpone raising the interest rate since there is a higher probability that the crisis or a turnaround take place earlier and the cost be saved. The third term is due to the fact that, by postponing the increase in the interest rate, and thus the crisis distribution, it is more likely that the interest rate cost in the future will be incurred. The fourth term is associated with the fact that if

the "effectiveness" of raising interest rates is increasing, the monetary authority has an incentive to postpone raising them. Finally, the larger the smoothing incentives (i.e. the higher the second derivative of the cost function) the less the previous four effects matter.[36] The condition that determines t_0 comes from the desire to smooth $r(s)$.

The solid lines in figure 1-3 show paths for $r(s)$, $a(s)$, and the probability density of time of first attack, corresponding to the solution to the monetary authority's problem when $\Phi = \infty$.[37] The paths of $r(s)$ and $a(s)$ are conditional on not having had an attack or turnaround prior to time s. The solution is characterized by a long initial period of "tranquility," in which $r = 0$ and the probability of a crisis is zero. Towards the end, however, interest rates must be raised sharply at the same time that the probability of crisis increases. The figure clearly illustrates the results described in the previous section. First, the positive relationship between the interest rate and the speed of learning is *point by point*. Namely, along the optimal path of $r(s)$, times of high interest rates are times in which the probability of observing an attack is high. This is true for both the conditional probability (given by the slope of $a(s)$ divided by $G(a(s))$) and unconditional probability (given by the density function). In addition, it is optimal to have a sharply increasing path for the interest rate rather than keeping it at a low constant value. This is because interest rates push back the $a(s)$ schedule for all *earlier* times; as a result, it is more "efficient" to raise them late. In addition, the probability that interest rate costs are incurred decreases with the time at which they are raised since it is possible that the game ends before that time.

However, the fact that the benefits from raising interest rates at a point in time is in postponing the crisis for *earlier* times suggests that a problem of time inconsistency might exist. As a result, I next consider the case in which $\Phi = 0$. To analyze this case, I need to make an assumption regarding the point at which the monetary authority sets interest rates for times close to $t = 0$.

Technical Assumption 5 *The model is the limit, as $\Delta t \to 0$, of a model in which interest*

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[36]Note that partial time derivatives are present instead of total time derivatives. The reason for this is that the effect of $r(s)$ on the path of a exactly cancels out the term corresponding to the partial derivative with respect to a.

[37]There are two initial conditions and one final condition for system 1.8. To carry out the simulation, I iterated over different t_0 until $a(0) = a_m$. It should be possible to prove (I have not done it yet) that $a(0)$ is an increasing function of t_0 and, as a result, there exists only one path that satisfies all conditions.
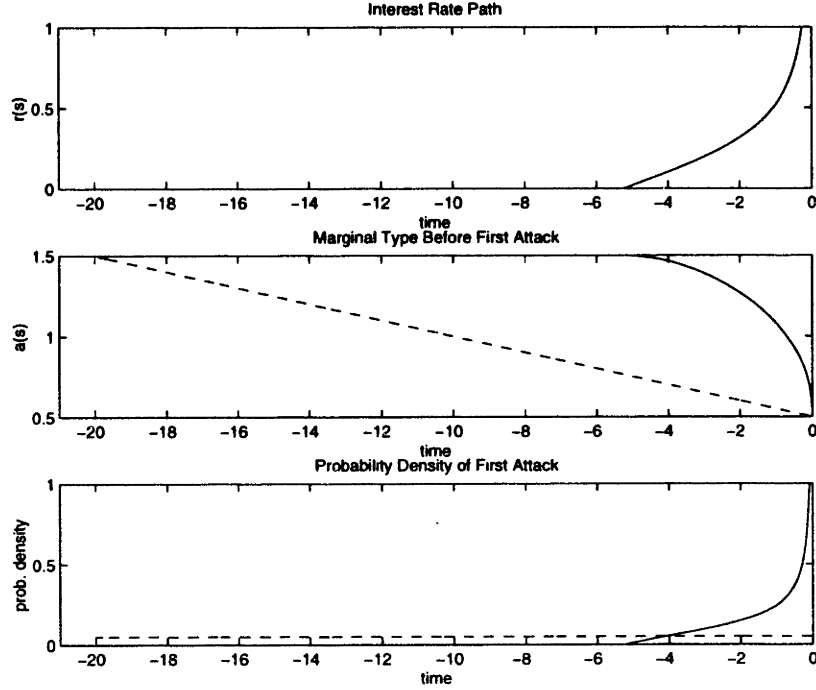
Figure 1-3: Optimal path for $r(s)$, corresponding marginal type $a(s)$, and density function of times of first attack. $a_m = 0.5$, $a_M = 1.5$, $g(a)$ is uniform, $\mu = 0.1$. $e_0 = 0.2$, $\rho = 0.1$, $\bar{D} = 1$, and $c(r) = 0.5r + r^2$. Solid line: with full commitment. Dashed line: with no commitment ($r = 0$).

rates are constant within $(-\Delta t, 0]$, $(-2\Delta t, -\Delta t]$, $(-3\Delta t, -2\Delta t]$, and so for. In addition the interest rate for $s \in (-(n + 1)\Delta t, -n\Delta t]$ is set at time $-n\Delta t$.

Proposition 6 *If $\Phi = 0$ and TA5 holds, the monetary authority cannot commit to any interest rate policy different from $r(s) \equiv 0$.*[38]

Proof: The proposition follows from a simple backward induction argument. Regardless of previous play, the monetary authority will set $r = 0$ for $s \in (-\Delta t, 0]$ at time 0. As a result, the peg must be abandoned at the latest at time $-\Delta t$ if $E_s(-\Delta t) < 1$. Assume that $r = 0$ for $s \in (-n\Delta t, 0]$ and that the peg must be abandoned at the latest at time $-n\Delta t$ if $E_s(-n\Delta t) < 1$. The monetary authority then does not have any incentive to set $r > 0$ for $s \in (-(n + 1)\Delta t, -n\Delta t]$ at time $-n\Delta t$. By induction, $r(s) \equiv 0$. $\square$

The dashed line in figure 1-3 shows paths for $r(s)$, $a(s)$, and the probability density of time of first attack, corresponding to the solution to the monetary authority's problem

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[38] *It can be shown that if $c'(0) > \frac{\rho \bar{D}}{8} \frac{a_m}{\mu e_0}$ the proposition is true even if the interest rate for $s \in (-(n + 1)\Delta t, -n\Delta t]$ is set at time $-(n + 1)\Delta t$.*

when $\Phi = 0$. The monetary authority cannot commit to raising interest rates and, as result, $r(s) \equiv 0$. The case of low interest rates was discussed in the previous section, and involves investors' leaving as soon as a devaluation is possible. This can be seen in the $a(s)$ schedule, which satisfies $f(s) + e_0 - 2\bar{a}(s) = 1$. The no-commitment case is then characterized by low interest rates, small devaluations, and vulnerable pegs.

In order to highlight the problem of time inconsistency, figure 1-4 illustrates the incentives to deviate from the optimal full-commitment interest rate policy. The solid line shows the expected *future* costs faced by the monetary authority as the crisis progresses, conditional on no previous attacks or turnaround. For early times the expected costs are an increasing function of time, since as time passes the probability that the turnaround takes place decreases. The expected costs eventually become larger than $\bar{D} = 1$, since they include both the likely devaluation and interest rate costs. As the interest rate costs become sunk, the expected future costs start decreasing. As $s \to 0$, the costs tend to $\bar{D} = 1$ since the crisis is imminent but no further interest rate costs need to be incurred. This is in sharp contrast with the behavior of the expected future costs if the monetary authority deviated from its pre-announced policy. The dashed line shows the expected costs, as of time s, assuming the monetary authority deviates at s and sets $r = 0$ thereafter.[39] The reputation cost Φ is not accounted for in the schedule. For early times, while $f(t) + e_0 - 2a_M > 1$, this path coincides with the expected costs under $\Phi = 0$, which are much higher than under full commitment. As the crisis progresses, though, the benefits from high future interest rates become sunk, and the two schedules start approaching each other. Eventually, the schedule becomes lower than that under commitment, and the monetary authority has an incentive to deviate.[40]

As a result, in order for the pre-announced full-commitment interest rate policy to be credible, Φ needs to be larger than the maximum distance between the two schedules in figure 1-4. For intermediate Φ, the monetary authority can only credibly commit to an interest rate defense which is less "aggressive."

Finally, note that if investors did not have private information, the timing of the crisis would simply be given by the condition that the size of the devaluation be zero. But

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[39] Once the monetary authority deviates, Φ is sunk and it becomes impossible to credibly announce any policy different from $r(s) \equiv 0$.

[40] Note that the schedule with deviation can *never* be larger than $\bar{D} = 1$.

Expected Losses with Commitment: Deviate vs. Not Deviate
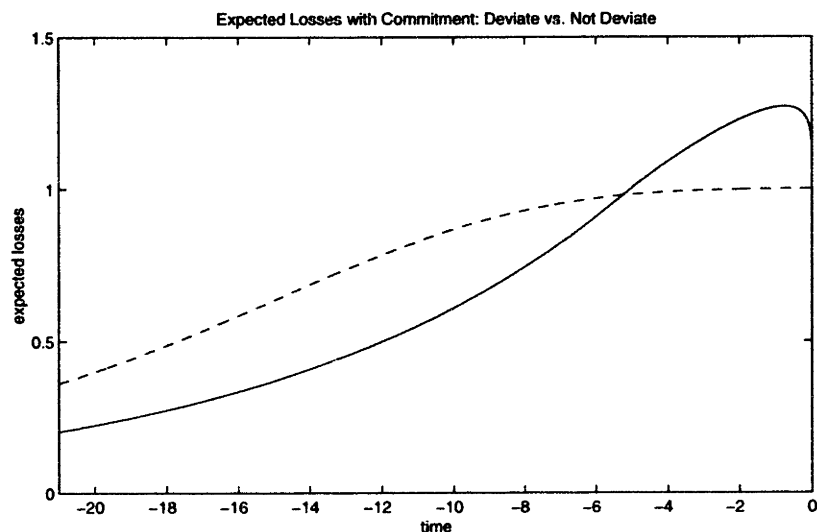
Figure 1-4: Solid line: $L(t)$, as of t, conditional on reaching t before the first attack. Dashed line: Idem, but assuming $r = 0$ thereafter.

this is exactly the same condition that determines the time of devaluation under the no-commitment solution. As a result, as was hinted by the model in the previous section, the monetary authority is better off in the presence of asymmetric information. Note that this is not due to some form of transfer from investors, because with perfect information investors would get 0 ($r = 0$), whereas they get, in expectation, a positive return under imperfect information. In a sense, the monetary authority is willing to pay investors to stay longer in order to have a higher probability that the peg be saved. In addition, investors would like to "coordinate" into staying for longer in order to receive this payment, but they cannot do so unless there is private information.[41]

Furthermore, the results presented in this section are *stronger* when crises have a higher liquidity component. The higher ρ, the larger the incentives to pre-announce a strong interest rate defense because it is less likely that their associated costs will need to be incurred. Also, it is important to note that the effect of future interest rates on the speed of learning does *not* depend on ρ. As a result, it is optimal to have a more aggressive interest rate defense when ρ is high.[42]

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[41]I cannot make strong claims as to the welfare implications of private information, since this chapter ignores important ingredients of BOP crises, such as moral hazard considerations. The results presented in this chapter suggest that, although there might be good reasons for monetary authorities to require financial institutions to provide them with information regarding their activities, it might not be a good idea to make this information public. However, it is possible that monetary authorities that are better informed than investors would have even more time consistency problems than an uninformed one.

[42]An aggressive defense in the context of this chapter means a commitment to raise interest rates sharply

1.5 Robustness and Alternative Scenarios

Many of the ingredients of the model were introduced in reduced form. Apart from making the model more tractable, the reduced-form approach allows for a fairly general interpretation of the results. However, special attention needs to be paid to the question of robustness. This section explains which assumptions are essential for the results, and in which scenarios they are likely to be valid.

Monetary authority instruments:

In a more general setting, the government's decision to float, possibly when there are still some reserves left, could be endogenized. If the objective function of the monetary authority included a benefit from reserves left after the crisis, the problem of time inconsistency would be even more serious, as the monetary authority would have an incentive to devalue before selling its reserves.

Sources of private information:

If I assumed that investors have private information about the post-devaluation exchange rate, without assuming that there is any relationship between "types" and holdings of liquid assets, the results of the model would not change. However, I prefer to assume that this information is due to some characteristic that also affects the size of the outflows because, otherwise, I would need to assume that reserves are enough to cover one group but not both. In the model presented in this chapter, this constraint is satisfied without any special assumptions on initial reserves. Other sources of private information that would imply similar results include: (i) risk characteristics of bank lending, since banks have better information about their own clients than about those of other banks; (ii) liquidation value of investments; (iii) outside opportunities of investors; (iv) margin calls investors would be forced to make if a crisis occurs; and (v) investors' assessments about the prospects of the country.

Information structure:

The assumption of aggregate uncertainty is necessary for the results and, as a result, it is important that there be only two groups. However, similar results can be obtained with a

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when fundamentals are very weak. When ρ is high, most times crises can be avoided by committing to raising interest rates in the few cases in which the turnaround does not take place. If ρ is low, it is not worth committing to raising interest rates because the peg will have to be abandoned with high probability.

unimodal distribution if two requirements are met: there exist "steep" edges or discontinu-
ities, because if the distribution were smooth private information would be revealed slowly;
in addition, if an investor with type a knows that the discontinuity in the distribution is
to the left of $a + \epsilon$, he must assign a probability to the discontinuity being in $[a, a + \epsilon]$
that goes to zero as ϵ goes to zero. A distribution that satisfies these requirements is the
one used in Chamley (1998): a rectangular distribution whose position is unknown, on top
of a wider rectangular distribution. In addition, these two assumptions can be somewhat
relaxed if one adds observation "noise." I chose to assume the existence of two groups for a
number of reasons. First, this allows for the existence of "probing attacks," which are nec-
essary to illustrate the one-sided arbitrage channel in which private information delays the
crisis. Second, with the unimodal distribution I would need to make an ad-hoc assumption
about the order in which investors that did not initiate the attack access foreign currency
reserves, which might make the results suspect. Third, there are actually different types of
investors and sometimes crises can be traced to the actions of one of them. For example,
some researchers believe the behavior of hedge funds was important in the onset and spread
of the Asian crisis, and versions exist about the Russian crisis being triggered by domestic
investors refusing to roll over Russia's short-term debt which prompted a similar response
from foreign investors.

Existence of excess returns:

The assumption that investors cannot bring in more capital is not crucial. What is
needed is that the informed investors (or specialists) be capital constrained in a way that
their types are not revealed by how much more capital they bring in the run-up to the
crisis. A totally inelastic supply of capital serves this purpose, but it is not necessary
that the maximum amount of capital they have access to equal their initial holdings.[43]
Adding uninformed investors with a more elastic supply of capital actually makes the effects
presented in this chapter stronger. To see this point, assume that uninformed investors bring
$k(\bar{r}(t))$ capital, where $\bar{r}(t)$ are excess returns which take into account expected devaluation

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[43]This simplification can be thought of as representing the fact that even though the supply of capital is
not perfectly elastic, there is enough noise and uncertainty in the economy such that investors cannot infer
other investors' types perfectly. In the context of herding in financial markets, Avery and Zemsky (1998)
show that if there exists uncertainty in a large enough number of dimensions, it can take a long time for
investors to learn even if they observe at which price other investors trade. In the context of my model, I
could make the case that it is possible that investors are unable to determine other investors characteristics
even if they observe capital flows.

losses for investors who do not know a_1 or a_2. In addition, assume that when a group pulls out, the uninformed investors have the same probability of taking their capital out before the devaluation as the group of investors that did not initiate the attack. The only difference this would make to the equilibrium comes from the ratio $\left(\frac{2a(t)-f(t)}{a(t)} \right)$ in equation 1.3, which would be replaced by $\left(\frac{2a(t)-f(t)}{a(t)+k(\bar{r}(t))} \right)$. This would imply that learning could take place even faster, and the crisis would be postponed more than before.[44]

Different scenarios:

There are other possible scenarios that could be associated with the model presented in this chapter. Most literally, one could think that investors have their capital deposited in local banks in domestic currency. Or that they have to decide whether to attack the currency by borrowing in domestic currency at the prevailing interest rate. Another possible scenario is that of a government which is trying to roll over short-term debt, with investors deciding whether the promised returns compensate for the risk of default. Even if government finances are in order, the private sector (especially domestic banks) might face similar liquidity needs. The fundamental could then represent domestic credit, as in first-generation models, the size of government's or banks' short-term liabilities, or the size of bad loans in the financial sector. All that is needed is that investors receive high returns while the crisis does not occur, that their decisions about whether to invest and receive this return have an effect on the timing of the crisis, and that there be an incentive to be the first to "leave."

1.6 Concluding Remarks

This chapter presents a framework for understanding the dynamics and timing of BOP crises. It shows that the presence of private information on the part of investors in a simple first-generation model can account for important features of BOP crises. First, crises can involve large drops in asset prices in the absence of large shocks even in a single equilibrium model. Second, even countries whose fundamentals are known to be weak can delay the onset of crises for long periods of time by raising interest rates.

The chapter shows that the effectiveness of interest rate defenses increases with the

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[44]Uninformed investors are at an informational disadvantage. As a result, even if excess returns exist from the point of view of specialists, uninformed investors might still find it optimal to stay out. In addition, the existence of excess returns for informed investors does not mean that the free entry condition to become a specialist does not hold in the first place, since this decision is made earlier and might involve other costs.

degree of private information. When interest rates are low *or* there is no private information, pegs are abandoned at a time such that the exchange rate is continuous. When interest rates are high *and* there is private information, pegs last longer and are abandoned at a point such that the exchange rate depreciates by a large amount.

In addition, the chapter shows that the optimal interest rate policy in episodes of BOP crises is to sharply raise interest rates if fundamentals deteriorate, rather than raising interest rates by a smaller amount for a longer period of time. However, a problem of time inconsistency arises. The monetary authority has an incentive to deviate and not to raise interest rates once fundamentals become weak enough. This emphasizes the importance of commitment devices such as currency boards or a role for international financial institutions such as the IMF.

The model also shows that crises are more likely when interest rates are high, even conditioning on the level of fundamentals. This has important implications for empirical studies on the effectiveness of interest rate defenses against BOP crises (e.g. Kraay 1999). For example, an episode in which interest rates are raised but the monetary authority is nonetheless forced to abandon the peg could be taken as evidence that raising interest rates is not very useful in defending a currency under attack. However, in the model presented in this chapter pegs are more likely to survive if interest rates are expected to be sharply raised in the future (i.e. strong defense) even though crises are more likely while interest rates are high.[45]

Finally, when there is a high probability that the peg is "viable" if the crisis can be postponed, these results are *stronger*. Such episodes can be associated with liquidity crises.

If the dimension along which investors have private information reflects some "intrinsic" characteristic, the model can be easily extended to account for the phenomenon of contagion. In such an extension, crises would only be transmitted to countries whose fundamentals are sufficiently weak.[46] In addition, an externality would exist between the setting of monetary policy in different countries since, by delaying the crisis in one country, monetary

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[45]In the aftermath of the Brazilian devaluation in January 1999 the Argentine peso suffered very little pressure. This is likely because investors knew that interest rates would be sharply raised in case of a speculative attack due to the strong commitment to the currency board. After the Mexican devaluation in December 1994, when this commitment had not been previously tested, the pressure on the Argentine peso was much greater.

[46]See Tornell (1998) for evidence that crises are more likely to be transmitted to countries with weak fundamentals.

authorities delay the learning process in all other countries as well. This externality implies an important role for the IMF.

In future research, I intend to apply the framework presented in this chapter to the areas of asset-markets bubbles and banking crises. The relationship between the rate of return on domestic assets and the speed of information revelation in the model presented in this chapter is analogous to the relationship between the high returns to holding an asset with a bubble and the probability that the bubble "bursts." Under the assumption that investors have private information regarding the fundamental value of the asset (i.e. its price when the bubble bursts), bubbles could probably exist even if investors know that the bubble cannot last forever (for example if the price is limited by the size of the economy). In episodes of banking crises, the relationship between the interest rate on deposits and the probability that some investors assign to the bank failing due to other investors' withdrawals poses a similar trade off on investors' actions.

1.7 Appendix

1.7.1 Analysis of Model with Constant Interest Rate

Here I present a more formal analysis of the model. Since investors are atomistic and there are no transaction costs, investors' actions are taken so as to maximize expected returns pointwise. Thus, the model can be divided in different "stages," depending on the information investors have about each other. At the beginning of the first stage, types are private information. As the stage progresses, information is slowly revealed until a first "crisis" occurs, in which a group of investors pulls out, revealing their type. If the attack is not large enough to force the abandonment of the peg, a second stage begins, which is similar to the first, except that now the type of one of the groups is common knowledge. The "interaction" between the different stages is limited, in the sense that the different stages can be analyzed almost independently.

The first stage of the game lasts until some investors "move" for the first time. To be more precise, let

$$A_i(t) = \int_j (1 - x(i, j, t))\, dj$$

47

be the proportion of their capital taken out by investors in group i. The first stage of the game ends at time

$$t_1 = \sup\left\{\tau : \forall \tau' \in (\underline{t}, \tau] \; A_1(\tau') = 0 \text{ and } A_2(\tau') = 0\right\}$$

since that is the first time at which some investors observe a "movement" by investors in the other group.

First Stage:

Let

$$
\begin{aligned}
a_i(t, \nu) \;=\; & \left\{ a_i : \sup\left\{\tau : \forall \tau' \in (\underline{t}, \tau] \; A_i(\tau') = 0 \right. \right. \\
& \left. \left. \text{if } \forall \tau' \in (\underline{t}, \tau] \; A_{-i}(\tau') = 0 \right\} \in (t - \nu, t + \nu) \right\}
\end{aligned}
$$

be the set of types a_i such that, conditional on not having observed any movement by investors in the other group, the earliest time a positive amount of capital from investors in group i leaves the country falls in the interval $(t - \nu, t + \nu)$.[47] Let

$$a_i(t) = \bigcap_{\nu > 0} a_i(t, \nu)$$

be the set of types a_i that would start pulling out exactly at t, conditional on the other group not having pulled out before. Let

$$T = \{t : a_i(t) \neq \emptyset \text{ or } a_{-i}(t) \neq \emptyset\}$$

Proposition 7 *In equilibrium, $\exists t_0 \in \left(-\frac{2(a_M - a_m)}{\mu}, 0\right)$ such that, for $i \in \{1, 2\}$, $a_i(t)$ is a continuous strictly-decreasing function of t for $t \in [t_0, 0]$, $a_i(0) = a_m$, $a_i(t_0) = a_M$, and $A_i(t) = 0$ for $t < t_0$.*

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[47]It is not possible for investors to play mixed-like strategies in the first stage of the game in equilibrium. The reason is that if investors are indifferent between moving at two different times when they are of type a_i, they will strictly prefer to move at the earlier (later) time when their type is higher (lower) than a_i. As a result, since the probability of investors being of a certain type is zero (i.e. $g(a)$ has no atoms), the mass of investors who can play mixed-like strategies is zero. The situation is different in the following stages, since the type of one group of investors is common knowledge; hence, that group can play mixed-like strategies.

Proof: The proof contains several intermediate steps:

(i) *For all t and ν, $a_1(t,\nu) = \emptyset$ iff $a_2(t,\nu) = \emptyset$. In addition, $\forall a_i \in a_i(t,\nu) \ \exists a_{-i} \in a_{-i}(t,\nu)$ such that $a_i + a_{-i} - f(t + \nu) - e_0 > 0$.* This follows from the fact that investors can only condition their actions at t on flows up to $t - \epsilon$ (TA1). As a result, an investor in group i would not pull out at time $t' \in (t - \nu, t + \nu)$ if the probability of the other group pulling out is zero or if, even if the probability is positive, the crisis cannot bring about a positive devaluation.

(ii) *For all t, $a_i(t) = \emptyset$ iff $a_{-i}(t) = \emptyset$. In addition, $\forall a_i \in a_i(t) \ \exists a_{-i} \in a_{-i}(t)$ such that $a_i + a_{-i} - f(t) - e_0 \geq 0$.* This follows from (i) and the definition of $a_i(t)$.

(iii) *If $a' \in a_i(t)$, $a'' \in a_i(t)$, $a'' > a'$, then $[a', a''] \subseteq a_i(t)$.* This depends on the form of the equilibrium in the second stage of the game, which will be analyzed below. For now, I just need that if a group starts pulling out and $a_i + a_{-i} - f(t) - e_0 > 0$ a crisis with positive devaluation takes place immediately with probability 1. As a result, if an investor of type a' finds it optimal to leave (or is indifferent between leaving and staying) then an investor with more liquid investments will strictly prefer to leave. In addition, if an investor of type a'' has not left before time t, then an investor with less liquid assets would have strictly preferred to stay until t.

(iv) *For $i = 1,2$ and for all t $a_i(t)$ is either empty or a single point.* First, $a_i(t)$ cannot have positive measure. If it did, there would be a positive probability of group i reaching its "threshold value" at t. As a result, for all $a_i \in a_i(t)$ and $a_{-i} \in a_{-i}(t)$, $a_i + a_{-i} - f(t) - e_0 \leq 0$ since otherwise there would be a positive probability of crisis with positive devaluation at t which cannot occur in equilibrium. But then there would be $a_i' \in a_i(t)$ such that $a_i' + a_{-i} - f(t) - e_0 < 0$ for all $a_{-i} \in a_{-i}(t)$ which contradicts (ii). Since $a_{-i}(t)$ cannot be empty either due to (ii), I conclude that $a_i(t)$ cannot have positive measure. This, together with (iii) implies (iv).

(v) *T is dense in $T' \equiv [\inf\{T\}, \sup\{T\}]$.* That T is dense at $\inf\{T\}$ and $\sup\{T\}$ is obvious. Now assume $\exists \ \tau_1, \tau_2 \in T'$ such that $[\tau_1, \tau_2] \bigcap T = \emptyset$. Let $\tau_1' = \sup\{t \in T : t < \tau_1\}$. Now I use the assumption that takes the model to be the limit of a model with transaction costs as these costs tend to zero (TA3). For any positive transaction cost, and regardless of how short $[\tau_1, \tau_2]$ is, $\exists \tau_1'' \in T$ that is so close to τ_1' that the probability of having a crisis before τ_1 is low enough so that $a_i(\tau_1'')$ has to be empty.[48] This contradicts $\tau_1'' \in T$.

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[48]Investors would compare an arbitrarily small probability of crisis with the transaction costs associated

(vi) $T = T'$. Since $a_i(t)$ is either empty or a single point, and for every $a \in [a_m, a_M]$ $\exists t$ such that $a \in a_i(t)$, I can define a function $t_i(a) : [a_m, a_M] \to T'$ as the inverse of $a_i(t)$. $t_i(a)$ is decreasing and, from (v), its image is dense in T'. This implies $T = T'$.[49]

(vii) *For $i = 1,2$, $a_i(t) : T \to [a_m, a_M]$ are continuous strictly decreasing functions.* This follows from the fact that $a_i(t)$ is 1-to-1 and decreasing.

(viii) $T = [t_0, 0]$, *where* $t_0 \in \left(-\frac{2(a_M - a_m)}{\mu}, 0 \right)$. If $t_i(a_m) < 0$, as $t \to t_i(a_m) < 0$ the expected devaluation losses would tend to infinite since the hazard rate of crisis tends to infinite while the size of devaluation does not tend to zero. In addition, in equilibrium an investor of type a_m would not leave at $t_i(a_m) > 0$ because the devaluation would be negative with probability 1, and he would prefer to stay longer. Finally, $t_0 < -\frac{a_M - a_m}{\mu}$ is impossible because investors would not leave if, even in the case where $a_1 = a_2 = a_M$, liquid investment are not large enough to exhaust all reserves. $\square$

Proposition 8 *The first stage of the game has a unique and symmetric equilibrium. The equilibrium is characterized by a function $a(t)$, which denotes the type of investors that would take their capital out at time t. $a(t)$ is continuous, strictly-decreasing, differentiable, and is the unique solution to differential equation*

$$r = \frac{g(a(t))}{G(a(t))}(-\dot{a}(t)) \left(\frac{2a(t) - f(t)}{a(t)} \right) (2a(t) - f(t) - e_0) \qquad (1.9)$$

that satisfies the boundary condition

$$a(0) = a_m. \qquad (1.10)$$

Note: The function $a(t)$ is only defined for $t \in [t_0, 0]$, where t_0 satisfies $a(t_0) = a_M$.

Proof: The proof contains several intermediate steps:

(i) *For $i = 1,2$, $a_i(t) : T \to [a_m, a_M]$ is differentiable.* Since $a_i(t)$ is monotone it must be differentiable almost everywhere. (See Kolmogorov and Fomin (1970) page 321.) Thus,

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with leaving at τ_1'' and coming back right after τ_1', or the losses associated with being out of the country at a time when a crisis cannot take place (which is at least $r(\tau_2 - \tau_1)$).

[49]This must be a known result but I will present a proof. Assume $\tau \in T'$ but $\tau \notin T$. Since T is dense, $\exists \{\tau_1, \ldots, \tau_n, \ldots\}$ such that $\tau_n \to \tau$, $\tau_1 < \cdots < \tau_n < \tau_{n+1} \cdots < \tau$, and $\forall n$ $\tau_n \in T$. (For $\tau = \inf\{T\}$ a symmetric argument applies.) Let, for all n, $\alpha_n \equiv a_i(\tau_n)$. Then $\{\alpha_1, \ldots, \alpha_n, \ldots\}$ is a bounded decreasing sequence. Let α be its limit. If $t_i(\alpha) < \tau$, then τ_n is bounded away from τ and $\tau_n \not\to \tau$. If $t_i(\alpha) > \tau$, then it is impossible that $\tau_n < \tau$ $\forall n$.

if $a_i(t)$ is not differentiable at τ, $\exists \nu > 0$ such that $a_i(t)$ is differentiable at all points in $[\tau - \nu, \tau + \nu]$ except at τ. I want to show that $a_i(t)$ must be differentiable from the left and from the right at τ. Assume it is not differentiable from the left. This means that $\exists \epsilon_l$ such that $\forall \nu' > 0$, $[\max\{\dot{a}_i(t) : t \in (\tau - \nu', \tau)\} - \min\{\dot{a}_i(t) : t \in (\tau - \nu', \tau)\}] > \epsilon_l$. But this is not possible because, since $a_{-i}(t)$ is monotone, the hazard rate of group 1's reaching its threshold value (which equals $\mu(-\dot{a}_i(t))$) cannot decrease arbitrarily fast. As a result, the derivatives from the left and from the right must exist at τ. But they cannot be different because $a_{-i}(t)$ is continuous at τ, which implies $a_i(t)$ is differentiable at τ.

(ii) *For $i = 1,2$ all investors in group i move simultaneously and take all their capital out at $t_i(a_i)$.* This follows from the fact that, for all $t > t_i(a_i)$, $\exists a_i' < a_i$ such that investors would leave at $t = t_i(a_i')$ if their type were a_i'. But that means that for all $t > t_i(a_i)$ investors of type a_i are strictly worse off staying in the country than outside and, as a result, they would leave at $t_i(a_i)$.

(iii) *$a_1(t)$ and $a_2(t)$ are solutions to the system of differential equations*

$$r = \frac{g(a_1(t))}{G(a_1(t))}(-\dot{a}_1(t))\left(\frac{a_1(t) + a_2(t) - f(t)}{a_2(t)}\right)(a_1(t) + a_2(t) - f(t) - e_0)$$
$$r = \frac{g(a_2(t))}{G(a_2(t))}(-\dot{a}_2(t))\left(\frac{a_2(t) + a_1(t) - f(t)}{a_1(t)}\right)(a_2(t) + a_1(t) - f(t) - e_0)$$

and satisfy

$$a_1(0) = a_2(0) = a_m$$

$$a_1(t_0) = a_2(t_0) = a_M$$

for some $t_0 \in \left(-\frac{a_M - a_m}{\mu}, 0\right)$. The boundary conditions were obtained in proposition 7. The form of the differential equations is derived in the main text.

(iv) $\forall t\ a_1(t) = a_2(t)$. The system of differential equations that determine $a_1(t)$ and $a_2(t)$ is symmetric and, in addition, $a_1(t)$ and $a_2(t)$ must satisfy the same initial condition. As a result, $a_1(\cdot) = a_2(\cdot)$. $\square$

Later Stages:

Without loss of generality, I assume that group 2 is the one that started pulling out at the end of the first stage and, as a result, a_2 is common knowledge. In addition, agents in the second group know that $a_1 \in [a_m, a_2]$. I start the analysis of the second stage assuming that $f(t)$ is high enough when the first stage ends, so that a crisis cannot occur immediately, i.e.

$$f(t_1) > 2a_2 - e_0.$$

This is impossible in equilibrium, but it is easier to start with this case.

Let

$$a^1(t, \nu) = \left\{ a_1 : \sup \left\{ \tau : \forall \tau' \in (t_1, \tau] \ A_1(\tau') = 0 \right.\right.$$
$$\left.\left. \text{if } \forall \tau' \in (t_1, \tau] \ A_2(\tau') = 0 \right\} \in (t - \nu, t + \nu) \right\}$$

be the set of types a_1 such that, conditional on not having observed any movement by investors in group 2, the earliest time a positive amount of capital from investors in group 1 leaves the country falls in the interval $(t - \nu, t + \nu)$.[50] Let

$$a^1(t) = \bigcap_{\nu > 0} a^1(t, \nu)$$

be the set of types a_1 that would start pulling out exactly at t, conditional on group 2 not having pulled out before.

The characterization of group 2's play is different from that of group 1, because a_2 is known and, as a result, investors in group 2 can play mixed-like strategies. Let

$$d(t, \nu) = \Pr \left[\sup \left\{ \tau : \forall \tau' \in (t_1, \tau] \ A_2(\tau') = 0 \right.\right.$$
$$\left.\left. \text{if } \forall \tau' \in (t_1, \tau] \ A_1(\tau') = 0 \right\} \in (t - \nu, t + \nu) \right]$$

be the probability that, conditional on not having observed any movement by investors in

---

[50]As in the first stage, group 1 cannot play a mixed-like strategy in equilibrium because the are no points with positive mass in the distribution of types a_1.

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group 1, the earliest time a positive amount of capital from investors in group 2 leaves the country falls in the interval $(t - \nu, t + \nu)$. Let

$$d(t) = \lim_{\nu \to 0} \frac{d(t, \nu)}{2\nu}$$

be the probability density of investors in group 2's starting to pull out exactly at t, conditional on group 1 not having pulled out before.[51] Let

$$T = \left\{ t : a^1(t) \neq \emptyset \text{ or } d(t) > 0 \right\}$$

and

$$t_m = -\frac{a_2 - a_m}{\mu}.$$

Proposition 9 *In equilibrium, $\exists t_0^1 \in \left(-\frac{2(a_2 - a_m)}{\mu}, t_m \right)$ such that $a^1(t)$ is a continuous strictly-decreasing function of t and $d(t) > 0$ for $t \in (t_0^1, t_m)$, $a^1(t_m) = a_m$, $a^1(t_0^1) = a_2$, $\int_{t_0^1}^{t_m} d(t)\, dt = 1$, and $A_i(t) = 0$ for $t < t_0^1$.*

Proof: It is not necessary to present it because it is very similar to the proof of proposition 7.

Proposition 10 *When a_2 is common knowledge, $a_1 \in [a_m, a_2]$, and time starts at $t <$ $-\frac{2(a_2 - a_m)}{\mu}$, the game has a unique equilibrium in which all investors in each group share the same strategies. The equilibrium is characterized by a function $a^1(t)$, which denotes the type of investors in group 1 that would take their capital out at time t, and $d(t)$, which denotes the probability density of investors in group 2's pulling out. The function $a^1(t)$ is continuous, strictly-decreasing, differentiable, and is the unique solution to differential equation*

$$r = \frac{g(a^1(t))}{G(a^1(t))}(-\dot{a}^1(t)) \left(\frac{a^1(t) + a_2 - f(t)}{a_2} \right) \left(a^1(t) + a_2 - f(t) - e_0 \right) \qquad (1.11)$$

that satisfies the boundary condition

---

[51] If $\lim_{\nu \to 0} d(t, \nu) > 0$, I can define $d(t)$ like a distribution with positive mass at t, i.e. a "delta function." But it is not necessary to worry much about this because in equilibrium, as will be shown below, the limit always exists.

$$a^1(t_m) = a_m. \tag{1.12}$$

The function $d(t)$ is given by

$$d(t) = \frac{d}{dt} \left(\frac{e^{\int_{t_1}^{t} h(\tau)d\tau}}{e^{\int_{t_1}^{t_m} h(\tau)d\tau}} \right)$$

where $h(t)$ is the hazard rate of investor 2's pulling out, which satisfies

$$r = h(t) \left(\frac{a^1(t) + a_2 - f(t)}{a^1(t)} \right) \left(a^1(t) + a_2 - f(t) - e_0 \right). \tag{1.13}$$

Note: The function $a^1(t)$ is only defined for $t \in [t_1, t_m]$, where t_1 satisfies $a^1(t_1) = a_M$.

Proof: It is not necessary to present it because it is very similar to the proof of proposition 8. The only difference is in step (ii) of the proof. In this case, it is not necessary that investors in group 2 move simultaneously if there is a positive response time. However, only the equilibrium in which they move simultaneously survives in the limit as the response time goes to zero (TA1). Also, note that although in the proofs I used $d(t)$, $h(t)$ is a more useful characterization of the equilibrium. $\square$

Now consider a case when

$$f(t_1) < 2a_2 - e_0.$$

In this case there are multiple equilibria; however, one of them strongly *dominates* the others. Let

$$\underline{a}(t; a_2) \equiv \max\{f(t) - a_2 + e_0, a_m\} \tag{1.14}$$

be the lowest a_1 such that $E_s(t_1) \leq 1$ (or a_m if no such a_1 exists). Also let

$$\bar{a}(t; a_2) \equiv \min\{a_2, a^1(t; a_2)\}.$$

Proposition 11 *When a_2 is common knowledge, $a_1 \in [a_m, a_2]$, and time starts at $t_1 > -\frac{2(a_2 - a_m)}{\mu}$, the game has multiple equilibria. The equilibria are characterized by $a^* \in$*

$[\underline{a}(t_1; a_2), \bar{a}(t_1; a_2)]$. *Investors in group 2 try to take their capital out immediately. Investors in group 1 do the same if $a_1 \in (a^*, a_2]$. If $a_1 \in (a^*, a_2]$, reserves are exhausted and the peg is abandoned immediately. Otherwise, investors in group 2 learn that $a_1 \leq a^*$ and bring their capital back. After that point the game follows the unique equilibrium described in proposition 10. Namely, there is a period in which no attack can occur, which lasts until time $t_0^1(a^*)$ such that $a_1(t_0^1(a^*); a_2) = a^*$. After $t_0^1(a^*)$ the learning process starts, following $a^1(t; a_2)$ and $h(t, a_2)$.*

Proof: In the proposed equilibria no investor has an incentive to deviate. First, at the beginning of the game investors in group 2 have an incentive to leave because there is a positive probability that group 1's type is such that a crisis immediately follows. In addition, an investor in group 1 also has an incentive to leave immediately if $a_1 > a^*$ because he knows that all other investors will leave and, as a result, he would suffer devaluation losses if he stayed. After that point, the proposed strategies constitute a unique equilibrium as proved in proposition 10. That no other equilibria exist follows from the fact that, if $a_1 < f(t_1) - a_2 + e_0$, there would be a *revaluation* if the peg were abandoned immediately and, as a result, investors in group 1 would not leave. $\square$

Out of the continuum of possible equilibria, the one that corresponds to $a^* = \underline{a}(t_1; a_2)$ *dominates* the others. For example consider an equilibrium corresponding to $a^* > \underline{a}(t_1; a_2)$. Imagine, though, that an investor in group 1 thinks there is an arbitrarily small probability $\epsilon > 0$ that the equilibrium is actually the one corresponding to $a^{*'} \in [\underline{a}(t_1; a_2), a^*)$. Then if that investor had a type $a_1 \in [a^{*'}, a^*)$, he would think there is a *positive* probability ϵ that the devaluation takes place immediately. As a result, he would have an incentive to deviate and leave for a brief moment, to return only after observing that, in fact, the other investors in group 1 did not leave. The equilibrium corresponding to a^* should then not be expected to be played. Note that the equilibrium corresponding to a^* is dominated not only by the one corresponding to $\underline{a}(t_1; a_2)$, but also by all intermediate equilibria. In addition, investors would deviate even if they assign an arbitrarily small probability of deviation by other investors. The equilibrium corresponding to $a^* = \underline{a}(t_1; a_2)$ then strongly dominates all others.[52]

---

[52] This is an extreme form of *risk dominance*. See Harsanyi and Selten (1988) for an introduction to the concept of risk dominance.

I can now give a full description of the equilibrium of the game when both types are private information.

Proposition 12 *When both a_1 and a_2 are private information, $a_1, a_2 \in [a_m, a_M]$, and time starts at $\underline{t} < -2\frac{(a_M - a_m)}{\mu}$, the game has a unique and symmetric equilibrium, with a multi-stage structure. In the first stage, investors stay in the country until time t_1 such that $\max\{a_1, a_2\} = a(t_1)$, where $a(t)$ is determined by equations 1.9 and 1.10. Without loss of generality, I assume $a_2 > a_1$. At time t_1, investors in group 2 leave. If $a_1 > \underline{a}(t_1; a_2)$, where $\underline{a}(t_1; a_2)$ is defined in equation 1.14, investors in group 1 also leave, reserves are exhausted and the peg is abandoned. Otherwise, investors in group 2 return and the second stage begins. Investors stay in the country until investors in group 1 pull out when $a_1 = a^1(t)$, where $a^1(t)$ is determined by equations 1.11 and 1.12, or until investors in group 2 pull out, which occurs with hazard rate $h(t)$, where $h(t)$ is determined by equation 1.13. If the "attack" is initiated by investors in group 1, investors in group 2 follow, reserves are exhausted, and the peg is abandoned. If it is initiated by investors in group 2 and $a_1 > \underline{a}(t; a_2)$ investors in group 1 follow, reserves are exhausted, and the peg is abandoned. Otherwise, investors in group 2 return and stage 3 begins. The game then continues with all other stages being identical to stage 2.*

1.7.2   Government's Problem with Commitment

In order to solve the problem, I find the first order condition with respect to changes in r at a particular point in time, taking into account the fact that t_0 needs to change accordingly in order for the boundary conditions to be satisfied. For any functional F, let

$$\frac{\partial F[\{r(s)\}]}{\partial r(v)} = \lim_{\epsilon \to 0} \frac{1}{\epsilon} \left. \frac{dF[\{\bar{r}(s; v, r, \epsilon)\}]}{dr} \right|_{r=r(v)}$$

where

$$\bar{r}(s; v, r, \epsilon) = \begin{cases} 0 & \text{for } s < t0(v, r, \epsilon) \\ r(t_0) & \text{for } s \in [t0(v, r, \epsilon), t_0) \\ r(s) & \text{for } s \in [t_0, v - \frac{\epsilon}{2}) \\ r & \text{for } s \in [v - \frac{\epsilon}{2}, v + \frac{\epsilon}{2}] \\ r(s) & \text{for } s \in (v + \frac{\epsilon}{2}, 0] \end{cases}$$

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and $t0(v, r, \epsilon)$ is such that the boundary conditions are satisfied. This definition is just a way of formalizing the simple intuition that I look at the effect of changes in the interest rate at times close to v, tracking their effect on t_0.

I start by determining how changes in $r(v)$ affect $a(\tau)$. It can be shown that

$$\frac{\partial a(\tau)}{\partial r(v)} = -\frac{\partial \dot{a}(v)}{\partial r(v)}\phi(\tau, v)$$

where

$$\phi(\tau, v) = \begin{cases} e^{-\int_\tau^v \frac{\partial \dot{a}(l)}{\partial a(l)}dl} & \text{for } \tau < v \\ \frac{1}{2} & \text{for } \tau = v \\ 0 & \text{for } \tau > v \end{cases}$$

Then, I can obtain the effect of changes in $r(v)$ on t_0:[53,54]

$$\frac{\partial t_0}{\partial r(v)} = \frac{k(v, a(v))}{k(t_0, a(t_0))}\frac{\phi(t_0, v)}{r(t_0)}$$

The effect of $r(v)$ on $L[t, \{r(s)\}]$ is calculated by taking into account the direct effects on $c(r(v))$ and the indirect effects through the path $\{a(\tau)\}_{\tau=t}^{\tau=v}$. It is given by

$$
\begin{aligned}
e^{-\rho t}&\frac{\partial L[t, \{r(s)\}]}{\partial r(v)} = \\
&-\frac{k(v, a(v))}{k(t_0, a(t_0))}\frac{\phi(t_0, v)}{r(t_0)}e^{-\rho t_0}\left[c(r(t_0)) + 2g(a(t_0))D(t_0, a(t_0))r(t_0)k(t_0, a(t_0))\right] + \\
&e^{-\rho v}\left[G(a(v))^2 c'(r(v)) + 2g(a(v))G(a(v))D(v, a(v))k(v, a(v))\right] + \\
&\int_{t_0}^v \left[2g(a(\tau))G(a(\tau))c(r(\tau)) + 2g(a(\tau))^2 D(\tau, a(\tau))r(\tau)k(\tau, a(\tau)) + \right. \\
&\qquad 2g'(a(\tau))G(a(\tau))D(\tau, a(\tau))r(\tau)k(\tau, a(\tau)) + \\
&\qquad 2g(a(\tau))G(a(\tau))D(\tau, a(\tau))r(\tau)k_a(\tau, a(\tau)) + \\
&\qquad \left. 2g(a(\tau))G(a(\tau))D_a(\tau, a(\tau))r(\tau)k(\tau, a(\tau))\right]k(v, a(v))\phi(\tau, v)e^{-\rho\tau}d\tau
\end{aligned}
$$

(1.15)

where the subscript "a" means partial derivative with respect to a.

---

[53]Note that $\frac{\partial \dot{a}(v)}{\partial r(v)} = -k(v, a(v))$.

[54]This expression is well defined only if $r(t_0) > 0$. This problem can be solved by assuming $r(t_0)$ or $r(0)$ rather than t_0 are adjusted to satisfy the boundary conditions. The solution presented here is right nonetheless.

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I then set $\frac{\partial L[t,\{r(s)\}]}{\partial r(v)} = 0$, use $\phi(\tau, v) = \frac{\phi(t_0, v)}{\phi(t_0, \tau)}$ and $\frac{d}{dv}[k(v, a(v))\phi(t_0, v)] = k_t(v, a(v))\phi(t_0, v)$, and take the derivative with respect to v. After a few cancellations and rearrangements, I obtain

$$
\begin{aligned}
\dot{r}(s) \;=\;& \frac{1}{c''(r(s))} \left\{ [\rho D(s, a(s)) - D_t(s, a(s))] \, 2 \frac{g(a(s))}{G(a(s))} k(s, a(s)) + \right. \\
& c'(r(s)) \left[\rho + r(s) 2 \frac{g(a(s))}{G(a(s))} k(s, a(s)) \right] - \\
& \left. c(r(s)) 2 \frac{g(a(s))}{G(a(s))} k(s, a(s)) + c'(r(s)) \frac{k_t(s, a(s))}{k(s, a(s))} \right\} .
\end{aligned}
$$

Finally, setting $v = t_0$ in equation 1.15 and equating to zero, I obtain[55]

$$
c(r(t_0)) = r(t_0) c'(r(t_0)).
$$

---

[55]Since $c(0) = 0$, this condition is equivalent to $r(t_0) = 0$.

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Chapter 2

Emerging Market Crises and Macroeconomic Fundamentals (1)

2.1 Introduction

Developing countries have suffered economic crises repeatedly during the 1990s. In all cases, these crises were associated with large movements in both asset prices and macroeconomic fundamentals. For example, between December 1994 and March 1995, Mexico's stock market fell 26% in peso terms, the Mexican peso depreciated by 50%, industrial production fell 12%, and peso interest rates rose to 70% in annualized terms. These patterns were repeated, to a varying extent, during the Asian crisis of 1997, the Russian crisis of 1998, and the Brazilian crisis of 1999 in a large number of emerging economies.

The suddenness and size of asset-price swings during emerging market crises have led many observers to question the importance of fundamentals during these episodes. For example, explanations based on irrationality or herding have gained popularity in the aftermath of these crises. In addition, economists have been hard-pressed to identify which fundamentals, if any, played leading roles in these emerging market crises. Against this background, this paper provides insights regarding two broad issues. First, what do these large movements in asset returns tell us about the market's assessment of fundamentals during crises? Specifically, if we assume that stocks sensitivities to innovations to macroeconomic fundamentals are stable, what are the implied fundamentals that are most consistent

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[1]This chapter is co-authored with Mark Aguiar.

with the cross-section of returns during a crisis? How much of the cross-sectional variance during crises can we "explain"? Are we able to explain during crises as much as during "normal times"? And second, can this information be used to evaluate competing theories of emerging market crises?

In response to the first question, our findings are that we can explain a considerable amount of the cross-sectional variance, and that we do similarly well during crises and during normal periods. As for the second, our results are consistent with a focus on credit-channel effects in modeling emerging market crises.

In answering these questions, we must deal with the reality that emerging market crises are short-lived episodes. This, together with the likely occurrence of structural breaks in the behavior of macroeconomic variables during such episodes, implies that time-series procedures that use only aggregate variables have limited power. Previous work has addressed this problem by pooling a cross-section of countries. However, while such studies provide valuable information regarding the general characteristics of crises in emerging markets, they are constrained by the fact that crises might have different characteristics in different countries and at different times.

Our approach is complementary to these previous studies: we use the information provided by the cross-sectional behavior of equity prices within a given country. This is motivated by the observation that the cross-sectional variance of asset price movements is large during crises. As an illustration, figure 2-1 plots the cross-sectional variance of monthly returns for 23 industry-based portfolios of Mexican stocks. As evident from the graph, the cross-sectional variance increases during periods of crisis (e.g. the Peso devaluation of December 1994 and Russia's devaluation of August 1998).

An immediate question prompted by figure 2-1 is whether fundamentals can explain the increase in the cross-sectional variance during the crises. We pursue this question using a two-stage procedure. First, we measure the sensitivity of industry returns to macroeconomic variables using a standard multi-factor model. Given the important structural reforms taking place in the developing world, long and stable time-series for macroeconomic fundamentals and stock data are not available for the countries under study. As a result, we estimate the sensitivities using U.S. data, under the assumption that industries in different
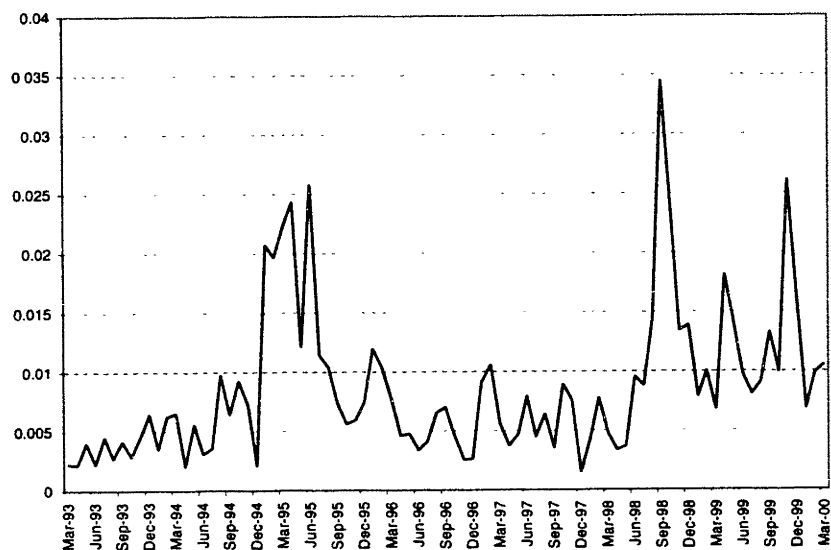
Figure 2-1: Cross-sectional variance of returns in Mexico.

countries have similar factor sensitivities.[2,3] This provides us with a collection of "factor loadings" or "betas" that describe how each industry responds to macroeconomic innovations. Second, we run cross-sectional regressions of returns during crises on the betas. That is, we ask whether we can explain the cross-section of returns based on the cross-section of covariances with fundamentals. We find that our cross-sectional regressions explain a similar percentage of the cross-sectional variance (as measured by R^2) during crises relative to tranquil periods. In this sense, stocks seem to respond to fundamentals similarly during crises and during normal times.

Our approach provides a methodology for evaluating "effective" macroeconomic magnitudes during crises. It is difficult to properly assess the impact of abnormal fundamentals observed during crisis periods. For example, consider the behavior of interest rates during a balance of payments crisis. The standard interest rate defense of a currency usually entails a dramatic rise in borrowing costs to deter currency speculation. Even after a devaluation, interest rates are often high to reduce excessive depreciation and inflationary pass-through (Goldfajn and Gupta, 1998; Borensztein and De Gregorio, 1999). These phenomena can be seen in the case of Mexico in 1995. Figure 2-2 shows the annualized nominal peso interest

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[2]This assumption is analogous to the one used by Rajan and Zingales (1998) in their study of financial development and growth.

[3]In a previous draft we estimated the sensitivities using data from the countries under study. The results, which we present in the appendix, are not very different from those using U.S. betas. We chose not to emphasize them because they are not very robust, and because the betas were estimated very imprecisely.

rate offered on 28-day government bonds, and an associated measure of the real interest rate constructed by subtracting ex post inflation. Since the ex ante real interest rate depends on expectations of future inflation, it is difficult to measure real interest rates during crises.[4] In addition, it is difficult to evaluate the effect of a one or two month spike in interest rates when the typical pattern exhibits considerable persistence. A small rate increase in tranquil periods may have a substantial impact if it is expected to last for a long time, while a sharp jump in rates expected to last only a month or two may not impact a firm with long-term obligations or considerable cash on hand. Our cross-sectional regressions provide a measure of the effective fundamentals during crisis periods, by estimating the macroeconomic innovations that best explain the observed cross-sectional behavior of returns. Since we use sensitivities of U.S. stocks, these effective fundamentals are the macroeconomic fundamentals that would generate a similar cross-sectional pattern of returns in the U.S.
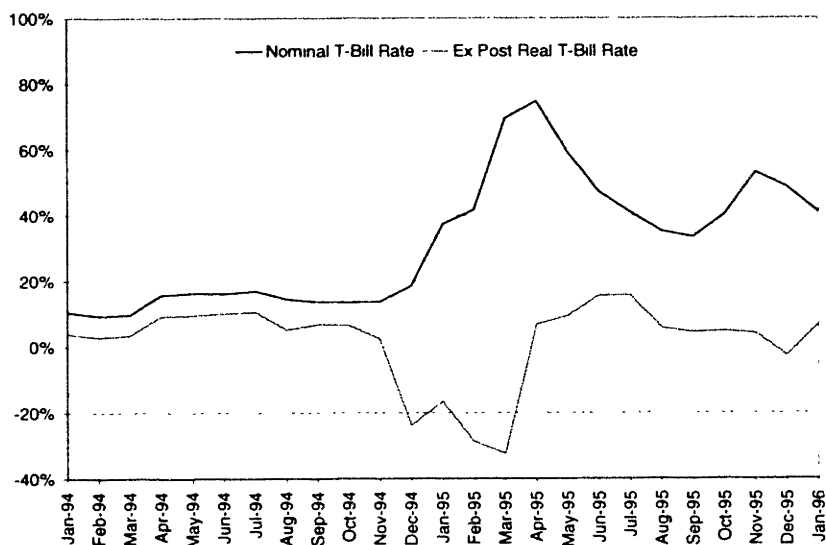
Figure 2-2: Mexican T-Bill Rate.

Finally, the procedure presented in this chapter provides a means for evaluating which macroeconomic factors play significant roles during crises, which can help in distinguishing between different types of theories of emerging market crises.[5]

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[4]The ex post real interest rate most likely overestimates inflationary expectations. For example, in January 1995, the private Banco Nacional de Mexico (BANAMEX) forecasted annualized inflation of around 31% for the first quarter following the peso's devaluation, compared with an ex-post annualized value of 72%.

[5]The economics profession has responded to the crises of the 1990s with considerable progress on theoretical models. These explanations have built up from the classic BOP crisis models of Krugman (1979) and Obstfeld (1994). For example, Chang and Velasco (1998) introduces an open-economy bank run model

Our results suggest credit market conditions played an important role during the Mexican crisis, both in Mexico and in Argentina, and during the Asian crisis in Mexico. In particular, the cross-sectional behavior of stock returns during the crises is consistent with a large and significant positive innovation to interest rates. In addition, during the Asian crisis and at the end of 1998. the cross-sectional behavior of stock returns in Argentina was consistent with recessionary expectations, which suggests that investors expected an adjustment to the negative terms-of-trade shock through a contraction in aggregate demand. Finally, neither macroeconomic factor seems to have played any role during the Russian crisis, suggesting a widespread (and indiscriminate) sell-off of Mexican and Argentine assets.

The chapter is organized as follows. Section 2.2 outlines the theoretical framework for relating stock returns to macroeconomic fundamentals; section 2.3 describes the empirical methodology; section 2.4 contains the empirical results; and section 2.5 concludes.

2.2 Theoretical Motivation

This section provides the theoretical foundation for the empirical results presented later in the chapter. It is divided in three subsections. In the first, we derive a multi-factor model of asset returns that emphasizes the effect of macroeconomic fundamentals and corresponding risk premia on asset returns. In the second, we use the model to show how innovations to macroeconomic fundamentals and risk premia during crises can be understood in terms of innovations to effective fundamentals. In the third. we show that different theories of crises imply a different cross-sectional behavior of asset returns, enabling us to test empirically the relative importance of these theories.

2.2.1 A Multi-Factor Model of Asset Returns

Our model begins with Campbell and Shiller's (1988) decomposition of returns. Define the one-period log return on a stock as

$$Z_t = \log(P_{t+1} + D_{t+1}) - \log(P_t).$$

---

based on Diamond and Dybvig (1983); Caballero and Krishnamurthy (1998) argue that the inability to fully collateralize wealth can generate fire sales of emerging market assets; and Krugman (1999) notes that the need to balance the current account during a BOP crisis requires a drop in aggregate demand. which will feed back into asset prices.

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A Taylor expansion yields

$$Z_t \approx k + \rho p_{t+1} + (1 - \rho)d_{t+1} - p_t, \tag{2.1}$$

where lower-case letters represent logs, and ρ and k are constants. By imposing the terminal condition that $\lim_{i \to \infty} E_t \rho^i p_{t+1} = 0$, Campbell and Shiller solve the difference equation 2.1 to yield an expression for the price of a stock as the discounted sum of dividends and future required returns:

$$p_t = \frac{k}{1 - \rho} + (1 - \rho)E_t \sum_{s=0}^{\infty} \rho^s d_{t+1+s} - E_t \sum_{s=0}^{\infty} \rho^s Z_{t+1+s}.$$

Following Campbell (1991), we can use this expression to write the realized return as a sum of the expected return and innovations to dividends and future expected returns:

$$Z_{t+1} = E_t Z_{t+1} + (E_{t+1} - E_t)\sum_{s=0}^{\infty} \rho^s \Delta d_{t+1+s} - (E_{t+1} - E_t)\sum_{s=1}^{\infty} \rho^s Z_{t+1+s}, \tag{2.2}$$

where Δd_{t+1} is the dividend growth rate between period t and $t + 1$ and $(E_{t+1} - E_t)x$ represents revision in the expectation of x due to information gained between periods t and $t + 1$. In this framework, an unexpected shock to returns is attributed to some combination of revisions to expected dividend growth and changes in future expected returns.

Expression 2.2 is an approximation of an identity, not a particular model of returns. Our first restrictive assumption is to assume that the revision to expected future dividend growth for a given stock is a linear function of macroeconomic and idiosyncratic innovations realized at time t. This enables us to express equation 2.2 as a linear combination of innovations to macroeconomic variables and an idiosyncratic residual. In particular, for stock j at time $t + 1$:

$$(E_{t+1} - E_t)\sum_{s=0}^{\infty} \rho^s \Delta d_{j,t+1+s} = \beta_{j,1} F_{1,t+1} + \cdots + \beta_{j,k} F_{K,t+1} + \varepsilon_{j,t+1}, \tag{2.3}$$

where $F_{k,t+1} : k = 1, \ldots, K$, represent innovations to macroeconomic variables and $\varepsilon_{j,t+1}$ represents shocks to the idiosyncratic component of dividends. The important assumption behind equation 2.3 is the existence of a stable, linear relationship between current macroeconomic fundamentals and future dividend growth.

Further, assume that expected returns (i.e. the risk premia) are constant during tranquil

periods. As a result, $(E_{t+1} - E_t) \sum_{s=1}^{\infty} \rho^s Z_{j,t+1+s} = 0$, and

$$E_t Z_{j,t+1} = \beta_{j,0} \text{ for } t \text{ outside crisis.}$$

We can therefore represent returns on stock j at time t as a linear function of innovations to macroeconomic variables plus an idiosyncratic noise term:

$$Z_{j,t} = \beta_{j,0} + \sum_{k=1}^{K} \beta_{j,k} F_{k,t} + \varepsilon_{j,t}. \tag{2.4}$$

Equation 2.4 is a multi-factor model of asset returns. Although many asset pricing theories impose restrictions on this expression we do not impose any in our empirical implementation; our main interest is in using asset prices as a source of information about the economy rather than testing a specific model of asset pricing. For example, the Arbitrage Pricing Theory (APT) implies that

$$\beta_{j,0} = \lambda_0 + \sum_{k=1}^{K} \beta_{j,k} \lambda_k, \tag{2.5}$$

where λ_k are the risk premia associated with factor F_k and λ_0 is the return on the "zero-beta" portfolio.[6] Although we do not test that the APT holds, we will point out how the results can be interpreted through the APT.

2.2.2 Effective Fundamentals

Directly measuring macroeconomic fundamentals during crises and analyzing them as if they occurred during tranquil periods provides an incomplete, and possibly misleading, description of the economic consequences of crisis fundamentals. In particular, it is likely that the stochastic properties of these variables and their associated risk premia change during crises.[7] The methodology we propose allows us to estimate effective innovations to

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[6]The Capital Asset Pricing Model (CAPM) implies that the risk premium on stock j is proportional to the risk premium on the market portfolio. That is,

$$\beta_{j,0} = \beta_{j,M} \lambda_M,$$

where λ_M is the expected excess return on the market and $\beta_{j,M}$ is the regression coefficient obtained by regressing stock j's return on the market. The Arbitrage Pricing Theory (APT) generalizes this expression by including risk premia for other factors.

[7]For example, the T-Bill interest rate on Mexican government bonds approached 80% in annualized terms during the Tequila crisis of 1995. However, no one expected such interest rates to persist and presumably the high nominal rates reflected concerns about inflation following the abandonment of the currency peg.

fundamentals by studying the cross-sectional behavior of stocks rather than fundamentals themselves. What we call effective innovations to fundamentals incorporate innovations to both expected future dividends and risk-premia. The values of macroeconomic fundamentals that capture the change in expected dividend growth will be referred to as "present value" fundamentals to distinguish them from those that also reflect the changes in risk premia. The following example illustrates this point.

Suppose that at time T an unexpected crisis of length τ starts. The response of asset prices reflects the innovations to present-value fundamentals as well as expected future returns. Denoting present-value fundamentals as $\tilde{F}_{k,T}$, the change in expected dividend growth is given by

$$(E_T - E_{T-1}) \sum_{s=0}^{\infty} \rho^s \Delta d_{j,T+s} = \sum_k \beta_{j,k} \tilde{F}_{k,T} + u_{j,T}.$$

Assuming that risk premia are constant during the crisis and that they revert to their pre-crisis levels once the crisis is over, the change in expected future returns is given by

$$
\begin{aligned}
(E_T - E_{T-1}) \sum_{s=1}^{\infty} \rho^s Z_{j,T+s} &= \sum_{s=1}^{\tau} \rho^s \Delta\beta_{j,0} \\
&= \frac{\rho - \rho^{\tau+1}}{1 - \rho} \Delta\beta_{j,0},
\end{aligned}
$$

where $\Delta\beta_{j,0}$ is the increase in asset j's risk premium during the crisis. Under APT, we can decompose the change in expected returns into changes to factor risk premia during the crisis:

$$\Delta\beta_{j,0} = \Delta\lambda_0 + \sum_k \beta_{j,k} \Delta\lambda_k \tag{2.6}$$

Defining the present value innovation to risk-premia as $\Delta\tilde{\lambda} \equiv \frac{\rho - \rho^{\tau+1}}{1-\rho} \Delta\lambda$, we obtain

$$(E_T - E_{T-1}) \sum_{s=1}^{\infty} \rho^s Z_{j,T+s} = \Delta\tilde{\lambda}_0 + \sum_k \beta_{j,k} \Delta\tilde{\lambda}_k. \tag{2.7}$$

The return at time T is then given by

66

$$
\begin{aligned}
Z_{j,T} &= E_{T-1}Z_{j,T} + (E_T - E_{T-1})\sum_{s=0}^{\infty}\rho^s \Delta d_{j,T+s} - (E_T - E_{T-1})\sum_{s=1}^{\infty}\rho^s Z_{j,T+s} \\
&= \left(\lambda_0 + \sum_k \beta_{j,k}\lambda_k\right) + \left(\sum_k \beta_{j,k}\tilde{F}_{k,T} + u_{j,T}\right) - \\
&\quad \left(\Delta\tilde{\lambda}_0 + \sum_k \beta_{j,k}\Delta\tilde{\lambda}_k\right) \\
&= \lambda_0 - \Delta\tilde{\lambda}_0 + \sum_k \beta_{j,k}\left(\tilde{F}_{k,T} + \lambda_k - \Delta\tilde{\lambda}_k\right) + u_{j,T} \\
&= \lambda_0' + \sum_k \beta_{j,k}\left(\tilde{F}_{k,T} + \lambda_k'\right) + u_{j,T},
\end{aligned}
\tag{2.8}
$$

where $\lambda_k' \equiv \lambda_k - \Delta\tilde{\lambda}_k$ incorporates both pre-crisis risk premia and present-value innovations to risk-premia.

Finally, we define the effective innovation to fundamental k as

$$
\hat{F}_{k,T} \equiv \tilde{F}_{k,T} + \lambda_k',
\tag{2.9}
$$

where $\tilde{F}_{k,T}$ is the present-value innovation to fundamental k and λ_k' incorporates the pre-crisis factor risk premium and changes in this premium during the crisis.

2.2.3 Alternative Crisis Scenarios

Given that one of the central objectives of the chapter is to assess the importance of different theories of crises, it is crucial to determine what implications these theories have for asset returns during crises. Perhaps the simplest explanation for an emerging market collapse is an expected devaluation of the currency. In particular, suppose that at time T investors suddenly anticipate a devaluation of Δe percent in the next period, but that the returns in local currency are not affected by the devaluation.[8] A given dividend stream in local currency is now discounted when converted to dollars. That is, d_T is evaluated at the current exchange rate, but from $T + 1$ on, all dividends are reduced in dollar terms. Thus, $(E_T - E_{T-1})\sum_{s=0}^{\infty}\rho^s \Delta d_{T+s} = -\rho\Delta d_{T+1}$. Given a constant required return in dollars, we have

---

[8]This is just an illustrative example. We ignore the differential effects that devaluations may have on different sectors of the economy such as the distinction between tradable and non-tradable sectors.

$$Z_{j,T} = E_{T-1}Z_{j,T} + (E_T - E_{T-1})\sum_{s=0}^{\infty}\rho^s\Delta d_{j,T+s} - (E_T - E_{T-1})\sum_{s=1}^{\infty}\rho^s Z_{j,T+s}$$
$$= E_{T-1}Z_{j,T} - \rho\Delta e$$
$$= \beta_{j,0} - \rho\Delta e.$$

which implies a generalized drop in asset prices: the return on every stock equals $-\rho\Delta e$ (plus the (likely different) risk-premia $\beta_{j,0}$).

A similar phenomenon would be observed if a crisis is driven by a broad change in investor sentiment. For example, suppose that a crisis in Russia generates an increase of size δ in the risk premia charged on all emerging market assets. A similar exercise implies that

$$Z_{j,t+1} = E_t Z_{j,t+1} - (E_{t+1} - E_t)\sum_{s=1}^{\infty}\rho^s Z_{j,t+1+s}$$
$$Z_{j,t+1} = \beta_{j,0} - \frac{\rho}{1-\rho}\delta.$$

Other theories predict that assets would fall according to their sensitivity to different macroeconomic factors. For example, suppose that a balance of payments crisis generates a recession to lower aggregate demand and balance the current account (Krugman, 1999). The we should expect the market's assessment of the likelihood of a BOP crisis to be reflected in stock returns. In particular, the price of stocks that are more sensitive to output should fall more than those that are less sensitive. Namely, those stocks with a high β on aggregate output will fall more than the market average.

Similarly, when credit market conditions deteriorate (or are expected to deteriorate) we should expect the stock of firms that are more sensitive to interest rates to fall disproportionately. As a result, the cross-sectional behavior of stock returns during BOP crises can provide information as to the relevance of credit-channel stories (e.g. Caballero and Krishnamurthy, 1998).

2.3 Empirical Methodology

The empirical procedure we propose consists of two stages. In the first stage we estimate the factor sensitivities for each industry. Since there are no long and stable time-series data for fundamentals and stock market returns for the countries under study, we proxy the industry sensitivities by using the corresponding U.S. betas. The betas are estimated by regressing returns on innovations to macroeconomic fundamentals for each industry, according to equation 2.4:

$$Z_{j,t} = \hat{\beta}_{j,0} + \sum_{k=1}^{K} \hat{\beta}_{j,k} F_{k,t} + \hat{\varepsilon}_{j,t}. \tag{2.10}$$

This yields, for each fundamental k, a cross-section of factor sensitivities for each industry j. We thus obtain $J \times K$ betas $\hat{\beta}_{j,k}$ representing how innovations to the K macroeconomic factors affect the returns of the J assets in our sample.

In the second stage, these sensitivities are used to estimate the effective innovations to fundamentals. In particular, we can obtain estimates of innovations to macroeconomic factors that best explain the cross-section of returns by regressing returns during period T on factor sensitivities. In other words, in the second stage we take the betas estimated in the first regression $\hat{\beta}_{j,k}$ as our independent variables and perform the cross-sectional regression[9]

$$Z_{j,T} = \gamma_0 + \sum_{k=1}^{K} \hat{\beta}_{j,k} \hat{F}_{k,T} + u_{j,T}. \tag{2.11}$$

where $\hat{F}_{k,T}$ is the implied innovation to factor k (or effective factor k) during period T. In a sense, this reverses the logic applied in the first stage: we take stock returns as a source of information on the market's assessment about the innovation to future dividends and risk premia. It is important to note that this gives us estimates of macroeconomic fundamentals "as if" the fundamentals were realized in the U.S.[10]

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[9] A similar two-step procedure has been used extensively to test models of pricing risk. Our approach is most similar to Chen, Roll and Ross (1986). These papers focused on estimating risk premia (λ_k) subtracting out observed fundamentals.

[10] If we estimate the betas using data from the countries under study during non-crisis times (as done in the appendix), the effective fundamentals can be interpreted as if the fundamentals were realized in normal times in the same country. Since fundamentals are more stable in the U.S. than in the countries under study, the innovations as if in the U.S. are probably smaller than those as if in the affected countries. For example, if the cross-sectional behavior of stocks is consistent with a certain increase in interest rates in the U.S. it is probably consistent with a larger increase in interest rates in Argentina, as innovations to interest rates in Argentina are more transitory.

In interpreting our second-stage coefficients, we make use of equation 2.8. Recalling the definition of effective innovation in equation 2.9, we observe that these coefficients incorporate both $\bar{F}_{k,T}$, the present-value innovation to the fundamental, and λ'_k, the present-value innovation to the factor risk-premium and the risk-premium in the previous period.

The results of the second-stage regression provide insights regarding two issues. First, can we ascribe the cross-sectional behavior of stock prices during crises to innovations to macroeconomic fundamentals? In particular, can we find effective fundamentals that, when combined with the sensitivities estimated in the first stage, explain the observed cross-section of returns during crises?

Second, can we use the estimated values for the effective fundamentals to distinguish between alternative crisis scenarios? As long as competing theories have different implications regarding the behavior of fundamentals, we can use our second-stage regressions to assess the relevance of different theories. For example, as described in the previous section, if the drop in prices is due to an increase in the probability of future devaluation or in the country risk premium, we would not expect a major cross-sectional variation in asset returns. As a result, our second-stage regression of $Z_{j,T}$ on $\hat{\beta}_{j,k}$ would produce a large and negative constant term, but no other large coefficients. In contrast, if the crisis gives rise to a recession a large and negative coefficient in output variables would be expected, while credit-channel stories would predict large and positive coefficients on interest rate and other credit variables.

It is important to highlight at this point that we cannot distinguish how much of the effective fundamental we estimate is due to revisions to present-value fundamentals and how much is due to changes in risk premia. In a sense, we estimate a "line" in the space of innovations to fundamentals and risk premia. However, we do not see this as an important problem. First, the distinction between factor innovations and risk-premium innovations is not crucial to interpret the results. For example, if the returns on industries that are very sensitive to credit market conditions are much lower than those on other industries during a particular month, we would conclude that credit market conditions worsened during that month (or investors learned that they are going to worsen in the future). This could be due, among others, to an increase in interest rates, or to an increase in the volatility of interest rates and a consequent increase in the risk premium. In either case, it would still be true that credit market conditions deteriorated. In addition, innovations to fundamentals and

risk-premia affect effective fundamentals with the *same* sign (equation 2.9). As a result, bad news add to bad news and good news add to good news, and no identification problem arises.[11,12]

In addition, the linear approximation may sometimes break down, particularly during crises. For example, many credit channel stories involve an inequality constraint that be-comes relevant only when liquidity is scarce. If firms in the U.S. are further away from this constraint than those in Mexico or Argentina, the linear second-stage regressions may be misspecified during crisis episodes. However, we can interpret the effective fundamentals produced by our cross-sectional regressions as (imperfectly) incorporating the nonlinearities inherent to crises.[13]

2.4 Empirical Results

In this section, we apply the methodology described above to study the effects of a number of episodes on Mexico and Argentina. We focus on the Mexican, Asian, and Russian crises, and on the Brazilian devaluation.[14] To illustrate the strong impact of these episodes, table 2.1 summarizes the effects of the Mexican and Russian crises on Mexico and Argentina.

Our methodology requires long time series of industry returns and fundamentals for the U.S., and industry returns for Mexico and Argentina covering the four episodes. Monthly data on industry returns was obtained from Datastream, and on macroeconomic fundamen-tals from IMF's *International Financial Statistics.*

We construct industry excess returns by subtracting currency depreciation (against the U.S. dollar) and the U.S. T-bill rate from the monthly change in each industry's return

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[11]We can identify how far the line is from the origin, even if we cannot identify between different points on the line.

[12]We are implicitly assuming that for fundamentals on which a positive innovation is "bad news", such as interest rates, risk premia are negative. Namely, when we say that the risk premium on such variables increases, we mean that it is becoming more negative. Alternatively, we could define new fundamentals as the negative of these, which would have positive risk premia.

[13]We are also assuming that the betas are stable. This is a reasonable assumption, since the intrinsic characteristics of firms are likely to be stable, even when the economic environment (e.g. the stochastic process for fundamentals) is not. However, we need to assume that the *relative* sensitivities of industries is stable. Otherwise, we would not be able to capture the behavior of fundamentals with a single beta per fundamental per industry.

[14]The Mexican crisis is associated with the aftermath of Mexico's devaluation in December 1994. The Asian crisis refers to the turmoil in international capital markets initiated with the devaluation in a number of East Asian countries after mid-1997. The real effects of this crisis only began to be felt strongly in Latin American after the Russian crisis, when Russia defaulted on its debt in August 1998. We also look at the effect of the Brazilian devaluation in January 1999.

Table 2.1: Summary Statistics

	Mexico				Argentina			
	Market	IP growth	T-Bill	ER	Market	IP growth	Loan Rate	ER
Jan 93 - Nov 94	1.6%	0.4%	14.4%	3.2	1.3%	0.4%	8.3%	1.0
Dec 94	-9.1%	-4.2%	18.5%	5.3	-6.4%	-2.2%	9.8%	1.0
Jan 95	-15.1%	-2.1%	37.25%	5.7	-6.7%	-10.3%	11.5%	1.0
Feb 95	-24.1%	-6.5%	41.7%	5.8	-21.4%	20.0%	12.1%	1.0
Mar 95	26.7%	7.4%	69.5%	6.8	14.7%	-10.7%	23.0%	1.0
Jul 95 - Jul 98	1.7%	0.7%	27.0%	7.8	0.6%	0.7%	8.8%	1.0
Aug 98	-28.3%	-0.8%	22.6%	10.0	-24.4%	-2.4%	8.4%	1.0
Sep 98	-13.3%	2.9%	40.8%	10.1	-5.6%	-2.1%	13.2%	1.0
Oct 98	20.0%	-4.1%	34.9%	10.2	24.3%	-1.6%	12.2%	1.0

Notes: Market is the return on the domestic stock market. IP growth is industrial production growth. T-Bill is the interest rate on short-term peso bonds. Loan rate is the interest rate on dollar loans to prime firms. ER is the exchange rate (the price of a dollar in local currency). All rates are annualized.

index. There are two advantages to using industry returns rather than returns on individual stocks. First, using industry portfolios reduces the idiosyncratic disturbances in the first-stage regressions (Chen et al 1986). Second, it allows for a direct identification of similar industries in the U.S., Mexico, and Argentina. There are approximately $J = 23$ industry indices for Mexico and $J = 25$ industries for Argentina.[15]

We use two macroeconomic fundamentals to capture credit-market conditions and the level of economic activity. In particular, we calculate innovations to interest-rates (T-bill). and U.S. industrial production.[16]

In the first stage, we estimate the matrix B of factor sensitivities for U.S. industries as in equation 2.10. The sensitivities were estimated using data going as far back as possible, which is 1973 for most industries. Table 2.2 reports summary statistics for the J first-stage regressions. which include one regression for each industry for which data is available in either Mexico or Argentina.

The table shows that returns on the average industry fall by 1.5% with an innovation of +1% in interest rates, and by 3.4% with an innovation of +1% in annualized industrial production growth.[17] It also shows that the interest-rate sensitivities are estimated quite

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[15]There data on industry returns for Mexico and Argentina only starts in early 1993 for most industries. The data on most U.S. industries goes back to 1973.

[16]The innovations to the T-bill and industrial production are obtained by running a three-variable VAR including these two variables and inflation. In the appendix we describe the estimation procedure in detail.

[17]The negative industrial-production coefficient is probably due to the fact that positive innovations to industrial production are associated with future increases in interest rates. As a result, the sensitivities we estimate are not "pure", in the sense that industrial-production sensitivities partly incorporate sensitivity to future interest rates. (Something similar can probably be said of interest-rate sensitivities.) This affects the interpretation of the second stage results only in that the effective innovations we estimate incorporate

Table 2.2: First-Stage Betas

Interest rate	Mean	-1.5
innovation	S.D.	2.0
	Mean |t-stat|	2.31
Industrial production	Mean	-3.4
innovation	S.D.	6.4
	Mean |t-stat|	0.99
Mean R^2		0.03
No. of industries		40

Notes: Means and standard deviations refer
to the distribution of betas and the absolute
value of t-stats across industries. Innovations
are annualized.

precisely, although that is not the case for industrial-production sensitivities. In addition, there is a large cross-sectional variation in sensitivities, which is good news for the power of the second-stage regressions.

After obtaining the factor sensitivities for each industry, we turn to the second-stage of the empirical procedure. We regress the monthly returns observed in Mexico and Argentina on the cross-section of estimated factor loadings $\hat{\beta}_{j,k}$. This is the regression referred to in equation 2.11, which is repeated here:

$$Z_{j,T} = \gamma_0 + \sum_{k=1}^{K} \hat{\beta}_{j,k} \hat{F}_{k,T} + u_{j,T}.$$

This regression tests, for each month in the sample, the explanatory power of industry sensitivities proxied by the U.S. covariance structure. Table 2.3 summarizes the ability of our second-stage regression to explain the cross-sectional distribution of returns. As noted in the introduction, the cross-sectional variance of returns rises during crises; as a result, we split the sample in crisis and tranquil periods.[18]

Table 2.3 shows that, even though we use only two factors, factor sensitivities explain a considerable amount of the cross-sectional variance of returns (around 10%). In addition, despite the higher dispersion of returns during crises, we can explain a similar proportion of the cross-sectional variance of returns as in non-crisis periods, suggesting that the covariance

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the future effects on interest rates and industrial production. However, a slight problem arises because even if industries sensitivities to different types of shocks are similar across countries, the stochastic process of fundamentals is not. (For example, monetary policy in the U.S. is very different than that in developing countries.) In a future draft, we plan to address this problem by constructing "pure" or present-value innovations for the first stage regression, by using the estimated VAR.

[18]See tables 2.4 and 2.5 for the list of crisis months. Tranquil periods include non-crisis months from January 1993 through February 2000.

Table 2.3: Explanatory Power of Cross-Sectional Regressions

	Mexico		Argentina	
	Crisis	Tranquil	Crisis	Tranquil
Average cross-sectional variance	0.013	0.008	0.018	0.016
Average R^2 of cross-sectional regressions	0.09	0.12	0.08	0.10

Notes: Averages are across monthly cross-sectional regressions.

structure does not break down during crises. Although our methodology does not account for the constant term, it sheds light on how stocks move relative to the average; that is, if one decided to remain invested in a country, fundamentals are a good guide as to which stocks will outperform the average, even during crises.

After showing that fundamentals have similar explanatory power during crisis and non-crisis periods, we now characterize the behavior of the estimated effective fundamentals. Figure 2-3 shows histograms of the estimated interest-rate and industrial-production innovations for Mexico and Argentina, comparing crisis and tranquil periods. The black lines and grey bars show, respectively, the histograms of effective innovations during tranquil and crisis periods.[19,20] The figure highlights a number of features of innovations during crises. With respect to interest rate innovations, for both Mexico and Argentina there are a few outliers during the crisis periods, two positive innovations for Mexico and one positive and three negative for Argentina. Below we show that the negative innovations are probably due to large standard errors but the positive ones are very significant. In addition, for Argentina the crisis innovations have a larger variance than the non-crisis ones, and for both Argentina and Mexico the distribution of innovations seems non-normal during crises. A similar, although less pronounced, pattern is present in the industrial production innovations. There are two positive outliers for Mexico which we show to be significant below. The variances of the distributions are similar for crisis and non crisis periods, but the distributions seem non-normal during crisis. Figure 2-3 thus shows that crises are times in which innovations

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[19]To construct these graphs, we used innovations estimated with least absolute values (LAV) rather than least squares because the distributions of the error terms have fat tails.

[20]We excluded 1993 for the tranquil-period histograms because the estimated innovations have very large standard errors, especially for Argentina. (For example, the average standard errors of interest rate innovations for Argentina are 8.6% during 1993 and 4.4% during the rest of the periods.) Including 1993 innovations would not affect the distributions for Mexico, and would fatten the tails of the tranquil period distributions for Argentina.

to fundamentals are larger and characterized by outliers.

We now focus in more detail on the cross-sectional regressions for crisis months. Table 2.4 reports the results for Mexico and table 2.5 for Argentina. The coefficients reported refer to the $\hat{F}_k$ estimated with equation 2.11. We estimated the effective fundamentals by ordinary least squares and least absolute values. LAV estimation is our preferred specification because the data presents outliers that suggest that errors have fat tails.

Table 2.4: Second-Stage Regressions: Mexico

	OLS				Median Regression			Obs.
	Int. Rate	Indus. Prod	Constant	R^2	Int. Rate	Indus. Prod	Constant	
Dec 94	0.24	0.00	-0.37***	0.01	0.17	-0.02	-0.40***	22
	(0.84)	(0.02)	(0.03)		(0.31)	(0.02)	(0.03)	
Jan 95	0.60	0.00	-0.21***	0.02	3.03**	0.07*	-0.11**	22
	(1.05)	(0.03)	(0.04)		(1.20)	(0.04)	(0.05)	
Feb 95	1.21	-0.05*	-0.22***	0.34	1.59***	-0.01	-0.17***	22
	(0.87)	(0.02)	(0.03)		(0.47)	(0.03)	(0.04)	
Mar 95	-1.21	0.02	-0.03	0.08	-0.74	0.02	-0.05	22
	(1.50)	(0.04)	(0.05)		(1.56)	(0.05)	(0.06)	
Apr 95	-0.33	0.03	0.28***	0.08	0.19	0.04	0.27***	22
	(1.21)	(0.03)	(0.04)		(0.63)	(0.04)	(0.06)	
Sep 97	1.47	0.03	0.16***	0.13	3.15***	0.04**	0.18***	24
	(0.91)	(0.02)	(0.03)		(0.54)	(0.01)	(0.02)	
Oct 97	0.51	-0.03*	-0.14***	0.25	0.33*	-0.03**	-0.14***	24
	(0.57)	(0.01)	(0.02)		(0.19)	(0.01)	(0.02)	
Nov 97	-0.28	0.00	0.02*	0.03	-0.48	0.00	0.03*	24
	(0.38)	(0.01)	(0.01)		(0.47)	(0.01)	(0.01)	
Dec 97	0.68	0.00	0.06**	0.05	0.92	0.01	0.07**	24
	(0.70)	(0.02)	(0.02)		(0.69)	(0.02)	(0.03)	
Aug 98	0.06	0.05*	-0.27***	0.15	0.23	0.07*	-0.25***	24
	(1.16)	(0.03)	(0.04)		(1.18)	(0.03)	(0.05)	
Sep 98	0.63	0.04	0.04	0.04	-0.19	-0.03	0.02	24
	(1.54)	(0.04)	(0.05)		(0.33)	(0.02)	(0.03)	
Oct 98	-0.69	-0.02	0.03	0.04	-0.96	-0.05	0.02	24
	(0.99)	(0.03)	(0.03)		(1.57)	(0.05)	(0.06)	
Nov 98	-0.56	-0.02	-0.01	0.03	0.29	0.02	0.00	24
	(1.17)	(0.03)	(0.04)		(0.71)	(0.02)	(0.03)	
Dec 98	-0.98	0.00	0.05*	0.07	-0.23	0.01	0.05	24
	(0.88)	(0.02)	(0.03)		(1.42)	(0.03)	(0.04)	
Jan 99	0.16	-0.01	-0.07**	0.03	-0.18	-0.01	-0.07*	24
	(0.86)	(0.02)	(0.03)		(0.85)	(0.02)	(0.03)	
Feb 99	0.73	0.01	0.07**	0.03	0.34	-0.03	0.03	24
	(0.92)	(0.02)	(0.03)		(0.89)	(0.03)	(0.04)	

Notes: Cross-sectional regressions of Mexican industry excess returns on U.S. factor loadings (betas). Constants not reported. SE in parantheses. * indicates significant at 90% confidence level, ** 95%, *** 99%.

The results show some similarities and some differences between the experiences of Mexico and Argentina during the episodes considered. In the aftermath of the Mexican devaluation, especially after the near collapse in the market for Mexican short-term debt during January 1995, market participants anticipated a drastic tightening in capital markets in both countries, revealed by the fact that the stock valuation of firms in industries more
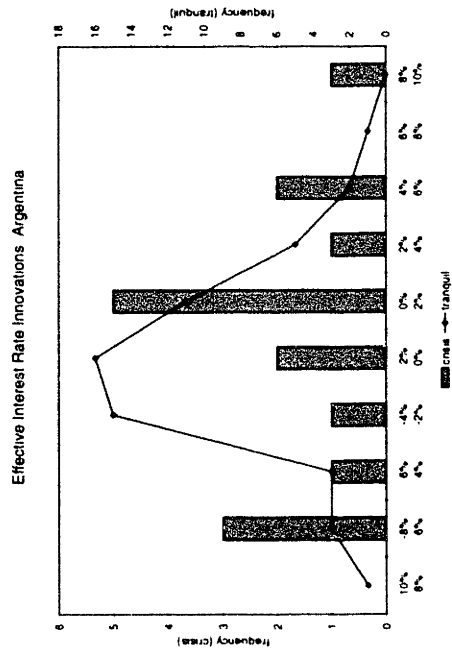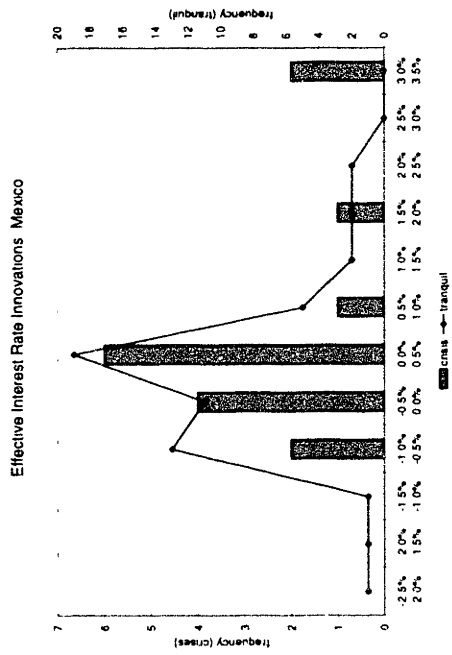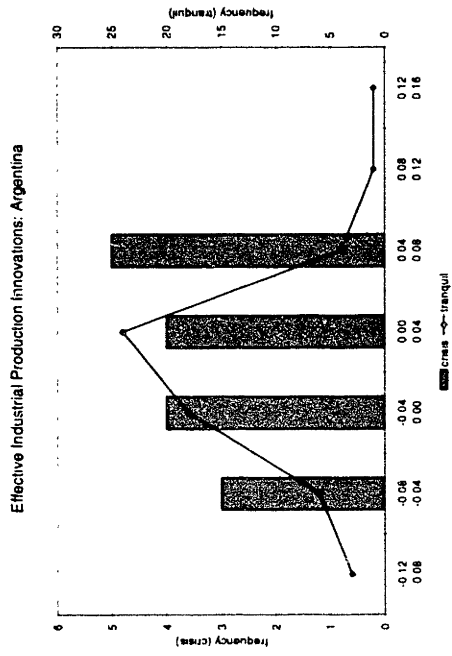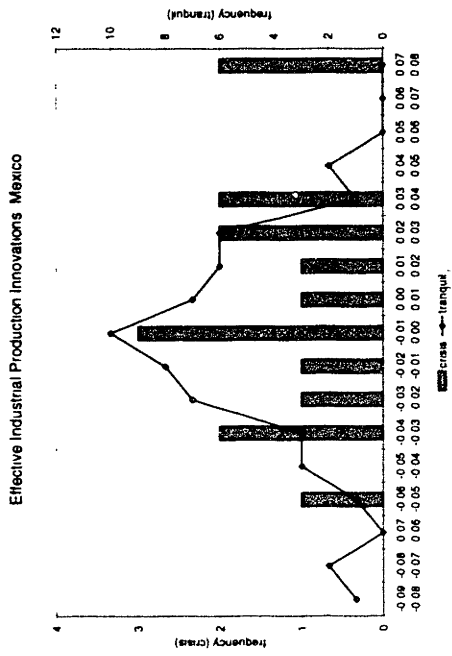
Figure 2-3: Crisis vs. tranquil period innovations.

Table 2.5: Second-Stage Regressions: Argentina

	OLS				Median Regression			Obs.
	Int. Rate	Indus. Prod	Constant	R^2	Int. Rate	Indus. Prod	Constant	
Dec 94	-1.47	-0.01	-0.10**	0.03	-0.99	0.00	-0.06	24
	(2.14)	(0.02)	(0.04)		(4.77)	(0.03)	(0.09)	
Jan 95	2.36	0.01	-0.06	0.03	9.04***	0.07**	0.07	24
	(3.05)	(0.03)	(0.05)		(2.68)	(0.03)	(0.05)	
Feb 95	4.57	-0.02	-0.13*	0.14	2.49	-0.04	-0.19	24
	(4.11)	(0.04)	(0.07)		(8.84)	(0.06)	(0.16)	
Mar 95	-5.47	-0.02	-0.02	0.03	-7.06	0.01	-0.03	24
	(7.00)	(0.06)	(0.12)		(7.06)	(0.05)	(0.13)	
Apr 95	-3.30	0.01	0.00	0.07	-5.57	0.01	-0.02	24
	(3.84)	(0.04)	(0.07)		(4.91)	(0.03)	(0.08)	
Sep 97	-0.94	0.03	0.02	0.06	-0.59	0.01	0.01	26
	(3.60)	(0.05)	(0.06)		(5.52)	(0.05)	(0.10)	
Oct 97	0.76	0.05*	-0.13***	0.17	0.07	0.05	-0.13	26
	(2.46)	(0.02)	(0.04)		(4.56)	(0.04)	(0.08)	
Nov 97	-1.24	0.01	-0.03	0.01	-2.03	0.00	-0.06	26
	(3.21)	(0.03)	(0.06)		(7.17)	(0.05)	(0.13)	
Dec 97	0.87	-0.07**	0.04	0 30	0.51	-0.08**	0.01	26
	(2.96)	(0.03)	(0.05)		(3.93)	(0.04)	(0.07)	
Aug 98	5.93	0.06*	-0.15**	0.15	4.16	0.07*	-0.18*	26
	(3.65)	(0.03)	(0.07)		(5.59)	(0.04)	(0.10)	
Sep 98	1.89	-0.06	-0.11	0.11	1.37	-0.06	-0.08	26
	(5.23)	(0.05)	(0.09)		(9.78)	(0.06)	(0.18)	
Oct 98	-3.70	0.01	0.16	0.03	-6.91	0.05	0.15	26
	(6.47)	(0.06)	(0.12)		(7.17)	(0.05)	(0.13)	
Nov 98	-4.15	-0.04	-0.02	0.09	-6.46	-0.08***	-0.09	26
	(3.55)	(0.03)	(0.06)		(4.11)	(0.03)	(0.08)	
Dec 98	0.16	-0.01	-0.08**	0.03	1.43	-0.01	-0.07	26
	(1.81)	(0.02)	(0.03)		(2.36)	(0.02)	(0.04)	
Jan 99	3.19	0.04	-0.04	0.06	4.56	0.08	0.00	26
	(3.98)	(0.04)	(0.07)		(7.11)	(0.07)	(0.13)	
Feb 99	2.07	0.02	0.01	0.04	1.09	-0.01	0.01	26
	(2.29)	(0.02)	(0.04)		(4.81)	(0.04)	(0.09)	

Notes: Cross-sectional regressions of Argentina industry excess returns on U.S. factor loadings (betas). Constants not reported. SE in parentheses. * indicates significant at 90% confidence level. ** 95%. *** 99%.

sensitive to interest rates suffered much more than firms in other sectors. In Mexico, the cross-sectional behavior of the stock market is consistent with a worsening in credit conditions during January equivalent to the effect of a 3% increase in the T-bill on U.S. firms, with a further deterioration equivalent to an increase of 1.6% during February. In Argentina, the expected deterioration in credit conditions was even worse: equivalent to a 9% increase in the T-bill. Furthermore, these "implied" fundamentals are all highly significant.[21] Even though both countries were entering very deep recessions, stocks sensitive to aggregate output did not fare significantly worse than others. These results clearly suggest that if we seek an explanation for the effects of the Mexican crisis, we should focus on credit-market

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[21]Note that when we say "equivalent to an increase of X% in the T-bill" we mean an increase of X% in the T-bill with the *same persistence* as that of the characteristic interest rate innovation during the last 30 years (i.e. large).

issues.

The Asian crisis of late 1997 had moderate effects on both Mexico and Argentina. As in the previous crisis, the Mexican stock market reacted in a manner consistent with expected deterioration in credit markets during September 1997. As the Mexican banking system had been all but wiped out after the Mexican crisis, it is likely that market participants predicted a slow down in capital inflows, and a consequent deterioration in the prospects of sectors heavily dependent on them. As during the Mexican crisis, the sectors sensitive to aggregate output did not do particularly bad. In fact, they did better than the others during September, but this was undone in the following month. At first, the cross-sectional behavior of stocks in Argentina did not display any pattern consistent with sizeable shocks to macroeconomic fundamentals. However, in December 1997 industries more sensitive to industrial production fell much more than others, suggesting that market participants anticipated a slow down in the economy.

The Russian crisis had little effect on Mexico, but marked the beginning of a recessionary period in Argentina. In this case, the culprit does not seem to have been the conditions in capital markets. The strengthening of the banking system in the aftermath of the Mexican crisis seems to have made the credit market more resilient, although one could have expected sectors dependent on foreign investment to have had a worse performance.[22] The recession is more likely to have been due to a worsening in the terms of trade and a deflationary world environment, combined with a credible fixed exchange rate and rigid labor markets. Towards the end of 1998, speculation began that Brazil would soon devalue its currency. Such a devaluation was expected to further deteriorate Argentina's international competitiveness. The Argentine recession can thus be interpreted as a "necessary" adjustment to a current account imbalance through a contraction in aggregate demand.[23] This effect can be seen in the significant negative coefficient on industrial production in Argentina as the Brazilian crisis heated up in late 1998.

Finally, the stock-market behavior in both Mexico and Argentina during the Russian crisis does not signal any cross-sectional dependence on interest rate or output sensitivities. The cross-sectional behavior of asset returns thus seems consistent with an indis-

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[22]The interest-rate coefficient in the OLS estimation of August 1998 is significant at the 89.3% confidence level. But the OLS estimation is very sensitive to outliers.

[23]Why could Argentina not simply borrow to compensate for a temporary negative income shock and avoid a recession? This probably has to do with financial market frictions.

criminate sell-off of emerging-market assets, possibly due to an increase in their associated risk-premium.

2.5 Conclusion

In this chapter we study the relationship between asset prices and macroeconomic fundamentals during emerging market crises. In particular, we study the effects of the Mexican, Asian, and Russian crises, and the Brazilian devaluation on Mexico and Argentina. First, we show that a significant part of the cross-sectional movements in stock market returns during crises can be attributed to macroeconomic factors, and that the explanatory power of macroeconomic factors during crises is similar to that during normal times. Second, we estimate which factors play leading roles during the crises, which helps us distinguishing between different possible "theories." We find that stocks that are sensitive to interest rates usually fall disproportionately during crisis, suggesting that credit market conditions are an important element in emerging market crises. This is especially true during the Mexican crisis, both in Mexico and in Argentina, and during the Asian crisis in Mexico. In other episodes, such as the effects of the Asian and Russian crises on Argentina, sensitivity to industrial production was a significant determinant of relative performance, which is consistent with stories based on adjustment to adverse external shocks through a reduction in aggregate demand.

2.6 Appendix

2.6.1 Estimation of Macroeconomic Fundamentals

This section describes the procedure used to generate the innovations used as fundamentals in the first-stage regressions. The data used consists of monthly observations on T-Bill interest rates, CPI, and Industrial Production (index) for the United States covering the period January 1966 through December 1998. All data was obtained from the *International Financial Statistics* published by the IMF. We ran the vector autoregression:

$$y_t = \Phi_0 + \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + \Phi_{12} y_{t-12} + \varepsilon_t \tag{2.12}$$

The vector $y_t = [R_t, IPG_t, \Pi_t]'$ where R represents the annualized T-Bill interest rate

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in percentage terms, IPG represents monthly industrial production growth calculated as $IPG_t = 100 \times \left(\frac{IP_t}{IP_{t-1}} - 1\right)\%$, and $\Pi_t = 100 \times \left(\frac{CPI_t}{CPI_{t-1}} - 1\right)\%$. The parameters to be estimated are the 3×1 vector of constants Φ_0 and the coefficients on the one, two, and twelve-month lagged vector of fundamentals $(\Phi_1, \Phi_2, \Phi_{12})$. The estimated parameters of the VAR are:

Table 2.6: Fundamentals VAR

	Independent Variable		
	R	IPG	Π
C	0.11	0.58***	0.06*
	(0.09)	(0.12)	(0.04)
R_{t-1}	1.20***	0.16**	0.03
	(0.05)	(0.07)	(0.02)
R_{t-2}	-0.25***	-0.22***	0.00
	(0.05)	(0.07)	(0.02)
R_{t-12}	0.02	0.01	-0.03***
	(0.02)	(0.02)	(0.01)
IPG_{t-1}	0.06*	0.24***	0.01
	(0.04)	(0.05)	(0.02)
IPG_{t-2}	0.06	0.12**	0.01
	(0.04)	(0.05)	(0.02)
IPG_{t-12}	-0.05	-0.07	0.01
	(0.04)	(0.05)	(0.01)
Π_{t-1}	0.36***	0.05	0.37***
	(0.12)	(0.16)	(0.05)
Π_{t-2}	-0.18	-0.31	0.12**
	(0.12)	(0.16)	(0.05)
Π_{t-12}	-0.02	0.11	0.24***
	(0.11)	(0.15)	(0.05)
R^2	0.96	0.22	0.51

Notes: * indicates significant at 90% confidence level, ** 95%, *** 99%.

The fundamentals or innovations used in the first-stage regressions (equation 2.10 in the text) are the residuals from this VAR, that is,

$$\text{fundamentals} \equiv \hat{\varepsilon}_t = y_t - (\hat{\Phi}_0 + \hat{\Phi}_1 y_{t-1} + \hat{\Phi}_2 y_{t-2} + \hat{\Phi}_{12} y_{t-12}).$$

2.6.2 Results Using Tranquil-Time Betas

Here we summarize the results presented in a previous draft, in which we run the first-stage regressions independently for each of the countries under study. We estimated the betas using non-crisis times, to avoid possible structural breaks during crises.

For factors, we use innovations to the interest rate, industrial production, and domestic credit growth. For Mexico, we use the 28-day (annualized) T-Bill rate offered on Peso denominated bonds (Cetes). For Argentina, we use the average 90-day (annualized) dollar

prime-lending rate. Data was obtained from the Central Banks of Argentina and Mexico as well as the IFS. Aside from the interest rate, the other fundamentals are in monthly log differences. Innovations to these macro variables are calculated using residuals of a three-variable VAR. A separate VAR is run for before and after the Tequila crisis (not including crisis months) to account for the change in regime subsequent to Mexico's abandonment of its currency peg. We also include the Market return for each country, as suggested by the CAPM. We use the IPC Index for Mexico and Datastream's total market index for Argentina.

We define the tranquil periods in two ways. First, we take the interval of January 1993 through November 1994 combined with August 1995 through July 1998 as our tranquil months. Alternatively, we restrict our normal times estimation to before the Tequila crisis to avoid including the Asian crisis (which does not dramatically affect Latin America) in our tranquil period.

Table 2.7 reports summary statistics for the J first-stage regressions. The column entitled "All" refers to the fact that the first-stage regression utilized tranquil months from before and after the Tequila crisis. The column entitled "Pre" refers to betas estimated using pre-Tequila crisis data only.

Table 2.7: First-Stage Betas

		Mexico		Argentina	
		All	Pre	All	Pre
Market	Mean	0.8517	0.8081	0.8732	0.8908
	Std. Dev	0.2243	0.3560	0.2435	0.3309
IR	Mean	-0.0028	0.0009	-0.0045	-0.0166
	Std. Dev	0.0021	0.0099	0.0099	0.0779
IP growth	Mean	0.2131	0.1769	0.0708	0.4577
	Std. Dev	0.3273	0.3716	0.2216	0.8663
DC growth	Mean	-0.0514	-0.4332	-0.0939	0.5782
	Std. Dev	0.0863	0.6021	1.0355	1.7631
R^2		0.53	0.62	0.45	0.51

Notes: All and Pre results correspond to regressions using pre-tequila and both pre and post-tequila data, respectively. IR is the interest rate variable and DC growth is domestic credit growth. We report averages across stocks of estimated coefficients and standard deviations.

Table 2.8 summarizes the ability of our second-stage regression to explain the cross-sectional distribution during normal and crisis months.[24]

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[24]For each tranquil month, the cross-sectional regression used β's estimated from other tranquil periods (i.e. if the cross-section focused on month j, the first-stage regression used months $\{t|t \neq j$ and t tranquil$\}$.

Table 2.8: Explanatory Power of Cross-Sectional Regressions

		Mexico		Argentina	
		Crisis	Tranquil	Crisis	Tranquil
Average cross-sectional variance		0.0146	0.0057	0.015	0.008
Average R^2 of cross-sectional regressions	All	0.49	0.25	0.27	0.37
	Pre	0.26	0.29	0.40	0.36

Notes: Crisis and Tranquil results correspond, respectively, to averages taken over the Tequila and Russian crises, and over the pre and post-tequila tranquil periods. All and Pre refer to whether post-tequila data was used in estimating the betas in the first stage.

We explain a larger percentage of the cross-sectional variance in the All specification and roughly the same using the Pre-Tequila betas. In Argentina, we explain less during crises with the All betas, but more using the Pre specification.[25]

For an additional comparison between crisis and tranquil periods, table 2.9 presents the average difference between observed and effective fundamentals (i.e. $\hat{F} - F$). On average, effective fundamentals differ more from the observed values during crises. For Mexico, on average the effective fundamentals during crises are less severe than the observed values: the effective interest rate rises less and output and domestic credit fall less than the observed fundamentals. Similarly for Argentina, except for the fact that effective domestic credit growth falls more than observed, which we will see reflects the Russia crisis of 1998.

Table 2.9: Second-Stage Regressions: Tranquil vs. Crisis Months

	Average $\hat{F}$-F over:		Market	IR	IP growth	DC growth
Mexico	Tranquil Months	All	-0.02	-4.35	-0.02	-0.01
	Crisis Months		0.12	13.39	0.22	0.30
	Tranquil Months	Pre	-0.02	-2.90	-0.02	-0.01
	Crisis Months		0.00	-11.94	0.11	0.11
Argentina	Tranquil Months	All	-0.01	-0.44	-0.01	-0.01
	Crisis Months		0.08	-4.67	0.04	-0.02
	Tranquil Months	Pre	-0.01	-0.27	0.00	-0.00
	Crisis Months		0.06	-3.75	0.02	-0.01

Note: All and Pre refer to whether the factor sensitivities were estimated using post-tequila data. For each month, a cross-section regression was run to estimate F. The difference $\hat{F}$-F was averaged over tranquil months and crisis months.

Table 2.10 reports the results of the second-stage results for Mexico and Argentina. The

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[25]The tranquil period variance in Argentina does not include the paper industry index, which jumped abnormally in April 1997. Leaving this industry in, the tranquil and crisis period variances are 0.016 and 0.015, respectively. Despite the questionable month, using the paper index in the regressions does not significantly change the results.

dependent and independent variables were averaged over the crisis periods. For the Tequila crisis, the averages were taken over December 1994 through March 1995. For the Russian crisis, the averages were taken over August and September 1998.

For Mexico, the preferred specification is the Pre column, given the exchange rate regime shift in 1994 and the fact that we use Peso interest rates. The estimates using the pre-crisis betas can thus be interpreted as the innovations to macro fundamentals as if the peg had been maintained. For Argentina, the exchange rate regime did not change during the Tequila crisis and so both columns represent the pegged regime.

The actual variables are the observed innovations to the macro variables (residuals from the VAR estimated during tranquil periods). The numbers in parentheses are standard errors adjusted for the mismeasurement of the betas.[26] We do not correct the point estimates for the potential bias induced by this measurement error.

Table 2.10: Second-Stage Regressions: Whole Crises

			Const.	Market	IR	IP gr.	DC gr.	R^2
Mexico	Dec 94 Mar 95	All	-0.17 (-3.69)	0.03 (0.6!)	31.32 (3.74)	0.11 (2.59)	0.44 (2.61)	0.42
		Pre	-0.13 (-4.37)	-0.10 (-3.36)	5.03 (4.97)	-0.03 (-1.12)	0.04 (2.40)	0.56
		Actual		-0.05	15.7	-0.08	0.04	
	Aug 98 Sep 98	All	-0.06 (-1.09)	-0.07 (-1.08)	15.50 (1.70)	0.12 (2.53)	0.07 (0.41)	0.32
		Pre	-0.04 (-0.93)	-0.08 (-2.10)	3.34 (2.57)	-0.01 (-0.36)	0.08 (3.58)	0.36
		Actual		-0.08	13.63	0.02	-0.22	
Argentina	Dec 94 Mar 95	All	-0.06 (-1.60)	-0.00 (-0.02)	0.55 (0.49)	0.08 (1.44)	-0 01 (-1.05)	0.21
		Pre	-0.06 (-2.12)	-0.00 (-0.12)	0.28 (1.99)	0.02 (1.67)	-0.00 (-0.29)	0.11
		Actual		-0.05	4.64	-0.03	-0.03	
	Aug 98 Sep 98	All	-0.22 (-2.16)	0.00 (0.03)	-3.56 (-1.30)	-0.05 (-0.41)	-0.03 (-1.00)	0.17
		Pre	-0.12 (-1.50)	-0.07 (-0.84)	-0.26 (-0.73)	0.00 (0.00)	-0.04 (-2.27)	0.32
		Actual		-0.15	2.78	-0.02	-0.00	

Notes: All and Pre refer to whether the factor sensitivities were estimated using post-tequila data. The "Actual" rows contain the measured values of the variables during the crises.

The results from Mexico suggest that the rise in the interest rate had a significant impact on stock returns during the 1994-1995 crisis. The regression using betas estimated both before and after the '94 crisis suggests an effective interest rate double the actual innovation, but the betas estimated using only pre-crisis data suggest an effective interest

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[26]The standard errors were calculated using the results of Shanken (1992 - section 2) to adjust a scalar OLS variance-covariance matrix.

rate innovation one third the observed value. Recall that for Mexico, the Pre column indicates the effective innovation as if the peg were still in effect. That is, during the crisis, investors considered the sharp spike in interest rates as if it were a 5% unexpected increase during the previous tranquil period. For Mexico, the first column also indicates that industrial production had a positive impact, but we will see below that this result reflects the growth in December 1994 before the devaluation. Domestic credit has a positive impact, and in the Pre results the point estimate is equal to the actual value. For the 1998 crisis in Mexico, we again see some evidence that the interest rate is a significant contributing factor, although the regressions imply a positive boost from domestic credit growth despite an actual tightening of credit.

For Argentina, the regressions have less explanatory power. The Pre results suggest a significant tightening of domestic credit in 1998, but the effect is not significant using the entire sample betas. The inability to explain the cross-section of returns with fundamentals is consistent with a random selling of Argentine assets in both crises, but we gain more insight by looking at individual months rather than averaging over the crisis periods. Month by month results are reported in tables 2.11 and 2.12.

The month by month results for Mexico during the Tequila crisis confirm that the rise in interest rates had a significant impact on stock prices. The interest rate was immediately incorporated into stock prices in December 1994, while the actual rate continued to move upward through the first quarter of 1995. In March, the stock market bounced back by 27%, but interest sensitive stocks continued to suffer, with the effective shock to interest rates estimated at 28% and 5% versus the actual shock of 34%. In the month by month results, we also see that table 2.11's positive shock to industrial production was generated in December, suggesting that pro-cyclical stocks at first benefited (relative to the average) from the devaluation, but then fell as the crisis progressed.

The results from Argentina also underscore the importance of interest rate movements during the Tequila crisis. In December 1994 and January 1995 the interest rate innovation is significantly different from zero and close to the observed value; the actual interest shocks of 1.6% in December and January corresponded to statistically significant increases of 0.7% in effective interest rates using the pre-crisis specification.

The month by month results during the Russian crisis also highlight the importance of credit conditions. In Mexico, the effective innovation to interest rates is significantly positive

Table 2.11: Second-Stage Regressions: Monthly Regressions for Mexico

		Constant	Market	IR	IP growth	DC growth	R^2
Dec 94	All	-0.40 (-3.94)	0.13 (1.09)	69.87 (3.84)	0.28 (2.98)	1.28 (3.55)	0.53
	Pre	-0.39 (-5.94)	-0.12 (-1.88)	11.14 (4.93)	0.05 (0.86)	0.03 (0.69)	0.48
	Actual		-0.09	4.13	-0.04	-0.06	
Jan 95	All	-0.06 (-1.00)	-0.13 (-1.92)	17.94 (1.74)	0.04 (0.68)	-0.04 (-0.21)	0.37
	Pre	-0.60 (-1.35)	-0.14 (-3.21)	2.68 (1.82)	-0.03 (-0.72)	0.08 (3.48)	0.37
	Actual		-0.15	19.28	-0.10	0.06	
Feb 95	All	-0.07 (-1.00)	-0.11 (-1.33)	9.48 (0.78)	0.08 (1.26)	0.54 (2.24)	0.35
	Pre	-0.06 (-1.14)	-0.15 (-3.10)	1.06 (0.63)	-0.03 (-0.76)	0.02 (0.87)	0.29
	Actual		-0.24	5.48	-0.26	0.04	
Mar 95	All	-0.16 (-2.30)	0.24 (2.86)	27.97 (2.19)	0.05 (0.80)	-0.01 (-0.15)	0.40
	Pre	-0.01 (-0.22)	0.02 (0.40)	5.22 (3.17)	-0.10 (-2.51)	0.03 (0.95)	0.52
	Actual		0.27	33.91	0.09	0.12	
Aug 98	All	-0.15 (-1.48)	-0.26 (-2.18)	9.94 (0.55)	0.18 (1.94)	-0.63 (-1.78)	0.51
	Pre	-0.09 (-1.23)	-0.22 (-2.84)	5.52 (2.13)	0.04 (0.61)	0.16 (3.70)	0.36
	Actual		-0.28	1.05	0.02	-0.11	
Sep 98	All	0.04 (0.44)	0.13 (1.25)	21.06 (1.40)	0.06 (0.76)	0.78 (2.63)	0.27
	Pre	0.02 (0.35)	0.06 (0.88)	1.14 (0.53)	-0.06 (-1.17)	-0.00 (-0.14)	0.12
	Actual		0.13	23.20	0.03	-0.33	

Notes: All and Pre refer to whether the factor sensitivities were estimated using post-tequila data. The "Actual" rows contain the measured values of the variables during the crises.

in August 1998 and comparable to the observed innovation. The effective innovation for September 1998 is imprecisely measured for the All specification, but the point estimate is comparable to the actual innovation. For the pre-crisis specification, the interest rate is not significantly different from zero. but significantly lower than the observed shock to interest rates. Anomalous results for Mexico include significantly positive values for effective domestic credit growth when the actual values are negative.

The results for Argentina from 1998 also provide some support for a credit channel story, but through quantities rather than interest rates. In particular, the effective domestic credit growth is significantly negative for August 1998 and double the observed contraction. The interest rate variables have the wrong sign three out of four times, but are not statistically significant from zero or the actual positive values in August 1998.

Table 2.12: Second-Stage Regressions: Monthly Regressions for Argentina

		Constant	Market	IR	IP growth	DC growth	R^2
Dec 94	All	0.04 (0.66)	-0.10 (-1.76)	0.92 (0.62)	-0.02 (-0.32)	-0.01 (-0.63)	0.20
	Pre	-0.03 (-0.71)	-0.03 (-0.47)	0.66 (2.95)	0.01 (0.41)	0.01 (1.00)	0.63
	Actual		-0.06	1.57	-0.03	-0.07	
Jan 95	All	0.01 (0.25)	-0.12 (-1.81)	0.24 (0.20)	-0.04 (-0.48)	-0.01 (-0.56)	0.20
	Pre	-0.08 (-1.47)	-0.00 (-0.01)	0.73 (2.82)	0.00 (0.21)	0.00 (0.30)	0.56
	Actual		-0.07	1.62	-0.11	-0.01	
Feb 95	All	-0.13 (-1.53)	-0.09 (-1.03)	-1.34 (-0.57)	-0.06 (-0.48)	-0.01 (-0.44)	0.12
	Pre	-0.19 (-2.62)	-0.03 (-0.34)	0.37 (1.09)	0.06 (1.62)	-0.02 (-1.09)	0.22
	Actual		-0.21	2.58	0.13	0.01	
Mar 95	All	-0.18 (-0.87)	0.31 (1.39)	2.30 (0.40)	0.44 (1.55)	-0.02 (-0.33)	0.44
	Pre	0.06 (0.43)	0.04 (0.26)	-0.66 (-1.08)	0.02 (0.37)	-0.00 (-0.14)	0.13
	Actual		0.15	12.49	-0.07	0.10	
Aug 98	All	-0.17 (-1.66)	-0.12 (-1.09)	-2.09 (-0.76)	-0.13 (-0.97)	-0.06 (-1.91)	0.51
	Pre	-0.13 (-1.71)	-0.13 (-1.57)	0.29 (0.83)	0.03 (0.88)	-0.05 (-3.24)	0.67
	Actual		-0.24	0.80	-0.01	-0.02	
Sep 98	All	-0.26 (-2.01)	0.12 (0.88)	-5.04 (-1.40)	0.02 (0.12)	-0.00 (-0.06)	0.13
	Pre	-0.10 (-0.98)	-0.02 (-0.13)	-0.80 (-1.64)	-0.03 (-0.61)	-0.02 (-1.03)	0.20
	Actual		-0.06	4.76	-0.02	0.01	

Notes: All and Pre refer to whether the factor sensitivities were estimated using post-tequila data. The "Actual" rows contain the measured values of the variables during the crises.

Chapter 3

Supply of Funds, Maturity, and Spreads on Emerging Market Sovereign Bonds (1)

3.1 Introduction

During the 1990's a large number of balance-of-payments (BOP) crises took place in the developing world. These crises were blamed, to varying degrees, on a mismatch in the maturity of assets and liabilities in the affected countries. In particular, observers have argued that these countries were relying too heavily on short-term borrowing to finance long-term projects. Empirical studies have found that the ratio of short-term liabilities over liquid assets (e.g. international reserves) can go a long way in explaining why some countries suffered crises while others did not. In Russia in 1998 and Brazil in 1998, governments had accumulated large amounts of short-term debt. In Indonesia, Korea, and Thailand in 1997 domestic financial institutions were responsible for large amounts of short-term borrowing. In Mexico in 1995, both the government and domestic banks played an important role in the crisis, as a large amount of short-term government debt was held by domestic banks which had borrowed short-term abroad.[2] There is by now significant consensus that countries can decrease their vulnerability to capital-flow reversals by lengthening the maturity structure

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[1]This chapter is co-authored with Guido Lorenzoni.

[2]Although a large part of short-term government bonds were held by foreign investors, these bonds were involved in swap operations with domestic banks (Garber, 1998).

of their liabilities.[3]

However, there is less agreement on why countries sometimes resort to short-term financing, and on what the trade-offs are in the maturity management of sovereign debt. The literature has emphasized the time consistency issues that arise when countries issue large amounts of long-term liabilities. For example. Rodrik and Velasco (1999) and Jeanne (1999) show that opportunistic governments have less incentives to willingly default on their debts and more incentives to carry out revenue-raising reforms when they have to meet early debt repayments. Namely, short-term debt can serve as a commitment device.[4]

This chapter introduces another important aspect to debt management, by focusing on the "supply side" of funds and its effects on the cost of borrowing at different maturities.

Consider first the case in which debt holders are risk-neutral deep-pockets investors. In this case the expected discounted value of debt repayments necessarily equals total borrowing. As a result, spreads on sovereign bonds should only reflect default probabilities and, in the case of local currency bonds, expectations about future inflation. However, it is difficult to reconcile the observed behavior of spreads with this view. In particular, spreads on long-term bonds are too volatile. For example, consider the behavior of the spread (over U.S. bonds) of Argentine dollar-denominated debt of different maturity. The spread on these bonds should be approximately equal to the average of default probabilities throughout the lifetime of the bond. As a result, in periods of financial turmoil, when the probability of default increases, the spread on long-term bonds should increase much less than that on short-term bonds, as crisis periods are very short compared to the lifetime of long-term bonds.

This is not what casual observation of the data suggests. As figure 3-1 illustrates, the spread on long-term bonds increased almost as much as that on short-term bonds during the Asian crisis. To a varying extent, this behavior can also be observed in other crisis episodes.

In this chapter, we argue that this observation is more easily reconcilable with a world in which borrowing constraints and liquidity shocks play an important role in investors'

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[3] Giavazzi and Pagano (1990) and Alesina, Prati, and Tabellini (1990) formalize this idea.

[4] Missale and Blanchard (1994) and Calvo (1988) focus on governments' incentives to lower the real value of debt by creating inflation. They show that this incentive is higher when debt is non-indexed, in domestic currency, and long-term. However, this argument is probably more relevant for OECD countries, since developing countries seldom issue long-term debt in domestic currency. (Probably in part for this reason.)

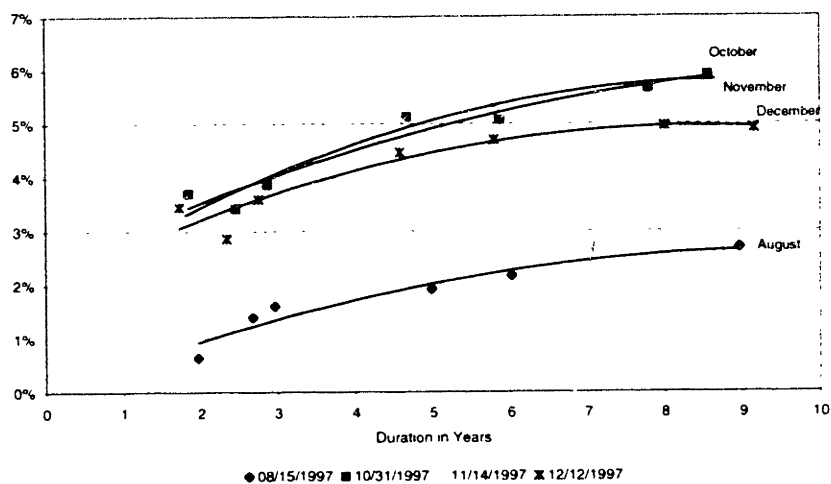Argentine Spreads at Different Maturities During Asian Crisis

Figure 3-1: Spreads of dollar-denominated Argentine bonds over U.S. bonds.

behavior. We present a simple model of sovereign debt, in which a government must borrow in order to finance a "project". Investors are assumed to be "specialists" who are risk-averse, financially constrained, and subject to liquidity shocks.[5]

In this context, we show that spreads on long-term bonds should substantially rise in periods of financial turmoil, as investors demand a larger risk-premium to compensate for the *price risk* associated with holding long-term debt. This result is due to the fact that crises are times in which information is likely to be revealed about the future prospects of the country and, in turn, the probability that long-term obligations will be met.[6] Since investors face liquidity shocks, and may need to liquidate their positions early, they effectively become more risk-averse and require a high expected return to hold long-term bonds. Short-term debt, on the other hand, carries less price risk and its return is less dependent on the realization of the "signal".

Governments thus have incentives to issue short-term debt because it is "cheaper", in the sense that expected debt repayments are lower than when issuing long-term debt.[7] This

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[5]Since we want to focus on the lender side, we assume that the government is risk-neutral. If this were not the case, the debt maturity structure would also have implications for risk sharing between investors and borrower countries.

[6]In this chapter, we assume that information is revealed about the probability of success of the project. Alternatively, we could assume that the long-term effects of the crisis are unknown, and that investors learn about them as the crisis progresses.

[7]We cannot say whether issuing short-term debt is cheaper than issuing long-term debt just by looking at spreads at different maturities, since spreads must themselves be endogenously determined by, among other factors, the debt maturity structure. For example, it is possible that short-term spreads be lower

is due to the fact that short-term debt allows investors to diversify away the idiosyncratic component of the liquidity shocks. Investors without liquidity needs provide funds to buy new short-term, and constrained investors are repaid at a price that does not depend on the realization of the signal.

The model highlights an important trade-off in the choice between short and long-term debt. By issuing short-term debt, countries can reduce expected debt repayments by shaping their debt maturity structure according to investors' liquidity needs. On the other hand, the larger the proportion of short-term debt, the larger the losses associated with inefficient liquidation of the project.

The chapter is organized as follows. Section 3.2 presents some evidence supporting the view that spreads on long-term bonds are too volatile to be consistent with investors being risk-neutral and not financially constrained. Section 3.3 presents a simple model that highlights the concept of price risk. Section 3.4 analyzes the model. Section 3.5 provides further evidence for the importance of specialists' balance sheets in determining spreads on long-term bonds. In particular, by studying realized returns and volatilities we show that the Sharpe ratio of holding emerging market bonds increases after price drops. Assuming that a drop in bond prices decreases the wealth of specialists, this is consistent with investors' effective risk aversion increasing when investors are closer to their borrowing constraints. Section 3.6 concludes.

3.2 Volatility of Spreads on Long-Term Bonds

In this section we show that the behavior of spreads on developing countries' sovereign bonds does not seem consistent with an environment in which investors are risk-neutral and spreads equal expected default losses. In particular we will show that spreads on long-term bonds move too much given the time-series properties of default hazard rates.[8]

Let $s_{t,j}$ denote the *log-spread* on a zero-coupon bond of maturity j at time t and let $s_t \equiv s_{t,1}$ denote the corresponding current variable. Also, let $f_{t,j}^s$ denote the *forward spread*, which satisfies

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than long-term spreads because long-term debt holders are residual claimants, without implying that issuing short-term debt is cheaper. This is the case in Rodrik and Velasco (1999).

[8]The methods used in this section are similar to those of Campbell, Lo, and MacKinlay (1997) chapter 10.

$$f^s_{t,j} = (j+1)s_{t,j+1} - j\, s_{t,j} \tag{3.1}$$

or, equivalently,

$$s_{t,j} = \frac{1}{j}\sum_{i=1}^{j} f^s_{t,i}. \tag{3.2}$$

In the rest of this section we assume that forward spreads arise as a result of expected default probabilities. However, the results we report could also be interpreted more generally as a failure of the expectations hypothesis in terms of forward spreads. Let $m_{t,j}$ denote the *default hazard rate*, or expected (as of time t) probability of default at time $t + j$ conditional on no default before time $t + j$. Let $m_t \equiv m_{t,1}$ denote the corresponding current variable. We assume that bonds are fully repaid if no default occurs, but that when default takes place no further payments are ever made.[9] Under risk-neutrality, the forward spreads must account for default hazard rates and, as a result,

$$m_{t,j} = f^s_{t,j}. \tag{3.3}$$

and

$$s_{t,j} = \frac{1}{j}\sum_{s=1}^{j} m_{t,s}. \tag{3.4}$$

We compute forward spreads using data on spreads on bonds of different maturities, and equations 3.1 and 3.3. We start by estimating the spread curve at time t by fitting a smooth curve through the existing $s_{t,j}$.[10,11] We report the results obtained using a quadratic function, but other functional forms (such as exponentials) led to similar results.

We then use the continuous time version of equation 3.1 and 3.3 to calculate $m(t,j)$ from the estimated spread curve:

$$m(t,j) = j\frac{\partial s(t,j)}{\partial j} + s(t,j).$$

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[9]This assumption is made to simplify the algebra. All repayment schedules would give the same results, even if long-term bonds have seniority over short-term bonds.

[10]Data on bond spreads was obtained from Datastream.

[11]Since there are no discount bonds for the countries we study, we proxy $s_{t,j}$ with the spread of a coupon bond of *duration* j at time t. Campbell *et al* show that this is in fact a good approximation.

Figure 3-2 shows the behavior of the implied default hazard rates at short (1 year), medium (3 years), and long (6 years) maturities as a function of time t, for both Mexico and Argentina. Figure 3-2 shows that during the Asian and Russian crises, the default hazard rates were very volatile at every maturity for both Mexico and Argentina.
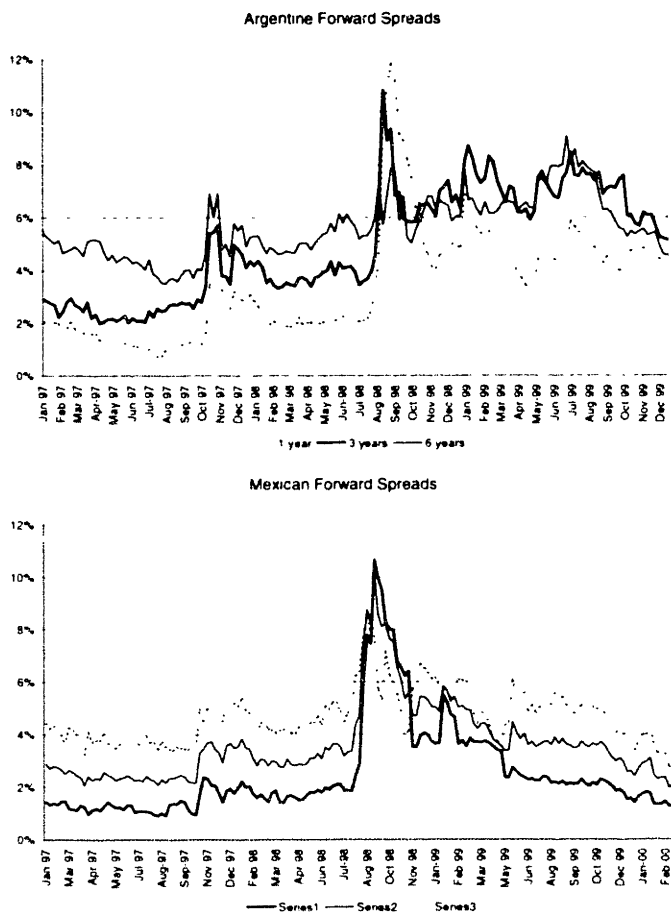

Figure 3-2: Forward spreads (or default hazard) at different maturities.

According to the j-period expectations hypothesis (EH), forward spreads should satisfy

$$f_{t,j}^s = E_t \left[f_{t+j}^s \right] + \gamma_j. \tag{3.5}$$

where γ_j is a constant risk-premium. Rather than focusing on the j-period EH, in what follows we test the j-period pure expectations hypothesis (PEH) by assuming $\gamma_j = 0$ for all j. In fact, both hypothesis impose the same restrictions on the data, since we are only interested on spread changes rather than levels. We thus test PEH for simplicity of exposition. Under the j-period PEH, the default hazard rates must satisfy:

$$m_{t,j} = E_t \left[m_{t+j} \right].$$ (3.6)

We assume that the current default hazard m_t follows the $AR(1)$ process

$$(m_{t+1} - \mu) = \rho(m_t - \mu) + \varepsilon_{t+1},$$ (3.7)

where μ is the average default hazard rate.[12] If condition 3.6 holds, this process implies that the default hazard rates must satisfy

$$(m_{t,j} - \mu) = \rho^{j-1}(m_t - \mu).$$ (3.8)

Since we are interested in studying the volatility of spreads rather than the spread curve at a particular point in time, we take first differences in equation 3.8 to obtain[13]

$$(m_{t+1,j} - m_{t,j}) = \rho^{j-1}(m_{t+1} - m_t).$$ (3.9)

Thus, there are two ways of estimating the persistence of shocks ρ: from the time series properties of m_t, and from the relative size of innovations to $m_{t,j}$ and m_t. For the former, we estimate the simple $AR(1)$ of equation 3.7. For the latter, we run the regression

$$(m_{t+1,3} - m_{t,3}) = \beta(m_{t+1,1} - m_{t,1}) + \varepsilon_{t+1}.$$ (3.10)

To estimate the $AR(1)$ process we used weekly data from January 1995 through January 2000. Since we have short time series for short-term bonds, we used default hazard rates of 2-year maturity.[14] To estimate regression 3.10 we used weekly data from January 1997 through January 2000, and default hazard rates for 1-year and 3-year maturities.

Table 3.1 summarizes the results of both estimations. To make the interpretation of the

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[12]We are assuming that m_t is stationary Although the fact that $m_t \in [0,1]$ implies stationarity, it is still the case that there might be more permanent shocks that we do not observe in our sample. In a next draft, we plan to estimate how likely this "peso problem" must be in order to make the observed behavior of spreads consistent with the expectations hypothesis.

[13]This also allows us to interpret the results in terms of the EH, since when 3.5 is satisfied, the process 3.7 implies a similar condition:

$$(f_{t+1,j}^* - f_{t,j}^*) = \rho^{j-1}(f_{t+1}^* - f_t^*).$$

[14]Under the null, default hazard rates at all maturities should have the same ρ.

coefficients more clear, it presents the "half-life" of innovations, rather than ρ. Table 3.1 shows that the half-life of innovations implied by the time-series behavior of the default hazard rates is significantly shorter than the one implied by the relative movements of hazard rates for different maturities.

Table 3.1: Test of EH

	Mexico		Argentina	
	Time series	Relative volatility	Time series	Relative volatility
half-life	3.4	34.0	3.7	22.9
95% conf. int.	2.0–12.6	24.2–49.5	2.4–7.9	16.4–31.5
N.obs.	202	153	215	165

Notes: Half-lives are given in months.

The simple empirical analysis presented in this section suggests that the behavior of spreads on emerging market sovereign debt is not consistent with spreads being driven solely by default probabilities. Rather, it seems that the excess risk-premium investors require to hold long-term bonds instead of short-term bonds is negatively correlated with changes in bond prices.

This behavior of spreads can be accounted for if bond holders are specialists who are financially constrained and subject to liquidity shocks. As a result, when bond prices fall, specialists' wealth decreases bringing them closer to their constrains and increasing their "effective risk-aversion." This increases the demanded risk-premium, especially on long-term bonds, as long-term bonds carry price-risk and are thus more risky than short-term bonds. In the next section, we present a simple model that incorporates these ingredients.

3.3 The Model

The model is composed of a government, which has to borrow in order to finance maturing debt, and a set of international investors of mass 1. There are three periods.

Debt structure and default

In period 0, the government must borrow D_0 in order to finance old debt coming to maturity. The government can sell either short-term (1-period) or long-term (2-period) bonds. In period 1, the government pays the short-term bonds issued in period 0 by issuing new short-term debt and by generating revenue. In period 2, the government generates revenue,

pays maturing long and short term bonds, and "consumes" the rest. We abstract from strategic default by assuming that the government repays its debts whenever it is feasible.[15]

The government's budget constraint in period 0 is

$$D_0 = q_S D_S + q_L D_L$$

where D_S and D_L are the amount of short-term and long-term bonds issued in period 0, and q_S and q_L are their respective prices.

In period 1, the government has to roll over an amount D_S of short-term bonds. The government's budget constraint in period 1 is

$$D_S = q_{S,1} D_{S,1} + X$$

where $D_{S,1}$ is the amount of short-term bonds issued in period 1, $q_{S,1}$ is their price, and X are government revenues in period 1. In order to generate an amount $X > 0$ of revenues in period 1, the government has to resort to "emergency" finance which entails a cost $X + c$. The cost $c \geq 0$ incorporates the inefficiencies associated with raising resources "too soon", and can be thought of as arising from the premature liquidation of long-term projects (for example, through excessive taxation).[16] It is assumed that the cost $X + c$ affects the country's welfare, but does not affect the availability of resources in period 2.[17]

In period 2, the government revenue is Y, where Y is a random variable which takes the value $\bar{Y}$ in the good state and 0 otherwise. The extreme case of zero realization in the bad state, and the fact that it will always be the case that in the good state no default takes place (i.e. $\bar{Y} \geq D_{S,1} + D_L$) considerably simplifies the analysis. This is because, in equilibrium, there is never partial default. In order to avoid the possibility of dilution of

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[15]We are implicitly assuming the existence of costs of default. These costs can be reputational, or involve direct interference by creditors on debtors' transactions in international goods and capital markets. (See Bulow and Rogoff (1989) for a discussion of the later.)

[16]The choice of $X = 0$ as the maximum amount of revenues that can be generated without incurring the cost c is just a simple normalization.

[17]By assuming the existence of a fixed cost c that does not decrease future resources we can solve the model very easily. Alternatively, we could assume that the "liquidation cost" is proportional to X, and that it reduces resources in period 2. In both cases, liquidity crises arise when period 2 resources are expected to be too low to allow the government to issue a sufficient amount of short-term debt in period 1 to repay all maturing short-term debt. Under the second set of assumptions, the liquidation costs would also resemble a fixed cost, as a small reduction in expected future resources can make the equilibrium in which investors accept to roll over the short-term bonds disappear, generating a sizeable liquidation cost. (Namely, liquidation costs are discontinuous in the sense that they are either zero or large.)

long-term debt by issuing short-term bonds in period 1, we assume that long-term bonds are senior.

As of period 0, the probability of $Y = \bar{Y}$ is p_0. We assume that between periods 0 and 1, information is revealed about the likelihood of success and the probability is updated to p. As of period 0, p is a random variable distributed with distribution F, which by construction satisfies $p_0 = \int p\, dF(p)$.[18]

The government maximizes the objective function

$$W = E_0 \left[\max\left\{ \bar{Y} - D_L - D_{S,1}, 0 \right\} - I_{(X>0)} \left(X + c \right) \right]$$

where the first term accounts for the resources that can be consumed by the country's residents in period 2 (i.e. output minus debt payments) minus the costs incurred in order to raise revenue in period 1.

Investors

Investors preferences are described by

$$E_0 \left[c_0 + u(c_1) + c_2 \right]$$

where u is a concave function. Investors' budget constraint is

$$b_0 + q_S d_S + q_L d_L + c_0 = w_0$$
$$b_1 + q_{S,1} d_{S,1} + q_{L,1} d_{L,1} + c_1 = w_1 + b_0 + d_S + q_{L,1} d_L$$
$$c_2 = I_{(Y=\bar{Y})}(d_{S,1} + d_L) + b_1$$
$$c_1, b_1, d_{1j} \geq 0$$

where the d's denote holdings of the country's bonds, the q's denote bond prices, and the b's denote holdings of a risk-free international short-term asset which is offered at exogenous price 1 (e.g. US treasury bills).

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[18]Alternatively, we could assume that in period 1 there is a shock that affects the repayment capacity of the country in period 2. This would make the analysis more difficult if it involves the possibility of partial default.

Investors' income in period 1, w_1, is a random variable distributed with density g. We assume pure idiosyncratic uncertainty and, as a result, g corresponds to the ex post cross-sectional distribution of w_1.[19]

This setup captures the idea of specialized investors with limited wealth and subject to liquidity shocks.[20] We can think of liquidity shocks as arising from low cash flows in other activities or because of high returns in alternative investment opportunities. Let us define $\bar{c}$ such that

$$u'(\bar{c}) = 1.$$

The higher an investor's initial wealth, the more she would behave as risk-neutral. In particular, if she could achieve period 1 consumption larger than or equal to $\bar{c}$ with probability 1, she would act as totally risk-neutral. Otherwise, when w_1 is low enough such as the period 1 borrowing constraint binds, she liquidates all her portfolio. This corresponds to $c_1 = w_1 + b_0 + d_S + q_{L,1}d_L < \bar{c}$, as portfolio liquidation entails selling the whole portfolio at current prices.

An essential feature of the model is that the period-1 price of long-term debt $q_{L,1}$ is a random variable affected by news on revenue prospects for the government. As a result, holding long-term bonds between periods 0 and 1 is more risky than holding short-term debt.

3.4 Equilibrium

We solve the model in two steps. First, we take the maturity structure as given (namely the choice of D_L) and find the equilibrium bond prices and investment decisions. Then, we choose the maturity structure such as to maximize welfare. We divide the analysis into three special cases. In case 1, there is no information revealed in between periods 0 and 1. As a result, in period 1 investors are able to sell their assets at the same price at which they bought them and, similarly, the government can refinance its debt at constant terms. The debt structure is thus irrelevant. In case 2, there is some information revelation in period 1.

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[19] In a future draft we will study the case with aggregate uncertainty
[20] Holmstrom and Tirole (1998) derive similar reduced form preferences from primitive assumptions about alternative investment opportunities

but the ex post probability of default is always small enough such that there is no problem rolling over short-term debt in period 1, even in the case in which the all liabilities are short term debt. In this case, since investors dislike the price risk associated with long term debt, full short term financing is optimal. In case 3, the ex post probability of default can be large enough such that the government has trouble rolling-over the short-term debt in period 1. In this case, the trade off between optimal risk sharing with investors and illiquidity risk implies an optimal debt structure with both short and long term liabilities.

Case 1: No price risk

No information is revealed between periods 0 and 1; namely, F is degenerate and $p = p_0$. We make the following two assumptions:

Assumption 7 *The government is ex-ante solvent:*

$$p_0 \bar{Y} > D_0$$

Assumption 8 *Investors expected resources satisfy*

$$\int_{\bar{c}-w_0}^{\infty} (w_1 + w_0 - \bar{c})g(w_1)dw_1 \geq D_0$$

where $u'(\bar{c}) = 1$.

Under assumptions 7 and 8, for any $D_S \in [0, D_0]$ there is an equilibrium in which bond prices satisfy

$$q_S = 1 \tag{3.11}$$
$$q_L = q_{L,1} = q_{S,1} = p_0.$$

The government can issue any combination of short and long-term bonds such that $p_0 D_L + D_S = D_0$ and the short-term bonds are rolled over in period 1 by issuing an amount $D_{S,1} = \frac{1}{p_0} D_S$ of new short-term bonds.

In period 1, investors whose income is such that $w_0 + w_1 < \bar{c}$ liquidate all their assets and consume $w_0 + w_1$. Those for whom $w_0 + w_1 \geq \bar{c}$ consume $\bar{c}$ and buy the outstanding

long-term bonds and the new short-term bonds.

Assumption 7 guarantees that the government can always roll over all short-term debt in period 1. Assumption 8 guarantees that unconstrained investors have enough resources to buy all outstanding long-term bonds and the new short-term bonds issues. Since unconstrained investors have access to the risk-free asset the risk neutral pricing equations 3.11 have to hold.

Since bonds carry no risk-premium it is trivial to prove the following proposition.

Proposition 13 *If no information is revealed between periods 0 and 1, and if assumptions 7 and 8 hold, the government is indifferent among all debt structures that satisfy $p_0 D_L + D_S = D_0$. For all debt structures the government payoff is constant and equal to $W_1 = p_0 \bar{Y} - D_0$.*

Case 2: Pure price risk

Consider now the case in which information is revealed between periods 1 and 2 on the probability of the good state. In this case, the price of long-term bonds in period 1 depends on the realization of p. Since investors who receive low income in period 1 need to liquidate their investments, they need to be compensated *ex ante* for the price-risk associated with holding long-term bonds.

We assume first that short-term debt can always be rolled-over in period 1, with no need of emergency finance.

Assumption 9 *The probability of the good state as of period 1 is always high-enough such that the short-term debt can be rolled over. There is some $\varepsilon > 0$ such that*

$$F\left(\frac{D_0}{\bar{Y}} - \varepsilon\right) = 0.$$

Assumption 10 *Investors' wealth satisfies*

$$G\left(\bar{c} - w_0\right) > 0$$

Proposition 14 *Under assumptions 7 through 10, there is a $\underline{D} < D_0$ such that for any D_S in $[\underline{D}, D_0]$, there is an equilibrium with $X \equiv 0$ in which bond prices satisfy*

$$q_S = 1$$

$$q_L = Q(D_L)$$

$$q_{S,1} = q_{L,1} = p$$

$Q(\cdot)$ satisfies $Q(D_L) \leq p_0$ with equality if and only if $D_L = 0$.

Proof: Assumption 8 guarantees that unconstrained investors have enough resources in period 1 to buy all outstanding long-term bonds and enough new short-term bonds to repay the period-0 short-term bonds. Assumption 9 guarantees that there is never partial default provided that D_L is small enough. Since unconstrained investors have access to the risk-free asset, ex post prices must satisfy $q_{S,1} = q_{S,1} = p$.

The ex ante asset pricing condition for long-term bonds is $q_L = \frac{E_0[u'(c_1)p]}{E_0[u'(c_1)]}$. If $D_L = 0$, investors do not hold any long term bonds and their period-2 consumption is independent of p. Therefore we obtain $q_L = \frac{E_0[u'(c_1)]E_0[p]}{E_0[u'(c_1)]} = E_0[p]$ which implies $Q(0) = p_0$. If instead they hold a positive amount of long-term debt, and assumption 10 holds, period-2 consumption will have a positive covariance with p and since u' is decreasing we get $q_L < \frac{E_0[u'(c_1)]E_0[p]}{E_0[u'(c_1)]} = E_0[p]$ which implies $Q(D_L) < p_0$ if $D_L > 0$. $\square$

In the equilibrium described above the government issues an amount $D_0 - q_L D_L$ of short term debt. Therefore, in period 1 the government is able to roll over the short-term bonds if $p\bar{Y} - (p - q_L)D_L \geq D_0$. For D_L small enough this condition is always met. However, if D_L is large, it can be the case the condition is not met and the government is forced to raise revenue in period 1 when p is low. In this case there is no equilibrium with $X \equiv 0$.

As a result, for low levels of long-term debt the government's payoff in equilibrium is equal to

$$W = p_0\bar{Y} - D_0 - (p_0 - q_L)D_L, \tag{3.12}$$

while for high levels of long-term debt the government's payoff is lower than that. The following proposition follows immediately.

Proposition 15 *Under assumptions 7 through 10, the optimal debt structure consists of*

issuing only short-term debt. In this case, the government's payoff is equal to the one in case 1, namely $W_1 = p_0 \bar{Y} - D_0$.

This simple example illustrates in which type of environments the price-risk associated with holding long-term bonds makes long-term borrowing for the government expensive. First, investors must expect that in the near future information will be revealed about the long-term prospects of the country. And second, investors must be close to their borrowing constraints, and be subject to liquidity shocks. Both of these features are present in episodes of international financial markets turmoil. On the one hand, crises are times in which a large amount of information is revealed about emerging-market fundamentals.[21] On the other hand, investors specialized on emerging-market assets are in danger of becoming constrained, either by withdrawals from their own investors or by further loses.

However, as previously argued, issuing too much short-term debt increases countries' vulnerability to reversals in capital flows. The trade-off is made clear in the case we consider next.

Case 3: Liquidity crises

We now consider the case in which assumption 9 does not hold. As a result, for any debt structure there is a positive probability that the government cannot issue enough short-term bonds in period 1 in order to repay maturing debt. Since the maximum amount of funds the government can raise in period 1 is $p(\bar{Y} - D_L)$, the government is forced to set $X > 0$ if and only if $p(\bar{Y} - D_L) < D_S$. In such a case, the government sets $X = D_S - p(Y - D_L)$, and incurs the fixed welfare cost c.

For a given debt structure, let $\hat{p}$ be the minimum p such that the government is solvent in period 1,

$$\hat{p} = \frac{D_0 - q_L D_L}{\bar{Y} - D_L}.$$

From investors' point of view nothing changes since short term debt in repaid with probability 1 in period 1. As a result, prices are determined as in proposition 14. The

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[21]Alternatively, we could just assume that countries are subject to shocks that reduce their long-term prospects, especially during crises.

government's objective function, on the other hand, now includes a term for the costly roll-over and takes the form

$$W = p_0 \bar{Y} - D_0 - (p_0 - q_L)D_L - c\,G(\hat{p}).$$

In this case the optimal debt structure may involve the use of both short and long term debt. The first order condition for government maximization is

$$-\left(p_0 - q_L - Q'D_L\right) - c\,g(\hat{p})\frac{d\hat{p}}{dD_L} = 0.$$

The first term is positive and reflects the fact that investors value long term debt less than p_0 because of its associated price-risk. The second term reflects the marginal gain in terms of reduced risk of a costly roll over, and is typically positive.[22]

To illustrate the nature of the optimal solution and to provide some simple comparative statistics we present an example. We assume that u is quadratic

$$u(c_1) = A\,c_1 - B\,c_1^2$$

and that w_1 is a binary random variable. In this case, we can obtain an explicit form for Q, and derive an explicit expression for the government's objective function. Using the pricing equation in proposition 14 the ex ante price of long-term bonds is

$$Q(D_L) = p_0 - \frac{1}{2BD_L}\left((1 + A) - \sqrt{(1 + A)^2 - 4B^2 D_L^2 \sigma_p^2}\right).$$

Note that the second term is zero if any of the following applies: consumers are risk neutral ($B = 0$), no information is revealed between periods 0 and 1 ($\sigma_p^2 = 0$), or no long term debt is issued ($D_L = 0$). As shown above, in all three cases the spreads on long-term bonds only reflect the probability of default. If instead neither condition applies, the bond price will be strictly smaller than p_0 reflecting the price risk of long-term bonds.

The expression for the government's payoff is

$$W = p_0 \bar{Y} - D_0 - (p_0 - q_L)D_L - c\,G(\hat{p})$$

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[22]It is easy to show that $\frac{d\hat{p}}{dD_L} < 0$ if the elasticity of Q is not too large.

$$= p_0 \bar{Y} - D_0 - \frac{1}{2B} \left((1+A) - \sqrt{(1+A)^2 - 4B^2 D_L^2 \sigma_p^2} \right) +$$

$$c\, G \left(\frac{D_0 - p_0 D_L + \frac{1}{2B} \left((1+A) - \sqrt{(1+A)^2 - 4B^2 D_L^2 \sigma_p^2} \right)}{\bar{Y} - D_L} \right)$$

When $\sigma_p^2 = 0$, the expression above is equal to $p_0 \bar{Y} - D_0$ for all D_L and we obtain the irrelevance result of case 1. When $c = 0$ the last term disappears and W is strictly decreasing in D_L. Therefore, if the government can raise emergency finance with no distortionary effects it will choose to issue only short-term debt. Finally, under risk neutrality and $c > 0$, the third term disappears and W is unambiguously non-decreasing in D_L. As a result, it is optimal to issue a large amount of long term debt at price p_0.[23]

3.5 Empirical Evidence

This section provides preliminary empirical evidence consistent with the main assumptions and predictions of the model presented above. We study the ex-post excess returns on emerging-market debt, after drops in bond prices, concentrating on Argentine and Mexican sovereign bonds. We show that: (i) the expected returns on emerging-market bonds increase substantially during crises; (ii) the increase is much more pronounced for long-term bonds; (iii) there is no appreciable increase in volatility that could account for the increase in expected returns; (iv) the returns on long-term bonds are more volatile; (v) the rise in Sharpe ratios is increasing in the size of previous price drops; and (vi) the rise in Sharpe ratios is increasing in the holding period (for holding periods between 4 and 16 weeks).[24]

To determine how the behavior of bond returns depends on their maturity, we construct return indices for different maturities. Given data limitations, we estimated return indices for three maturities: short (residual life of less than 2 years), medium (residual life between 2 and 10 years) and long (residual life of more than 10 years).[25] For each point in time,

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[23]We have also computed the optimal debt structure for different parameters in the case of $c > 0$ and p uniformly distributed over $[p_0 - \varepsilon, p_0 + \varepsilon]$. As one would expect, a larger value of c implies that more long term debt is optimal, while an increase in investors risk aversion implies a shorter optimal maturity. An increase in price variability increases the probability of a costly roll-over, while at the same time lowers the ex-ante price of long-term bonds. Although this seems to imply an ambiguous effect on the optimal debt structure, in the examples we simulated the price risk effect always dominates and the optimal amount of short-term bonds increases with σ_p^2.

[24]The last result was unexpected and seems at odds with the spirit of the model.

[25]Datastream provides data for all outstanding sovereign bonds. As a result, we do not have data on

we estimate the return for different maturities by averaging the return on bonds whose maturities fall within the specified range. Figure 3-3 shows the return indices for Argentina. The figure illustrates the high price-volatility of long-term bonds.

The main prediction of the model is that investors should be more sensitive to the high volatility associated with holding long-term bonds when they are closer to their borrowing constraints. Since we cannot observe investors' balance sheets, we use the past performance of bond prices as a proxi for investors' capital level. Specifically, we look at the return during the previous 4 weeks on the JPMorgan EMBI index corresponding to the country under study.

The following investment strategies are considered. If the JPMorgan index fell by more than D in the previous 4 weeks, invest in Argentine bonds of maturity M for H weeks, where $D \in \{0\%, 3\%, 5\%, 10\%\}$, $M \in \{short, medium, long\}$, and $H \in \{4, 8, 12, 16\}$. We estimate the expected excess returns (over U.S. bonds) and riskiness of each strategy by taking the average and standard deviation of the ex-post returns over all episodes in which the general index fell by more than D.
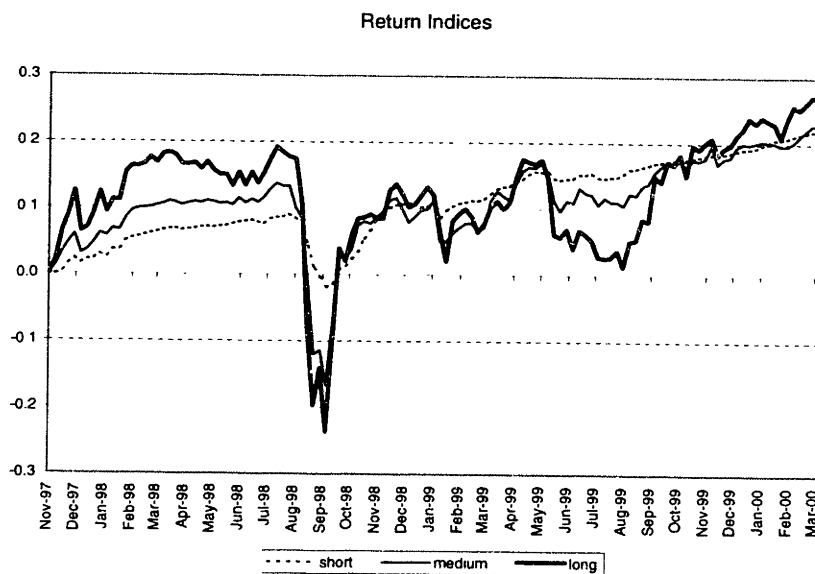
Return Indices

Figure 3-3: Return-indices of Argentine sovereign bonds at different maturities.

Figure 3-4 shows the estimated expected excess returns for bonds of different maturities, for crises of different magnitude. Each panel corresponds to different holding periods. It is clear that returns of longer maturities have higher expected excess returns and that, for

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bonds that already expired, which limits the length of our return series, especially for short maturities.

each maturity, the expected returns increase with the depth of the crisis.

However, we need to account for the possibility that the increase in excess returns be a response to an increase in volatility. Figure 3-5 plots the estimated standard deviations for each strategy. Although the figure shows that the return on long-term bonds during crises is indeed larger than that of short-term bonds, the volatility of returns does not seem to increase appreciably with the magnitude of the crisis.

Figure 3-6 illustrates how the relationship between expected excess returns and volatility changes during crises. The figure highlights a number of important points. First, even though long-term bonds have higher excess returns, this can be explained by their higher associated volatility. In other words, the Sharpe ratio (i.e. the ratio of expected excess return over its standard deviation) of long-term bonds is similar to that of short term bonds.[26] In addition, the Sharpe ratio is increasing in the magnitude of the crisis. This is consistent with investors "effective" risk-aversion increasing as they get closer to their borrowing constraints. Figure 3-7 summarizes this result by plotting the average Sharpe ratio (over different maturities) as a function of the size of the previous price drop. This figure also shows a result which we cannot explain: the Sharpe ratio increases with the holding period, at least for the range of holding periods considered here.

3.6   Concluding Remarks

In this chapter we show that in order to understand the behavior of spreads on developing country sovereign debt it is necessary to take into account the supply side of funds; in particular, the fact that spreads present a large (and highly volatile) risk-premium component.

We further show that the behavior of spreads is consistent with an environment in which bonds are held by specialists subject to liquidity shocks. After drops in bond prices (which presumably bring investors closer to their borrowing constraints), the risk-premium on emerging market bonds rises sharply. Moreover, the rise in the risk premium seems to reflect an increase in the effective risk aversion of investors as changes in the volatility of returns, which remain almost constant, cannot account for the increase in demanded excess returns.

This behavior of spreads has important implications for debt management. Since the

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[26]Namely, the points for different maturities fall approximately on a straight line through the origin.

price of long-term bonds is very volatile, investors require a higher risk-premium on them than on short-term bonds. As a result, governments can save substantially on financing costs by adapting the debt maturity structure to the liquidity needs of investors. In particular, in periods in which investors are subject to liquidity shocks, such as in times of financial turmoil, governments should try to shorten the maturity of debt. However, there is a trade-off in the choice of debt maturity, since the probability that governments will face difficulties in rolling over their debt increases with the amount of short-term bonds issued.

Further work is needed in a number of areas. First, we need to obtain longer time series for short-term bonds in order to make sure that the empirical results we present are robust. Second, we need to take into account the "peso problem," namely the fact that the spreads observed in our sample might reflect the possibility of a large crisis that is not present in our sample.[27] One way of addressing this issue is to estimate how likely (and how large) such a crisis would need to be to explain the observed spreads.[28] Third, we need to extend the model to account for the possibility of aggregate liquidity risks. And fourth, the model should have more than three periods to account for more than two debt maturities. The reason why this is important is that the roll-over difficulties associated with short-term debt are likely to fall rapidly as the maturity increases, while the price-risk associated with long-term debt is likely to fall more slowly. As a result, it seems reasonable that the optimal debt policy in episodes of crises be to issue medium-term bonds (around 4 or 5 years) rather than very short or very long-term ones.

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[27]For example, there are no episodes of default in our sample. Benczur (2000) addresses this issue by using spread data covering a much longer period.

[28]However, it seems unlikely that a peso problem could account for the difference in the behavior of short and long-term bonds, as long-term bonds are in general senior.
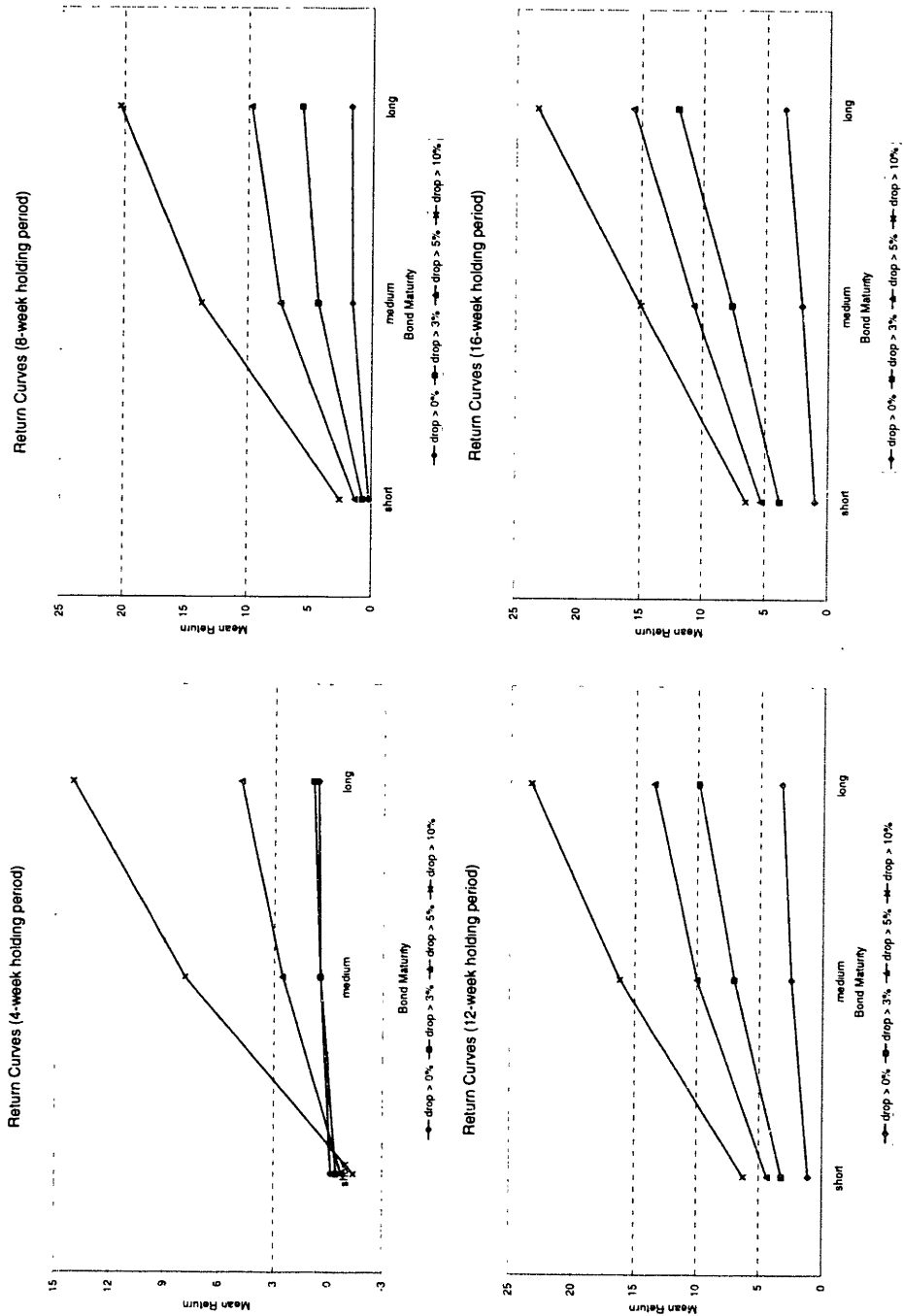
Figure 3-4: Expected excess returns on Argentine bonds during crises.
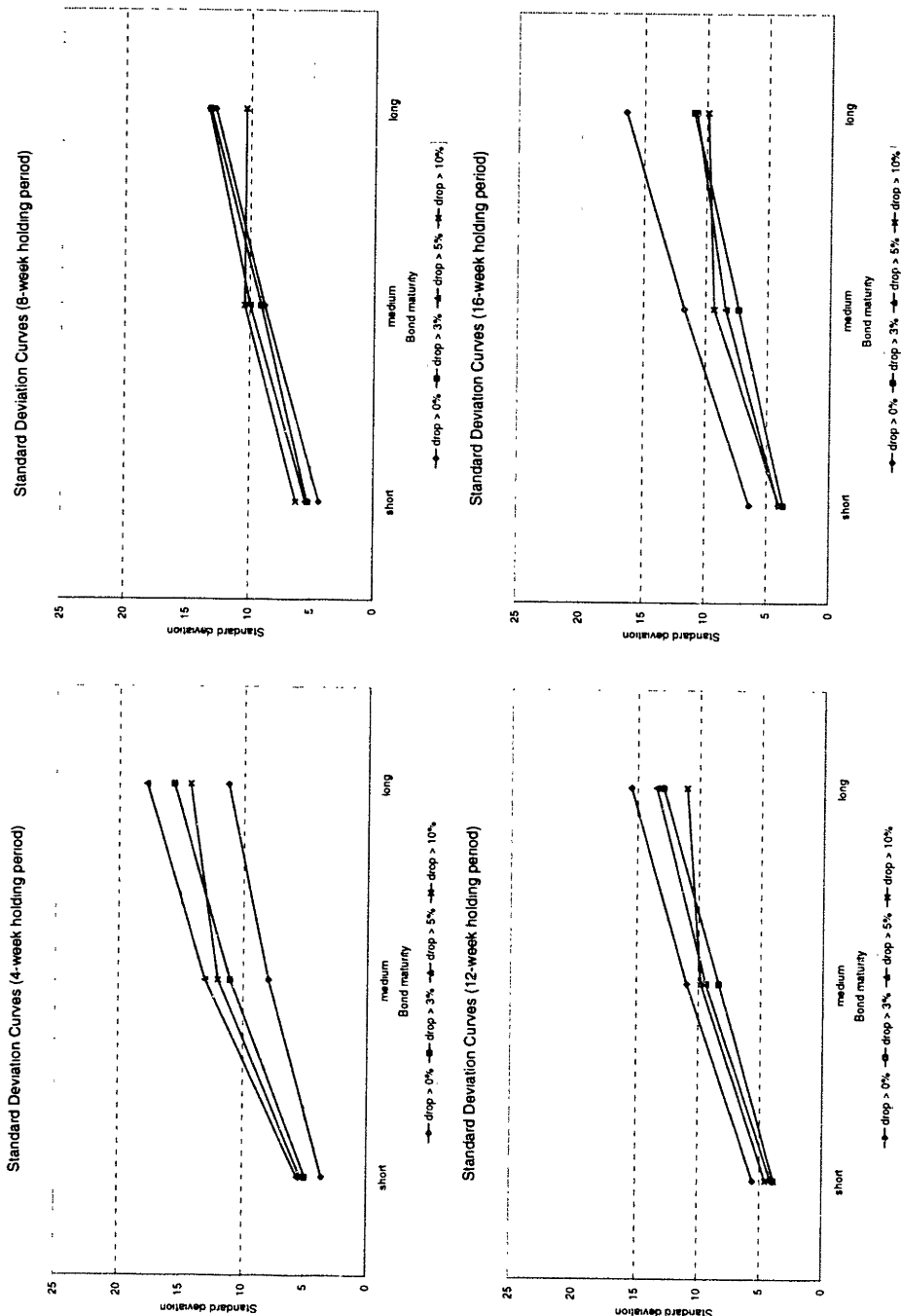
Figure 3-5: Volatility of returns on Argentine bonds during crises.
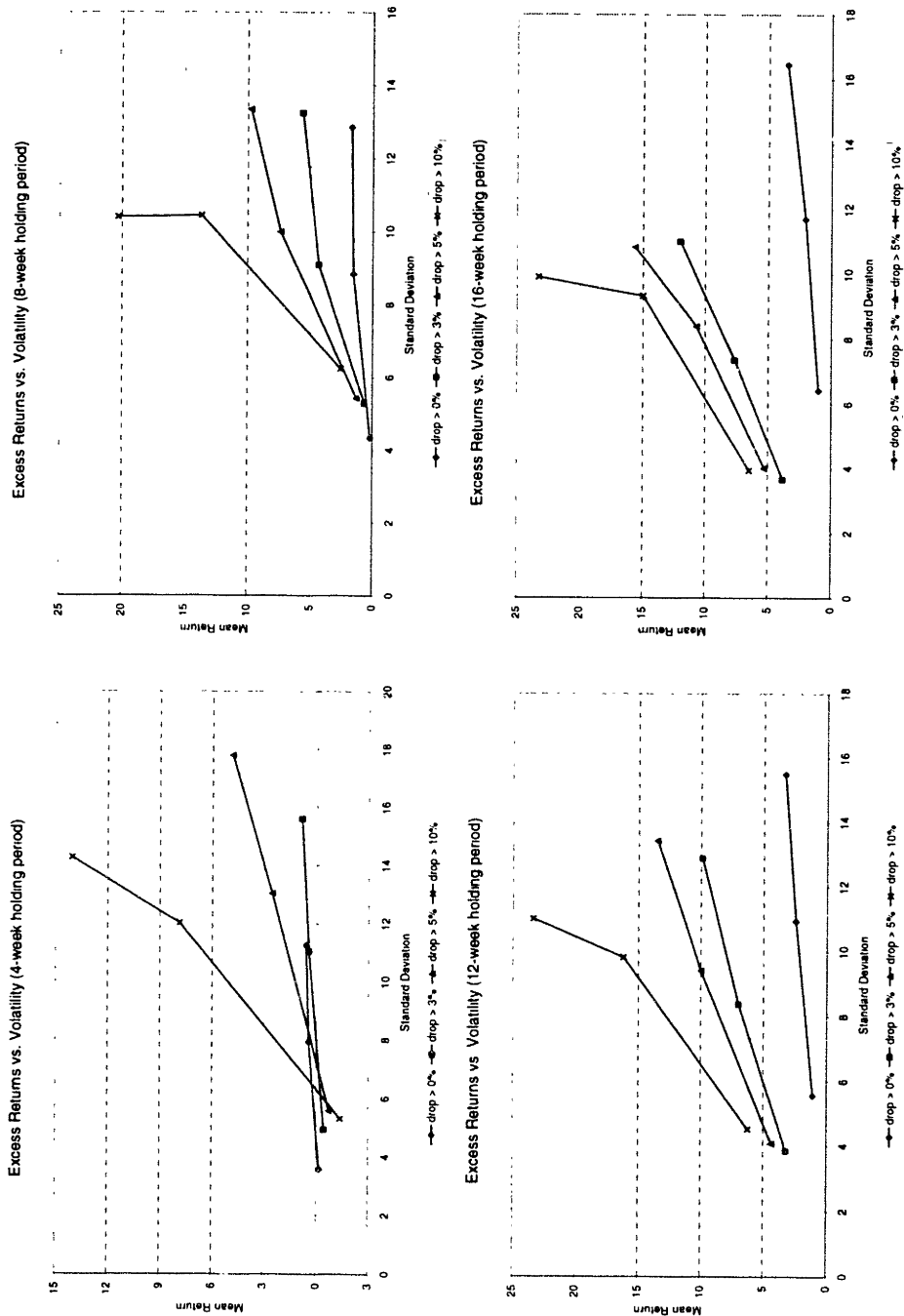
Figure 3-6: Excess returns vs. standard deviation on Argentine bonds during crises. Points farther from the origin always correspond to longer-term debt.
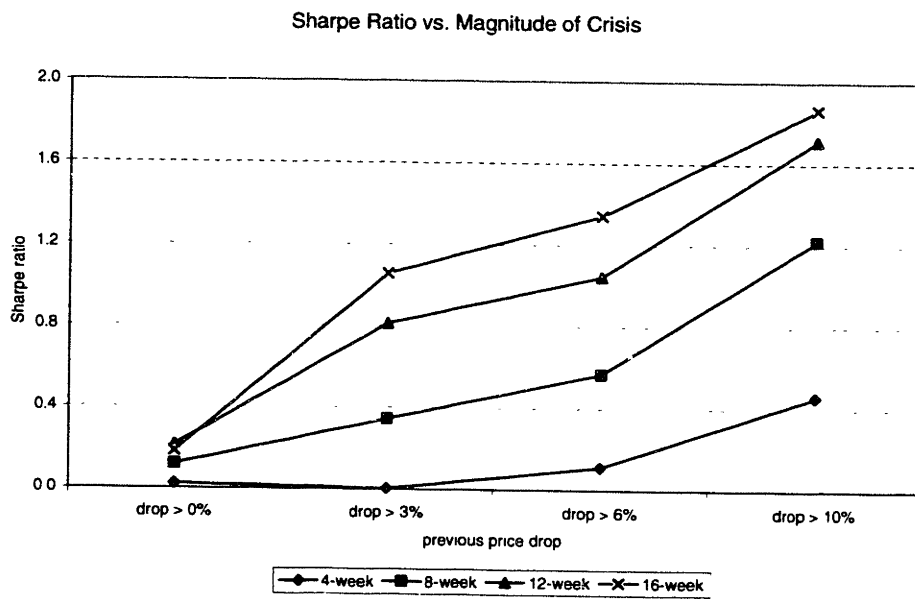
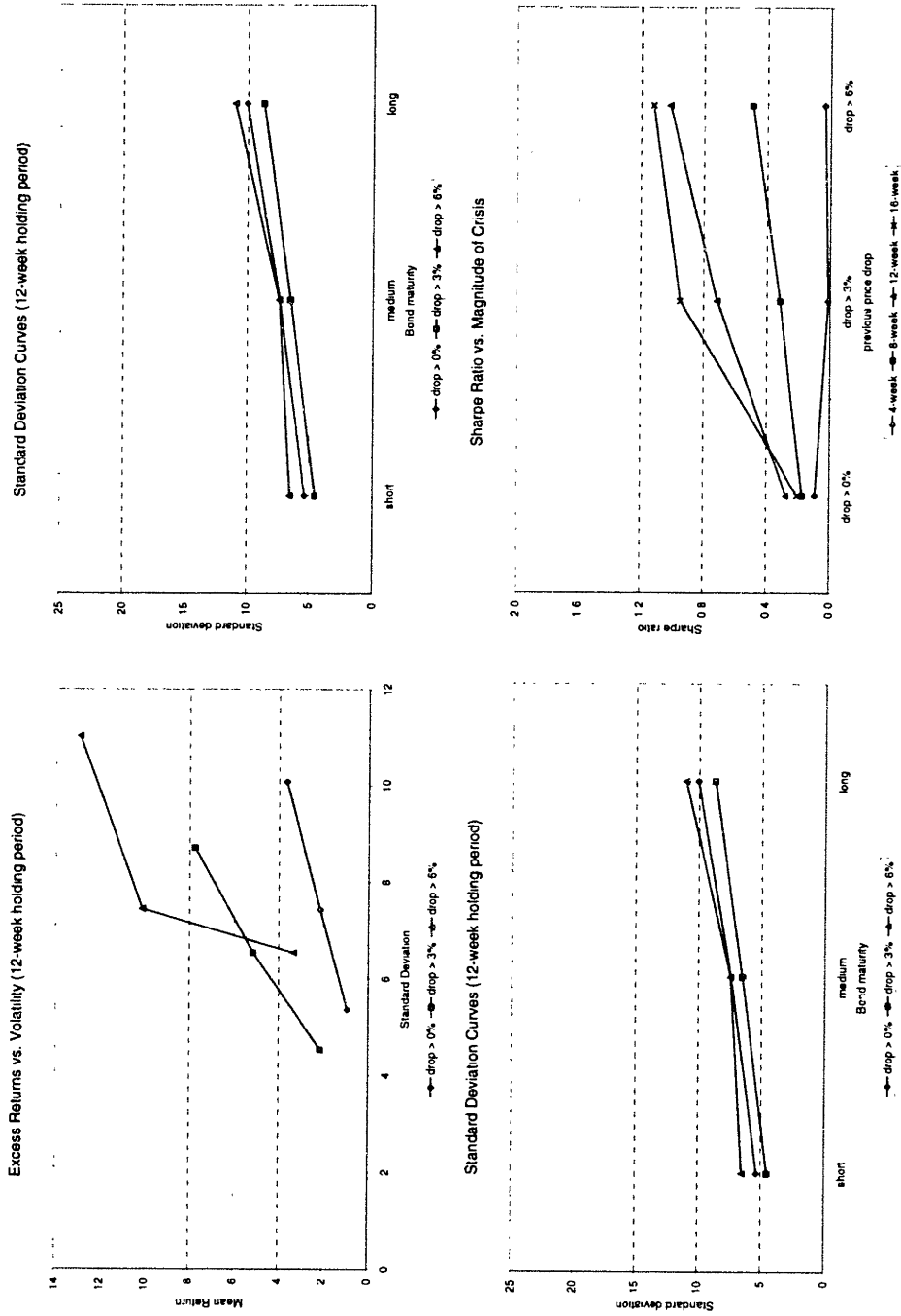Figure 3-7: Sharpe ratio on Argentine bonds as a function of previous price drops.

Figure 3-8: Returns, volatility, and Sharpe ratio on Mexican bonds.

Chapter 4

Real Exchange Rate Misalignment in Latin America (1)

4.1 Introduction

The real exchange rate (q) is one of the most important relative prices of the economy. Sustained deviations from its equilibrium level may lead to severe macroeconomic disequilibrium, whose correction "will generally require both demand management policies and a real exchange devaluation" (Edwards 1994). The success of a stabilization program is often seen as result of the proper management of the real exchange rate. The 1994 Mexican currency crisis has been blamed on a mismanaged exchange rate, that is, a policy that combined rather rigid nominal exchange rates with an expansionary monetary policy (Sachs and Tornell 1996, Edwards 1996). Other recent currency collapses, as those in East Asia (1997) and Brazil (1999) have also highlighted the importance of appropriate exchange rate management. More generally, analyzing the evidence provided by a sample of 93 countries in the period 1960-94, Goldfajn and Valdes (1996) conclude that when a currency has over-appreciated by more than 25 percent, it is highly unlikely that the currency have a smooth return. In their sample, in 90 percent of the cases that arrived to such level of misalignment, the overappreciation ended abruptly in a collapse of the currency.

Assessing the degree of misalignment is not, however, straightforward. The most commonly used method relies on the theory of relative purchasing power parity (PPP). This

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[1]This chapter is co-authored with Norman Loayza and Humberto Lopez.

theory maintains that changes in nominal effective exchange rates must compensate for the inflation differential between the country and its trading partners, implying that the equilibrium real exchange rate is constant. Measuring exchange rate misalignment according to relative purchasing power parity consists of, first, establishing (often in an *ad hoc* manner) a period when the the exchange rate was in equilibrium and, second, computing the difference between the actual real exchange rate in subsequent periods and the (constant) equilibrium (denoted $\bar{q}$); this difference is called "misalignment from parity."

The PPP approach to the study of misalignment is not acceptable given that exchange rates, as relative prices, change as its fundamental determinants change. This criticism is particularly important in periods of fiscal adjustment, structural reform, and international trade and capital openness given that the fundamental determinants of the real exchange rate are bound to change substantially under those circumstances. An exchange rate policy based on the PPP notion of equilibrium exchange rate may result in worsening external imbalances. Citing evidence provided by Aghevli, Khan, and Montiel (1991), Montiel and Ostry (1991), and Calvo, Reinhart, and Végh (1994), Faruqee (1995) points out that "efforts to stabilize an inappropriate target for the real exchange rate have sometimes lead to increased macroeconomic instability".

This paper models the equilibrium real exchange rate as the value or path consistent with both external balance, that is, a balance of payments position where any current account imbalance is compensated by a sustainable flow of international capital, and internal balance, that is, the efficient utilization of domestic capital and labor. The efficient use of domestic resources is obtained when the relative price of nontradable goods is at its equilibrium value, to which it converges gradually. The sustainable rate of capital flows is modeled following the stock-flow approach to balance of payments equilibrium presented in both the theoretical models of Mussa (1984) and Frenkel and Mussa (1985) and their empirical application presented in Faruqee (1995), MacDonald (1995a), Broner, Loayza, and Lopez (1998) and Alberola and Lopez (1999). According to this approach, the rate of sustainable capital flows is determined by the desired stock of foreign assets and liabilities among nations, given an adjustment process toward this desired stock. The real exchange rate moves to ensure both stock and flow market equilibrium, where the latter follows from the former. Under the stock-flow external balance approach, two levels of equilibrium can be distinguished: a short-run equilibrium consistent with flow equilibrium, and a long-run equilibrium con-

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sistent with stock equilibrium. By definition, actual values of the real exchange rate are identified with its short run equilibrium values, and the degree of misalignment is given by the difference between the actual and the long-run equilibrium $\bar{q}$. In what follows, the term "equilibrium" is applied only to the concept of long-run (stock) equilibrium.

According to the model presented below, the fundamental determinants of the equilibrium real exchange rate are factors that affect the net trading position of the home country in international markets and those that affect the propensity of the home country to be a net lender or borrower of capital. That is, the equilibrium real exchange rate is given by the interaction of permanent structural determinants of the current and capital accounts.

The most important factor affecting the country's net trading position are trend movements in the relative price of non-tradable goods, which to a large extent are caused by productivity-growth differentials between the tradable and non-tradable sectors (the Balassa-Samuelson effect); other factors affecting the net trading position are trend movements in the terms of trade and permanent changes in openness, whether induced by trade policy or natural market integration. On the capital account, the underlying propensity of a country to be net lender of capital is given by its saving behavior (determined by, for example, demographic factors through life-cycle effects and fiscal financing requirements in the absence of Ricardian equivalence) and by investment opportunities in the country (opportunities which can be permanently expanded by, for example, liberalization of the foreign investment regime. macroeconomic stabilization, and improvements in public infrastructure that augment private capital productivity).

The rest of the chapter is structured as follows. Section 4.2 presents an illustrative model of exchange rate determination. Section 4.3 links the concepts of economic equilibrium and cointegration for the problem under analysis. Section 4.4 studies the econometric issues involved in the estimation of the unobserved long-run equilibrium. Section 4.5 describes the data and section 4.6 presents the empirical results. Section 4.7 concludes.

4.2   The Model

As noted above, our estimation of misalignment is based on a model that accounts for both the internal and the external dimension of the economy. The model use closely resembles the one presented by Alberola and Lopez (1999) in their estimation of misalignment for the

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Spanish Peseta. To start with, we define the (log) real exchange rate (q), taking as reference the CPI:

$$q = s + p - p^*, \qquad (4.1)$$

where s is the (log) nominal exchange rate, defined as the price of the foreign currency in terms of the domestic currency and p, and p^* are the log of domestic and foreign price indices.[2] Hence, an increase in q indicates an appreciation of the real exchange rate.

Next, we express the domestic and foreign CPI indices as functions of three different types of goods, domestic traded, foreign traded, and non-traded goods[3] (superscripts T and N indicate traded and non traded respectively), so that for each country the CPI may be expressed as:

$$p = (1 - \alpha_N - \alpha_T)p_T + \alpha_N p_N + \alpha_T(p_T^* - s), \qquad (4.2)$$

$$p^* = (1 - \alpha_N^* - \alpha_T^*)p_T^* + \alpha_N^* p_N^* + \alpha_T^*(p_T + s),$$

where α_i and α_i^* (i=N,T) determine the shares of each good in the general index. Substituting these expressions in 4.1 and rearranging terms we get,

$$q = (1 - \alpha_T - \alpha_T^*)[s + p_T - p_T^*] + [\alpha_N(p_N - p_T) - \alpha_N^*(p_N^* - p_T^*)]. \qquad (4.3)$$

Equation 4.3 involves two different components in the determination of the real exchange rate: the evolution of tradable prices at home and abroad, expressed in a common currency, and the evolution of sectoral prices between countries, weighted by the corresponding share of nontradables in consumption. These terms will be denoted by q_X and q_I, respectively,

$$q_X = (p_T + s - p_T^*), \qquad (4.4)$$

$$q_I = [\alpha_N(p_N - p_T) - \alpha_N^*(p_N^* - p_T^*)],$$

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[2]In what follows, ∗ denotes a foreign variable

[3]Domestic and foreign traded goods are not perfect substitutes, and hence a price divergence may appear.

and they are associated to the external and internal dimension of the economy: q_X determines external competitiveness and therefore is associated to the evolution of the current account, and q_I influences the allocation of resources between sectors and hence, it is related to the internal equilibrium in the economy.

The equilibrium real exchange rate $(\bar{q})$ implies both internal and external equilibrium, so that it will be attained when both q_X and q_I are equilibrium: $\bar{q}_X$ and $\bar{q}_I$:

$$\bar{q} = (1 - \alpha_T - \alpha_T^*)\bar{q}_X + \bar{q}_I. \tag{4.5}$$

4.2.1   The external equilibrium real exchange rate

Excess saving over investment is reflected in a current account surplus, which implies an accumulation of net foreign assets (f). The current account balance (b) may be expressed as the trade balance (x) plus interest payments (or receipts) on the stock of net foreign assets:

$$b = x + r^* f, \tag{4.6}$$

where r^* is the real foreign interest rate. Assuming that an appreciation of the external real exchange rate $(q_X > 0)$ worsens the competitiveness of domestic products and the trade balance position, we can rewrite q_X, $x = -\gamma q_X$ $(\gamma > 0)$, which allows expressing 4.6 as:

$$b = -\gamma q_X + r^* f. \tag{4.7}$$

Following Mussa (1984), the current account balance adjusts to the difference between the current level (f) and the target level $(\bar{f})$ of net foreign assets that home residents would like to hold, so that a current account surplus reflects a net foreign asset position below the desired level:

$$b = \eta[\bar{f} - f]. \tag{4.8}$$

From these expressions it follows that:

$$q_X = \frac{\eta}{\gamma}[\bar{f} - f] + \frac{r^*}{\gamma} f. \tag{4.9}$$

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In the long run, $\bar{f} = f$ and the equilibrium external exchange rate is given by:

$$\bar{q}x = \frac{r^*}{\gamma}\bar{f}. \tag{4.10}$$

Note from 4.8 that in the long run, when agents net foreign asset positions are at their desired level, the current account balance is zero. This implies that the (equilibrium) external exchange rate is such as to generate a trade balance surplus equal to the flow of interest payments derived from the net foreign asset position.

4.2.2 The internal equilibrium real exchange rate

As noted above, the different behavior of sectoral relative prices between countries determines the evolution of the internal real exchange rate; in turn, sectoral relative prices are related to the evolution of sectoral productivity. We can illustrate the previous notions with a simple model with two production factors, labor (L) and capital (K) which are fully employed in the production of tradables and non-tradables. Output in each sector is determined by a Cobb-Douglas production technology:

$$
\begin{aligned}
Y_T &= A_T L_T^\theta K_T^{1-\theta}, \\
Y_N &= A_N L_N^\delta K_N^{1-\delta},
\end{aligned}
\tag{4.11}
$$

where θ and δ represent the labor intensity of production in each sector. Labor is assumed to be perfectly mobile between sectors, implying nominal wage equalization, $W_T = W_N = W$. Finally, labor is paid the value of its marginal product $\partial Y_i/\partial L_i = W/P_i$. Under Cobb-Douglas technology it is easy to show that the ratio of marginal productivities is proportional to the ratio of average productivities:

$$\frac{\partial Y_T/\partial L_T}{\partial Y_N/\partial L_N} = \frac{\theta Y_T/L_T}{\delta Y_N/L_N}. \tag{4.12}$$

It immediately follows that the sectoral price differential is equal to the level of sectoral productivity differentials, plus a constant term, represented by relative labor intensity. Expressing this result in logs, where y_i is the log of average productivity, we can write:

$$\bar{p}_N - \bar{p}_T = log(\theta/\delta) + [y_T - y_N]. \tag{4.13}$$

An implication of these features is that the ratio of prices of non-traded goods to traded goods is higher in countries with higher productivity levels in the traded sector. Then, neglecting constant terms, the internal equilibrium exchange rate may be expressed as

$$\bar{q}_I = [\alpha_N(\bar{p}_N - \bar{p}_T) - \alpha_N^*(\bar{p}_N^* - \bar{p}_T^*)] = \alpha_N(y_T - y_N) - \alpha_N^*(y_T^* - y_N^*), \tag{4.14}$$

or under the assumption that $\alpha_N = \alpha_N^*$ (i.e. the share of traded goods is the same in the domestic and foreign price index),

$$\bar{q}_I = \alpha_N[(\bar{p}_N - \bar{p}_T) - (\bar{p}_N^* - \bar{p}_T^*)] = \alpha_N[(y_T - y_N) - (y_T^* - y_N^*)]. \tag{4.15}$$

Finally, denoting

$$n = (p_N - p_T) - (p_N^* - p_T^*) = (y_T - y_N) - (y_T^* - y_N^*),$$

we may write the following expression for the equilibrium:

$$\bar{q}_I = \alpha_N \bar{n}.$$

4.3 Cointegration and Economic Equilibrium

In this section we link the concept of economic equilibrium to those of integration and cointegration in time series econometrics. Let's start from the equilibrium notion for the real exchange rate $(\bar{q})$ derived from the theory of relative purchasing power parity (PPP),

$$\bar{q} = \mu. \tag{4.16}$$

Obviously, in practice one is not to expect that the real exchange rate be equal to its equilibrium value at every time period. The real exchange rate (q_t) would be given by the following empirical model

$$q_t = \mu + v_t, \tag{4.17}$$

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where the element v_t captures all the stochastic properties of the real exchange rate at time t. One would expect that on average the real exchange rate be equal to its equilibrium value μ, that is,

$$E(q_t) = \mu, \tag{4.18}$$

where $E(\cdot)$ is the expectations operator. Secondly, one would expect that there is a bounded limit to the deviations of q_t from μ, that is,

$$\text{var}(q_t) = \sigma^2 < \infty. \tag{4.19}$$

This condition also ensures that when q_t at a given period is far from its equilibrium value μ there will be a tendency for q_t to approach μ in the next period.

We notice here that if v_t follows a stationary process, $I(0)$ in short, then it will satisfy conditions 4.18 and 4.19. As explained above, when those conditions are met, it makes sense to consider μ as the equilibrium value of q.

However, if v_t is better described by the following process

$$v_t = v_{t-1} + \eta_t,$$

where for simplicity η_t is white noise with zero mean and variance σ_η^2, then, it is clear that although

$$E(q_t) = \mu, \tag{4.20}$$

it is also the case that

$$\text{var}(q_t) = t\sigma_\eta^2. \tag{4.21}$$

From 4.21 it follows that as t increases the variance of q_t increases without bound, which in turn implies that q_t may drift away from μ without bound. In other words, as time goes on any value of q_t would be feasible, and therefore, there is no room to talk about equilibrium.

Variables that are not stationary in levels but are stationary in first differences are

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known as *integrated* of order 1, $I(1)$ in short. They have the characteristic of not returning to an equilibrium or mean value. Therefore, a simple test of whether PPP is an appropriate theory would be a test of whether q is better described by an $I(0)$ process or by an $I(1)$ process.

In the empirical part of the chapter, we will initially test for the PPP theory. As explained later we find that there is little evidence to reject the hypothesis that q is well represented by an $I(1)$ process, thus pointing towards a failure of PPP. Clearly, this claim does not imply that there is not an equilibrium value for the real exchange rate, but instead that this equilibrium may be time varying.

Assume for example the hypothesis highlighted by the model of the previous section,

$$\bar{q}_t = \beta_1 \bar{f}_t + \beta_2 \bar{n}_t \qquad (4.22)$$

where the bar indicates the fundamental of long-run equilibrium values of f and n. Assume also that although v_t above is $I(1)$, one could express it as

$$v_t = \beta_1 f_t + \beta_2 n_t + u_t. \qquad (4.23)$$

Neglecting the constant term μ in 4.17, the actual real exchange rate would then follow

$$q_t = \beta_1 f_t + \beta_2 n_t + u_t. \qquad (4.24)$$

Again if u_t is $I(0)$ then q will fluctuate around $\beta_1 f_t + \beta_2 n_t$, and we could accept as a sensible hypothesis that the equilibrium exchange rate is given by f and n. In such a case we would say that q, f and n are *cointegrated* with cointegration vector $[1 \ -\beta_1 \ -\beta_2]$. If on the contrary, u_t is $I(1)$ then q might shift apart without bound from the linear combination given by f and n. In such a case we would say that q, f and n are not cointegrated and that our equilibrium hypothesis fails and must be replaced.

An additional comment refers to the empirical estimation of $\bar{q}_t$, since in practice policy makers may find interesting to asses the difference between the equilibrium value $\bar{q}_t$ and the observed value q_t. If we denote the estimate of $\bar{q}_t$ by $\widehat{\bar{q}}_t$ one could be tempted to use 4.24 and compute

$$\widehat{\overline{q}}_t = \beta_1 f_t + \beta_2 n_t. \tag{4.25}$$

Observe, however that this estimate of the equilibrium real exchange rate would be based on the assumption that the observed values of both f and n are the long-run values $\overline{f}_t$ and $\overline{n}_t$, something not very appealing from an empirical point of view. A more plausible assumption is that

$$\begin{aligned} f_t &= \overline{f}_t + \hat{f}_t, \\ n_t &= \overline{n}_t + \hat{n}_t, \end{aligned} \tag{4.26}$$

where both $\hat{f}_t$ and $\hat{n}_t$ are zero mean $I(0)$ processes, and therefore, we would assume that f_t and n_t would fluctuate around the long-run values but we would not force them to be at those values permanently. Otherwise from 4.25 and 4.26 we would obtain

$$\begin{aligned} \widehat{\overline{q}}_t &= \beta_1 f_t + \beta_2 n_t \\ &= \beta_1 \overline{f}_t + \beta_2 \overline{n}_t + \beta_1 \hat{f}_t + \beta_2 \hat{n}_t \\ &= \overline{q}_t + \hat{q}_t \end{aligned} \tag{4.27}$$

where

$$\hat{q}_t = \beta_1 \hat{f}_t + \beta_2 \hat{n}_t. \tag{4.28}$$

In other words, one would obtain an estimate of the equilibrium exchange rate that would fluctuate around the actual value $\overline{q}$ and clearly, the assessment of the degree of misalignment could be misleading. Below we will take into account this point in order to compute the estimates of $\overline{q}_t$.

We want to finish this section with a warning. If PPP holds and one finds that the real exchange rate is overvalued by say 10 percent, one would expect the real exchange rate to fall in the near future by this 10 percent. Time varying equilibria add the problem of future developments in the determinants of $\overline{q}$ (in our case f and n). For example, a consistent finding would be that a currency at time t is undervalued (and thus one would expect it to appreciate); in $t+1$ the observed real exchange rate remains unchanged and yet one finds that in $t+1$ is overvalued. A possible reason for this finding is that the long-run value of the controlling variables has changed. Therefore, with a time-varying equilibrium

one would have to infer not only the likelihood of a movement due to the misalignment at time t, but also the possibility of changes in the long-run equilibrium values at time $t + 1$. In consequence, the degree of misalignment at a given time period may give only relative information on the misalignment in the next period. By the same token, a currency which is showing a sustained appreciation (depreciation) could still be undervalued (overvalued).

4.4 Estimation and Inference

In this section we review the econometric methodology used for the identification and estimation of the exchange rate long-run equilibrium and corresponding misalignment. As noted in the previous section, a necessary condition for the existence of a long run equilibrium between the real effective exchange rate, the stock of net foreign assets, and the relative price of nontradable goods is the existence of a cointegration vector linking the long-run dynamics of the series. In addition, finding that the real exchange rate is well represented by an integrated process of order 1, $I(1)$, would imply that the empirical evidence rejects the PPP theory. Since integration and cointegration techniques have been widely explored in the econometrics literature, we will just concentrate on the estimation of the equilibrium ($\bar{q}$) and disequilibrium components ($\hat{q}$) on the basis of the observed variables.

An additional theoretical issue in this section refers to the estimation of the time varying equilibrium real exchange rate. As noted in the previous section, using the cointegration vector and the observed values of the explanatory variables may lead to misleading results since the estimate is likely to differ from the actual value $\bar{q}$ due to the presence of transitory components in both f and n. The situation studied here is analogous to the decomposition of economic time series into permanent and transitory components. The permanent components would capture the long-run behavior of the system, whereas the transitory components would capture the temporary deviations of the observed variables from the long-run or fundamental values.

The natural question that now arises is how estimate these unobserved components. Unfortunately, there is not a unique decomposition between permanent and transitory components. (See Maravall (1993) for the theoretical issues involved in the identification of permanent and transitory components. Also see, among others, Quah (1992), Kasa (1992) and Gonzalo and Granger (1995) for different decompositions.) Notice that since differ-

ent decompositions rely on different econometric restrictions the results are likely to differ among them.

Here we follow Gonzalo and Granger (1995) decomposition since unlike other approaches, it allows to clearly isolate shocks to the transitory (or misalignment) component from shocks to the permanent (or equilibrium) component. In fact, the basic identifying restrictions of their decomposition are that the transitory components do not Granger-cause the permanent components in the long run and that the permanent components are a linear combination of contemporaneous observable variables. In other words, the first restriction implies that a change in the transitory component today, will not affect the fundamental or long-run values of the variables. The second restriction makes the permanent component observable and assumes that the contemporaneous observations contain all the necessary information to extract the permanent component.

Specifically assume that $x_t = [q_t \ f_t \ n_t]$ admits the following representation:

$$\Delta x_t = \Delta D_1 x_{t-1} + \cdots + \Delta D_{p-1} x_{t-p+1} + \Pi x_{t-p} + e_t, \qquad (4.29)$$

where e_t is a vector white noise process with zero mean and variance Σ. Moreover, assume the existence of a cointegration vector (i.e. an indication of a long-run equilibrium among the three variables under analysis). In this case, Π would be of rank 1 and can be written as the product of two rectangular matrices α (the matrix of loading factors) and β (the matrix of cointegration vectors) of order 3×1 such that $\Pi = \alpha \beta'$.

Given the matrices of loading factors α and of cointegrating vectors β, one can always define the orthogonal complements $\alpha_\perp$ and $\beta_\perp$ as the eigenvectors associated with the unit eigenvalues of the matrices $(I - \alpha(\alpha'\alpha)^{-1}\alpha')$ and $(I - \beta(\beta'\beta)^{-1}\beta')$ respectively. Observe that $\alpha'_\perp \alpha = 0$ and $\beta'_\perp \beta = 0$. With this notation it is possible to write

$$x_t = \beta_\perp (\alpha'_\perp \beta_\perp)^{-1} \alpha_\perp x_t + \alpha(\beta'\alpha)^{-1} \beta' x_t, \qquad (4.30)$$

where the permanent and transitory components are captured by the terms $\beta_\perp (\alpha'_\perp \beta_\perp)^{-1} \alpha_\perp x_t$ and $\alpha(\beta'\alpha)^{-1} \beta' x_t$ respectively. Gonzalo and Granger show that the transitory components defined in this way will not have any effect on the long-run value of the variables captured by the permanent components.

In other words, the (3×1) vector $\beta_\perp (\alpha'_\perp \beta_\perp)^{-1} \alpha_\perp x_t$ will capture the long-run equilib-

rium values of the three variables in x_t whereas the vector $\alpha(\beta'\alpha)^{-1}\beta'x_t$ will capture the disequilibrium values.

4.5 The Data

We estimate equilibrium real exchange rates for a sample of seven Latin American countries, namely, Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela and the US. In the estimation process, we use average annual data for the period 1960 to 1996. We also use preliminary figures of the relevant variables for 1997 and 1998 in order to obtain a preliminary estimate of the degree of misalignment at those dates.

Real Exchange Rate (q):

For the real exchange rate, we use a CPI-based index of the real effective exchange rate. Then q was constructed as follows,

$$q = \frac{(CPI/e)}{\Pi_i(CPI_i/e_i)^{\delta_i}} \tag{4.31}$$

where CPI is the domestic consumer price index, e is the domestic-currency price of one U.S. dollar, CPI_i and e_i are the corresponding series of the home country's trading partners, and δ_i are the respective trade shares. According to this definition, an increase in q means a real appreciation of the domestic currency. Following common practice, we use the natural logarithm of q in the estimation process.

Relative Price of Nontradable Goods (n):

We use a comparative index of the relative price of nontradable versus tradable goods. Specifically, this comparative index consists of the domestic ratio of the consumer price index (CPI) to the whole sale price index (WPI) relative to the corresponding ratio of the home country's trading partners. The ratio of CPI to WPI is an increasing function of the relative price of nontradable goods given their larger share (mainly services) in the consumer price index. The n series was constructed as follows:

$$n = \frac{(CPI/WPI)}{\Pi_i(CPI_i/WPI_i)^{\delta_i}} \tag{4.32}$$

We use the natural logarithm of n in the estimation process.

Observe however, that using this variable one might expect to find a parameter β_2 close to 1 in the estimated regressions. To better understand this point, notice that rewriting p in terms of the non-traded price index and the wholesale price index (denoted p_w), which includes both domestic and foreign traded goods, we get

$$p = \alpha_N p_N + (1 - \alpha_N)p_w,$$

and after rearranging

$$p - p_w = \alpha_N(p_N - p_w).$$

In this regard, if the wholesale price indices mostly reflect domestically produced traded goods (i.e. if $p_w = p_T$ and $p_w^* = p_T^*$), it will follow that $(p - p_w) - (p^* - p_w^*) = \alpha_N n = q_I$.

Net Foreign Assets (NA):

The change in the net foreign asset position (NA) for each country is obtained by adding up the current account balances (CAB). However, to obtain the stock of NA at a given time period we need a value of initial assets, which is not available but for Venezuela and the US. Instead, we estimate it for the remaining countries using the following reasoning. Net foreign income at time t (NI_t) is given by

$$\begin{aligned}
NI_t = i_t NA_t &= i_t(NA_0 + \sum_{s=1}^{t} CAB_s) \\
&= i_t NA_0 + i_t(\sum_{s=1}^{t} CAB_s) \\
&= i_t NA_0 + i_t ACAB_t,
\end{aligned} \tag{4.33}$$

where i_t is the average effective interest rate paid or received on NA at time t. Equation 4.33 is the basis to estimate the initial value NA_0. If i_t was observed, then one could obtain immediately the value of NA_0. Unfortunately, i_t is not observed and therefore, we will try to jointly estimate i_t and NA_0 by imposing some restrictions. Our first restriction is that $i_t = i$ in a given period t. Clearly, for the estimation results to make sense one would expect that this restriction is satisfied, something that during the late 1970s and 1980s is not realistic. Thus, the span where our restriction could be acceptable is very limited (the

1960s) and, consequently, the results of the estimation would not be efficient (accurate). An additional problem is that the sample of NI does not cover the whole decade of the 1960s for all the countries. The first observation of NI corresponds to 1965 for Argentina and Chile, 1966 for Brazil, 1967 for Mexico, 1968 for Colombia and Venezuela, and 1969 for Peru. Thus if we attempted the estimation on a country by country basis, even if we span up to 1972, we would be using sample sizes that would range from 4 to 8 observations. We try to overcome this problem by imposing an additional restriction: the interest rate for all the countries in our sample is the same. This allow us to estimate a panel of 7 countries with fixed effects: the starting date for each country is the first available observation for NI and the final date 1972. Formally, we estimate

$$NI_{tj} = \gamma_j + \beta ACAB_{tj} + \eta_{tj}, \tag{4.34}$$

where t is a time index, j is a country index, and η_{tj} is an error term. Observe that $\beta = i$ and $NA_{0j} = \gamma_j/\beta$. Thus an estimate of NA_{0j} may be obtained by replacing the unknown parameters with consistent estimates.

Table 4.1 contains the results of the OLS estimation of 4.34. All the estimates are significant, and the values are sensible. Moreover, the estimated interest rate (7 percent) seems acceptable. The R^2 of the regression is .86. GLS and IV estimation of the same model, produced basically unchanged results but the R^2 was lower in the latter cases. Thus we proceed to compute the stock of net of foreign assets, using as initial condition $\widehat{NA_{0j}}$. In the empirical application below, in order to control for the size of the economy, we will use the ratio of NA to the GNP and will denote this ratio by f.

4.6 Results

Tables 4.2 through 4.9 report the results of the Johansen tests for the 8 countries under analysis in this chapter as well as the results of the stationarity tests for each of the variables. We also test exclusion restrictions for each of the variables in the cointegration vector. Observe that stationarity of q would imply that the PPP holds. Observe also that the rejection of the existence of at least a cointegration vector leads to the rejection of the PPP.

Each table reports the number of lags used in the VAR estimation. With these orders for the VARs none of the residuals present problems of serial correlation. The tables also

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report the value of the eigenvalues used in the calculation of the tests, the Trace test and the λ-max test together with the corresponding five and ten percent critical values.

The main results are the following. For all the countries there is evidence of the presence of one and only one cointegration vector. The coefficients of all the cointegration vectors have the right sign and the magnitudes are sensible, although changes in f affect in different ways to different countries. For example, while a change of ten percent in the long run value of f leads to a change of twenty percent in the values of q in Argentina and around twenty seven percent in Colombia, it leads to a change of five percent in Brazil, about seven percent in Peru and Chile and less than three percent in Mexico, Venezuela and the US. Thus, the most sensitive countries to changes in the value of f are Argentina and Colombia with changes of around 2 to 1 with respect to f, whereas the other countries present changes of less than 1 to 1. Notice also that for Mexico the exclusion test is not able to reject the null hypothesis of a zero value for the parameter of f.

Next we proceed to the estimation of the misalignment $q - \bar{q}$. Figures 4-1 through 4-8 plot the estimated misalignment (values above the 0 line indicate an overvaluation whereas values below zero an under valuation) for the different countries in our sample. We also present 95 percent confidence bands for the estimated deviations from the equilibrium. The appendix gives details on the computation of these bands.

Inspection of these figures suggests that in 1998 there were only two real exchange rates below their equilibrium values (i.e. undervalued). For Chile we estimate the undervaluation at 9 percent (s.e. 4.8) and for Peru at 3 percent (s.e. 4.8). However, judging from 95 percent confidence bands, the Chilean currency might be undervalued by as much as 19 percent or instead overvalued by about 1 percent. For Peru, the same band would cover a range going from an undervaluation of 18 percent to an overvaluation of about 6 percent.

For the rest of the countries, in 1998 we estimate an overvaluation that ranges from 8 percent in Venezuela to 26 percent in Colombia. Observe also that the point estimate for the US dollar in 1998 indicate an overvaluation of about 16 percent, with a 95 percent confidence band of $(6, 26)$. Specifically, we find that the Argentine Peso would be overvalued by about 24 percent, the Brazilian Real by about 26 percent, and the Mexican Peso by about 22 percent. Although for those currencies presenting an overvaluation by more than 20 percent the accuracy of the estimates differ largely (the s.e range from 2.74 for Mexico to 11.30 for Brazil), they are all significantly different from zero. Table 4.10 summarizes the

results presented in this section.

4.7 Conclusions

The main objective of this chapter is to assess the degree of real exchange rate misalignment in, respectively, Argentina, Brazil, Colombia, Mexico, Peru, Venezuela and the US in the period from 1960 to 1998. This is done by estimating a path for the (long-run) equilibrium real exchange rate based on the cointegrating relationship it has with its fundamental determinants. We follow a model in which the equilibrium real exchange rate is the value consistent with both a balance of payments position where any current account imbalance is compensated by a sustainable flow of international capital (external equilibrium) and the efficient use of domestic resources (internal equilibrium). The rate of sustainable capital flows is in turn determined by the desired stock of foreign assets and liabilities among nations, given an adjustment process towards this desired stock. The efficient use of domestic resources is obtained when the relative price of nontradable goods is at its equilibrium value, to which it converges gradually. Guided by this model, we use as fundamental determinants of the equilibrium real exchange rate the stock of net foreign assets and the relative price of nontradable goods.

We find that, for all countries, the real exchange rate exhibits a unit root, which constitutes evidence against the theory of relative purchasing power parity. Furthermore, we find that for all countries, there exists a single cointegrating relationship between the real exchange rate and its fundamental determinants. Under the assumption that movements in the transitory components of the variables in the model do not affect their long-run components, we use the cointegrating relationship to estimate (long-run) equilibrium values for the real exchange rate.

Regarding the degree of misalignment in 1998, our results suggest that in Chile the real exchange rate would be undervalued by about 9 percent, in Peru the real exchange rate would be basically in equilibrium; in Venezuela the exchange rate would be slightly overvalued (less than 10 percent); in the US overvalued by 10 to 20 percent and in the remaining countries by more than 20 percent.

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4.8 Appendix

To derive the asymptotic distribution of $\hat{C}_t$,

$$\hat{C}_t = \hat{\alpha}(\hat{\beta}'\hat{\alpha})^{-1}\hat{\beta}'x_t,$$

observe that conditional on x_t the only source of variation could arise from $\hat{\alpha}$ and $\hat{\beta}$.

Next notice that a first order expansion of $\hat{C}_t$ around α and β yields

$$\hat{C}_t - C_t = \partial C_t/\partial\alpha'(\hat{\alpha} - \alpha) + \partial C_t/\partial\beta'(\hat{\beta} - \beta) + O_p(T^{-1})$$

and

$$T^{1/2}(\hat{C}_t - C_t) = \partial C_t/\partial\alpha' T^{1/2}(\hat{\alpha} - \alpha) + \partial C_t/\partial\beta' T^{1/2}(\hat{\beta} - \beta) + O_p(T^{-1/2}).$$

Notice also that since $\hat{\beta}$ is T consistent,

$$T^{1/2}(\hat{\beta} - \beta) \xrightarrow{p} 0,$$

and therefore we can write,

$$T^{1/2}(\hat{C}_t - C_t) = \partial C_t/\partial\alpha' T^{1/2}(\hat{\alpha} - \alpha) + o_p(1).$$

Thus, all the variation of $\hat{C}_t$ arises from $\hat{\alpha}$. Tedious but straightforward matrix algebra yields

$$\partial C_t/\partial\alpha' = -C_t(\beta'\alpha)^{-1}\beta' + (\bar{\alpha}'C_t \otimes I_N) = Z,$$

where $\bar{\alpha} = \alpha(\alpha'\alpha)^{-1}$, $\otimes$ is the Kronecker product and I_N is an identity matrix of order N. We therefore, can write

$$T^{1/2}(\hat{C}_t - C_t) = ZT^{1/2}(\hat{\alpha} - \alpha) + o_p(1),$$

or

$$T^{1/2}(\hat{C}_t - C_t) = ZZ_1 T^{1/2}(\hat{\Pi} - \Pi) + o_p(1),$$

where $Z_1 = (\bar{\beta}' \otimes I_N)$, with $\bar{\beta} = \beta(\beta'\beta)^{-1}$. The asymptotic distribution of $T^{1/2}(\hat{\Pi} - \Pi)$ is known to be Normal with variance Σ_π (see Lutkepohl (1993) for the form of Σ_π). This implies that $\hat{C}_t$ will also be asymptotically normal and therefore,

$$T^{1/2}(\hat{C}_t - C_t) \stackrel{a}{\sim} N(0, ZZ_1\Sigma_\pi Z_1' Z').$$

Table 4.1: Net Foreign Asset Estimation

COUNTRY	$\hat{\gamma}_j$	t-st	$\hat{\beta}$	t-st	NA_{0j}	$t-st$
ARGENTINA	-265.9	-8.9	.068	5.0	-3853.3	-4.6
BRAZIL	-338.7	-8.3	.068	5.0	-4913.4	-3.4
CHILE	-146.9	-4.9	.068	5.0	-2130.9	-3.2
COLOMBIA	-109.0	-2.8	.068	5.0	-1581.6	-2.2
MEXICO	-300.1	-6.0	.068	5.0	-4352.6	-2.9
PERU	-149.9	-3.6	.068	5.0	-2174.5	-2.9

Table 4.2: Johansen Cointegration Tests

	λ_i	Trace-test	λ_{max}-test	5% cv T	5% cv λ	10% cv T	10% cv λ
ARGENTINA, VAR(3)
$r \leq 2$	.01	.42	.42	8.18	8.18	6.50	6.50
$r \leq 1$	.15	5.87	5.45	17.95	14.90	15.66	12.91
$r = 0$	.46	26.98	21.10^a	31.52	21.07	28.71	18.90

(a) Significance at 5%. (b) Significance at 10%

q=2.09f+.79n

Stationarity Tests (cv 5.99) q:27.23. f:37.06. n:40.08.

Exclusion Tests (cv 3.84) q:32.90. f:20.44. n:24.74.

Table 4.3: Johansen Cointegration Tests

	λ_i	Trace-test	λ_{max}-test	5% cv T	5% cv λ	10% cv T	10% cv λ
BRAZIL, VAR(2)
$r \leq 2$	.07	2.40	2.40	8.18	8.18	6.50	6.50
$r \leq 1$	.17	8.92	6.51	17.95	14.90	15.66	12.91
$r = 0$	.44	28.99^b	20.07^b	31.52	21.07	28.71	18.90

(a) Significance at 5%. (b) Significance at 10%

q=.53 f+.85n

Stationarity Tests (cv 5.99) q:33.65. f:33.95. n:36.93.

Exclusion Tests (cv 3.84) q:27.49. f:3.29. n:21.65.

Table 4.4: Johansen Cointegration Tests

	λ_i	Trace-test	λ_{max}-test	5% cv T	5% cv λ	10% cv T	10% cv λ
CHILE, VAR(3)
$r \leq 2$	.07	2.26	2.26	8.18	8.18	6.50	6.50
$r \leq 1$	.28	13.49	11.23	17.95	14.90	15.66	12.91
$r = 0$	.50	37.31^a	23.81^a	31.52	21.07	28.71	18.90

(a) Significance at 5%. (b) Significance at 10%

q=.67f+.65n

Stationarity Tests (cv 5.99) q:46.54. f:35.34. n:46.60.

Exclusion Tests (cv 3.84) q:11.94. f:23.29. n:5.23.

Table 4.5: Johansen Cointegration Tests

COLOMBIA, VAR(2)							
	λ_i	Trace-test	λ_{max}-test	5% cv T	5% cv λ	10% cv T	10% cv λ
$r \leq 2$	.05	1.99	1.99	8.18	8.18	6.50	6.50
$r \leq 1$	.13	4.94	4.94	17.95	14.90	15.66	12.91
$r = 0$	.50	31.64^a	24.70^a	31.52	21.07	28.71	18.90
(a) Significance at 5%. (b) Significance at 10%							
q=2.77f+1.00n							
Stationarity Tests (cv 5.99) q:42.96. f:29.82. n:46.27.							
Exclusion Tests (cv 3.84) q:24.57. f:40.56. n:11.27.							

Table 4.6: Johansen Cointegration Tests

MEXICO, VAR(2)							
	λ_i	Trace-test	λ_{max}-test	5% cv T	5% cv λ	10% cv T	10% cv λ
$r \leq 2$	.00	.02	.02	8.18	8.18	6.50	6.50
$r \leq 1$	.25	10.03	10.08	17.95	14.90	15.66	12.91
$r = 0$	.52	35.97^a	25.44^a	31.52	21.07	28.71	18.90
(a) Significance at 5%. (b) Significance at 10%							
q=.06f+1.58n							
Stationarity Tests (cv 5.99) q:41.54. f:52.79. n:46.23.							
Exclusion Tests (cv 3.84) q:28.79. f:.07. n:25.61.							

Table 4.7: Johansen Cointegration Tests

PERU, VAR(1)							
	λ_i	Trace-test	λ_{max}-test	5% cv T	5% cv λ	10% cv T	10% cv λ
$r \leq 2$	.01	.58	.58	8.18	8.18	6.50	6.50
$r \leq 1$	.22	9.25	9.25	17.95	14.90	15.66	12.91
$r = 0$	.47	32.41^a	22.57^a	31.52	21.07	28.71	18.90
(a) Significance at 5%. (b) Significance at 10%							
q=.74f+1.01n							
Stationarity Tests (cv 5.99) q:34.34. f:17.25. n:40.99.							
Exclusion Tests (cv 3.84) q:17.03. f:18.69. n:15.32.							

Table 4.8: Johansen Cointegration Tests

VENEZUELA, VAR(2)							
	λ_i	Trace-test	λ_{max}-test	5% cv T	5% cv λ	10% cv T	10% cv λ
$r \leq 2$	.07	2.81	2.81	8.18	8.18	6.50	6.50
$r \leq 1$	.10	6.66	3.84	17.95	14.90	15.66	12.91
$r = 0$	.44	27.47	20.81^b	31.52	21.07	28.71	18.90
(a) Significance at 5%. (b) Significance at 10%							
q=.17f+2.86n							
Stationarity Tests (cv 5.99) q:36.06. f:35.61. n:35.57.							
Exclusion Tests (cv 3.84) q:32.24. f:14.26. n:35.47.							

Table 4.9: Johansen Cointegration Tests

US, VAR(2)							
	λ,	Trace-test	λ_{max}-test	5% cv T	5% cv λ	10% cv T	10% cv λ
$r \leq 2$	.05	1.97	1.97	8.18	8.18	6.50	6.50
$r \leq 1$	.12	6.55	4.58	17.95	14.90	15.66	12.91
$r = 0$	.55	34.75^a	28.20^a	31.52	21.07	28.71	18.90
(a) Significance at 5%. (b) Significance at 10%							
q=.23f+1.58n							
Stationarity Tests (cv 5.99) q:44.32. f:52.24. n:49.54.							
Exclusion Tests (cv 3.84) q:49.53. f:22.63. n:34.73.							

Table 4.10: Results Summary Table

| Country	Misalignment %				Accuracy	Misalignment Characteristics
	95	96	97	98		
Argentina	-2	4	16	24	High	Large swings Large Overappreciation in 1998
Brazil	19	19	24	25	Medium	Many swings Large Overappreciation
Chile	-14	-9	-7	-8	Medium	Polonged Transitions $\bar{q}$ leads q
Colombia	-17	-6	16	26	Medium	$\bar{q}$ leads q
Mexico	-10	5	23	21	Medium	Important since 80s Large Overappreciation in 1998
Peru	-2	-1	-5	-3	Low	Prolonged Transitions
Venezuela	21	11	12	8	Medium	Important since 80s
US	-7	-1	7	16	Medium	Overappreciation in the early 80s and late 90s

Degree of Misalignment: Argentina
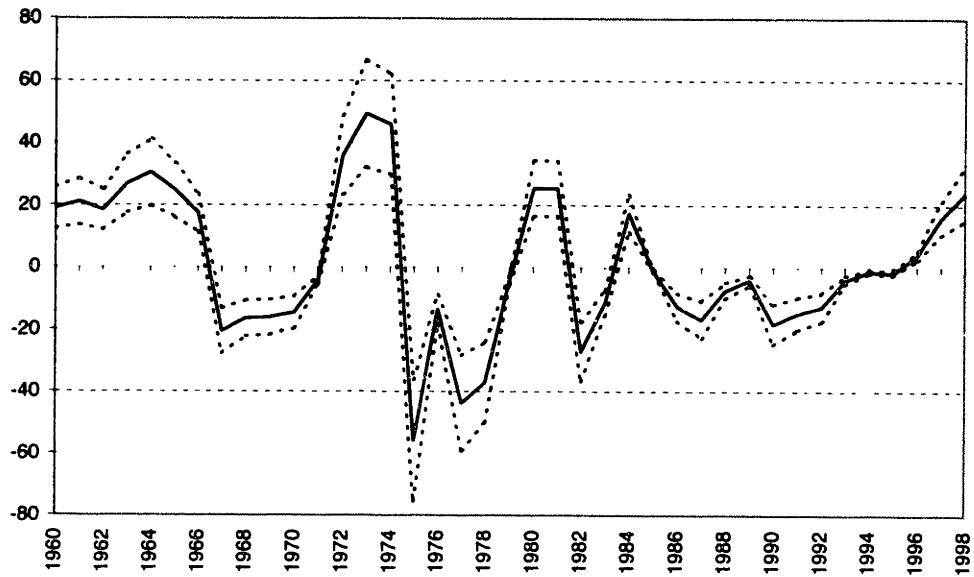
Figure 4-1: REER Misalignment in Argentina. Dashed lines show 95% confidence band.
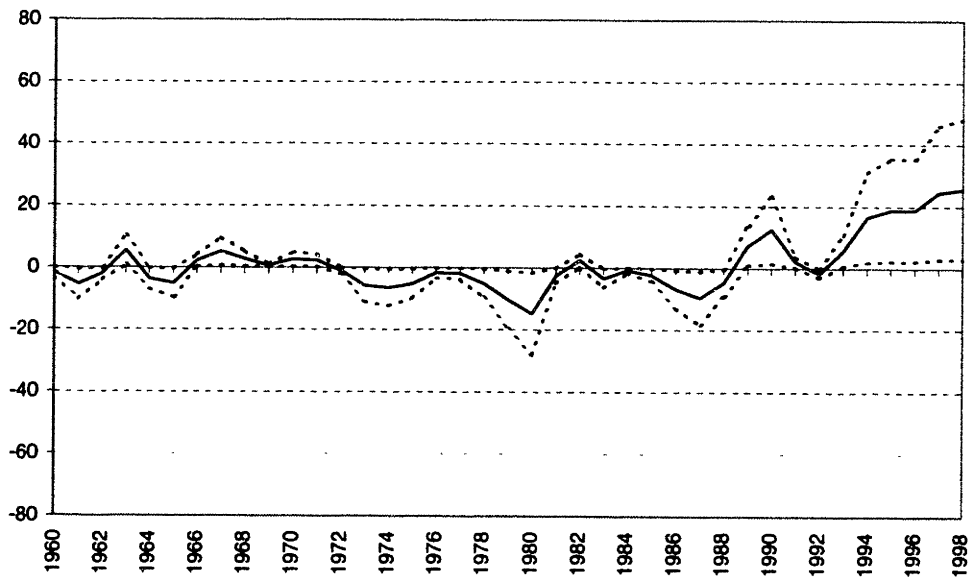
Degree of Misalignment: Brazil

Figure 4-2: REER Misalignment in Brazil. Dashed lines show 95% confidence band.
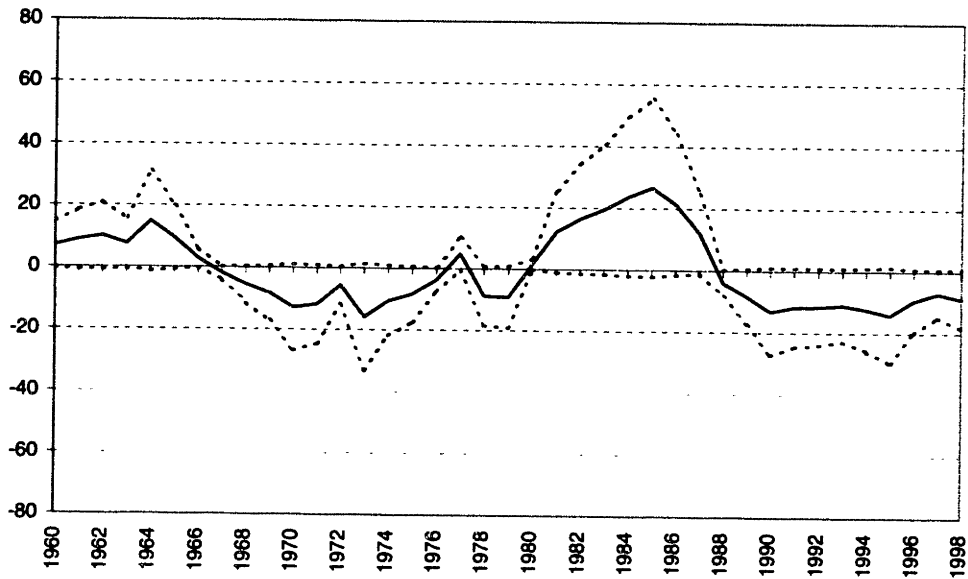
Degree of Misalignment: Chile

Figure 4-3: REER Misalignment in Chile. Dashed lines show 95% confidence band.
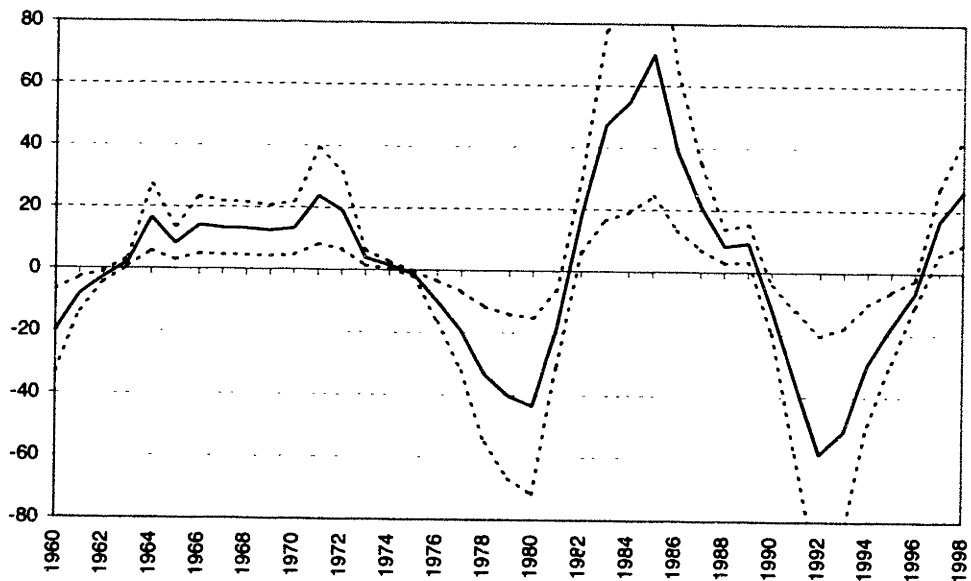
Degree of Misalignment: Colombia

Figure 4-4: REER Misalignment in Colombia. Dashed lines show 95% confidence band.
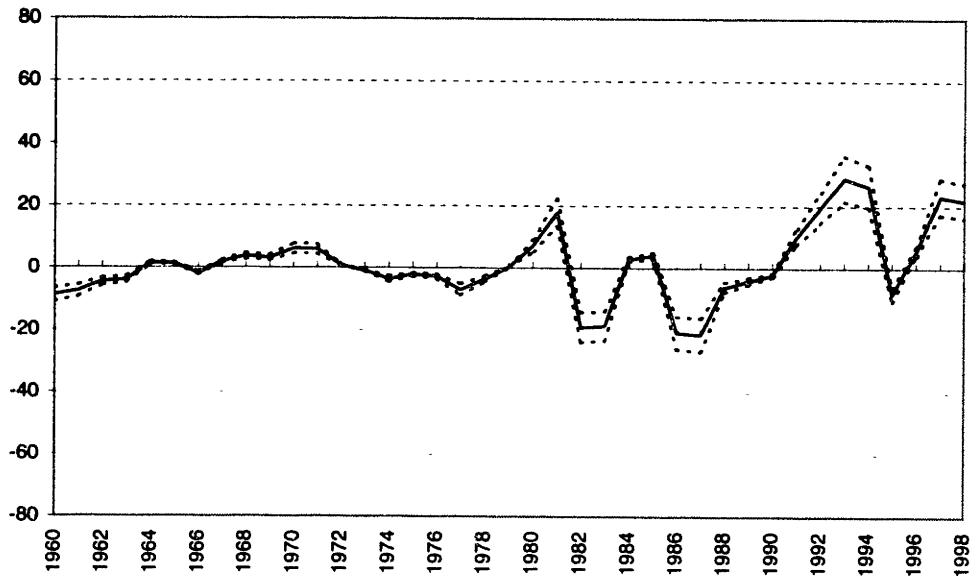
Degree of Misalignment: Mexico

Figure 4-5: REER Misalignment in Mexico. Dashed lines show 95% confidence band.
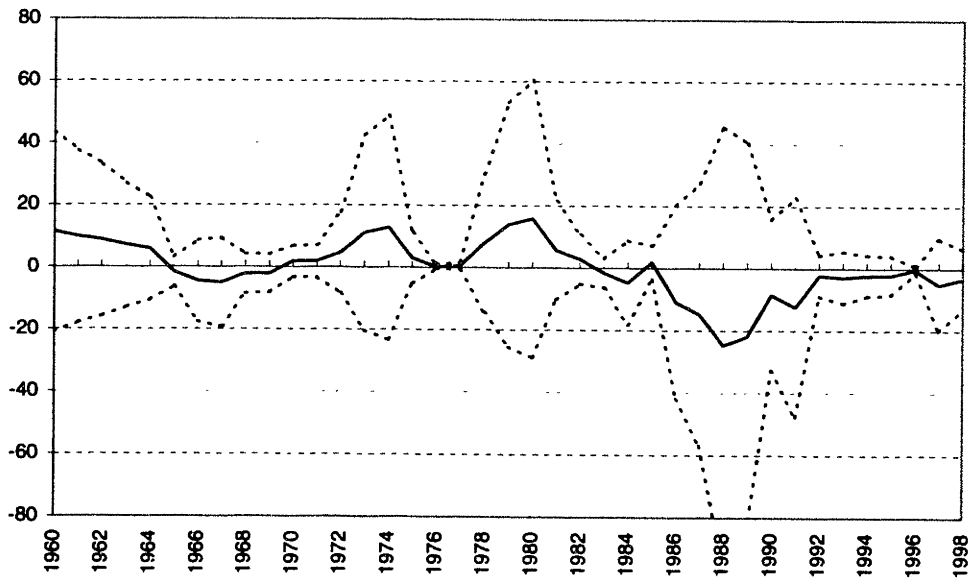
Degree of Misalignment: Peru

Figure 4-6: REER Misalignment in Peru. Dashed lines show 95% confidence band.
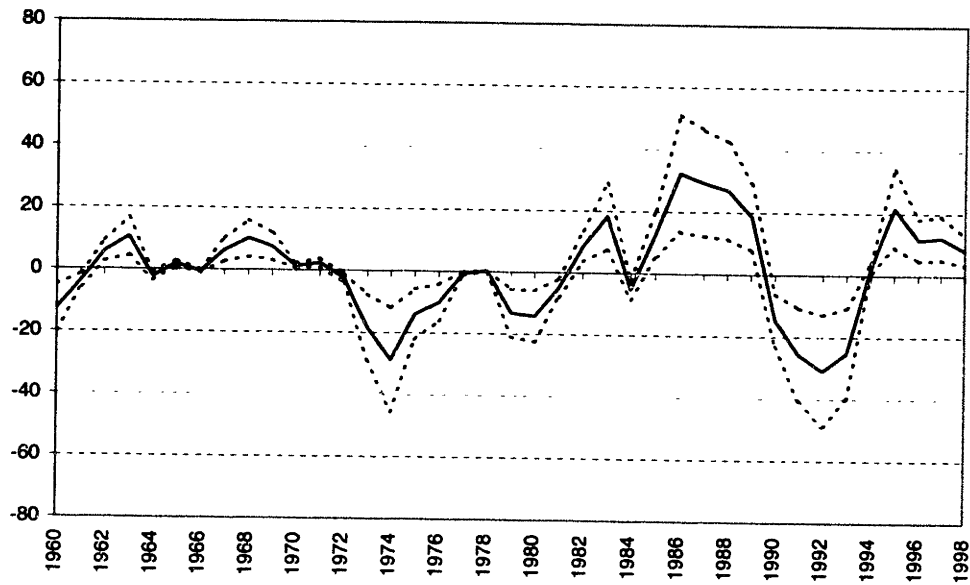
Degree of Misalignment: Venezuela

Figure 4-7: REER Misalignment in Venezuela. Dashed lines show 95% confidence band.
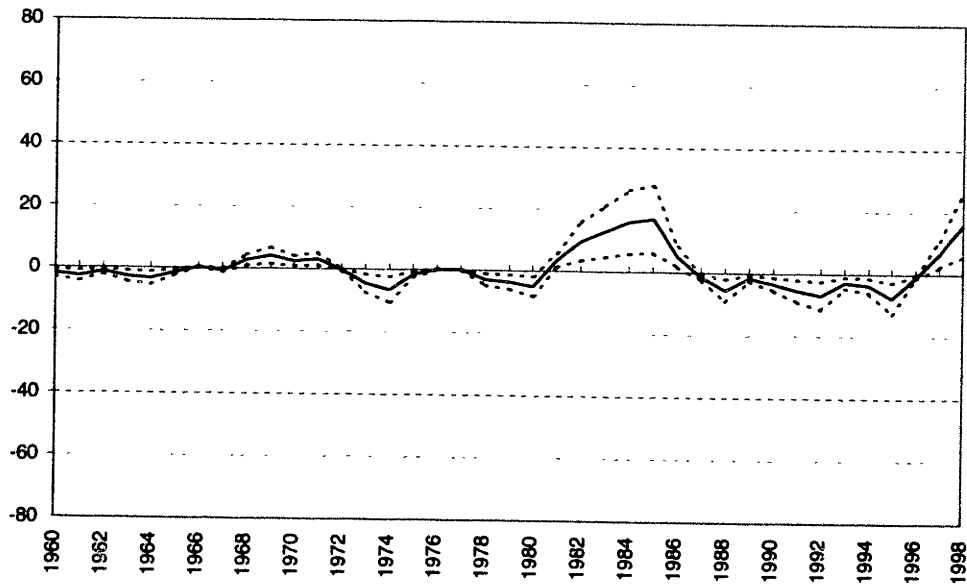
Degree of Misalignment: USA

Figure 4-8: REER Misalignment in USA. Dashed lines show 95% confidence band.

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