The Informational Content of Asset Prices and Emerging Market Crises

by

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Abstract

This thesis studies the interplay of international capital mobility and the informational content of asset prices. Chapter 2 explores the benefits and costs of limiting exchange rate volatility, emphasizing the fact that currency markets aggregate and reveal information dispersed across private agents. I find that a managed exchange rate generates less information about long run fundamentals than a freely floating rate, even though all government intervention is observed. The result turns on the fact that by reducing profitable trading opportunities, government stabilization of the exchange rate crowds out private speculation. The chapter concludes that while government intervention may reduce exchange rate uncertainty, it pays for this through increased fundamental uncertainty. Chapter 3 also relies on the premise that asset prices summarize the information and beliefs of market participants. In particular, I use the cross-section of asset prices during emerging market crises to gauge the market's assessment of fundamentals. I find that the normal period covariance structure between fundamentals and stock returns has substantial explanatory power regarding the relative performance of stocks during crises. The data suggest that investors discount the dramatic movements of macroeconomic fundamentals common to crises. Moreover, the regression results are consistent with a focus on credit-channel effects in modeling emerging market crises. Chapter 4 explores the effect of taxing capital account transactions on information-based volatility. I find that imposing capital controls increases the uncertainty of agents in the economy by reducing the likelihood that informed agents act on their private signals. This weak prior makes the uninformed agent sensitive to any new information, including an entry or exit of an informed trader. In terms of capital flow volatility, I find that the presence of capital controls may increase the bunching of informed and uninformed actions.

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To Mary

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Contents

[1]**This chapter is co-authored with Fernando Broner.**

Chapter 1

Introduction

The last 20 years have witnessed a dramatic increase in the breadth and complexity of international capital markets. The growing number of countries and firms that regularly access financial markets places an increased informational burden on investors; the opportunity cost of a dollar invested in Buenos Aires real estate may be a missed opportunity in Thailand. Moreover, not all information is public knowledge or easily accessible and each investor may have his or her own expertise. By coordinating and centralizing the activities of heterogeneously informed agents, asset markets efficiently aggregate and reveal information that is dispersed across agents. However, the large movements of prices and quantities in international capital markets have led many to believe that there may be more noise than signal in asset prices. Certainly, international capital flows are volatile. Exchange rates, when allowed to float, move much more than can be explained by observed fundamentals. The collapse of asset prices in Latin America and Asia in the last five years also underscores the ability of capital flows to quickly reverse course. Against this backdrop, this thesis explores the relationship between volatility and information in international capital markets.

Chapter 2 takes a new approach to a classic question: What are the benefits and costs of limiting exchange rate volatility? The analysis emphasizes that currency markets play an important role in aggregating information. The main insight of the chapter is that managing the exchange rate reduces the informational content of the exchange rate regarding persistent fundamentals and increases the information concerning short-run shocks. In particular, a fixed rate regime produces a currency market that is less informative about long run fundamentals than a floating rate regime, even though all trades by the government are publicly observed.

The result arises from the impact of government intervention on private speculation. Currency speculators have an incentive to differentiate shocks based on capital gains potential (which is related to persistence), trading against mean-reverting movements while allowing permanent shifts to be passed through to prices. In this way, speculative trading determines how exogenous shocks are reflected in the equilibrium exchange rate. As the government smooths the exchange rate, it translates price movements into quantity movements. However, it is price movements that motivate speculators and therefore government stabilization reduces the speculative incentive to separate shocks. The premise that market participants in aggregate contain more information than any one individual, including the government, implies that the government is less efficient than the free market at separating short-run volatility from long-run volatility. While government intervention limits overall volatility, the percentage of the total variance made up of short-run movements actually increases, and it is the proportional impact of short-run shocks that determines an asset's information and correlation properties. Assuming agents are interested in long run fundamentals, the presence of disaggregated information favors a floating rate regime.

Chapter 3[1] studies the interaction of macroeconomic fundamentals and the movements of stock prices during emerging market crises. The dramatic movements of asset prices in emerging markets in the 1990s have led many observers to question the importance of fundamentals during crisis periods. However, it is difficult to measure the impact of fundamentals during crises; for example, how should one interpret an annualized interest rate of 70% that is expected to last only a month or two when the normal interest rate process shows considerable persistence? In this chapter, we develop a methodology to measure "effective" fundamentals. Specifically, for each asset we regress returns on macroeconomic fundamentals during tranquil periods to estimate the "normal" return-fundamental relationship. Then, for each crisis period, we regress the cross-section of returns on the estimated normal-period covariances. The second stage regression estimates the implied fundamentals that best explain the cross-section of returns during a crisis. Under certain assumptions, these fundamentals can be interpreted as the "tranquil period equivalents" of the observed crisis fundamentals; that is, these are the

[1] Chapter 3 is co-authored with Fernando Broner.

fundamentals that would generate the observed cross-section of returns if they had occurred during tranquil periods.

Using this methodology, the chapter explores two broad issues. First, what do large movements in asset returns tell us about the market's assessment of fundamentals during crises? Specifically, if we assume that stocks maintain the same covariance structure with macroeconomic fundamentals during crises as during tranquil periods, what are the implied fundamentals that best explain the cross-section of returns in a crisis? How do these differ from the observed crisis fundamentals? And second, what does this information tell us about competing theories of emerging market crises? We answer these questions using stock prices in Mexico and Argentina during the Tequila crisis of 1994-1995 and the Russian crisis of 1998. In response to the first question, we find that the tranquil-period relationship between fundamentals and returns retains considerable explanatory power during crises. In particular, an asset's normal-period covariance with macroeconomic fundamentals is a good indicator of that asset's performance relative to other assets in the country. Moreover, the implied "effective" fundamentals that best explain the cross-section of returns are in general less severe than the measured crisis fundamentals – the implied interest rate and contraction in output are less than the realized values – suggesting investors discount the dramatic movements of fundamentals during crises. As for the second, our results are consistent with a focus on credit-channel effects in modeling emerging market crises.

Motivated by the importance of informational frictions in understanding capital flows, chapter 4 looks at the interaction between taxing capital account transactions and information-based volatility. In particular, I show how imposing capital controls increases informational fragility – on average, a higher cost of moving capital increases the uncertainty of agents in the economy. The presence of transactions costs delays the entry and exit of the informed agent for a given signal. The longer the inaction of the informed, the less certain the uninformed agent is about the underlying fundamental. The increased information differential between relatively informed and uninformed agents exacerbates the tendency of uninformed investors to magnify market fluctuations.

To understand the implications of increased informational fragility on capital flows, I look at the effect of capital controls on how quickly uninformed traders pull out of a country after observing another trader's exit. That is, *conditional* on an informed trader having exited (perhaps for liquidity or other "non-fundamental" motivations), how long does it take for the uninformed to follow. This measure reflects the importance of whether investor movements are synchronized: everyone entering simultaneously may lead to an overvaluation, while everyone exiting together may generate fire-sales. The first finding of the paper is that in the presence of transactions costs, the uninformed agents have on average a less precise estimate of the fundamental. This weak prior makes the uninformed agent sensitive to any new information, including an entry or exit of an informed trader. In terms of capital flow volatility, I find that although the unconditional duration of investment is lengthened by imposing transaction costs, the exit conditional on the informed having left may be hastened. In particular, I find very small and very large costs of moving capital tend to delay the conditional exit of the uninformed, but at intermediate levels an increase in transaction costs may exacerbate the tendency of the uninformed agents to mimic informed trades.

Chapter 2

Informed Speculation and the Choice of Exchange Rate Regime

2.1 Introduction

This chapter revisits the classic question of whether a country should limit exchange rate volatility. The chapter concludes that intervention is costly if short-run shocks are considered "noise". The inquiry's main departure from previous analyses is to emphasize the role speculators play in determining the sensitivity of the equilibrium exchange rate to fundamental innovations. The chapter's primary insight is that as the government intervenes in the currency market, the equilibrium exchange rate becomes less correlated with (and less informative of) long-run fundamentals and more correlated with transitory shocks. The informational effect applies to a fixed exchange rate as well, assuming capital flows are observed.

The intuition of the result hinges on the fact that speculators are motivated by capital gains. As a result, speculators use their information to determine whether a shock is temporary or permanent. For example, suppose on average speculators believe (based on private and public signals) that a given shock is transitory. If the shock implies a temporary depreciation, then speculators foresee an appreciation and buy the currency. The positive speculative response to a *temporary* depreciation off-sets the exchange rate's response to the fundamental shock. Conversely, a permanent shock to a fundamental offers little capital gains potential and therefore induces limited trading by speculators. Thus speculators actively trade against mean-reverting shocks while ignoring more persistent innovations. By limiting price changes, the government reduces the incentive for speculators to distinguish between shocks. The result of less speculation is an exchange rate relatively more responsive to transitory shocks. Although the managed exchange rate has less overall variance, a larger proportion of its variance consists of high-frequency fluctuations.

To see how this determines the government's optimal policy, suppose domestic residents would like the exchange rate to respond to productivity shocks but not to liquidity trades, a scenario reminiscent of the classic IS/LM analysis.[1] Therefore, the government improves social welfare by maximizing the influence of productivity shocks on the exchange rate. However, the government may not be able to observe the nature of a given shock, although information regarding the source of the shock may be dispersed throughout the economy. The traditional approach involves the relative variances of real and nominal shocks, concluding that if real shocks dominate in expected magnitude then a float is preferred and vice versa. In the present analysis, the correlation of the exchange rate with the underlying shocks is endogenous and depends on the behavior of speculators. If productivity shocks are relatively persistent, speculators mainly trade against temporary liquidity shocks and thereby increase the relative influence of real shocks on the equilibrium exchange rate. In this case, the government's best course is to float the currency and encourage speculative activity. If productivity shocks are mean-reverting on the other hand, private speculation works against the government's objectives and should be discouraged through a managed float or peg.

Aside from the IS-LM tradition, this chapter relates to several other literatures on exchange rate regimes. The absence of complete markets underlies the importance of the exchange rate's informational and insurance properties. In the context of incomplete markets, Helpman and Razin (1982) note that fixing the exchange rate eliminates an asset, which under certain conditions reduces welfare. In the jargon of incomplete markets, fixing the exchange rate reduces the span of the marketed subspace. Alternatively, eliminating an asset may eliminate a source of uncertainty (or provide credibility), an approach taken by Neumeyer (1998). The model presented below is more concerned with the orientation of the marketed subspace rather

[1] The IS-LM approach follows Bailey (1962) and Poole's (1970) closed-economy analysis (see Genberg (1989) for a discussion of the many extensions).

than its dimension. Through its interaction with speculators, the government influences the exchange rate's payouts in the various states of nature, even though the government does not (or cannot) distinguish between the state variables.

In the mid 1980s, several authors noted that a completely fixed price (e.g. fixed exchange rates or targeted interest rates) could have adverse informational consequences (e.g. Kimbrough (1984), Flood and Hodrick(1985) and Dotsey and King (1986)). As in models in which fixing the exchange rate eliminates an asset, these papers equate fixing the exchange rate to eliminating a signal. However, in principle the signal can be reclaimed by observing capital flows or money supply. This chapter allows for complete observability of prices and quantities. The effect is not one of signal elimination, but rather the endogenous nature of the signal's informativeness.

Lastly, this chapter relates to a large literature on the informational content of prices. The classic reference is Hayek (1945). Lucas (1972, 1973) and Grossman (1989) made seminal contributions on the importance of prices as signals and motivated a considerable finance literature on information revelation (e.g. Kyle (1985, 1989), Admati (1991), Wang (1993)). This chapter pushes the literature in a new direction by focusing on government intervention – a topic of growing relevance as some central banks contemplate the benefits of limiting stock price volatility.

The chapter is organized as follows. Section two motivates the chapter's main results and outlines the key interaction between speculators and the government. Section three explicitly models the exchange rate market and derives a welfare measure to compare alternative regimes. Section four extends the analysis to consider disaggregated information and explores the effect of government intervention on social learning. Section five concludes. Appendices contain a general equilibrium welfare analysis and an infinite horizon extension as well as technical details.

2.2 Motivating Scenario

This chapter studies the consequences of limiting asset price volatility. Although the mechanism applies to any asset, we will motivate the analysis by considering the costs and benefits of smoothing the exchange rate. The particular example chosen to illustrate the trade-offs is straightforward – the "home" country wishes to maximize foreign direct investment. While the motivation is rather specific, the intuition is robust: increasing uncertainty lowers welfare.

Suppose foreign entrepreneurs face a decision about whether to locate their physical capital in the home country or leave it abroad. One issue that arises in this decision is the productivity of physical capital in the home country. The determinants of productivity, such as the quality of domestic workers or the efficiency of the local infrastructure, may not be directly observable to the foreign entrepreneur. However, these hidden "fundamentals" will be implicit in a range of economic variables that are observable. In particular, they will have some influence on the demand for our asset of interest – local currency - which in turn will influence the exchange rate (or changes in government reserves). A main question of this chapter is to determine how observed government trading affects the market's ability to aggregate and reveal information about hidden fundamentals.

The informational consequences result from the interaction of government trading and currency speculators. A key element of the model will be that these speculators have some information regarding the underlying fundamentals. This information may be in disaggregated form. That the market as a whole contains more information than any one individual (including the government) is a seminal insight of Hayek (1945). It eases the exposition to consider the speculators as separate from the entrepreneurs, but conceptually the crucial point is that there exists some demand for the currency that is motivated by capital gains. The analysis will then turn on how a less volatile asset price influences speculators' use of private information.

The basic mechanism can be outlined with a familiar supply and demand diagram (figure 1) that plots the exchange rate[2] ($\mathcal{E}$) against the quantity of domestic currency. The private sector has a demand for currency that is driven by speculative and fundamental motivations. Examples of fundamentals include shocks to income, liquidity, asset supply, or dividends. Specifically, fundamental demand is not motivated by capital gains. The aggregate private sector demand curve can be parameterized by these fundamentals, which may not be fully observable otherwise. The observable sequence of equilibrium prices and quantities provides information regarding the underlying shocks. We assume that fundamental demand is a composite of more than one process to capture the notion of incomplete markets (i.e. there are more exogenous shocks

[2]We define $\mathcal{E}$ as the price of domestic currency in terms of foreign currency (e.g. if the U.S. is "home", then $\mathcal{E}$ is Yen per Dollar). Note that an increase in $\mathcal{E}$ is an appreciation of the home currency.

than asset prices). With complete markets, the market fully aggregates and reveals private information regardless of regime (see Grossman (1989) and Hellwig (1980)). Moreover, as pointed out by Lucas (1982) and Helpman (1981), exchange rate policy is irrelevant in the absence of incomplete or imperfect markets.

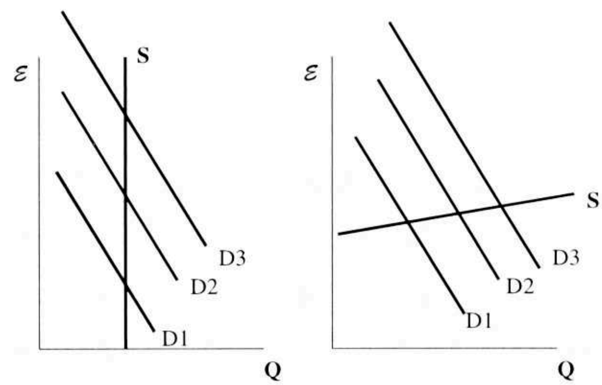

Figure 2-1:

The government controls the supply of currency by trading domestic currency for foreign exchange via open market operations. As can be seen in figure 1, the slope of this supply curve determines how changes in the private sector demand are translated into changes in the exchange rate. In particular, an elastic supply implies a less volatile exchange rate for a given series of demand shocks. Obviously, the slope of the supply curve does not influence the *observability* of private sector demand (assuming quantities are always observable). A main result of the chapter is that the slope of the supply curve alters the *behavior* of private sector demand.

As fundamentals are buffeted by exogenous shocks, private sector demand shifts along the supply curve. The resulting change in the exchange rate offers the opportunity for speculative profit. As the government absorbs these shocks into quantities, the potential for capital gains is reduced and speculators have less incentive to differentiate between shocks. The crowding out of speculators will, in turn, alter the informational and correlation properties of the equilibrium exchange rate. Note the forward looking nature of this mechanism. In particular, it is next period's supply curve that determines the potential for capital gains. This blurs the distinction between fixed and floating exchange rates. A fixed regime on the verge of collapse presents a large speculative opportunity and therefore is informationally closer to a float than a hard peg. The next section explicitly models and explores the welfare implications of this intuition.

2.3 The Model

This section derives and studies the implications of government intervention outlined in the previous section. We first model the behavior of speculators and the determination of the equilibrium exchange rate. Then a simple model of foreign direct investment is introduced to motivate the government's objective function. Finally, we combine these two elements to study the government's problem in detail.

2.3.1 The Equilibrium Exchange Rate

This subsection focuses on speculators who allocate their financial wealth between foreign and domestic currency. Each period, a measure-one continuum of speculators solve a one-period portfolio problem. Appendix C extends the analysis to infinite horizons. A key assumption is that the speculators have some information regarding the underlying fundamentals. It is unrealistic to assume that speculators have all relevant information and other agents have none. However, it is reasonable to suppose that the private sector as a group holds information in disaggregated form that is unavailable to any one individual (including the government). For expositional purposes, in this section we proceed as if speculators have full information, but then relax this assumption in section 4.

To analyze the equilibrium in period t, we focus on speculators who trade between t and $t+1$. Speculators begin period t with wealth W_t (calculated in foreign currency) and solve the following portfolio problem:[3]

$$\max E\left\{-e^{-\psi W_{t+1}}\right\} \tag{2.1}$$

$$s.t.\ W_{t+1} = (1+r)W_t + \left(\mathcal{E}_{t+1} - (1+r)\mathcal{E}_t\right) X_t^S, \tag{2.2}$$

where X_t^S represents the quantity of domestic currency held at the end of period t. For simplicity, we assume the domestic interest rate is zero so that r, the risk-free interest paid on foreign currency deposits, represents the interest differential.[4] The solution to this problem is[5]

$$X_t^S = \frac{E_t\left(\Delta\mathcal{E}_{t+1}\right) - r\mathcal{E}_t}{\psi\sigma_{\mathcal{E}}^2}, \tag{2.3}$$

where $\sigma_{\mathcal{E}}^2$ is the conditional variance of next period's exchange rate. The numerator is the risk premium on domestic currency assets. We assume that speculative demand is zero under a fixed rate.[6]

In addition to the demand for the asset due to price speculation, assume that there is also "fundamental" demand for the asset. In particular, there is demand for currency that is driven by two exogenous processes, f_1 and f_2. In subsection 3.4 we will use f_1 to represent the productivity of capital located in the home country. In general, the two fundamentals can represent any shocks that affect the demand for currency, including income shocks, liquidity shocks, or money supply shocks. We could also nest a model of noise traders in this framework by assigning a fundamental to represent noise trader's misperceptions.[7] We assume that fundamental demand and government demand are normalized by the term $\psi\sigma_{\mathcal{E}}^2$.[8] In particular, this demand

[3]For simplicity, we assume that the speculators are foreign, so that the domestic currency carries exchange rate risk. In general, there could be a consumption basket of foreign and domestic goods that would define the "risk free" combination of currencies. (e.g. Dornbusch 1983).

[4]We will assume that $r \geq 0$, but all results go through without change as long as the interest differential is less than 100% (i.e. as long as $1 + r \geq 0$).

[5]The results of the next subsection imply W_{t+1} is normally distributed.

[6]Technically, speculative demand is indeterminate under a peg as the two currencies are interchangeable. Rather than model how $r \to 0$ under a peg, assume that there is a slight amount of risk in home currency deposits. In that case, r remains arbitrary and investors adjust portfolios. It also ensures we never normalize by zero.

[7]For examples, see Appendices B and C.

[8]The normalized fundamental demand is consistent with f_1 and f_2 being dividends or investor misperceptions. Appendix D contains an alternative specification in which fundamental demand is invariant to $\sigma_{\mathcal{E}}^2$.

is linear in the exchange rate with the normalized exogenous shocks as the intercept:

$$\text{Fundamental Demand: } F = \frac{1}{\psi \sigma_{\mathcal{E}}^2} \left(f_{1,t} + f_{2,t} - \mathcal{E}_t \right). \tag{2.4}$$

It is not essential to separate the speculative and fundamental demand curves.[9] We distinguish between the two demands to isolate trading motivated by capital gains.

The government pursues a simple open-market trading strategy by purchasing its currency with foreign reserves when the price is below some target and selling domestic currency when above.[10] In particular, the government demand for home currency is characterized by

$$G_t = -\frac{\eta}{\psi \sigma_{\mathcal{E}}^2} (\mathcal{E}_t - \overline{\mathcal{E}}) + b_t, \tag{2.5}$$

$$\eta \geq 0. \tag{2.6}$$

We assume that this demand curve is known to all investors, so that the extent and behavior of government trading is public knowledge. The intercept b_t is assumed to be in the public information set and does not represent an additional source of uncertainty. The slope η represents government's sensitivity to the asset's price and can be interpreted as the intensity with which the government smooths exchange rate volatility around the target $\overline{\mathcal{E}}$. It also is the slope of the "private sector" supply curve as changes in government demand represent changes in supply to the rest of the market. This coefficient parameterizes the government's exchange rate policy, with a higher η implying a more interventionist regime. In analyzing information aggregation, it is this sensitivity parameter which matters and not the total level of government trading represented by the intercept term b.

Adding up the demands yields the following market clearing condition:

$$X^S + G + F = Q, \tag{2.7}$$

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[9] For example, if $f_1 + f_2$ represents the dividend paid to the domestic currency asset, the combined fundamental and speculative demand would be $\frac{1}{\psi \sigma_{\mathcal{E}}^2} \left(E\Delta\mathcal{E} + f_1 + f_2 - r\mathcal{E} \right)$.

[10] We assume that the government chooses a policy that does not lose reserves in expectation. A stronger assumption would be that the government does not lose (a set amount) of reserves path by path. We can justify the larger set of regimes by allowing cooperation with the foreign central bank. In particular, a foreign central bank may be willing to provide reserves in a crisis to be repaid in a boom. See Helpman (1981).

where Q is the known supply of the domestic currency. Given that the government's demand curve has an arbitrary constant, we can take $Q = 0$ without loss of generality. Therefore, substituting for X^S, G and F, and multiplying through by $\psi\sigma_{\mathcal{E}}^2$, our equilibrium condition can be stated as

$$E(\Delta\mathcal{E}_{t+1}) - r\mathcal{E}_t - \eta(\mathcal{E}_t - \overline{\mathcal{E}}) + \psi\sigma_{\mathcal{E}}^2 b_t + f_1 + f_2 - \mathcal{E}_t = 0. \tag{2.8}$$

2.3.2 A Case in which Government Trading Has No Informational Effect

We need to place more structure on the stochastic properties of our fundamentals to solve for the equilibrium exchange rate and study its properties. To clarify why the government may alter the informational content (or correlations) of the exchange rate, it is useful to start with a case in which the government does not have an effect. This will highlight that adding the government to an asset market is not equivalent to adding noise or removing a signal. It will also show that the government's intervention is in a sense neutral regarding the underlying fundamentals. For this subsection, assume that f_1 and f_2 are white noise with respective variances σ_1^2 and σ_2^2. Solving for the linear price equilibrium, we have

$$\begin{aligned} \mathcal{E}_t &= \beta_0 + \beta_1 f_{1,t} + \beta_2 f_{2,t} \\ \beta_1 &= \beta_2 = \frac{1}{2 + \eta + r} \end{aligned} \tag{2.9}$$

Given this reduced form, other agents in the economy can use the path of exchange rates to infer the values of f_1 and f_2. Suppose f_1 is the fundamental of interest to a particular observer. The ability to infer f_1 is hindered by the presence of the second fundamental. We will therefore refer to f_2 as "noise", keeping in mind that there is a companion inference problem in which f_2 is the target and f_1 is noise. The symmetry of the model allows us to obtain all results by considering only the first inference problem.

The minimum-variance estimate of f_1 based on the history of exchange rates is given by the Kalman filter.[11] A key feature of the Kalman filter in this context is that the precision of our f_1 estimate is increasing in the relative sensitivity of the exchange rate to the target fundamental:

[11] Appendix A describes the filter in detail.

$\frac{\beta_1}{\beta_2}$. That is,

$$V_{1,t} = V(\frac{\beta_1}{\beta_2}, ...) \qquad (2.10)$$
$$\frac{dV}{d\frac{\beta_1}{\beta_2}} < 0,$$

where $V_{1,t} = E_t(f_{1,t} - E_t f_{1,t})^2$ is the variance of our estimate of $f_{1,t}$ conditional on observing exchange rates up through $\mathcal{E}_t$. We will thus refer to $\frac{\beta_1}{\beta_2}$ as the "information ratio." The intuition for the importance of this ratio is straightforward. As one fundamental begins to dominate the movement of the exchange rate, a given change in the exchange rate becomes more informative about that fundamental and less about the other. Note that the information ratio is independent of scale: multiplying through by a constant will not affect the inference problem. Not surprisingly, the correlation of the exchange rate with f_1 is also monotonic in the information ratio.

From equation (2.9), it is immediately clear that the information ratio is invariant to government policy (i.e. $\frac{\beta_1}{\beta_2} = 1, \forall \eta$). Even in the case of a completely fixed exchange rate, as long as we can observe capital flows we will have no loss of information. To see this, note that to fix the exchange rate the government must meet all fundamental demand for currency at the target rate (i.e. $G = F$). If we use G as our signal under a fixed regime, we also obtain an information ratio of one. In general, as $\eta \to \infty$ the information ratio approaches that implied by the fundamental demand. In this sense, there is no informational discontinuity between a floating and fixed rate, an important departure from a signal elimination model.

2.3.3 When Government Trading Does Affect Correlations

The reason why government trading did not influence $\frac{\beta_1}{\beta_2}$ in the above example was that speculators had no reason to differentiate between the two types of shocks. An innovation in either fundamental had the same implication for tomorrow's price. As far as the reduced form expression for the exchange rate was concerned, we could have combined the two fundamentals into a single composite random variable. To examine the effect of government trading we need to expand the class of shocks. In particular, let the underlying processes follow:

$$\begin{aligned} f_{1,t+1} &= (1-\mu_1)f_{1,t} + u_{t+1} \\ f_{2,t+1} &= (1-\mu_2)f_{2,t} + v_{t+1}. \end{aligned} \tag{2.11}$$

Assume that u and v are uncorrelated with each other and across time, and jointly normal with zero mean and respective variances σ_1^2, σ_2^2.[12] The coefficients μ_1, μ_2 represent the intensity of mean-reversion and we assume that they take values between zero (random walk) and one (white noise) inclusive.

Solving for the equilibrium price as above, we have

$$\begin{aligned} \mathcal{E}_t &= \beta_0 + \beta_1 f_{1,t} + \beta_2 f_{2,t} \\ \beta_i &= \frac{1}{1+\eta+\mu_i+r},\ i=1,2. \end{aligned} \tag{2.12}$$

Now the information ratio is

$$\frac{\beta_1}{\beta_2} = \left(\frac{1+\eta+\mu_2+r}{1+\eta+\mu_1+r}\right). \tag{2.13}$$

Simple differentiation implies

$$\frac{d\left(\frac{\beta_1}{\beta_2}\right)}{d\eta} \gtreqless 0 \Leftrightarrow \mu_1 \gtreqless \mu_2. \tag{2.14}$$

Or in other words, the informativeness of the asset price increases with government intervention if and only if the target fundamental is more mean-reverting than the "noise" process.

The intuition for this result hinges on how speculators respond to government intervention. Speculators use their information to distinguish between the two shocks in their pursuit of capital gains. As the government eliminates profit-making opportunities, speculators have less reason to differentiate between the two fundamentals. The ultimate effect on the equilibrium exchange rate turns on whether speculative trading magnifies or dampens the distinction between the two shocks. In the set up we have used, the distinction arises from mean-reversion.

[12] The variance of a fundamental can be zero (i.e. f_i constant), but we need the variance of at least one fundamental to be strictly positive for a meaningful inference problem (and for the existence of a disaggregated-information equilibrium as pointed out by Diamond and Verrechia (1981)).

Speculators trade against or dampen a mean-reverting fundamental while ignoring a persistent shock. Discouraging speculation reverses this effect – accentuating the mean-reverting fundamental relative to the persistent shock. Government intervention thus results in more information regarding the high-frequency fundamental (and less of the persistent).

To see how the speculators respond to government trading, it helps to expand $E(\Delta\mathcal{E})$ to derive the reduced form risk premium RP:

$$RP = -\left\{r\beta_0 + \frac{\mu_1 + r}{1 + \eta + \mu_1 + r} f_1 + \frac{\mu_2 + r}{1 + \eta + \mu_2 + r} f_2\right\}. \tag{2.15}$$

The risk premium is negatively correlated with the fundamentals: an increase in fundamental demand lowers the risk premium required by speculators to hold the remaining assets (or increases the incentive to sell). The sensitivity of the risk premium to a given fundamental is increasing in the potential for capital gains (i.e. $\frac{\mu+r}{1+\eta+\mu+r}$ is increasing in μ). That is, speculative activity is concentrated on the high-frequency fundamental. When informed investors trade opposite to the noise fundamental, the amount of noise in aggregate private sector demand declines (which is all that an outsider observes), increasing the informativeness of the price. The same story holds in regard to the fundamental, except that increased speculation opposite to f_1 dampens informativeness. In this sense, the informativeness of a price depends on informed investors' *relative* sensitivity rather than their *absolute* sensitivity to the various shocks.

From equation (2.15), we see that an increase in η reduces the sensitivity of the risk premium to both the fundamental and noise. This reflects how the government crowds out speculators. However, the net effect on the exchange rate is relatively larger for the shock that has the most potential for capital gains. This is bad informationally if speculators mainly trade against the noise fundamental ($\mu_2 > \mu_1$), but will enhance the informativeness of a price if speculators were mainly diluting the impact of the target fundamental on the price.

This subsection identified how government intervention influences the informational and correlation properties of the equilibrium exchange rate. The next subsections use this insight to study the government's optimal choice of η.

2.3.4 Welfare Considerations – The Entrepreneurs

This subsection introduces a model of foreign direct investment that provides the welfare measure used to evaluate alternative regimes. For simplicity, we assume that the government wishes to maximize foreign direct investment. While this objective has a partial equilibrium flavor, the welfare conclusions can be obtained from a general equilibrium setting. In particular, Appendix B presents a macroeconomic model which supports the welfare considerations derived in this subsection.

A measure-one continuum of entrepreneurs have access to K units of physical capital to invest. They make their investment decision in period $t-1$ to maximize CARA utility over period t profits, where profits are calculated in foreign currency. If located in the home country, each unit of capital produces $1+f_1$ units of a tradeable output (which has price one in foreign currency). In this sense, f_1 is a fundamental that captures the productivity of the home country. All other shocks to the economy will be represented by the second fundamental f_2.

In operating a unit of capital in the home country, the foreign entrepreneurs must pay a cost w in local currency. This could, for example, represent rent or labor costs. If left abroad, capital yields a risk free return of $1+r$. Thus the flow profit (in foreign currency) is $f_1 - w\mathcal{E} - r$.

Therefore, the entrepreneur's problem is represented by:[13]

$$\begin{aligned} & \max_I E_I - \exp\{-\psi \Pi_t\} \\ s.t.\ \Pi_t &= (f_{1,t} - w\mathcal{E}_t - r)I + rK. \end{aligned} \tag{2.16}$$

The expectation operator E_I is conditional on the entrepreneur's information set Ω_I. The contents of this set will be discussed below in detail. The choice variable is the units of capital located in the home country (I), which may be negative (i.e. foreign entrepreneurs may borrow capital in the home country). The amount invested in the home country is thus

$$I = \frac{E_I(f_{1,t} - w\mathcal{E}_t - r)}{\psi \sigma_\Pi^2} \tag{2.17}$$

[13] We assume that entrepreneurs do not speculate/hedge in the currency market. Allowing such diversification does not change the main story, but does place added importance on correlations.

where

$$\sigma^2_{\Pi} = Var_I(f_{1,t} - w\mathcal{E}_t). \tag{2.18}$$

Note that investment declines in the level of uncertainty (σ^2_{Π}). This implication is a standard result of investment under uncertainty (see Dixit and Pindyck (1994)). Therefore, the objective of the home government is to choose an exchange rate regime that minimizes σ^2_{Π}.[14]

2.3.5 Optimal Intervention

To explore how the government can reduce investment uncertainty, we need to specify the entrepreneurs' information set Ω_I. We will consider three cases:

1. Entrepreneurs observe period t's exchange rate before investing, but have no direct information on productivity.

2. Entrepreneurs make their investment decision based on complete information as of $t-1$.

3. Entrepreneurs observe exchange rates (but not fundamentals) through $t-1$.

Consider the first case in which investors observe $\mathcal{E}_t$ before they make their investment decision, but possess no other information regarding the fundamental. Specifically, $\Omega_I = \{\mathcal{E}_j\}_{j=0}^{t}$. This scenario is comparable to the Lucas Supply model in which agents have flexibility but lack information. In this case, profit uncertainty is identical with the Kalman filter variance ($\sigma^2_{\Pi} = V_{1,t}$). Recall from (2.10) that the variance of the Kalman filter is decreasing in the information ratio. The information ratio itself is increasing in government intervention if and only if f_1 is relatively transitory ($\mu_1 > \mu_2$). The government's optimal[15] policy is therefore to peg if productivity shocks are relatively mean-reverting, but float if such shocks are relatively persistent.

Now suppose entrepreneur's have complete information up through time $t-1$ (i.e. $\Omega_I = \{f_{i,j}\}_{j=0}^{t-1}$, $i = 1, 2$). Entrepreneurs know the value of f_1 at $t-1$, but must predict next period's

[14] We will not focus on the numerator in equation (2.17) as the welfare implications of the (expected) level of the exchange rate are not robust. In particular, assuming that w adjusts to the expected exchange rate will negate any advantage of a "competitive undervaluation." See Appendix B for an alternative example.

[15] More accurately, we are studying a constrained optimum. To preserve the linearity of the equilibrium and Kalman filter, we have restricted the government to linear trading rules.

exchange rate and productivity ($\sigma_{\Pi}^2 = E_{t-1}\{f_{1,t} - \mathcal{E}_t - E_{t-1}(f_{1,t} - \mathcal{E}_t)\}^2$).[16] This is similar to a traditional sticky-price model in which informed agents commit a period in advance. In this case, the exchange rate reduces uncertainty by adjusting to unexpected shocks to productivity, but introduces additional risk by co-moving with f_2. We can represent the government's problem geometrically by considering our state processes as vectors of possible realizations.[17] Figure 2 depicts the unanticipated components of our two state variables, $\tilde{f}_{1,t}$ and $\tilde{f}_{2,t}$, where $\tilde{f}_i = f_i - E[f_i|\Omega_I]$. The exchange rate is a linear combination of the two state vectors. In attracting foreign capital, the government's objective is to minimize the expected squared deviation of the exchange rate from the productivity fundamental. That is, minimize the distance between the vectors $\tilde{f}_1$ and $\tilde{\mathcal{E}}$, where distance is measured by the L^2 norm (i.e. $\left\|\tilde{f}_1 - \tilde{\mathcal{E}}\right\|^2 = E_I(\tilde{f}_1 - \tilde{\mathcal{E}})^2 = \sigma_{\Pi}^2$).

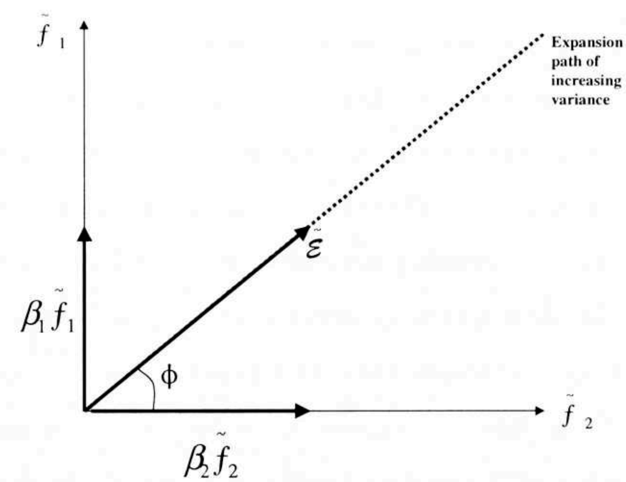

Figure 2-A

[16] Without qualitatively changing the analysis, we assume $w = 1$.
[17] This is only an heuristic device given that our state space is a continuum.

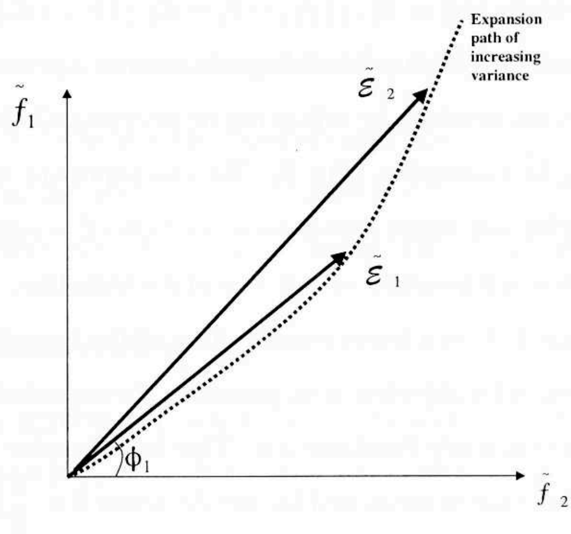

Figure 2-B

Figure 2-A represents the case when government intervention has no correlation effect ($\mu_1 = \mu_2$). The fact that $\frac{\beta_1}{\beta_2}$ is constant in η when $\mu_1 = \mu_2$ implies that the expansion path of $\widetilde{\mathcal{E}}$ is a straight line. The government chooses the variance of $\widetilde{\mathcal{E}}$ that yields an exchange rate that is closest to the first fundamental. Where this point occurs is determined by the orientation of the expansion path, which is nothing more than the correlation between the exchange rate and the fundamentals. In the diagram, ϕ represents the angle between the exchange rate and the second fundamental; as ϕ increases, the correlation between the exchange rate and the first fundamental increases.[18] In turn, ϕ is given by $\frac{\beta_1}{\beta_2}\frac{\|\tilde{f}_1\|}{\|\tilde{f}_2\|} = \frac{\sigma_1^2}{\sigma_2^2}$. In panel A, ϕ is determined exogenously. Note the effect of the relative lengths of $\tilde{f}_1$ and $\tilde{f}_2$. As $\tilde{f}_2$ increases, the expansion path tilts down, and the closer to the origin the optimal length of $\widetilde{\mathcal{E}}$. We thus recover the classic Poole result that the higher the relative variance of nominal (f_2) shocks, the more the government should smooth the exchange rate.

Alternatively, suppose $\mu_1 \neq \mu_2$. As the government changes the variance of the exchange rate, it will change its orientation as well. In this case, the expansion path of increasing variance is no longer linear. Figure 2-B, represents the case where f_1 is relatively persistent, so that government intervention decreases the correlation of $\mathcal{E}$ and f_1. The government thus faces a

[18] In particular, $\text{corr}(\mathcal{E}, f_1) = \cos(\frac{\pi}{2} - \phi)$.

trade-off between the length (variance) and the orientation (covariance) of $\mathcal{E}$.

To reintroduce the informational considerations, assume that entrepreneurs must make their investment decision at $t-1$ based only on exchange rate data. In this case, the government faces a trade-off between the variance of the exchange rate and its informational content. All the elements can be seen by solving out the entrepreneur's uncertainty term conditional on $\Omega_I = \{\mathcal{E}_j\}_{j=0}^{t-1}$:

$$\sigma_{\Pi}^2 = (1 - \mu_1 + \beta_1(\mu_1 - \mu_2))^2 V_{1,t-1} + (1-\beta_1)^2\sigma_1^2 + \beta_2^2\sigma_2^2, \tag{2.19}$$

where $V_{1,t-1}$ is the variance of the estimate of $f_{1,t-1}$ conditional on the exchange rates up to that period.[19] The first term represents the informational implications of government intervention. The term within the parenthesis decreases as η increases (and β_1 decreases) if the target fundamental is relatively transitory ($\mu_1 - \mu_2 > 0$), and vice versa.[20] The same holds for $V_{1,t-1}$ as the informational content increases with η iff $\mu_1 > \mu_2$. Thus the informational term decreases with government intervention when the target fundamental is mean-reverting, but increases when f_1 is relatively persistent. The second two expressions reflect that the exchange rate can buffer/transmit shocks. In the absence of an inference problem, $(1-\beta_1)^2\sigma_1^2 + \beta_2^2\sigma_2^2$ represents the length of $\tilde{f}_1 - \tilde{\mathcal{E}}$. We would like the exchange rate to reflect real disturbances ($\beta_1 = 1$) and dampen nominal shocks ($\beta_2 = 0$). These two terms thus reflect the role ϕ plays in the geometric analysis in figure 2.

Equation (2.19) is analyzed in more detail in figures 3-5.[21] Figures 3 and 4 highlight how the optimal choice of exchange rate regime depends on the quality of information available

[19] We have substituted for the estimate variance for the second fundamental using the fact that $\mathcal{E}_{t-1}$ is known at $t-1$:

$$\begin{aligned} \mathcal{E}_{t-1} - E_{t-1}\mathcal{E}_{t-1} &= 0 = \beta_1 \tilde{f}_{1,t-1} + \beta_2 \tilde{f}_{2,t-1} \\ &\Longrightarrow \\ Var_{t-1}(f_{1,t-1}) &= \left(\frac{\beta_2}{\beta_1}\right)^2 Var_{t-1}(f_{2,t-1}). \end{aligned}$$

[20] The fact that the term is squared is not important in that the expression is never negative.

[21] Parameter values for figures 3-5:
Figure 3: $\sigma_1^2 = 7.5$, $\sigma_2^2 = 10$, $\mu_1 = 0.5$, $\mu_2 = 1$;
Figure 4: $\sigma_1^2 = 1$, $\sigma_2^2 = 10$, $\mu_1 = 0.1$, $\mu_2 = 0.9$;
Figure 5: $\sigma_1^2 = 6$, $\sigma_2^2 = 10$, $\mu_1 = 0.5$, V_1 is steady state variance.

to entrepreneurs. Both figures consider the case in which f_1 is relatively persistent so that government intervention has a negative informational effect. Suppose entrepreneurs enter period $t-1$ with an estimate of $f_{1,t-2}$ based on some prior information. Entrepreneurs observe $\mathcal{E}_{t-1}$ and update their prior before making an investment decision. The quality of the updated estimate enters σ^2_{Π} through the term $V_{1,t-1}$ in equation (2.19). Through the mechanism outlined above, government intervention influences the usefulness of $\mathcal{E}_{t-1}$ as a signal.

The variance of the entrepreneurs' prior information is plotted along the horizontal axis of figures 3 and 4. Figure 3 looks at the change in σ^2_{Π} due to an increase in government intervention. In particular, it plots $\frac{d\sigma^2_{\Pi}}{d\eta}$ evaluated at a free float ($\eta = 0$). A negative derivative indicates that some intervention is warranted, while a positive derivative indicates that a free float is optimal (i.e. a corner solution). As the variance of entrepreneurs' prior information increases, the importance of the exchange rate as a signal increases. With enough uncertainty, informational considerations dominate and the government's optimal rule is to float the currency.

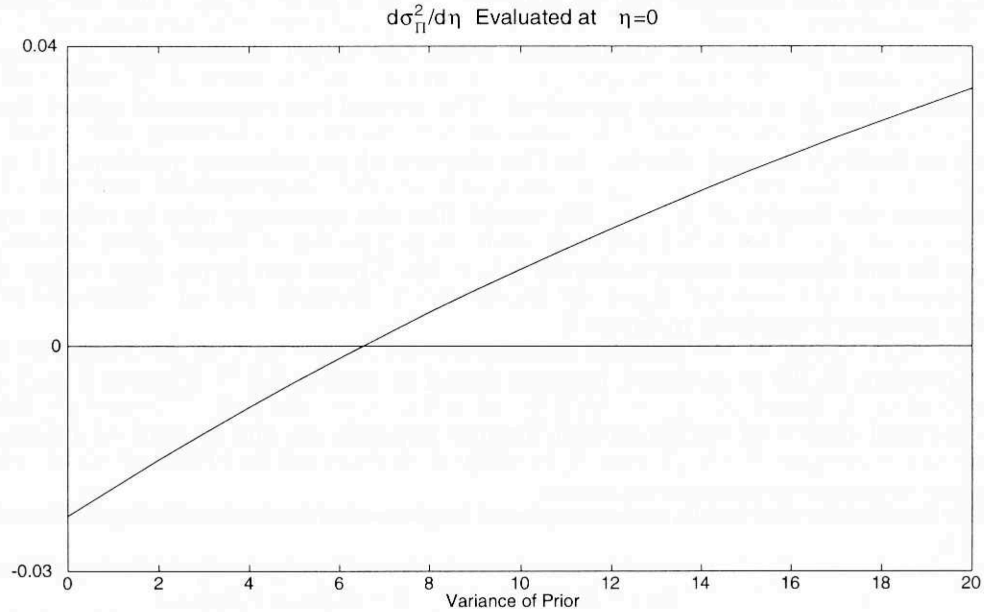

Figure 3

Figure 4 plots the optimal amount of exchange rate volatility (as a percentage of free float volatility) against increasing levels of (prior) fundamental uncertainty. The vertical axis is the amount of volatility implied by the government's optimal choice of η divided by the variance when $\eta = 0$. Thus a value of 100% indicates that a free float is optimal, while 0% reflects a complete peg. Figure 4 depicts that as the quality of the prior declines, the government must allow more exchange rate uncertainty to afford entrepreneurs a better estimate of the fundamental.

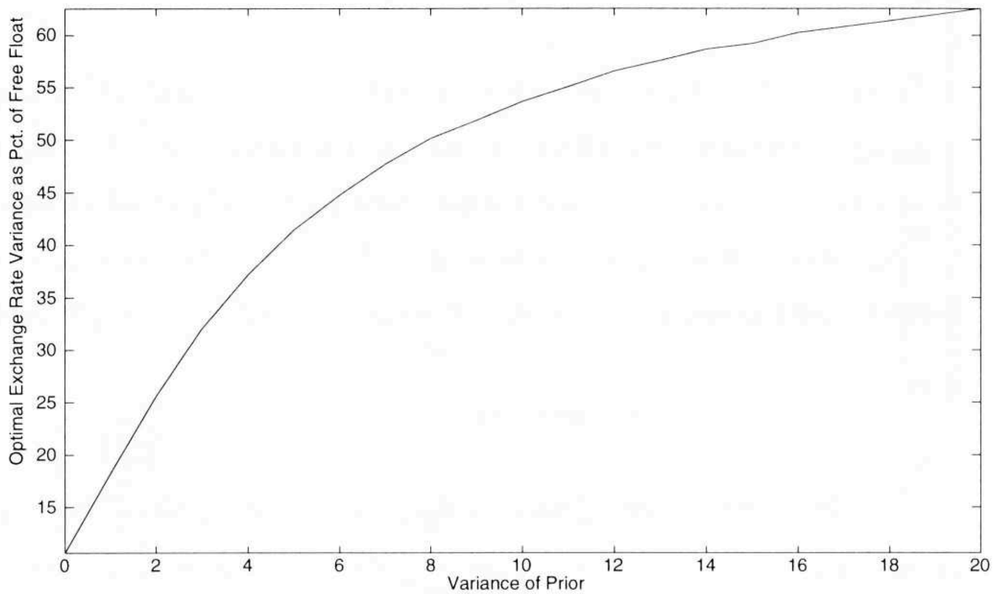

Figure 4

Figure 5 highlights the importance of capital gains. In particular, by varying $\mu_2 - \mu_1$, we alter the incentive for speculators to distinguish between the two fundamentals. The solid line represents the optimal amount of volatility if the entrepreneurs observe exchange rates up to $t-1$. This is the "Case 3" discussed at the top of the subsection and represents equation (2.19). The dashed line is the case of complete information as of $t-1$ (Case 2). This line represents the last two terms of equation (2.19) and reflects the insurance (correlation) properties of the exchange rate. The dotted line is the benchmark case of $\mu_2 = \mu_1$. That is, a traditional variance analysis implies an optimal volatility 25% of the free float. If productivity is highly cyclical ($\mu_2 - \mu_1 < 0$), the government has an increased incentive to intervene. This incentive exists for insurance reasons alone (dashed line), but is enhanced if the exchange rate also serves as an informative signal (solid line). As we increase the mean reversion of our noise fundamental ($\mu_2 \uparrow$), the government's incentives are reversed and the optimal rule favors exchange rate flexibility. The sensitivity of the optimal policy to $\mu_2 - \mu_1$ reflects the role speculators play in determining the equilibrium exchange rate. By altering the behavior of speculators, the government uses the difference in the capital gains potential of the two processes to influence the informational and insurance properties of the exchange rate.

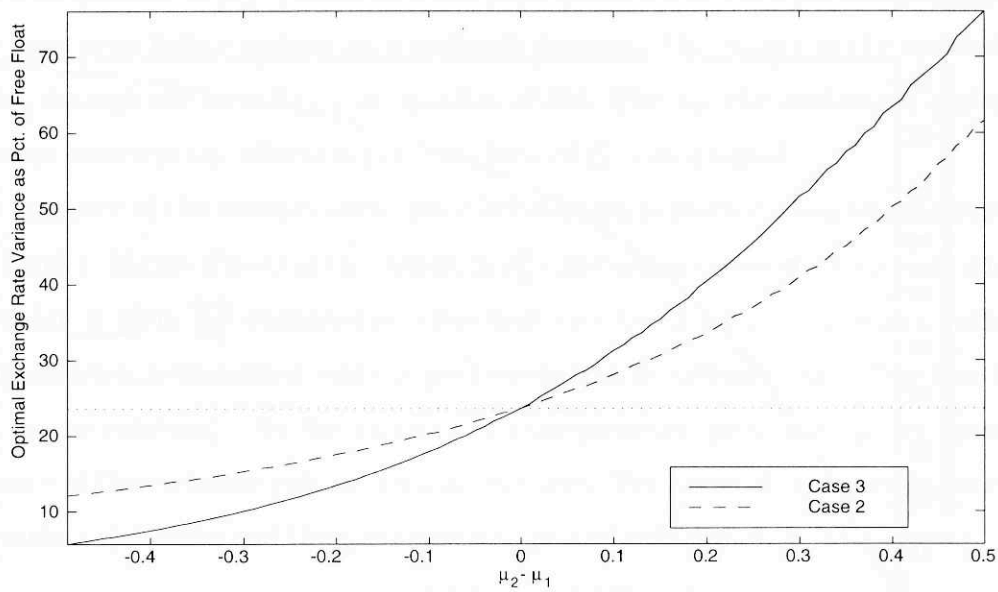

Figure 5

2.4 The Case of Disaggregated Information

The discussion above has focused on the ability of the exchange rate to reveal and transmit fundamental shocks when speculators have complete information. An alternative view would be that each individual has some private information but no one has access to all information. In this section, we consider the effect of government intervention on a market's ability to aggregate private information.

Conceptually, we can think of a distribution of existing enterprises located in the home country that exhibit productivities that are the true fundamental f_1 plus an idiosyncratic disturbance. Those with access to this noisy signal can use that additional knowledge to speculate in the currency market.[22] In particular, suppose that each speculator i receives a private signal s_i about the first fundamental that is a combination of the true value and an idiosyncratic

[22] We do not endow incoming entrepreneurs with private signals to keep the analysis simple. As there is only one source of uncertainty in direct investment, the flow of physical capital perfectly summarizes private information dispersed across entrepreneurs.

white-noise disturbance:

$$\begin{aligned} s_{i,t} &= f_{1,t} + \xi_{i,t}, \text{ with} \\ \xi &\sim N(0, \sigma_\xi^2). \end{aligned} \tag{2.20}$$

We appeal to the law of large numbers to state that $\int s_{i,t} di = f_{1,t}$, so there is no aggregate uncertainty in the currency market (but also no mechanism for perfect aggregation). Assuming joint normality between the idiosyncratic noise term and the other stochastic processes, investor i's conditional expectation of f_1 will be the least squares projection on the private signal s_i and the history of prices (a sufficient statistic for which is the Kalman filter estimate $\widehat{f_1}$). That is

$$E_{i,t} f_{1,t} = a s_{i,t} + (1-a)\hat{f}_{1,t}, \tag{2.21}$$

where $a = \frac{V_1(t)}{V_1(t)+\sigma_\xi^2}$ and $V_1(t)$ is the Kalman filter variance.

The continuous time Kalman filter is analytically cleaner, so to ease the exposition it is convenient to assume that investors maximize utility over the instantaneous change in wealth (i.e. let our time interval $\rightarrow dt$). Therefore, we will consider the continuous time analogues of our stochastic processes:

$$\begin{aligned} df_1 &= -\mu_1 f_1 dt + \sigma_1 dB_1 \\ df_2 &= -\mu_2 f_2 dt + \sigma_2 dB_2, \end{aligned} \tag{2.22}$$

where B_1 and B_2 are independent Brownian motions.

Solving for the price is the same as in the complete information case, however now the equilibrium price also depends on the Kalman filter estimate as well as noise and private signals (which aggregate to the true fundamental). That is

$$\mathcal{E}_t = \beta_0 + \beta_1 f_{1t} + \beta_{\widehat{f}} \widehat{f}_{1,t} + \beta_2 f_2. \tag{2.23}$$

Informativeness continues to depend on the ratio $\frac{\beta_1}{\beta_2}$. As in the case of complete information, the response of this ratio to an increase in government intervention depends on whether $\mu_2 \gtrless \mu_1$.

The intuition also remains the same. As the government smooths the price, the speculators have less incentive to distinguish between the two shocks. Thus each individual reveals less of their private signal and, aggregating across individuals the equilibrium price reveals less information about f_1 when f_1 is relatively persistent.

There are some new aspects that arise when we move from perfect to disaggregated information. In particular, we have

$$\beta_1 + \beta_{\widehat{f}} = \frac{1}{1 + \eta + \mu_1 + r}, \tag{2.24}$$

which is the coefficient on f_1 in the perfect information case (see equation 2.12). Thus, with disaggregated information investors put the same total weight on their estimate of f_1 as they do under perfect information, but now it is divided between the public estimate $\widehat{f_1}$ and the private signal s_i (which aggregates to f_1). One interesting point is that when f_2 is more persistent than f_1 (i.e. $\mu_1 > \mu_2$), the coefficient on the public estimate ($\beta_{\widehat{f}}$) is negative.[23] This implies that more weight is put on the true fundamental than was the case under complete information. Counterintuitively, there may be more information in the price under disaggregated information than under common information (keeping government policy constant).

This is not surprising if we consider that a more uncertain speculator is a less aggressive speculator. That is, a noisy private signal reduces the activity of speculators, inducing an information mechanism similar to that of government intervention. More formally, the intuition hinges on how speculators respond to a gap between their private and public signals. Using the linearity of the equilibrium price and expectations, we can write the speculator's estimate of f_2 as

$$\begin{aligned} \beta_2 E_{i,t} f_2 &= \mathcal{E}_t - \beta_0 - \beta_1 E_{i,t} f_1 - \beta_{\widehat{f}} \widehat{f_1} && (2.25) \\ &= \mathcal{E}_t - \beta_0 - \beta_1 a(s_i - \widehat{f_1}) - (\beta_1 + \beta_{\widehat{f}}) \widehat{f_1}. && (2.26) \end{aligned}$$

By substituting for the equilibrium price and rearranging, the (average) speculator's misper-

[23]See appendix D.

ception of f_2 is

$$\beta_2(Ef_2 - f_2) = \beta_1(1-a)(f_1 - \widehat{f}_1). \tag{2.27}$$

Now suppose that the average speculator's private signal is less than the public signal (i.e. $f_1 < \widehat{f}_1$). This implies that $Ef_2 < f_2$, so that speculators are underestimating f_2, while overestimating f_1. Recall that a positive shock means sell in anticipation of a declining price. Thus, speculators' underestimate of f_2 increases the incentive to buy, but their misestimate of f_1 provides too great an incentive to sell. Which effect dominates depends on the relative size of the mean reversion parameters. If μ_1 is relatively large, then the high estimate of f_1 generates an excess supply. To clear the market, the speculators need an additional incentive to buy. This may be provided by the expected decline in the public estimate of f_1 (recall that $\widehat{f}_1 > s_1 \Longrightarrow Ed\widehat{f}_1 < 0$). The additional motive to sell is secured when $\beta_{\widehat{f}} < 0$, that is when $Ed\widehat{f}_1 < 0$ implies a rising price. Thus $\beta_{\widehat{f}} < 0$ when $\mu_1 > \mu_2$.

From equation (2.24) we see that if $\beta_{\widehat{f}} < 0$, $\beta_1 > \frac{1}{1+\eta+\mu_1+r}$, its value under complete information. That is, the exchange rate's negative response to the public estimate increases the sensitivity to the private signal, enhancing the informational content of the exchange rate. Conversely, if $\mu_1 < \mu_2$, $\beta_{\widehat{f}} > 0$, and so $\beta_1 < \frac{1}{1+\eta+\mu_1+r}$. Thus disaggregated information reduces the quality of the public signal when the target fundamental is more persistent than noise but increases precision when $\mu_1 > \mu_2$.

This effect is related to the "self-defeating" result described in the social learning literature (see Vives 1996). Private signals comprise the only relevant information to the aggregate economy, yet individuals partially ignore their private signal in favor of the public signal (as implied by $a < 1$ and $\beta_{\widehat{f}} \neq 0$), which reduces the informativeness of the price and thus obstructs learning over time. In our set-up, the weight on the private signal is captured by β_1. However, the government cannot correct this externality. Government participation reduces the weight speculators place on the public signal, but only at the cost of reducing the importance of the private signal as well. That is an increase in η reduces both β_1 and $\beta_{\widehat{f}}$. Similarly, government intervention may increase the variance of the public signal, which shifts weight away from the public signal and toward the private signal. However, this will only be a second order effect and cannot correct the self-defeating effect of social learning.

2.5 Conclusion

This chapter highlights a key interaction between a government that smooths an asset price and informed speculators that trade for capital gains. In particular, we have seen that government intervention reduces the incentive for speculators to use their private information to differentiate between shocks. In the context of exchange rates, we have found that the policy implications depend on the relative capital gains potential of particular types of shocks. If we think of noise traders as generating high frequency fluctuations in the exchange rate, for example, the results favor less intervention. That is, by floating the exchange rate the government achieves less fundamental uncertainty and an exchange rate that is more efficient at buffering unwanted shocks. Conversely, if our "noise" shocks are relatively persistent, then the tendency should be to smooth the exchange rate. This may be the case of a developing country which has highly cyclical productivity but lacks the institutional framework to quickly reverse monetary shocks.

The chapter's main results extend beyond exchange rates to any asset that is traded for capital gains. There has been a recent trend toward government intervention in equity markets (e.g. Hong Kong in 1998 and Fed Chair Greenspan's famous "irrational exuberance" speech of 1996). The discussion about investing Social Security contributions in the stock market could also result in the smoothing of asset prices. This chapter points out that even with complete transparency, government trading may have adverse consequences on a market's ability to insure against risk and aggregate information.

2.6 Appendix

2.6.1 Appendix A - Kalman Filter

Continuous Time:

This is based on Kallianpur (1980). Suppose we have an unobserved process $X_t \in R^m$, and a signal $Y_t \in R^n$, and a multi-dimension Brownian motion $W_t \in R^{m+n}$, such that

$$\begin{aligned} dX_t &= [A_0(t) + A_1(t)X_t + A_2(t)Y_t]\, dt + B(t)dW_t \\ dY_t &= [C_0(t) + C_1(t)X_t + C_2(t)Y_t]\, dt + D(t)dW_t, \end{aligned} \tag{2.28}$$

where A_i, C_i, B, and D are matrices of appropriate dimension and satisfy certain measurability and integrability conditions. Then the optimal (minimum-variance) estimate of X_t conditional on $\{Y_s\}_{s=0}^{s=t}$ satisfies the stochastic differential equation

$$d\widehat{X}_t = \left[A_0(t) + A_1(t)\widehat{X}_t + A_2(t)Y_t\right] dt + [PC_1^T + BD^T] \left[DD^T\right]^{-1} \left[C_1(X_t - \widehat{X}_t)dt + DdW\right]. \tag{2.29}$$

The variance of this estimate satisfies the deterministic Riccati equation

$$\frac{dV}{dt} = A_1V + VA_1^T + BB^T - [VC_1^T + BD^T] \left[DD^T\right]^{-1} [C_1V + DB^T]. \tag{2.30}$$

In the models discussed in the text we assumed that the target for the inference was the first fundamental. This implies that $X = f_1$, $A_1 = -\mu_1$, $W = [B_1 \, ,B_2]$, and $B = [\sigma_1, \, 0]$. In the complete information case, $Y = \mathcal{E}$, while in the disaggregated information case $Y = \mathcal{E} - \beta_{\widehat{f}} f_1$ which is measurable with respect to the observed exchange rate process. In either case, $C_1 = \beta_1(\mu_2 - \mu_1)$ and $D = [\beta_1\sigma_1, \, \beta_2\sigma_2]$. We can then rewrite the Riccati equation as

$$\frac{dV}{dt} = -2\mu_1 V + \sigma_1^2 - \frac{((\mu_2 - \mu_1)V + \sigma_1^2)^2}{\sigma_1^2 + \left(\frac{\beta_1}{\beta_2}\right)^{-2} \sigma_2^2.}. \tag{2.31}$$

Note that starting from a given $V(0)$,

$$\frac{d\left(\frac{\partial V(t=0)}{\partial t}\right)}{d\left(\frac{\beta_1}{\beta_2}\right)^2} \leqslant 0, \tag{2.32}$$

where equality holds only when the numerator of the last term in (2.31) equals zero. Thus for a given starting value, the price process with a higher squared information ratio $\left(\frac{\beta_1}{\beta_2}\right)^2$ will generate a variance that rises slower (or falls faster). Along the path, therefore, the process with the higher squared information ratio will generate an equal or lower variance. Lastly, given our nonnegativity assumptions about μ_i, η and r, we will always have a nonnegative information ratio (note that we can relax the nonnegativity assumptions as long as β_1 and β_2 remain positive). Therefore, we need not distinguish between changes in the information ratio and changes in the squared ratio.

We can also solve explicitly for the steady state variance. For $\sigma_1 > 0$ and $\mu_2 \neq \mu_1$ the unique positive (and stable) steady state is

$$V^* = \frac{-\mu_2\sigma_1^2 - \mu_1\left(\frac{\beta_1}{\beta_2}\right)^2\sigma_2^2 + \sqrt{\left(\mu_2\sigma_1^2 + \mu_1\left(\frac{\beta_1}{\beta_2}\right)^2\sigma_2^2\right)^2 + (\mu_2 - \mu_1)^2\left(\frac{\beta_1}{\beta_2}\right)^2\sigma_2^2\sigma_1^2}}{(\mu_2 - \mu_1)^2}. \tag{2.33}$$

If $\mu_2 = \mu_1 \neq 0$, then

$$V^* = \frac{1}{2\mu_1}\left(\frac{\sigma_1^2\sigma_2^2}{\left(\frac{\beta_1}{\beta_2}\right)^2\sigma_1^2 + \sigma_2^2}\right). \tag{2.34}$$

If $\mu_1 = \mu_2 = 0$, then there is no steady state and $V \to \infty$.

Discrete Time (see Harvey (1989)):

The discrete time filter is a fairly straight-forward analogue of the continuous time case. In particular, our Riccati equation becomes

$$V_t = (1 - \mu_1)^2 V_{t-1} + \sigma_1^2 - \frac{\left((1 - \mu_1)(\mu_2 - \mu_1)V_{t-1} + \sigma_1^2\right)^2}{(\mu_2 - \mu_1)^2 V_{t-1} + \sigma_1^2 + \left(\frac{\beta_1}{\beta_2}\right)^{-2}\sigma_2^2}, \tag{2.35}$$

where V_t represents the variance of the filtered estimate using observations up to and including $\mathcal{E}_t$. Again an increase in the squared information ratio leads to a lower V_t given V_{t-1}. A simple induction argument shows that the variance will be equal or lower along the path the higher the ratio $\frac{\beta_1}{\beta_2}$.

2.6.2 Appendix B - A General Equilibrium Welfare Analysis

This appendix introduces a macro model that reproduces the welfare implications drawn from the simple investment problem used in the text. The model is based on the Blanchard-Kiyotaki (1987) type models developed by Obstfeld and Rogoff (1996). There exists a measure-one continuum of agents in the economy each producing a differentiated non-traded good. Agents also receive a homogenous endowment of the traded good, which is assumed to have price one in foreign currency (in this sense, our economy is "small").

There are two exogenous state variables in the economy. The first is taken to reflect productivity shocks. In particular, each individual receives a random (and identical) endowment of the tradeable good (Y_T) in period t. The second shock appears to the domestic agents as originating in the currency market. This could reflect liquidity shocks to foreigners holding domestic currency, exogenous shocks to money supply, or the presence of "noise traders" in the foreign exchange market. The key assumption is that the shock is transmitted via the exchange rate. This "nominal" shock will be labelled f_2 (and $y_T = \log(Y_T)$ takes the place of f_1 in the text). We assume y_T and f_2 are normally distributed and uncorrelated with each other.

Nontradeables are produced in period t by individuals. In period $t-1$, producers of the nontradeable goods set prices. These prices are set based on an information set Ω_p, the contents of which are identical to the Ω_I discussed in the text. Individuals produce and consume both tradeables and nontradeables in period t, save some of the proceeds by holding domestic currency, and then consume tradeables in the final period.

Individual i has the following preferences:

$$U_i = (1-\delta)\log C_{t,i} + \delta \log C_{t+1,i} - \frac{\kappa}{2} Y_N(i)^2. \tag{2.36}$$

First period consumption ($C_{t,i}$) is Cobb-Douglas between the tradeable good and a CES composite of the nontradeable goods:

$$\begin{aligned} C_{t,i} &= C_{T,i}^{\alpha} C_{N,i}^{1-\alpha} \\ C_{N,i} &= \left[\int_0^1 c_N(z)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}}. \end{aligned}$$

Second period consumption consists of only tradeables. The last term in (2.36) represents the disutility of producing a non-tradeable.[24] As all agents are identical up to the differentiated nontradeable, we can use the representative utility function

$$U = (1-\delta)\log C_{t,i} + \delta \log C_{t+1,i} - \frac{\kappa}{2}\int_0^1 Y_N(i)^2 di,$$

keeping in mind that the representative agent produces the various $Y_{N,i}$ noncooperatively. The

[24]See Obstfeld and Rogoff (1996) Chapter 10.

nominal income of our representative consumer in domestic currency is

$$I = P_T Y_T + \int_0^1 P_N(i) Y_N(i) di,$$

where $P_T = \frac{1}{\mathcal{E}}$ is the domestic currency price of the tradeable.

Solving the consumer's problem and assuming a symmetric equilibrium, we can express the representative agent's period $t-1$ expected utility as

$$\begin{aligned} & E_{t-1}U \\ = \quad & A + E_{t-1}\left\{(1-(1-\alpha)(1-\delta)y_T + \delta(e_{t+1}-e_t) - (1-\alpha)(1-\delta)Var_p(y_T - e_t)\right\}, \end{aligned} \tag{2.37}$$

where e represents the log exchange rate. The equilibrium exchange rate is determined as in the text, with fundamental demand arising from domestic residents' money demand (savings). Log-linearizing money demand and a slight modification of the government's trading rule[25] yields a linear equilibrium for the log exchange rate.[26]

The exchange rate regime enters equation (2.37) in two places. The first is in the term $(e_{t+1} - e_t)$. An appreciation in the value of domestic currency is welfare improving because residents hold domestic currency between periods. However, a trend appreciation is not sustainable for the domestic central bank. To rule out such policies, we will restrict the government to exchange rate regimes which do not lose reserves in expectation.

The relevant welfare consideration is the last term: $Var_p(y_T - \mathcal{E}_t)$. This term arises from price setters' response to increasing uncertainty about demand. In particular, the symmetric equilibrium implies a pricing rule

$$P_N = \gamma \left(E_p \left(\frac{Y_{T,t}}{\varepsilon_t} \right)^2 \right)^{\frac{1}{2}}, \tag{2.38}$$

where E_p indicates expectation conditional on the information set on which pricing decisions are made (Ω_p). Given the log normality of the exchange rate and output, we can expand the

[25] Namely, G has the same form as in the text, but calculated in foreign currency.
[26] The exchange rate derived in this way is log-normally distributed.

pricing equation (2.38)

$$\begin{aligned}\log(P_N) &= \log\gamma + \frac{1}{2}\log\left(E_p \exp 2(y_T - e)\right) \\ &= \log\gamma + E_p(y_T - e) + Var_p(y_T - e).\end{aligned}$$

Note that given a higher variance (conditional on Ω_p), firms set a higher price to insulate themselves against the volatility of demand.[27] Thus uncertainty about next period's income (valued in domestic currency) raises prices, reduces output, and so reduces welfare. This uncertainty depends on the information about income, the exchange rate and the covariance of the two, as was the case of the investment problem discussed in the text.

Consider $\Omega_p = \{y_{T,t},\ f_{2,t}\}$ as a benchmark. This is equivalent to assuming prices are flexible and set with full information. In that case, we have the familiar result that in the absence of any market friction, the choice of exchange rate regime is irrelevant. An alternative is to assume that the state variables are unobserved, but that agents can use the exchange rate as an informative signal. In particular, $\Omega_p = \{e_j\}_{j=0}^{j=t}$. Note that we allow agents to set prices contingent on the exchange rate at time t. Thus prices are flexible, but agents are incompletely informed as in the Lucas Supply model. In this case, welfare is determined by the variance of the estimate of y based on the exchange rate. A third possibility is the traditional "sticky price" framework in which agents set prices based on information available at date $t-1$ ($\Omega_p = \{y_{T,t-1},\ f_{2,t-1}\}$). In this case, the exchange rate is the only flexible price, which enables it to adjust to real shocks (a plus) but also propagate nominal shocks (a minus). If we make previous income shocks unobservable ($\Omega_p = \{e_j\}_{j=0}^{j=t-1}$), then the exchange rate remains an informative variable which helps predict next period's fundamentals (and next period's exchange rate). A trade-off similar to equation (2.19) arises because the government can increase the forecastability of the exchange rate, but only by altering the precision of the fundamental forecast.

[27] See Obstfeld and Rogoff (1998) for a more general discussion of the effect of variance on price setting.

2.6.3 Appendix C - Infinite Horizon

This appendix explores some of the issues that arise when speculators have infinite horizons.[28] The infinite horizon case involves a partial differential equation that does not allow for closed form solutions. To keep the analysis as simple as possible, this section departs slightly from the model in the text. In particular, assume that the government smooths the exchange rate by influencing the risk free interest rate. Recall from the text that the interest differential entered additively with η and so had an identical effect on $\frac{\beta_1}{\beta_2}$. Due to the Markov dynamics, a given shock today summarizes the future path and is discounted by the interest rate. The higher the discount rate, the less important the current innovation (over the infinite horizon) and the less prices respond. Of course the risk free rate is determined in equilibrium, and we are thus implicitly assuming that the government meets all demand for debt at a given rate. This is a reasonable assumption for a closed economy; it is less plausible that the home government can influence the risk free rate of speculators in an open economy. Nevertheless, this framework highlights the caveats introduced by a long horizon. The problem is further simplified by considering the first fundamental as a dividend payment or stochastic interest rate, rather than a separate demand for the asset. This implies that f_1 will be scaled by the variance in investor's demand curves. To avoid "blowing up" one fundamental versus the other as $\sigma_{\mathcal{E}}^2 \to 0$, we need to scale the second fundamental as well. One way to do this is to assume the second fundamental represents misperception of expected excess return by noise traders (as in DeLong et. al. (1990)). In this regard, the second fundamental will be denoted N and the one subscript will be dropped from the first fundamental.

The (informed) speculators are assumed to trade foreign and domestic currency continuously so as to maximize

$$U = E\int_0^\infty -e^{-\rho t - \psi C_t} dt, \tag{2.39}$$

where C_t is consumption of the tradeable good with price one in foreign currency. The derivation of this problem is now standard (see Merton (1992)), and the solution with noise traders follows Campbell and Kyle(1993) and Wang(1993). In particular, expected utility can be represented

[28] The infinite horizon entrepreneur's problem under incomplete information is studied in Detemple (1986) and Gennotte (1986). The informational considerations of the two-period investment decision carry over directly to the infinite horizon.

by a value function

$$J(W,N) = -\exp\{-\rho t - r\psi W - \frac{1}{2}b_1 - b_2 N^2 - b_3 N\},$$

where the constants b_i are determined by the Hamilton-Jacobi-Bellman equation and the equilibrium conditions for the exchange rate. Informed investor demand is

$$X_t^S = \frac{E_t(d\mathcal{E} + f dt - r\mathcal{E}dt) - \beta_N \sigma_N^2 (b_3 + b_2 N)}{r\psi\sigma_{\mathcal{E}}^2}. \tag{2.40}$$

The first term in the numerator of equation (2.40) represents the risk premium while the second term represents "hedging" demand. Hedging demand distinguishes the infinite horizon case from the short–horizon (myopic) demand studied in the text. This added element of demand arises from the desire to hedge against changes in the investment opportunity set (in this context, changes in the supply of domestic currency available to informed speculators). Hedging demand has two components:

$$\begin{aligned} \beta_N \sigma_N^2 &= \frac{cov\,(dN, dW)}{X^S} \qquad (2.41) \\ b_3 + b_2 N &= \frac{-J_{WN}}{J_W} \quad \left(= \psi \frac{\partial C}{\partial N}\right). \end{aligned}$$

The first term in (2.41) represents the covariance (per share of asset held) between changes in N and changes in wealth. This term declines with the risk free rate as the price's sensitivity to N declines (due to the discounting of the future implications of a current shock to N). The second term represents the percentage change in the marginal value of wealth due to a change in noise trader demand. This term becomes more sensitive to N (i.e. b_2 increases) as the risk free rate increases, reflecting the fact that the marginal utility of wealth becomes more sensitive to investment opportunities at high rates of return. The two terms pull in opposite directions, making the response of hedging demand to the risk free rate ambiguous.

To see how myopic and hedging demand influence informativeness, define $h = \beta_N \sigma_N^2 (b_3 + b_2 N)$. We can express the equilibrium exchange rate by

$$\mathcal{E}_t = \beta_0 + \beta_f f_t + \beta_N N_t$$

$$\beta_f = \frac{1}{\mu_f + r}$$
$$\beta_N = \frac{1-h}{\mu_N + r}.$$

Hedging demand increases the elasticity of informed investors' stabilizing demand to a noise shock, which dampens the net effect of noise trading on the price. We can see that this will improve the information ratio relative to the short-horizon case by noting that hedging demand reduces β_N (as $0 < h < 1$) from its myopic value ($\frac{1}{r+\mu_N}$). In particular, the information ratio can be written

$$\frac{\beta_f}{\beta_N} = \left(\frac{1}{1-h}\right)\left(\frac{\mu_f + r}{\mu_N + r}\right). \tag{2.42}$$

As before, we have the effect of relative mean reversion on capital gains, as implied by the second term in equation (2.42). The first term represents the effect of hedging. As noted above, its response to changes in government policy is ambiguous. Figure 6 shows how the two effects can interact. Across the columns, we have increasing mean reversion in noise (holding constant mean reversion in the fundamental). In the first row we have the information ratio plotted against the risk free rate. In the second row, we have the myopic information ratio, which increases iff $\mu_N < \mu_f$. The third row plots the hedging factor h against the interest rate. In the first case it is decreasing in r, but in the remaining columns it is increasing. The myopic rule of thumb provides a fairly reliable guide to the informational effect of government intervention, but there are cases when the informational response is complicated and/or reversed by the presence of hedging demand. This is illustrated in the third column in which the myopic factor is declining, but the rising hedging effect produces a declining and then increasing informational response to government intervention.

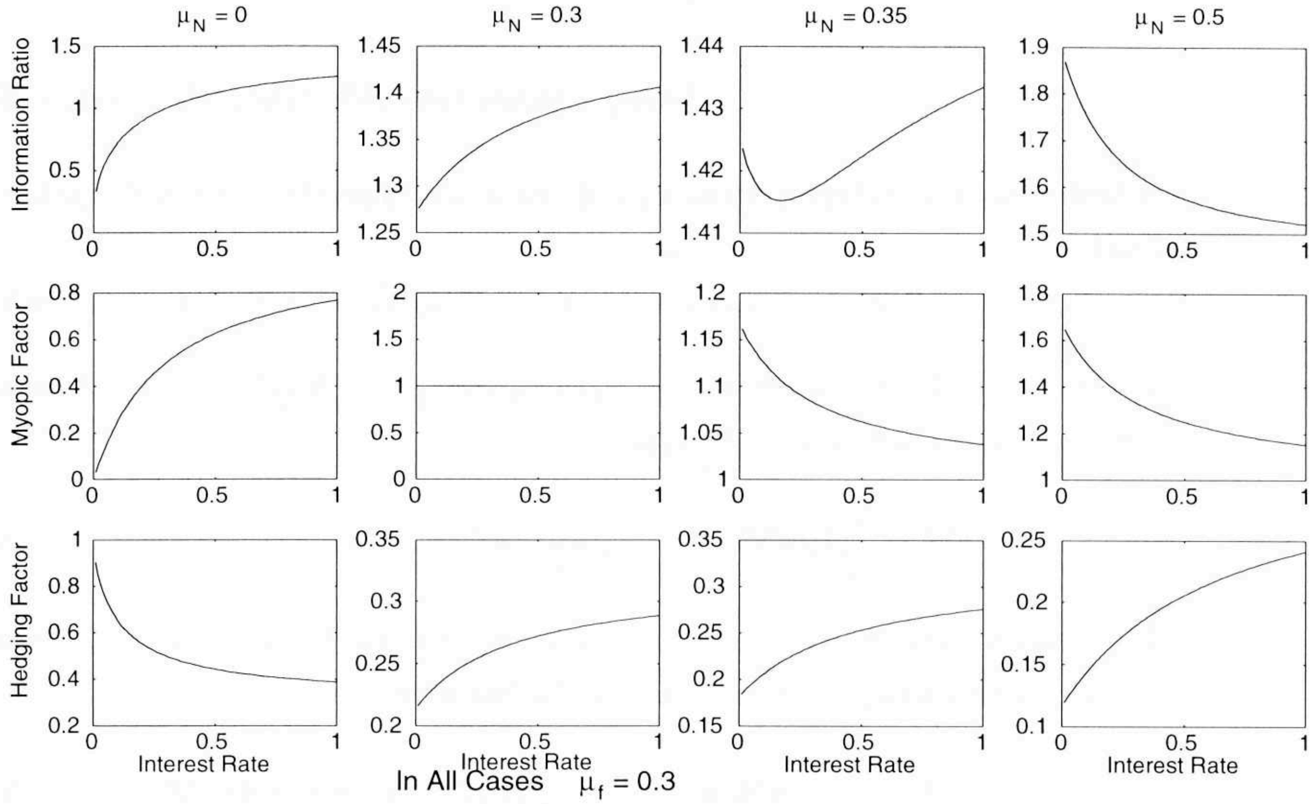

Figure 6

2.6.4 Appendix D - Derivations

This appendix derives results for disaggregated information and the basic model of section three under a different fundamental demand specification. To conserve notation, we take the interest differential to be zero (i.e. $r = 0$).

Disaggregated Information:

Here we solve for the equilibrium exchange rate under disaggregated information. We first posit the equilibrium form, determine the properties of the Kalman estimate, feed this estimate into the private sector demand curves and solve for the Rational Expectations Equilibrium.

The linear equilibrium price $\mathcal{E}$ satisfies

$$\mathcal{E} = \beta_1 f_1 + \beta_{\widehat{f}} \widehat{f}_1 + \beta_2 f_2 + \beta_0. \tag{2.43}$$

Differentiating

$$d\mathcal{E} = -\beta_1\mu_1 f_1 + \beta_{\widehat{f}} d\widehat{f_1} - \beta_2\mu_2 f_2 dt + \beta_1\sigma_1 dB_1 + \beta_2\sigma_2 dB_2. \tag{2.44}$$

Note that an individual investor i with private signal $s_i$will have the conditional expectation of (2.44):

$$E_i d\mathcal{E} = (-\beta_1\mu_1(as_i + (1-a)\widehat{f_1}) + \beta_{\widehat{f}} E_i d\widehat{f_1} - \beta_2\mu_2 E_i f_2)dt, \tag{2.45}$$

as $E_i f_1 = as_i + (1-a)\widehat{f_1}$, where the least squares projection coefficient $a = \frac{V_1}{V_1+\sigma_\xi^2}$. Aggregating across individuals and using $\int s_i di = f_1$,

$$Ed\mathcal{E} = \int (E_i d\mathcal{E})di = (-\beta_1\mu_1(af_1 + a\widehat{f_1}) + \beta_{\widehat{f}} Ed\widehat{f_1} - \beta_2\mu_2 Ef_2)dt. \tag{2.46}$$

To obtain $d\widehat{f_1}$, define $Y = \mathcal{E} - \beta_{\widehat{f}}\widehat{f_1}$, which is observable given the path of prices. Thus we can take dY as our signal process, which from (2.44) can be expressed:

$$dY = \{\mu_2\beta_0 + \beta_1(\mu_2 - \mu_1)f_1 - \mu_2 Y\}dt + \beta_1\sigma_1 dB_1 + \beta_2\sigma_2 dB_2. \tag{2.47}$$

Using these definitions of df_1 and dY, the Kalman filter gives

$$d\widehat{f_1} = -\mu_1\widehat{f_1}dt + A\left(\beta_1(\mu_2 - \mu_1)(f_1 - \widehat{f_1})dt + \beta_1\sigma_1 dB_1 + \beta_2\sigma_2 dB_2\right), \tag{2.48}$$

where $A \equiv \frac{V_1(\mu_2-\mu_1)+\sigma_1^2}{\sigma_1^2+\left(\frac{\beta_1}{\beta_2}\right)^{-2}\sigma_2^2}$. Investor i with private information $s_{i,t}$ will have conditional expectation of (2.48):

$$\frac{E_i d\widehat{f_1}}{dt} = -\mu_1\widehat{f_1} + A\beta_1(\mu_2 - \mu_1)(as_i - a\widehat{f_1}). \tag{2.49}$$

Integrating (2.49) across all individuals and using $\int s_i di = f_1$, we have

$$\frac{Ed\widehat{f_1}}{dt} = \frac{\int (E_i d\widehat{f_1})di}{dt} = -\mu_1\widehat{f_1} + A\beta_1(\mu_2 - \mu_1)(af_1 - a\widehat{f_1}). \tag{2.50}$$

Substituting into equation (2.46) and substituting for $\beta_2 Ef_2$ using (2.43):

$$\frac{Ed\mathcal{E}}{dt} = \mu_2\beta_0 + a(\mu_2 - \mu_1)\left[\beta_1 + \beta_{\widehat{f}}A\right] f_1 \tag{2.51}$$

$$+(\mu_2-\mu_1)\left[(1-a)\beta_1+\beta_{\widehat{f}}-a\beta_{\widehat{f}}A\right]\widehat{f}_1-\mu_2\mathcal{E}.$$

Recall that equilibrium in the asset market requires

$$E(d\mathcal{E})+f_1+f_2-\mathcal{E}-\eta(\mathcal{E}-\overline{\mathcal{E}})+\psi\sigma_{\mathcal{E}}^2 b=0. \tag{2.52}$$

Substituting in for $Ed\mathcal{E}$ we obtain

$$\begin{aligned}
\mathcal{E} &= \beta_1 f_1+\beta_{\widehat{f}}\widehat{f}_1+\beta_2 f_2+\beta_0 \\
\beta_1 &= \frac{1+\eta+aA(\mu_2-\mu_1)+\mu_1}{(1+\eta+\mu_1)(1+\eta+a(1-A)(\mu_2-\mu_1)+\mu_2)} \\
\beta_{\widehat{f}} &= \frac{(\mu_2-\mu_1)(1-a)}{(1+\eta+\mu_1)(1+\eta+a(1-A)(\mu_2-\mu_1)+\mu_2)} \\
\beta_2 &= \frac{1}{1+\eta+\mu_2} \\
\beta_0 &= \psi\sigma_{\mathcal{E}}^2 b_t+\eta\overline{\mathcal{E}}.
\end{aligned} \tag{2.53}$$

Note that A depends on $\frac{\beta_1}{\beta_2}$, so the expressions are defined implicitly. As discussed in the text, $\beta_1+\beta_{\widehat{f}}=\frac{1}{1+\eta+\mu_1}$ and $\text{sign}(\beta_{\widehat{f}})=sign(\mu_2-\mu_1)$ as $(1+\eta+\mu_1)(1+\eta+a(1-A)(\mu_2-\mu_1)+\mu_2)>0$. Differentiating $\frac{\beta_1}{\beta_2}$ with respect to η reveals that

$$\frac{d\left(\frac{\beta_f}{\beta_N}\right)}{d\eta}\gtreqless 0 \Longleftrightarrow \mu_1\gtreqless\mu_2. \tag{2.54}$$

Alternative Fundamental Demand:

The basic model in the text assumed that fundamental demand and government intervention were normalized by $\psi\sigma_{\mathcal{E}}^2$. This interpretation is consistent with fundamentals as dividends or noise trading. An alternative is to assume that fundamental demand is invariant to $\sigma_{\mathcal{E}}^2$

$$\text{Fundamental Demand } = f_1+f_2-\mathcal{E},$$

and government demand is

$$G=-\eta\mathcal{E}_t+b_t.$$

Speculative demand is given as before by

$$X_t^S = \frac{E(\Delta \mathcal{E})}{\psi \sigma_{RP}^2}.$$

The denominator σ_{RP}^2 is the variance of the risk premium. Market clearing requires

$$f_{1,t} + f_{2,t} - \mathcal{E}_t - \eta \mathcal{E}_t + b_t + \frac{E(\Delta \mathcal{E})}{\psi \sigma_{RP}^2} = 0.$$

Solving for the linear equilibrium:

$$\begin{aligned} \mathcal{E}_t &= \beta_0 + \beta_1 f_{1,t} + \beta_2 f_{2,t} \\ \beta_i &= \frac{1}{1 + \eta + \frac{\mu_i}{\psi \sigma_{RP}^t}}. \end{aligned}$$

Note that β_1 and β_2 are defined implicitly through σ_{RP}^2. In the text, we obtained explicitly solutions to β_1 and β_2 and could assume that $\sigma_{RP}^2 = \sigma_{\mathcal{E}}^2$. This implied no other payoff uncertainty besides the exchange rate (i.e. no dividend, interest rate or inflation uncertainty).

In the current context, we can solve for β_i by expressing

$$\sigma_{\mathcal{E}}^2 = \beta_1^2 \sigma_1^2 + \beta_2^2 \sigma_2^2.$$

That is,

$$\sigma_{\mathcal{E}}^2 = \left(\frac{\psi \sigma_{RP}^2}{(1+\eta)\psi \sigma_{RP}^2 + \mu_1} \right)^2 \sigma_1^2 + \left(\frac{\psi \sigma_{RP}^2}{(1+\eta)\psi \sigma_{RP}^2 + \mu_2} \right)^2$$

Note that β_1 and β_2 are increasing in $\sigma_{\mathcal{E}}^2$ and the two expressions on either side of the equal sign may not cross in the positive quadrant. To ensure a solution to this expression, we assume that there is some additional uncertainty. In particular, $\sigma_{RP}^2 = \sigma_{\mathcal{E}}^2 + \sigma_z^2$, with σ_z^2 as small as we like but strictly greater than zero. In other words, we assume the return on domestic assets is never completely certain. The existence of σ_z^2 also ensures that speculative demand declines as the risk premium$\rightarrow 0$ (that is, the numerator of $X^S = \frac{RP}{\psi \sigma_{RP}^2}$ approaches zero faster than the denominator). Once we have solved for σ_{RP}^2, we have unique expressions for β_1 and β_2.

The information ratio becomes

$$\frac{\beta_1}{\beta_2} = \frac{(1+\eta)\psi\sigma^2_{RP} + \mu_2}{(1+\eta)\psi\sigma^2_{RP} + \mu_1}.$$

As in the text, the relative magnitudes of μ_1 and μ_2 determines how the information ratio responds to a change in$(1+\eta)\psi\sigma^2_{RP}$. An added component here is how the term $(1+\eta)\psi\sigma^2_{RP}$ responds to a change in η (recall that $\sigma^2_{\mathcal{E}}$ declines in η). In the limit as $\eta \to \infty$, this term also approaches infinity. Therefore, the information ratio approaches that implied by Fundamental Demand. The rule of thumb that a pure float is more informative than a hard peg iff $\mu_1 < \mu_2$ remains true. However, the information ratio may not be monotonic for intermediate values of η. This implies that a "risk aversion" affect may compete with the capital gains and hedging effects discussed in the text and Appendix B. For small values of η the variance may fall faster than η increases, and the net effect of intervention is to magnify speculative demand relative to fundamental demand. A sufficient condition for this effect not to happen for any η is that $\frac{-d\log(\sigma^2_{RP})}{d\eta} < 1$ at $\eta = 0$. An alternative sufficient condition is that $\sigma^2_z = \sigma^2_{\mathcal{E}}$ at $\eta = 0$.

Chapter 3

Emerging Market Crises and Macroeconomic Fundamentals[1]

3.1 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 varying extents, 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 chapter 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

[1] **This chapter is co-authored with Fernando Broner.**

assume that stocks maintain the same covariance structure with macroeconomic fundamentals during crises as during tranquil-periods, what are the implied fundamentals that best explain the cross-section of returns in a crisis? How do these differ from the observed crisis fundamentals? And second, can this information be used to evaluate competing theories of emerging market crises?

In response to the first question, our first finding is that the tranquil-period relationship between fundamentals and returns retains considerable explanatory power during crises. In particular, an asset's normal-period covariance with macroeconomic fundamentals is a good indicator of that asset's performance *relative* to other assets in the country. Moreover, the implied "effective" fundamentals that best explain the cross-section of returns are in general less severe than the measured crisis fundamentals – the implied interest rate and contraction in output are less than the realized values – suggesting investors discount the dramatic movements in fundamentals during crises. 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 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 1 plots the cross-sectional variance of monthly returns for 30 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).

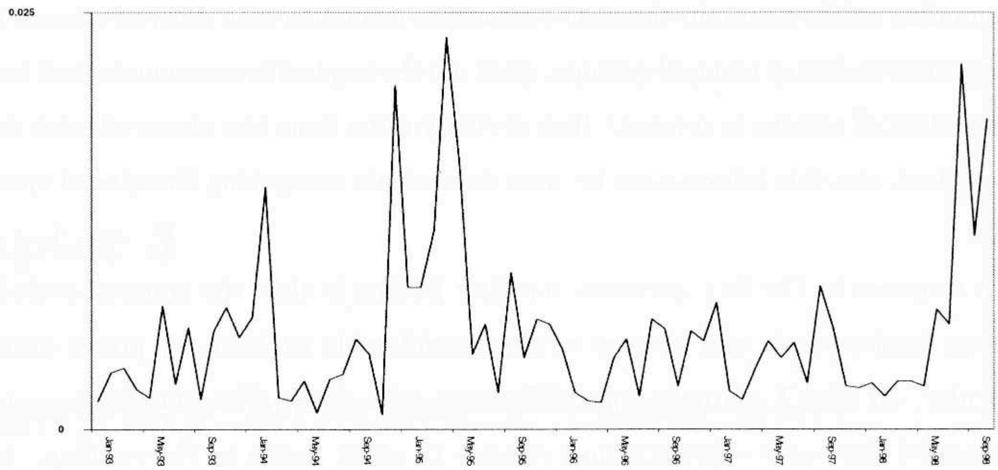

Figure 1: Cross-sectional variance of returns in Mexico

An immediate question prompted by figure 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 stock returns to macroeconomic variables during non-crisis periods using a standard multi-factor model. This provides us with a collection of "factor loadings" or "betas" that describe how each stock 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 the same or sometimes larger percentage of the cross-sectional variance (as measured by R^2) during crises relative to tranquil periods. In this sense, the normal-period covariance structure retains considerable predictive power during crises.

Note that we do not regress returns on fundamentals during our second-stage, cross-sectional regressions. Instead, we regress returns on factor *sensitivities*. This 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 (BoP) 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. (See Goldfajn and Gupta (1998) and Borensztein and De Gregorio (1999).) These phenomena can be seen in the case of Mexico in 1995. Figure 2 shows the annualized nominal peso interest 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.[2] In Argentina, the dollar lending rate also rose considerably in early 1995. 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. In particular, the second-stage regressions determine the macroeconomic innovations that best explain the observed cross-section of returns. These effective innovations can be thought of as tranquil-period equivalents.

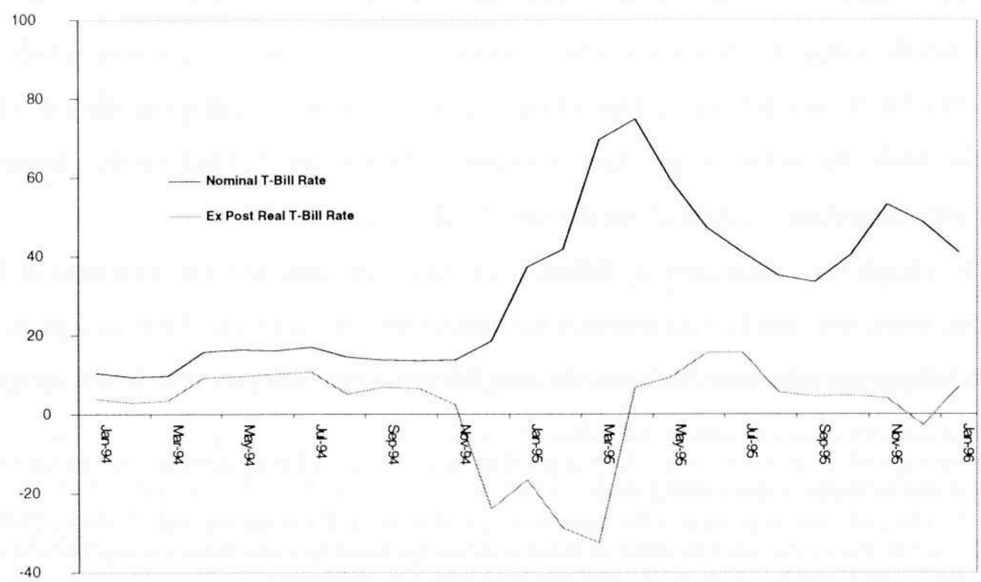

Figure 2: Mexican T-Bill Rate

With this procedure, we find that the effective macroeconomic shocks are generally less than the observed innovations. For example, the effective shock to interest rates during the

[2] 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%.

Tequila crisis of 1995 is roughly one third the observed value in Mexico and less than one tenth in Argentina.[3] The observed drop in industrial production was roughly double the effective value in Mexico and Argentina. This suggests that investors discount the relative magnitudes of observed shocks during crises, perhaps anticipating their transitory nature.

Finally, our procedure provides a means for evaluating which macroeconomic factors play significant roles during crises. In particular, we can assess whether sensitivity to a particular fundamental helps explain the pattern of returns.[4] This in turn helps distinguish between different types of theories of emerging market crises.[5]

In our empirical analysis, we find that the sensitivity to interest rates explains a significant portion of the distribution of returns during the Tequila and Russian crises. The sensitivity to domestic credit growth is also generally significant, while the sensitivity to industrial production, despite severe recessions, has little explanatory power. This points to the importance of credit availability as a crucial factor in emerging market crises. However, as noted above, the impact of credit tightening is generally less than the spike in observed interest rates or fall in domestic credit would suggest. A notable exception occurred during the Russian crisis of 1998. The estimates for Argentina during that crisis imply an unexpected drop in effective domestic credit growth, while the actual innovation was zero. This suggests that credit channel effects were especially important in Argentina during the Russian crisis.[6]

The chapter is organized as follows: Section two outlines the theoretical framework for relating stock returns to macroeconomic fundamentals; section three describes the empirical methodology; section four contains the empirical results; and section five concludes.

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[3] In the case of Mexico we do not have a good measure of actual real interest rate, so part of this difference could be due to higher expected inflation.

[4] In this regard, our approach is the mirror-image of that of Eichengreen and Mody's (1998) study of bond spreads. While they estimate the effect of fundamentals on bond spreads during crises, we use price movements and factor sensitivities to estimate implied fundamentals.

[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 Obtsfeld (1994). For example, Chang and Velasco (1998) introduces an open-economy bank run model 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.

[6] For recent theoretical work on emerging market crises that emphasize credit constraints, see Caballero and Krishnamurthy (1998) and Aghion, Bacchetta, and Banerjee (1999).

3.2 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.

3.2.1 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

$$Z_t = \log(P_{t+1} + D_{t+1}) - \log(P_t). \tag{3.1}$$

A Taylor expansion yields

$$Z_t \approx k + \rho p_{t+1} + (1-\rho)d_{t+1} - p_t, \tag{3.2}$$

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 (3.2) 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:

$$Z_{t+1} = E_t Z_{t+1} + (E_{t+1} - E_t) \sum_{s=0}^{\infty} \rho^s \Delta d_{t+1+s} - (E_{t+1} - E_t) \sum_{s=1}^{\infty} \rho^s Z_{t+1+s}, \tag{3.3}$$

where $\Delta d_{t+1}$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 (3.3) 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 (3.3) as a linear combination of innovations to macroeconomic variables and an idiosyncratic residual. In particular, for stock j at time $t+1$:

$$(E_{t+1} - E_t) \sum_{s=0}^{\infty} \rho^s \Delta d_{j,t+1+s} = \beta_{j,1} F_{1,t+1} + ... + \beta_{j,k} F_{K,t+1} + \varepsilon_{j,t+1}, \tag{3.4}$$

where $F_{k,t+1}, k = 1, ..., K$, represent innovations to macroeconomic variables and $\varepsilon_{j,t+1}$ represents shocks to the idiosyncratic component of dividends. The important assumption behind (3.4) 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

$$E_t Z_{j,t+1} = \beta_{j,0}, \text{ for } t \text{ outside crisis.} \tag{3.5}$$

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:

$$Z_{j,t} = \beta_{j,0} + \sum_{k=1}^{K} \beta_{j,k} F_{k,t} + \varepsilon_{j,t}. \tag{3.6}$$

Equation (3.6) 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

$$\beta_{j,0} = \lambda_0 + \sum_{k=1}^{K} \beta_{j,k}\lambda_k, \tag{3.7}$$

where λ_k are the risk premia associated with factor F_k and λ_0 is the return on the "zero-beta" portfolio.[7] Although we do not test that the APT holds, we will point out how the results can be interpreted through the APT.

3.2.2 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.[8]

Suppose that at time T an unexpected crisis of length τ starts. The response of asset prices will reflect both the innovations to expected dividend growth and expected future returns.[9] The values of macroeconomic fundamentals that capture the change in expected dividend growth during crises will be referred to as "present value" fundamentals to distinguish them from those that also reflect the changes in risk premia. Denoting present-value fundamentals as $\widetilde{F}_{k,T}$, the

[7] 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.

[8] 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.

[9] In this section we will assume that factor sensitivities do not change during crises.

change in expected dividend growth is given by

$$(E_T - E_{T-1})\sum_{s=0}^{\infty}\rho^s \Delta d_{j,T+s} = \sum \beta_{j,k}\widetilde{F}_{k,T} + u_{j,T}. \tag{3.8}$$

In addition, changes in risk premia are reflected in changes in expected future returns. 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

$$\begin{aligned}(E_T - E_{T-1})\sum_{s=1}^{\infty}\rho^s Z_{j,T+s} &= \sum_{s=1}^{\tau}\rho^s \Delta\beta_{j,0} \\ &= \frac{\rho-\rho^{\tau+1}}{1-\rho}\Delta\beta_{j,0},\end{aligned} \tag{3.9}$$

where $\Delta\beta_{j,0}$ is the increase in asset j's risk premium during the crisis. Assume that the APT holds and decompose the change in expected return into revisions in factor risk premia:

$$\begin{aligned}\frac{\rho-\rho^{\tau+1}}{1-\rho}\Delta\beta_{j,0} &= \frac{\rho-\rho^{\tau+1}}{1-\rho}(\Delta\lambda_0 + \sum_k \beta_{j,k}\Delta\lambda_k) \\ &= \Delta\tilde{\lambda}_0 + \sum_k \beta_{j,k}\Delta\tilde{\lambda}_k, .\end{aligned} \tag{3.10}$$

where $\frac{\rho-\rho^{\tau+1}}{1-\rho}\Delta\lambda = \Delta\tilde{\lambda}$. The return at time T is then given by

$$Z_{j,T} = E_{T-1}Z_{j,T} + (E_T - E_{T-1})\sum_{s=0}^{\infty}\rho^s \Delta d_{j,T+s} - (E_T - E_{T-1})\sum_{s=1}^{\infty}\rho^s Z_{j,T+s} \tag{3.11}$$

$$= \lambda_0 + \sum_k \beta_{j,k}\lambda_k + \sum_k \beta_{j,k}\widetilde{F}_{k,T} + u_{j,T} - (\Delta\tilde{\lambda}_0 + \sum_k \beta_{j,k}\Delta\tilde{\lambda}_k) \tag{3.12}$$

$$= \lambda_0 - \Delta\tilde{\lambda}_0 + \sum_k \beta_{j,k}\left(\widetilde{F}_{k,T} + \lambda_k - \Delta\tilde{\lambda}_k\right) + u_{j,T}$$

$$= \lambda_0' + \sum_k \beta_{j,k}\left(\widetilde{F}_{k,T} + \lambda_k'\right) + u_{j,T} \tag{3.13}$$

where $\lambda_k' \equiv \lambda_k - \Delta\tilde{\lambda}_k$.

We finally define the effective innovation to fundamental k as

$$\hat{F}_{k,T} = \widetilde{F}_{k,T} + \lambda_k', \tag{3.14}$$

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

3.2.3 Alternative Crises 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.[10] 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

$$\begin{aligned} Z_{j,T} &= E_{T-1}Z_{j,T} + (E_T - E_{T-1})\sum_{s=0}^{\infty}\rho^s \Delta d_{j,T+s} - (E_T - E_{T-1})\sum_{s=1}^{\infty}\rho^s Z_{j,T+s} \\ &= E_{T-1}Z_{j,T} - \rho\Delta e \qquad (3.15) \\ &= \beta_{j,0} - \rho\Delta e. \end{aligned}$$

This is true for all stocks, and so the entire market should fall by $\rho\Delta e$ (below the expected return).

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 in the risk premia charged on all emerging market assets. Let the required return after time $t+1$ increases by a factor of δ. A similar exercise implies that

$$\begin{aligned} Z_{j,t+1} &= E_t Z_{j,t+1} - (E_{t+1} - E_t)\sum_{s=1}^{\infty}\rho^s Z_{j,t+1+s} \qquad (3.16) \\ Z_{j,t+1} &= \beta_{j,0} - \frac{\rho}{1-\rho}\delta. \end{aligned}$$

[10] 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.

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 (as has been the experience in Asia and Latin American, but not that of Europe in 1992). A recession is often needed to balance the current account to offset a reversal of capital flows. The recession in turn will impact dividends, generating a drop in stock values. If the cycle works through aggregate demand, we expect stocks that are particularly sensitive to output to fall disproportionately. Namely, those stocks with a high β on aggregate output will fall more than the market average. Similarly, credit-channel theories also predict that some assets would fall more than others. In particular, firms that are more sensitive to interest rates and/or domestic credit growth should fall disproportionately more in a crisis typified by credit-channel shocks.[11]

3.3 Empirical Methodology

The empirical methodology can be divided in two stages. In the first stage the factor sensitivities of each stock are estimated, using only non-crisis data, based on equation 3.6. This yields a cross section of estimates, $\hat{\beta}_{j,k}$, and a fitted regression for each stock:

$$Z_{j,t} = \hat{\beta}_{j,0} + \sum_{k=1}^{K} \hat{\beta}_{j,k} F_{k,t} + \hat{\varepsilon}_{j,t}. \tag{3.17}$$

We thus obtain $J \times K$ betas representing how innovations to the K macroeconomic factors affect the returns of the J assets in our sample.

We then use equation 3.6, this time applied to crisis periods, to generate an alternative measure macroeconomic variables. In particular, we can obtain estimates of macroeconomic variables that best explain the cross section of returns during a crisis. This is done by regressing the cross section of returns during the crisis period T on the 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

[11] Caballero and Krishnamurthy (1998) and others have stressed that a market crash reduces collateral values, reducing the ability to obtain credit which in turn lowers dividends and leads to a further reduction in equity value. Stocks that are more likely to be credit constrained will therefore tend to fall disproportionately during a credit-channel crisis. One plausible scenario is that firms that are sensitive to interest rates have large debt to wealth ratios and are more likely to be affected by a collateral squeeze.

variables and perform the cross sectional regression:[12]

$$Z_{j,T} = \gamma_0 + \sum_{k=1}^{K} \hat{\beta}_{j,k} \hat{F}_{k,T} + u_{j,T}, \tag{3.18}$$

where $\hat{F}_{k,T}$ is the implied innovation to factor k (or effective factor k) during crisis period T. In a sense, this reverses the logic applied in tranquil times: we take stock returns as a proxy for future dividends and risk premia and translate them into macroeconomic fundamentals using the mapping estimated during tranquil periods. This gives us estimates of macroeconomic fundamentals "as if" the fundamentals were realized during tranquil periods.

In interpreting our second-stage coefficients, we make use of equation 3.11. Recalling the definition of effective innovation in equation 3.14, we observe that these coefficients incorporate both $\widetilde{F}_{k,T}$, the present-value fundamental, and λ'_k, the pre-crisis factor risk premium and changes in this premium during the crisis.[13]

As mentioned in the introduction, the results of this second-stage regression provide insights regarding two issues. First, can the (normal-period) responsiveness to macroeconomic factors explain the relative movements of asset prices during crises? In particular, can we find effective fundamentals that, when combined with tranquil-period covariances, explain the observed cross-section of returns during crises? We determine the explanatory power of normal-period betas by performing the second-stage regressions for both crisis and non-crisis periods, and comparing the fit of the two sets of regressions. The same regressions also yield estimates of effective fundamentals, which we compare with observed fundamentals for crisis and tranquil periods.

Second, we use the estimated values for the effective fundamentals to distinguish between alternative crisis scenario. In particular, we exploit the cross section behavior of stocks during a market crash to identify the important macroeconomic elements of a crisis. As long as

[12] This 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) by subtracting out observed fundamentals.

[13] If the $\beta_{j,k}$'s change during crises, $\hat{F}_{k,T}$ also incorporates the component of this change which is correlated with the non-crisis $\beta_{j,k}$'s. Since we cannot determine which part of the estimated $\hat{F}_{k,T}$ corresponds to changes in the $\beta_{j,k}$'s, when interpreting the results one has to keep in mind that these changes are included in our effective innovations to fundamentals. We do not consider this as a big problem, because only a particular component of the changes in the betas is reflected in our results. For example, if firms that are more sentitive to interest rates increase their sensitivity relatively more than those that are less sensitive, we will measure this as a larger effective innovation to the interest rate.

competing crisis scenarios hold different implications for the cross section of returns, 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 change in the cross-sectional variation of asset returns. As a result, our second-stage regression of $Z_{j,T}$ on $\hat{\beta}_{j,k}$ would produce a significant constant term, but no other significant coefficients. In contrast, if the crisis gives rise to a recession a significant coefficient in output variables would be expected, while credit-channel stories would predict significant coefficients on interest rate and credit variables.

It is important to understand at this point that we cannot distinguish how much of the effective fundamental is due to revisions to dividends and how much is due to changes in risk premia. If we assume that the relationship between macroeconomic fundamentals and future dividend growth is the same during crises as during tranquil periods, we can recover the crisis factor risk premia by subtracting the observed macro variable $\widetilde{F}_{k,T}$ and pre-crisis λ_k from our regression estimate $\hat{F}_k$. However, it is not likely that the macroeconomic variables observed during emerging market crises have the same relationship to future dividends as during tranquil periods. Alternatively, if we assume that the factor risk premia do not change during a crisis, then we can estimate λ_k during the tranquil periods and subtract these estimates from our regression $\hat{F}_k$ to obtain the true fundamental. Again, it is not plausible that risk premia do not change during crises.

In addition, the linear approximation may break down during crises. For example, many credit channel stories involve an inequality constraint that becomes relevant only when liquidity is scarce. This implies that a linear relationship may be valid during tranquil periods, but cannot be extrapolated to crisis periods. The fact that inequality constraints do not bind during normal periods makes them hard to measure. However, we can interpret the "effective" fundamentals produced by our cross section regressions as a measure of the nonlinearities inherent in a crisis. In this manner, the difference between the observed interest rate and the "effective" interest rate may be indicative of the extent to which firms are running up against an inequality constraint (or other nonlinearity) in obtaining loans.

3.4 Empirical Results

Our empirical section focuses on two crises – the Tequila crisis associated with Mexico's devaluation of the Peso in December, 1994, and the Russian devaluation of August 1998. We explore the effect of the two crises on stock market returns in Mexico and Argentina. Both economies were hit by the crises in question, as seen from the summary statistics in Table 1.

Table 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: IP is industrial production growth.T-Bill is the interest rate of short-term peso bonds. Loan rate is the interest rate on dollar loans to prime firms. ER is the price of a dollar in local currency. All rates are annualized.

We use industry indices of equities constructed by DataStream. The use of industry portfolios reduces the idiosyncratic element in estimating our first stage regressions (see Chen et al. 1986). Excess returns are calculated in dollar terms by taking the monthly change in each index and subtracting currency depreciation and the US T-Bill rate. We have J =30 industry indices for Mexico and J =22 for Argentina running from March 1993 until October 1998. We first estimate the matrix of factor sensitivities using "normal" months. That is we estimate the sensitivity of asset j to factor k from equation (3.17), which is repeated here:

$$Z_{j,t} = \hat{\beta}_{j,0} + \sum_{k=1}^{K} \hat{\beta}_{j,k} F_{k,t} + \hat{\varepsilon}_{j,t}. \tag{3.17}$$

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 were calculated using residuals of a three-variable VAR. A separate VAR was 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 period" estimation to before the Tequila crisis to avoid including the Asian crisis (which did not dramatically affect Latin America) in our tranquil period.

Table 2 reports summary statistics for the J first stage regressions. The mean and standard deviation reflect the cross-sectional distribution of $\beta' s$ over the J industries. 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: 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: "Pre" and "All" 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 accross stocks of estimated coefficients and standard deviations.

After running the first stage regressions, we regressed returns observed during the crisis months on the cross section of estimated factor loadings $\hat{\beta}_{j,k}$. This is the regression referred to in equation (3.18):

$$Z_{j,T} = \gamma_0 + \sum_{k=1}^{K} \hat{\beta}_{j,k} \hat{F}_{k,T} + u_{j,T}. \tag{3.18}$$

This regression tests the explanatory power of the normal-period covariance structure. As noted in the introduction, the cross-sectional variance of returns rises during crises. Table 3 summarizes the ability of our second stage regression to explain the cross-sectional distribution during normal and crisis months.[14]

Table 3: 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

Note: "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.

Despite the dispersion of returns during crises in Mexico, 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.[15] This suggests that normal period covariances retain considerable explanatory power during crisis periods, at least with respect to differences across stocks. Although our regressors do not explain why stocks fell on average during a crisis, they shed light on which stocks fell more relative to the average; that is, if one decided to remain invested in a crisis country, fundamentals are a good guide as to which stocks will outperform the average.

For an additional comparison between crisis and tranquil periods, table 4 presents the average difference between the observed fundamentals and the "effective" fundamentals (i.e.

[14]For each tranquil month, the cross-sectional regression used $\beta's$ estimated from other tranquil peirods (i.e. if the cross-section focused on month j, the first stage regression used months $\{t \mid t \neq j \text{ and } t \text{ tranquil}\}$).

[15]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.

$\hat{F} - F$) estimated from the cross-section regressions referred to in table 3.. On average, we see as expected that the effective fundamentals differ more from the observed values during crises. For Mexico, we see that 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 4: Second-Stage Regressions: Tranquil vs. Crisis Months

	Average $\widehat{F}$-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 $\hat{F}$. The difference $\hat{F}$-F was averaged over tranquil months and crisis months.

We now focus on the individual cross-sectional regressions for crisis months. Table 5 reports the results of this regression for Mexico and Argentina. The coefficients reported refer to the $\hat{F}_k$ estimated from equation (3.18). The 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. Argentina's peg to the dollar may have earned some credibility during the Tequila crisis, but it is not immediately apparent that the crisis permanently changed the covariance structure between returns and macro variables.

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.[16] We do not correct the point estimates for the potential bias induced by this measurement error.

Table 5: Second-Stage Regressions: Whole Crises

			Constant	Market	IR	IP growth	DC growth	R^2
Mexico	Dec.94 - Mar.95	All	-0.17	0.03	31.32	0.11	0.44	0.42
			(-3.69)	(0.61)	(3.74)	(2.59)	(2.61)	
		Pre	-0.13	-0.10	5.03	-0.03	0.04	0.56
			(-4.37)	(-3.36)	(4.97)	(-1.12)	(2.40)	
		Actual		-0.05	15.7	-0.08	0.04	
	Aug.98 - Sep.98	All	-0.06	-0.07	15.50	0.12	0.07	0.32
			(-1.09)	(-1.08)	(1.70)	(2.53)	(0.41)	
		Pre	-0.04	-0.08	3.34	-0.01	0.08	0.36
			(-0.93)	(-2.10)	(2.57)	(-0.36)	(3.58)	
		Actual		-0.08	13.63	0.02	-0.22	
Argentina	Dec.94 - Mar.95	All	-0.06	-0.00	0.55	0.08	-0.01	0.21
			(-1.60)	(-0.02)	(0.49)	(1.44)	(-1.05)	
		Pre	-0.06	-0.00	0.28	0.02	-0.00	0.11
			(-2.12)	(-0.12)	(1.99)	(1.67)	(-0.29)	
		Actual		-0.05	4.64	-0.03	-0.03	
	Aug.98 - Sep.98	All	-0.22	0.00	-3.56	-0.05	-0.03	0.17
			(-2.16)	(0.03)	(-1.30)	(-0.41)	(-1.00)	
		Pre	-0.12	-0.07	-0.26	0.00	-0.04	0.32
			(-1.50)	(-0.84)	(-0.73)	(0.00)	(-2.27)	
		Actual		-0.15	2.78	-0.02	-0.00	

Note: "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 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.

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

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 Argentinian 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 6 and 7.

Table 6: Second-Stage Regressions: Monthly Regressions for Mexico

		Constant	Market	IR	IP growth	DC growth	R^2
Dec. 94	All	-0.40	0.13	69.87	0.28	1.28	0.53
		(-3.94)	(1.09)	(3.84)	(2.98)	(3.55)	
	Pre	-0.39	-0.12	11.14	0.05	0.03	0.48
		(-5.94)	(-1.88)	(4.93)	(0.86)	(0.69)	
	Actual		-0.09	4.13	-0.04	-0.06	
Jan. 95	All	-0.06	-0.13	17.94	0.04	-0.04	0.37
		(-1.00)	(-1.92)	(1.74)	(0.68)	(-0.21)	
	Pre	-0.60	-0.14	2.68	-0.03	0.08	0.37
		(-1.35)	(-3.21)	(1.82)	(-0.72)	(3.48)	
	Actual		-0.15	19.28	-0.10	0.06	
Feb. 95	All	-0.07	-0.11	9.48	0.08	0.54	0.35
		(-1.00)	(-1.33)	(0.78)	(1.26)	(2.24)	
	Pre	-0.06	-0.15	1.06	-0.03	0.02	0.29
		(-1.14)	(-3.10)	(0.63)	(-0.76)	(0.87)	
	Actual		-0.24	5.48	-0.26	0.04	
Mar. 95	All	-0.16	0.24	27.97	0.05	-0.04	0.40
		(-2.30)	(2.86)	(2.19)	(0.80)	(-0.15)	
	Pre	-0.01	0.02	5.22	-0.10	0.03	0.52
		(-0.22)	(0.40)	(3.17)	(-2.51)	(0.95)	
	Actual		0.27	33.91	0.09	0.12	
Aug. 98	All	-0.15	-0.26	9.94	0.18	-0.63	0.51
		(-1.48)	(-2.18)	(0.55)	(1.94)	(-1.78)	
	Pre	-0.09	-0.22	5.52	0.04	0.16	0.36
		(-1.23)	(-2.84)	(2.13)	(0.61)	(3.70)	
	Actual		-0.28	4.05	0.02	-0.11	
Sep. 98	All	0.04	0.13	21.06	0.06	0.78	0.27
		(0.44)	(1.28)	(1.40)	(0.76)	(2.63)	
	Pre	0.02	0.06	1.14	-0.06	-0.00	0.12
		(0.35)	(0.88)	(0.53)	(-1.17)	(-0.14)	
	Actual		0.13	23.20	0.03	-0.33	

Note: "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.

Table 7: Second-Stage Regressions: Monthly Regressions for Argentina

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

Note: "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 variables during the crises.

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 5'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 underscores 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 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.

3.5 Conclusion

In this chapter we develop a methodology for evaluating movements in macroeconomic fundamentals during crises. The approach links the cross-section of asset returns during crises to the non-crisis covariance with fundamentals (or betas). We find that sensitivity to fundamentals explains a large part of the cross-sectional variance during crises, implying that the normal period relationship between returns and fundamentals retains explanatory power regarding relative price movements during crises. We also find that the effective fundamentals that best explain the cross-sectional movements are generally less than the observed values. In addition, we find that stocks that are sensitive to interest rates and domestic credit fall disproportionately during a crisis, while sensitivity to industrial production does not appear to be a significant determinant. This pattern suggests that credit market imperfections are an important element in emerging market crises.

Chapter 4

The Informational Implications of Capital Controls

4.1 Introduction

The last 20 years have witnessed a dramatic rise in the ability of capital to flow freely between countries. Major European economies dropped the last of their controls in the 1980s, and by the early 1990s many emerging markets had embraced capital account liberalization. The flow of foreign capital fueled dramatic growth in Asia and Latin America during this period, reconfirming the theoretical benefits of allowing capital to flow to its most productive uses.

However, the 1990s also demonstrated the volatility of international capital flows. For example, in 1997 several Asian currencies lost over half their value and inflows of private capital to emerging markets fell nearly 30%. Several explanations have been proposed to explain the boom-bust nature of capital movements. One prominent theme in this recent literature is informational imperfections in capital markets. For example, Calvo (1999) argues that the existence of information asymmetries makes relatively uninformed investors extremely sensitive to fluctuations in capital movements; a small sell-off becomes a run as the uninformed make inferences about private information from market transactions (see Gennotte and Leland (1990) for a similar mechanism). Chari and Kehoe (1997) build on the herding literature to model how sequential investment based on private signals generates informational cascades and volatile capital flows.

Countries caught between the need for foreign capital and the volatility inherent in openness have often relied on government intervention to try to cool off the "hot money" that appears to be an integral part of international financial markets. Perhaps the most commonly discussed strategy for facing this dilemma is a Tobin Tax, which is designed to "throw sand in the wheels" of international capital movements. The argument holds that a tax on capital account transactions will deter short-run flows, but have a relatively limited impact when amortized over a long-term investment. Chile implemented a slight variant of this scheme to discriminate between highly liquid flows and long-term investments. Between 1991 and 1998, Chile required a percentage of any capital inflow to be deposited for a year in the Central Bank. The opportunity cost of the idle deposits acted as a tax on capital inflows. [1]

Motivated by the importance of informational frictions in understanding capital flows, this chapter looks at the interaction between taxing capital account transactions and information-based volatility. In particular, I show how imposing capital controls increases informational fragility – on average, a higher cost of moving capital increases the uncertainty of agents in the economy. The increased information differential between relatively informed and uninformed agents exacerbates the tendency of uninformed investors to magnify market fluctuations. To understand the implications of increased informational fragility on capital flows, I look at the effect of capital controls on how quickly uninformed traders pull out of a country after observing another trader's exit. That is, *conditional* on an informed trader having exited (perhaps for liquidity or other "non-fundamental" motivations), how long does it take for the uninformed to follow. This differs from unconditional volatility, i.e. how frequently does the average investor move in or out of a market. Clearly, capital controls delay the average entry and exit decisions. However, an equally important phenomena is the grouping of movements. Everyone entering simultaneously may lead to an overvaluation, while everyone exiting together may generate fire-sales.

Suppose informed traders invest based on their knowledge of a country's fundamentals as

[1] A different example of capital controls involves suspending convertibility during Balance of Payments crises, as proposed by Krugman (1998) and implemented by Malaysia in 1998. Controls during crises are designed to stave off massive depreciation while the economy works its way out of recession and the government implements reforms. Buiter and Sibert (1999) propose a debt roll-over option that allows a bower to roll over a loan at a penalty rate. This option would proxy for an international lender of last resort by delaying the repatriation of foreign capital during a liquidity crunch.

well as for liquidity needs (as in Calvo) or because of a return in a private investment opportunity at home (as in Wang (1994)). Thus, when the uninformed agents see a sale by the informed investor, they must weigh the possibility of a bad fundamental against a liquidity shock. The first finding of the chapter is that in the presence of transactions costs, the uninformed agents have on average a less precise estimate of the fundamental. This weak prior makes the uninformed agent sensitive to any new information, including an entry or exit of an informed trader. In terms of capital flow volatility, I find that although the unconditional duration of investment is lengthened by imposing transaction costs, the exit conditional on the informed having left may be hastened. In particular, I find very small and very large costs of moving capital tend to delay the conditional exit of the uninformed, but at intermediate levels an increase in transaction costs may exacerbate the tendency of the uninformed agents to mimic informed trades.[2]

In the presence of a fixed cost of moving capital into or out of a country, an investor requires a more favorable fundamental to induce entry and a more severe downturn to prompt an exit. Thus, for a given fundamental process, informed investors will wait longer to enter or exit. This slowing of capital movements has an informational effect that can be decomposed into a decrease in the quality of the prior and an increase in the strength of the signal. Movements into or out of a country by informed traders constitute valuable signals to the uninformed. In particular, we will see how entry or exit provides a stronger signal than continuation of the status quo. Thus the longer the interval between entry and exit, the more imprecise the uninformed's prior at the time of exit. A weak prior results in a large updating at time of exit and thus a tendency for the uninformed to follow the informed out of the country. Transaction costs thus result in a more fragile informational regime at the date of capital reversals, exacerbating the tendency for the grouping of sales. A second effect of taxing flows is the strength of the signal. The higher the transactions costs, the stronger the signal at the point of entry and exit. Thus capital controls set the stage for a weak prior meeting a strong signal, generating a large updating of beliefs at the time of exit or entry.

Balancing the informational implications of capital controls is the direct cost of moving

[2]The model is symmetric with respect to entry and exit, so all results that apply to conditional exit apply (in reverse) to conditional entry.

capital. Although the uninformed agents' beliefs move more dramatically after observing the informed agents' exit, they must move enough to compensate for the higher costs of pulling their capital out. This generates the non-monotonicity: at some levels of taxes, the informational considerations outweigh the increased costs, but for a large range of costs the conditional exit of the uninformed is delayed.

4.2 The Model

4.2.1 Informed Investors

There are two types of agents in the economy – informed and uninformed. The particular dimension of information that separates the two will be introduced in the next paragraph. Both types of agents are risk neutral, and within each group all agents are identical. The representative agent of each type possesses a unit of capital that can be left abroad or invested in the "home" country. We can think of the unit of capital as a production project that can be located at home or abroad; alternatively, it could be an asset whose price is fixed (e.g. a pegged currency), but with an exogenous probability of devaluation (or revaluation). In particular, we assume that the return to a unit of capital is independent of the total level of investment, which allows us to solve the informed and uninformed problem separately – the flow of information will be the sole connection between the two agents.[3] We first solve the informed agent's problem and then turn to the uninformed agent's signal extraction problem in the next subsection.

If invested in the home country at time t, the investor receives a "fundamental" pay-out X_t. Additionally, suppose that by investing in the home country the informed investor pays an opportunity cost that reflects liquidity needs or alternative investment opportunities (that do not enter the objective functions of the uninformed traders in the market). Let N_t reflect these additional considerations, so that the net payoff to the informed investor of investing in the

[3] Introducing equilibrium asset prices would complicate the agents' problem, but may not affect the information results presented below. In particular, all quantities traded by the informed agent are observed by the uninformed. As explained in Chapter 2 of this thesis, this is not enough to guarantee informational equivalence between a fixed-price and equilibrium-price asset market. However, the model outlined below assumes the same mean-reversion parameter for fundamental and noise, which in Chapter 2 implied no loss of information from fixing an asset's price.

home country can be expressed by

$$Z_t = X_t + N_t. \tag{4.1}$$

Informed investors observe both X and N at each point in time. Direct knowledge of X and N is what distinguishes the informed from the uninformed investor.

The two stochastic processes X and N follow the following laws of motion:

$$\begin{aligned} X_{t+1} &= \alpha_X X_t + u_{t+1} \\ N_{t+1} &= \alpha_N N_t + v_{t+1}, \end{aligned} \tag{4.2}$$

where u and v are iid, zero-mean normally distributed shocks with variances σ_u^2 and σ_v^2 and zero covariance. For simplicity, we impose that $\alpha_X = \alpha_N$, so we can express

$$\begin{aligned} Z_{t+1} &= X_{t+1} + N_{t+1} \\ &= \alpha Z_t + u_{t+1} + v_{t+1}. \end{aligned} \tag{4.3}$$

In locating their capital, investors follow what Dixit and Pindyck (1994) refer to as "Marshallian" rules. In particular, they locate their capital to maximize the expected present value of profits, ignoring the possibility they may have to exit or enter again in the future. This departure from rational expectations is not crucial to the informational results presented in the rest of the chapter, as the information mechanism only requires that the "inaction zone" increases with the costs of entry and exit. The response of the inaction zone to transactions costs has the same sign under both rules.[4] Specifically, at each point in time, the informed investor's decision is determined by

$$\max \left\langle E \sum_{s=t}^{\infty} \beta^{s-t} Z_s - (1 - I_{t-1}) C_I, \; - I_{t-1} C_E \right\rangle,$$

where $I_{t-1} = 1$ if the capital is located in the home country at time $t - 1$ and zero otherwise. C_I and C_E are costs of entry and exit, respectively. We have assumed that investors earn

[4]This simplification takes on significance when applied to the uninformed's investment problem, which is taken up in the next two subsections.

zero when their capital is left abroad (or N captures all opportunity costs for the informed investors). β is the rate of time preference, which can be set to one if $\alpha < 1$ (this ensures the present value of returns is finite). For each pair of entry and exit costs, there are values of Z at which the informed agent moves its capital in or out of the country, which will be labelled U (entry) and L (exit). Note that U will increase in C_I and L will decrease in C_E. Thus, as the costs of entry and exit increase, the range of inaction increases. Given the one-to-one correspondence between entry and exit costs and the thresholds U and L, we will model changes in capital controls directly as movements in U and L. Figure 1 represents a sample path of Z and resultant entry and exits by the informed investor. Note that the higher the cost of moving capital (the wider the $U - L$ band), the larger the movement required of Z between entry and exits.

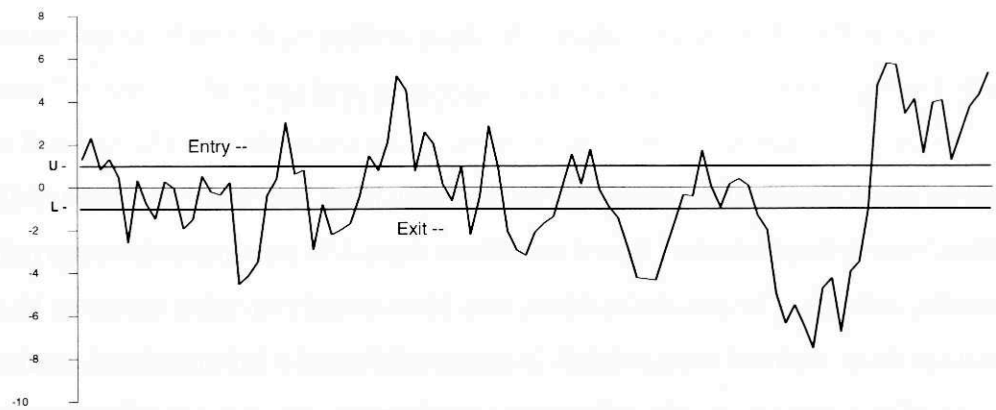

Figure 1

4.2.2 Uninformed Investors

The representative uninformed investor also has one unit of capital to invest. If left abroad, we assume that the rate of return is zero, while if invested in the home country the capital earns the fundamental X. The two important differences between the uninformed's problem and the informed's are that N does not enter the uninformed's payoff and the uninformed does not observe X (or N) directly. In particular, the uninformed's information set as of time t is the history of entry and exit decisions made by the informed trader.[5] As was the case with the informed agent, the uninformed agent also decides to invest if the expected present value of the home country project exceeds zero. The simplifying assumption of a present value rule implies that the informed and uninformed agents use the same cut-off rules U and L, with the uninformed agents replacing the true fundamental X with their conditional expectation, $\hat{x}$.[6] I now turn to the uninformed's signal extraction problem.

4.2.3 Learning Recursion

At each point in time, the uninformed observes whether the informed is invested in the home country. Recall that

$$I_t = \begin{cases} 1 \text{ if informed agent is invested at time } t \\ 0 \text{ otherwise.} \end{cases} \tag{4.4}$$

Then at time t, the uninformed can conclude

$$\begin{aligned} Z_t &\geq U \text{ if } I_t = 1 \text{ and } I_{t-1} = 0 \\ Z_t &\geq L \text{ if } I_t = 1 \text{ and } I_{t-1} = 1 \\ Z_t &\leq L \text{ if } I_t = 0 \text{ and } I_{t-1} = 1 \\ Z_t &\leq U \text{ if } I_t = 0 \text{ and } I_{t-1} = 0. \end{aligned} \tag{4.5}$$

Let $F_{t,t-1}(x, z)$ be the joint cumulative distribution function of X_t and Z_t given entry and exit decisions up through $t-1$. The uninformed then uses (4.5) to update to $F_{t,t}(x, z)$. Suppose

[5] We assume that the informed do not sell information to the uninformed. In the present model, there is no reason for an uninformed agent to masquerade as informed; this would not be the case if we allowed the sale of information. We do not pursue the question of whether a credible market for information exists. We could easily introduce an additional private signal for the uninformed agent. The optimal estimate of the fundamental would then be a combination of the private signal and the movements of the informed agent. The direction of the informational effects described below would be the same, but the magnitude would decrease in the quality of the alternative source of information.

[6] We will see in the next subsection that the uninformed agent's beliefs are parameterized by five state variables. This plus the location of the informed and uninformed agents at the start of the period implies that the true optimal rule of the uninformed depends on seven state variables. The present value simplification allows us to characterize the action of the uninformed as a function of mean beliefs and current location. This assumption is used in the last two figures of the paper.

that the informed investor was abroad at time $t-1$ but then enters at time t (i.e. $I_t = 1$ and $I_{t-1} = 0$). Bayes rule implies

$$\begin{aligned} F_{t,t}(x,z) &= \Pr\left(X_t \leq x, Z_t \leq z \mid \{I_s\}_{s=0}^{t}\right) \\ &= 1_{(z \geq U)} * \frac{F_{t,t-1}(x,z) - F_{t,t-1}(x,U)}{1 - F_{t,t-1}(x,U)}, \end{aligned} \tag{4.6}$$

where $1_{(z \geq U)}$ is the indicator function for $z \geq U$. A similar updating occurs for the three other possible signals at time t. To get to the next period, we project forward using the laws of motion of X and Z and the distribution of the innovations u and v. Thus $F_{t,t}$ is a truncation of $F_{t,t-1}$, and $F_{t+1,t}$ is $F_{t,t}$ plus jointly normal disturbances. In this sense, beliefs are a Markov process in the space of probability distributions.

We will make a simplifying approximation to reduce beliefs to a Markov process in the first two moments. In particular, we will approximate $F_{t,t-1}$ by a joint-normal distribution with moments $(\hat{x}_{t,t-1},\ \hat{z}_{t,t-1},\ \rho_{t,t-1},\ \sigma_{x,t,t-1},\ \sigma_{x,t,t-1})$. In practice, this implies truncating a joint-normal distribution to obtain $F_{t,t}$, adding normal innovations to generate $F_{t+1,t}$, calculating the moments of $F_{t+1,t}$ and then using a joint-normal distribution with the same first and second moments to approximate the true $F_{t+1,t}$. The next updating sequence starts after observing the informed investor at $t+1$.[7]

Using this approximation, we can obtain an explicit expression for the movement of beliefs over time. In particular, the expectation of X at time t given signals up through time t is a binomial random walk. If the informed investor is invested in the country at $t-1$, we have

$$\begin{aligned} \hat{x}_t &= \alpha \hat{x}_{t-1} + \rho \sigma_{x,t-1} \frac{\phi\left(\frac{L - \alpha \hat{z}_{t-1}}{\sigma_{z,t-1}}\right)}{1 - \Phi\left(\frac{L - \alpha \hat{z}_{t-1}}{\sigma_{z,t-1}}\right)} \text{ if } I_t = 1 \\ &= \alpha \hat{x}_{t-1} - \rho \sigma_{x,t-1} \frac{\phi\left(\frac{L - \alpha \hat{z}_{t-1}}{\sigma_{z,t-1}}\right)}{\Phi\left(\frac{L - \alpha \hat{z}_{t-1}}{\sigma_{z,t-1}}\right)} \text{ if } I_t = 0. \end{aligned} \tag{4.7}$$

If the informed investor is outside the home country at time $t-1$, the expressions are the

[7]The extent of the error implied by this approximation depends on the variance of the innovations $(\sigma_u^2 + \sigma_v^2)$ relative to the variance of $\hat{z}$. The larger the relative variance of the innovations, the more symmetric (and close to normal) the ex post distribution.

same with U replacing L. Note that a weak prior ($\sigma_{x,t-1}$ high) implies a volatile mean belief. Moreover,

$$\sigma^2_{x,t} = \alpha^2 \left((1-\rho^2)\sigma^2_{x,t-1} + \rho^2 \frac{\sigma^2_{x,t-1}}{\alpha^2 \sigma^4_{z,t-1}} (\sigma^2_{z,t} - \sigma^2_u - \sigma^2_v) \right) + \sigma^2_u, \tag{4.8}$$

where we have incorporated the signal at time t by using the expression for $\sigma^2_{z,t}$ in the formula for $\sigma^2_{x,t}$. (The evolution of the other state variables follow similar laws of motion). In general, a decision to exit by the informed agent increases the precision of the uninformed's estimate of X, while a decision by the informed to remain in the country provides a weaker signal and leads to increased uncertainty (the increase being due to the new innovations that continue to be realized).[8]

To get a clearer picture of how beliefs progress over time, figure 2 plots the standard deviation of the uninformed's estimate of the fundamental. The horizontal axis represents time passed since the entry of the informed trader into the home country. The top line plots equation (4.8) assuming that the informed has remained invested in the home country as of time t. The bottom line plots the value of $\sigma_{x,t+1}$ that results from observing the informed investor exiting at time t. The difference between the two lines is the increase in precision gained from observing the informed trader exiting at that point in time. Note that as the informed trader remains invested, the strong signal gained by entry becomes obsolete. The fact that the informed trader has not exited provides some information, but not as much as an actual entry or exit. Thus as time progresses, the quality of the uninformed's prior deteriorates until the next active movement of the informed trader.

[8] A decision to leave is more informative than a decision to stay if $\alpha\hat{z}$ is sufficiently large relative to L. For example, if $\alpha\hat{z} = L$, then the two signals are equivalent, but as $\alpha\hat{z}$ increases reltaive to L, continuation of the status quo is less informative.

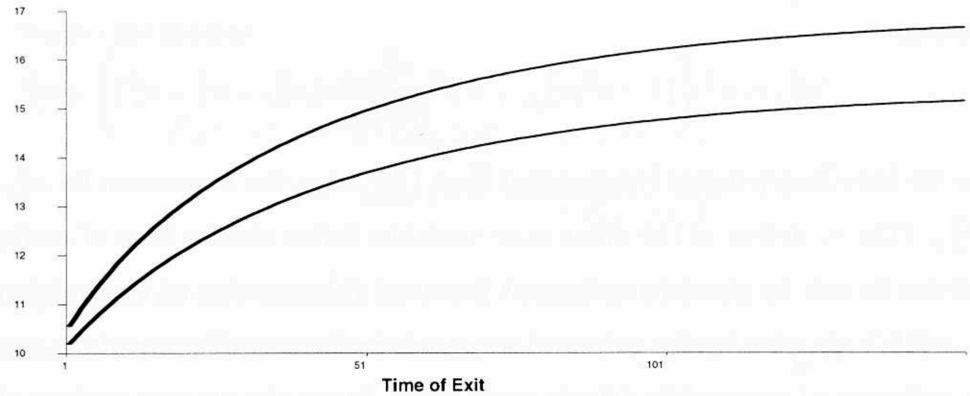

Figure 2: Std. dev. of estimate before informed exit (top) and after exit (bottom)

Figure 3 contains the equivalent time series of $\hat{x}_t$. Equation (4.7) contains the law of motion for the uninformed's estimate of X_t. The continued presence of the informed trader represents a positive signal regarding the fundamental. This is potentially off-set by the mean reversion of X (if $\alpha < 1$). Figure 3 plots the case where the first effect dominates at first, but then gives way to mean reversion. Again, the top line represents the path if the informed agent remains invested while the bottom line is the $\hat{x}$ that results from observing an exit by the informed trader at time t. Figure 4 plots the difference between the two lines, representing the movement of beliefs at the point of informed exit. As noted above, the longer the informed agent remains passive, the more fragile the uninformed's prior and the larger the revision once the informed's exit is observed.

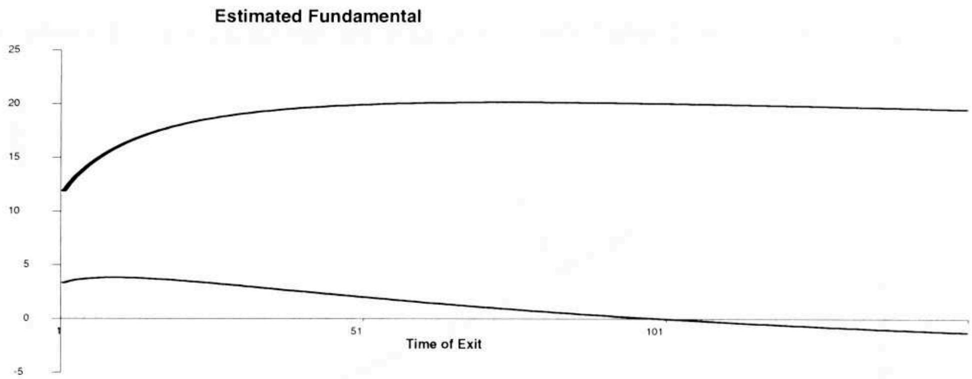

Figure 3

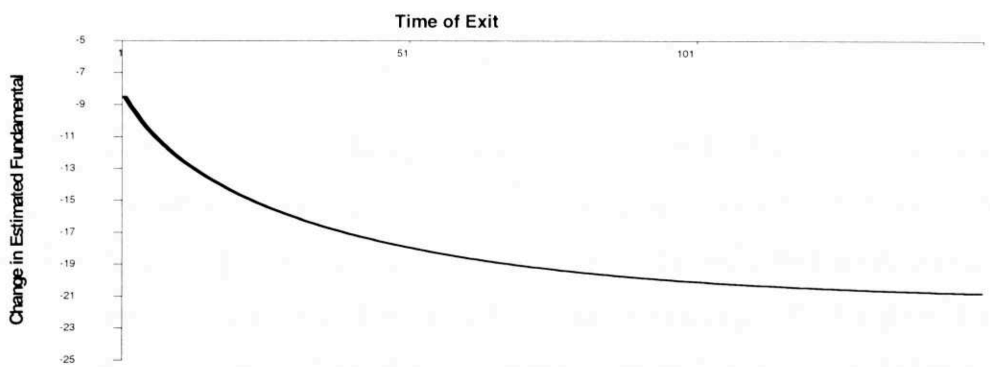

Figure 4

The learning dynamics thus indicate that the longer the inactivity of the informed trader, the more fragile the prior of the uninformed and the larger revision in beliefs once the informed makes a move. Therefore, holding everything else constant, the longer the period between entry and exit, the more likely is the uninformed trader to follow the informed investor out of the country. Figure 5 shows this effect explicitly. Let T_k represent the time of informed entry, $T_{k+1}$the next exit, T_{k+2} the next entry, and so on. The uninformed agent therefore receives an active signal every $T_{k+1} - T_k$ periods. Let T_k^U be the time at which the uninformed exits after observing the informed agent exiting at T_k. Figure 5 plots how quickly the uninformed agent follows the informed agent out of the country $(T_k^U - T_k)$ against the frequency of the informed agent's movement $(T_{k+1} - T_k)$. That is, figure 5 demonstrates how less frequent movement on the part of the informed generates a tendency for the uninformed to herd on the informed agent's action.

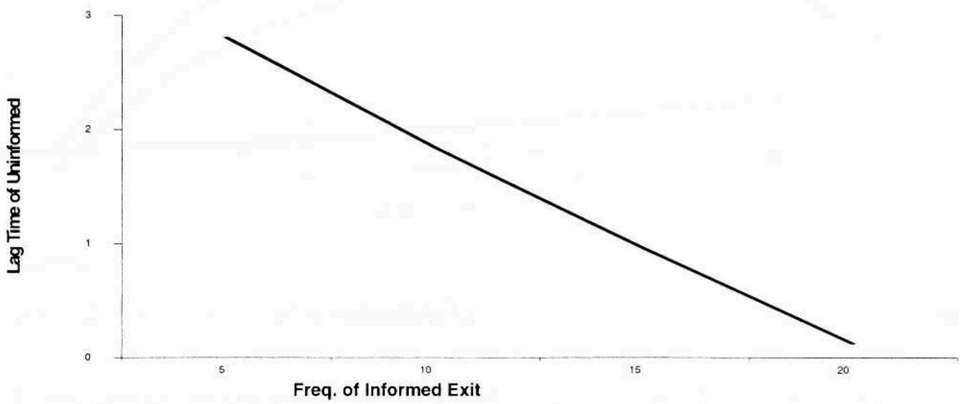

Figure 5

The above figures held the cost of moving capital constant (i.e. U and L remained fixed). An increase in the tax on capital account transactions increases the inactivity zone $(U - L)$, generating the informational fragility explored in the previous paragraphs. However, U and L enter directly into the updating equation (4.7) as well. A higher U increases the estimate of the fundamental at the time of informed entry, and a lower L represents a stronger negative signal upon exit. Figures 6 and 7 depict this strength of signal effect. Figure 6 plots the value of $\hat{x}$ against increasing U from a common initial value. A higher entry value raises the estimated fundamental thereafter (until the next exit). Figure 7 plots the drop in $\hat{x}$ at the time of the informed agent's exit as a function of lowering the exit threshold L. A lower threshold generates a stronger negative signal when the informed trader sells, prompting a larger negative revision in the uninformed's estimate of the fundamental.

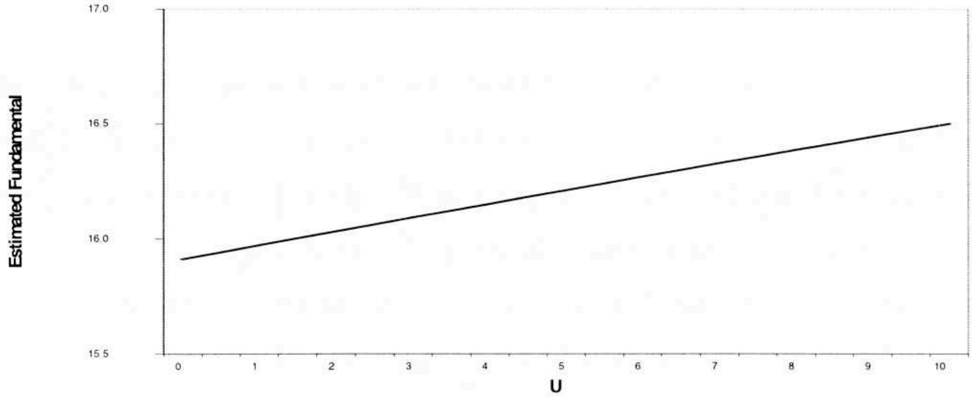

Figure 6

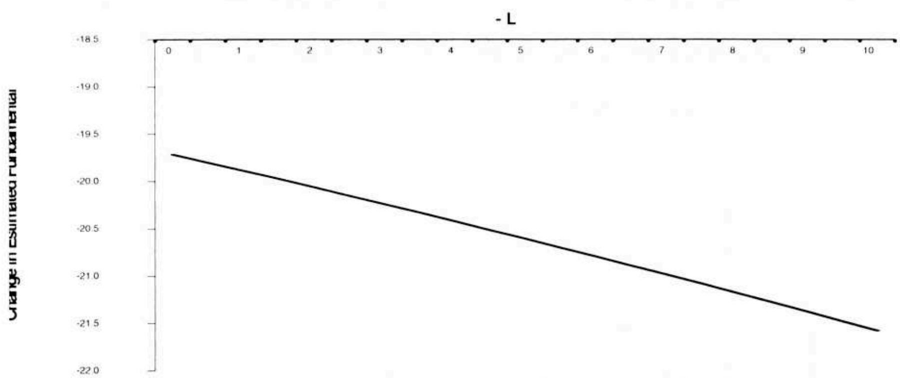

Figure 7

The preceding figures have demonstrated how increasing capital costs weaken beliefs during inactivity and strengthen the signal at the point of activity. This implies that capital controls lay the groundwork for herding. However, the uninformed agent must also pay the costs of moving capital, and this will tend to delay exit and entry (for a given signal). To see the net effect, the next two figures present results from simulating[9] the combined decisions of the informed and uninformed agents and averaging the conditional exit time of the uninformed

[9]These simulation used parameters $\sigma_u = 1$, $\sigma_v = 1.5$ and $\alpha = 0.99$. Similar patterns held for other parameters.

agent. Figure 8 explores increasing entry costs, while figure 9 imposes symmetric entry and exit costs.

Figure 8 holds the exit threshold fixed and varies the entry threshold. This corresponds to holding exit costs fixed and increasing entry costs (in a Dixit and Pindyck set-up, L moves with entry costs, but less than proportionately). Note the effect is non-monotonic. Initially, increased entry costs hastens the uninformed's conditional exit. This is due to the fact that the amount of time it takes between entry and exit increases with entry costs, weakening the uninformed's prior by the time the informed agent exits. However, a higher U also raises mean beliefs at the point of entry, implying that beliefs must move farther for the uninformed to exit. Moreover, after the exit by the informed agent, the relevant threshold is U and a higher U while the informed agent is *outside* the country provides a weaker signal. Therefore, beliefs move dramatically at the point of exit, but evolve slowly in the periods immediately after the informed agent's exit, potentially delaying the uninformed's exit. These latter two effects dominate at higher entry costs.

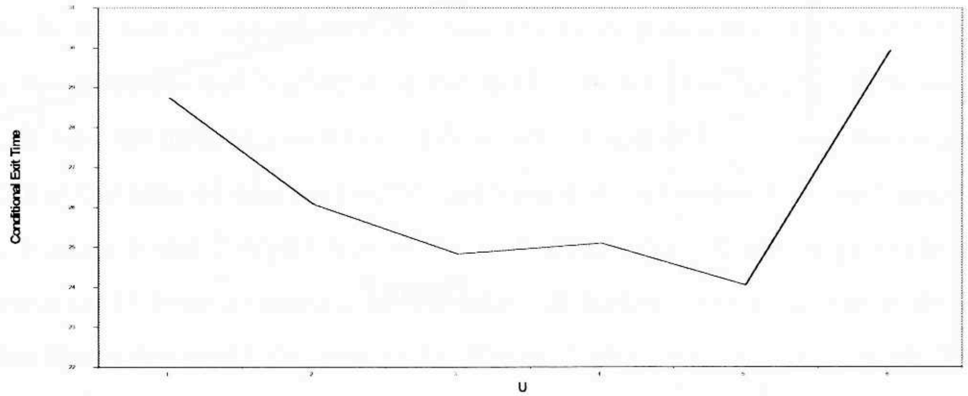

Figure 8

A similar non-monotonicity holds if we introduce exit costs as well. Figure 9 plots the mean conditional exit time against increasing, symmetric inactivity zones:

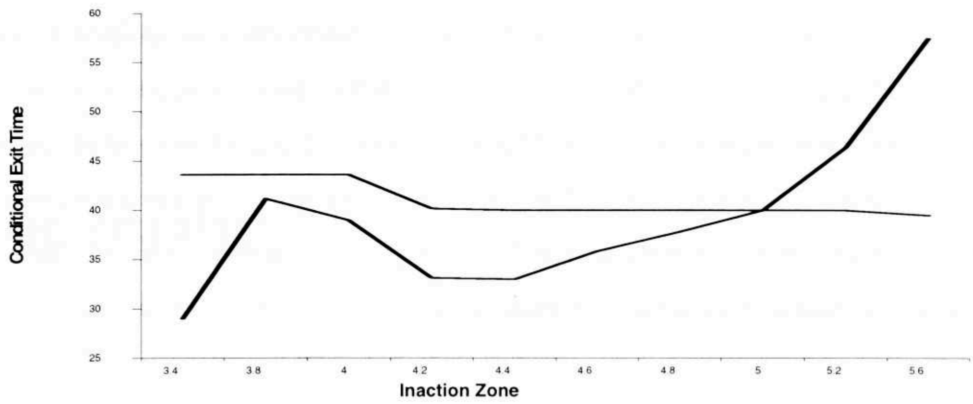

Figure 9

The horizontal line in figure 9 is the conditional exit time if the uninformed observes the fundamental perfectly; this benchmark slightly declines in the width of the inactivity zone. The other line is the conditional behavior of the uninformed investor based on the learning mechanism described above. The non-monotonicity in the conditional exit time is evident from figure 9. Small and large costs serve to delay the conditional exit of uninformed traders, while for intermediate values an increase in the inactivity zone hastens the uninformed's conditional exit. As noted in the introduction, the declining portion of the curve is a product of a weakened prior due to inactivity and a strong signal due to a lower exit threshold. The increase in mean exit time is a result of the high entry threshold and the higher costs of exit.

4.3 Conclusion

This chapter has looked at the informational implications of capital controls. We have found that capital controls increase informational fragility by reducing the frequency of informed agents' movements. This effect increases the tendency for herding at intermediate levels of transaction costs. Taxing capital flows throws sand in the wheels of information aggregation as well as in the incentive to move capital, generating a non-monotonic relationship between transactions costs and herding.

The ability of informational imperfections to turn small portfolio adjustments into massive reversals of capital flows requires that any proposed solution to excess volatility be examined for its impact on the ability of markets to aggregate and reveal private information. This chapter is a first step in that direction. Future research should combine these informational dynamics with an explicit government welfare function to determine the optimal transaction tax. More complicated portfolio decisions and signal structure (including price movements) should also be incorporated to fully understand the informational impact of capital controls. In particular, the information lost from capital account transactions may generate increased uncertainty in other markets. If these other markets do not pay the increased tax, the informational effect of capital controls may generate an unmitigated increase in volatility.

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