Noise Trading and Exchange Rate Regimes[1]

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Abstract

Policymakers often justify their choice of fixed exchange rate regimes as a shelter against non-fundamental influences in the foreign exchange market. This paper proposes a framework, based on endogenous noise trading, which makes sense of the policymakers' view. We show that as a result of multiple equilibria, the model violates Mundell's "Incompatible Trinity": under some conditions, it is possible to reduce the volatility of the exchange rate without any sacrifice in terms of monetary autonomy. We provide empirical evidence supportive of the existence of a non-fundamental channel in the link between exchange rate regimes and exchange rate volatility.

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> "Where exchange rates are floating, volatility is harder to explain (compared with fixed exchange rate regimes), especially when movements in fundamentals are modest. Swings in relative real values among the U.S. dollar, the deutsche mark, and the Japanese yen have approached 50 percent or more in the past decade and a half. Such swings complicate macroeconomic policies, generate the potential for resource misallocation, and give rise to protectionist pressures. While it can be argues that exchange markets are responding to policy divergences (actual and expected), the link is often not at all clear." (Andrew Crockett, quoted in Federal Reserve Bank of Kansas City, 1997, p.24)

1 Introduction

1.1 Motivation

Policymakers have often justified their choice of fixed exchange rates or target zones as a shelter against the vagaries of investors' sentiments in the foreign exchange market. This concern was at the heart, for example of the Plaza-Louvre strategy to stabilize the exchange rates between the main currencies:

> "If...markets come to believe exchange rate stability is not itself a significant policy objective, we should not be surprised that snowballing cumulative movements can develop that appear widely out of keeping with current balance-of-payments prospects or domestic price movements. At that point, freely floating exchange rates, instead of delivering on the promise of money autonomy for domestic monetary or other policies, can greatly complicate domestic economic management."(Paul Volcker, 1978-79, p.9).

The view that exchange rates should be insulated from destabilizing speculation has a long tradition, which goes back at least to Ragnar Nurkse and the interwar period. It was certainly one of the premises on which the Bretton Woods system was built. It is probably a component of the "fear of floating" in emerging economies documented by Calvo and Reinhart (2000).

It is surprising, how little the policymakers' concern about irrational market behavior in the real word has been taken into account in the *theory* of exchange rate regimes. Existing theories of regimes differ along a number of dimensions, but rely on models with rational expectations where exchange rate volatility is the reflection of shocks in the fundamentals. The choice of an exchange rate regime or a target zone, then, involves the allocation of a given amount of fundamental volatility between the exchange rate and domestic variables. Real world policymakers, by contrast, seem to believe that exchange volatility may include a non-fundamental component, which is large under floating rates, and is not transferred to the domestic economy when the currency is fixed. Instead this non-fundamental volatility – "noise" – simply disappears.

This paper proposes a model that makes sense of the policymakers' view, and provides some evidence in support of the model. We present a model of exchange rate regimes that departs from the standard approach by assuming the presence of "noise trading"—that is trading based on whims, fads and non-fundamental influences—in the foreign exchange market. The size of the noise component is endogenously determined; it depends on the decisions of noise traders who decide whether or not to enter the currency markets. Exchange rate policy can reduce exchange rate volatility by two channels: first, by reducing fundamental volatility — the standard channel — and second, by discouraging noise traders from entering the market — the microeconomic channel which we emphasize in this paper.

Departing from the standard paradigm has important implications for the way we think about exchange rate regimes. A non-conventional property of our model is that it violates Mundell's "Incompatible Trinity" of fixed exchange rates, monetary autonomy and capital mobility. Under some conditions it is possible to reduce exchange rate volatility without any sacrifice. The reason for this key result stems from multiple equilibria. In our model, floating exchange rate regimes are often associated with multiple equilibria with different levels of exchange rate volatility for the same level of fundamental volatility. Intense noise trading during a float causes high exchange rate volatility which then validates the presence of noise trading. We show that a credible commitment made by the policy authorities to limit exchange rate volatility pins down the economy on the equilibrium with low exchange rate volatility and low noise trading. Although the commitment to exchange rate stability constrains the monetary policy response function, there is no observable sacrifice of monetary autonomy *in equilibrium*. Indeed, adopting an objective of exchange rate stability gives the authorities *more* monetary autonomy— an apparent free lunch of exchange rate volatility.

1.2 The Existing Literature

This paper is a contribution to the literature on exchange rate regimes. The relevant literature is large, and it has evolved in different directions, which are impossible to review in detail here. One line of literature has focused on the trade-off between the benefits of a fixed exchange rate regime in terms of anti-inflationary credibility and its costs in terms of foregone monetary autonomy.[1] Here we completely leave aside the issue of credibility — although we readily acknowledge its importance in practice — in order to better focus on the original contribution of the paper. We take credibility for granted, and analyze a benefit of *credible* exchange rate regimes which, we think, has been overlooked in the previous literature.

Another line of research, starting with Krugman (1991), has highlighted the stabilizing effect of target zones. In Krugman's model target zones are stabilizing because expectations are rational: the exchange rate is stabilized inside the band by the expectations of interventions by the monetary authorities (the so-called "honey-moon effect"). By contrast in our model a target zone is stabilizing in part because it *makes market expectations more rational*. Expectations are more rational under stable exchange rates because it is more difficult for irrational traders to survive in an environment with little volatility.

This paper is also related to the literature that studies models of foreign exchange markets with traders that are imperfectly rational or use non-fundamental based trading techniques. Frankel and Froot (1990) analyze the destabilizing effects of feedback trading rules. A few papers have introduced noise trading—originally formalized, in a domestic context, by De Long *et al.* (1990)—in the context of foreign exchange markets.[2] Mark and Wu (1998) make some progress on the forward discount puzzle by investigating uncovered interest parity in a model with noise traders. Faruqee and Redding (1999) show that the entry of liquidity providers can accelerate the reversion

[1] Following the numerous currency crises of the 1990s, scholars have increasingly emphasized the dubious nature of the credibility benefits as well as the risk of self-fulfilling currency crises (Obstfeld and Rogoff, 1995).

[2] De Long *et al.* (1989) analyse some policy implications of noise trading with some reference to exchange rate policy.

of the exchange rate towards its fundamental value in an environment with noise traders. A closer precursor to our paper is Hau's (1998) analysis of the free entry of traders with noisy expectations into a foreign exchange market.[3] Hau finds that temporary noise may result in higher exchange rate volatility and multiple equilibria as we do, but abstracts from explicit consideration of macroeconomic or monetary policy. More generally, these papers do not share our focus on exchange rate regimes.

The paper which is closest in spirit to our analysis of exchange rate regimes is Krugman and Miller (1993). Krugman and Miller note that Williamson's (1985) original case for target zones relied on the risk of destabilizing speculation under floating. To capture Williamson's idea they introduce stop-loss trading in a Krugman (1991) type model of target zones. Stop-loss trading is defined as an upward jump in the risk premium on the domestic currency when the exchange rate crosses an (exogenous) threshold. It follows that the relationship between the fundamentals and the exchange rate is discontinuous, and "currency crashes" can occur. A target zone forestalls currency crashes by keeping the exchange rate below the threshold that triggers stop-loss trading.

There is a large body of evidence documenting deviations from rational expectations in foreign exchange markets and the use of non-fundamental-based trading techniques (Frankel and Froot, 1990; Taylor and Allen, 1992; Cheung and Wong, 1998). This evidence, however, bears primarily on floating exchange rates and has little to say on differences across exchange rate regimes. We present in this paper new empirical evidence suggesting, from different angles, the existence of a non-fundamental channel in the link between exchange rate regimes and exchange rate volatility. We successfully test three predictions of our theory: (i) the dispersion of currency forecasts across market participants — a measure of the heterogeneity, or noise, in market expectations— is larger in floating exchange rate regimes, even after controlling for the volatility of the exchange rate; (ii) bilateral trading volume in foreign exchange markets is higher for floating exchange rates than for fixed exchange rates; and (iii) unexplained deviations from Uncovered Interest Parity are higher in floating exchange rate regimes than in fixed ones.

[3] The free entry of utility-maximizing noise traders had been earlier analysed by Palomino (1996) in a domestic context.

Finally, this paper is related to the large empirical literature on the volatility of exchange rates. While most of this literature focuses on floating exchange rates,[4] two papers are particularly relevant to the present research because, like us, they examine exchange rate volatility across different exchange rate regimes: Baxter and Stockman (1989) and Flood and Rose (1995). Using data for a variety of OECD and developing countries, Baxter and Stockman analyze the variability of output, trade variables, and both private and government consumption, using different de-trending techniques, and are "unable to find evidence that the cyclic behavior of real macroeconomic aggregates depends systematically on the exchange-rate regime. The only exception is the well-known case of the real exchange rate." Flood and Rose examine a variety of structural exchange rate models across exchange rate regimes and find that "the volatility [of the exchange rate] is not in fact transferred to some other part of the economy: it simply seems to vanish" — in accordance with the motivation for this paper.

The paper is structured as follows. In section 2, the heart of the paper, we present a model of the foreign exchange markets with an endogenously determined number of noise traders. Section 3 then looks at the empirical evidence in the light of the model. The paper concludes with a brief summary and suggestions for future research.

2 A Micro-Structural Theory of Exchange Rate Regimes

The model we present mixes elements from two disparate branches of economic theory, the macroeconomic theory of exchange rate determination, and the noise trading approach to asset price volatility. As in chemistry, we make the experiment illuminating by combining two components which are as pure (uncontaminated by tangential complications) as possible. On the macroeconomic side, we use the conventional monetary model of the ex-

[4]Some papers explore whether foreign exchange markets exhibit "excessive volatility", transposing the questions and techniques developed by Shiller (1989) and others to study the volatility of stock markets (see e.g., Bartolini and Giorgianni, 1999). Although this literature is not entirely conclusive (for the same reasons as its closed-economy counterpart), the dominant view seems to be that floating exchange rates are excessively volatile relative to the economic fundamentals (Obstfeld and Rogoff, 2000).

change rate, augmented by portfolio considerations. On the micro-structure side we employ the well-known model of noise trading developed by De Long *et al.* (1990).

2.1 Macroeconomic Fundamentals

We begin with a conventional monetary model of the exchange rate with flexible prices. A simple money market equilibrium is posited in the domestic country, linking the natural logarithm of the money stock (m) deflated by the (log of the) price level (p) to the interest rate (i) at a point in time t; the same condition characterizes the foreign country (denoted with an asterisk). Prices are assumed to be perfectly flexible, and purchasing power parity is satisfied in average so that the (log of the) price of foreign exchange (e) is simply the ratio of price levels plus an i.i.d. normal shock. The model can be written:

$$m_t - p_t = -\alpha i_t \tag{1}$$

$$m_t^* - p_t^* = -\alpha i_t^* \tag{2}$$

$$e_t = p_t - p_t^* + \epsilon_t \tag{3}$$

so that:

$$e_t = (m_t - m_t^*) + \alpha(i_t - i_t^*) + \epsilon_t. \tag{4}$$

In order to better focus on the impact of policy changes in the domestic country we assume that the foreign country is in a steady state with constant money supply, price level and interest rate. Accordingly we drop the time index for variables m^*, i^* and p^* in what follows. The (log of the) foreign price level, p^*, is normalized to zero. We initially assume that domestic money supply, m_t, follows a stochastic i.i.d. normal process centered on $\overline{m}$. For the moment we assume that this policy variable is exogenous, as would be appropriate if the exchange rate floats freely. We relax this assumption when we consider official exchange rate policy below.

The interest rate is determined by equilibrium in the international bonds market. We assume that investors in the international bonds market care about the return of their portfolio measured in real terms (or equivalently in terms of the foreign currency, since the foreign price level is constant). Investors are risk averse and require a risk premium to hold bonds denominated in domestic currency if the exchange rate is stochastic. One may think of the foreign country as the center of the international financial system, and of the domestic country as a small open economy at the periphery. For the sake of brevity and *couleur locale* we shall sometimes call the domestic currency "peso" and the foreign currency "dollar" (though we do not wish to imply that our model is meant to work especially well for developing countries).

The quantity of domestic external liabilities results, in equilibrium, from the current account and the balance of payments. These external liabilities may take the form of bonds denominated in either currency. The supply of bonds denominated in peso results from the domestic fiscal and monetary authorities' actions, in particular the respective shares of peso- and dollar-denominated bonds on the asset side of the central bank's balance sheet. We assume hereafter that the domestic authorities maintain their supply of peso-denominated bonds to international investors at a constant real level $\overline{B}$. This assumption is made for the sake of analytical convenience, and can be relaxed without changing the thrust of our results.[5]

2.2 Micro-Structure: Trading Behavior

Foreign exchange traders are modelled as overlapping generations of investors who live for two periods and allocate their portfolio between peso and dollar-denominated one-period nominal bonds in the first period of their life. Traders have the same endowments and tastes, but differ in their ability to trade in the peso bonds market. Some of them are able to form accurate expectations on risk and returns costlessly, while others have noisy expectations and must pay an entry cost to invest in peso bonds. We refer to the former as "informed" traders and the latter as "noise" traders.

At each period a generation of N traders $j = 1, \ldots, N$ is borne. Each individual trader j receives a real endowment of W, which can be invested in dollar bonds at no cost. Traders decide whether or not to enter the peso bonds market. We denote by δ_t^j the dummy variable characterizing the entry decision of trader j at time t; it equals one if she enters, zero if not. Traders enter the market for peso bonds if this increases their utility. Trader j's entry

[5] *Some* assumption is needed, since there is no natural way to endogenize the currency composition of the domestic country's external debt in this model. The assumption we make has the advantage of keeping the model simple. It would not be very difficult to consider alternatives, such as a stochastic supply of domestic currency-denominated bonds.

decision is taken before the time t shocks are revealed, on the basis of the information available at $t-1$:

$$\forall j,\ t \qquad \delta_t^j = 1 \Longleftrightarrow \mathrm{E}_{t-1}^j(U_t^j|\delta_t^j = 1)\ \geq\ \mathrm{E}_{t-1}^j(U_t^j|\delta_t^j = 0), \tag{5}$$

where U_t^j is the utility of a new-born trader j at time t, and the expectations operator bears the trader's index to allow for heterogeneity (the expectations operator without index denotes the rational expectation).

A trader who has entered the domestic market invests b_t^j in peso bonds so as to maximize the expected utility of her end-of-life wealth. We assume that trader j's portfolio allocation problem at time t is:

$$max_{b_t^j} U_t^j = \mathrm{E}_t^j \left(-\exp(-aW_{t+1}^j) \right), \tag{6}$$

where W_{t+1}^j, the end-of-life wealth of trader j, is given by:

$$W_{t+1}^j = (1+i^*)W + \delta_t^j(b_t^j \rho_{t+1} - c_j). \tag{7}$$

Trader j's end-of-life wealth is equal to the trader's initial endowment times the yield on dollar bonds plus, if j enters, the excess return on peso bonds minus a fixed cost that must be borne in order to enter the peso bonds market. The excess return on peso bonds between t and $t+1$ is given by:

$$\rho_{t+1} = i_t - (e_{t+1} - e_t) - i^*. \tag{8}$$

The cost c_j reflects the costs associated with entering the peso bonds market for trader j. These costs are much discussed in the literature, and may include informational problems, tax issues, and other phenomena. There is no presumption that they are small, given the size of the "home market effect" (Lewis, 1995 provides a survey). We assume that foreign exchange traders are heterogeneous with respect to this cost.

There are two types of traders: *informed* traders, and *noise* traders. Each generation counts N_i informed traders $j = 1, \ldots, N_i$ and N_n noise traders $j = N_i + 1, \ldots, N \equiv N_i + N_n$.

Informed investors are knowledgable about the domestic economy, can process new information costlessly and make their decisions on the basis of rational expectations about the future. Thus, for $j \leq N_i$ one can write:

$$\begin{aligned} \mathrm{E}_t^j(\rho_{t+1}) &= \mathrm{E}_t(\rho_{t+1}) \quad (9)\\ \mathrm{Var}_t^j(\rho_{t+1}) &= \mathrm{Var}_t(\rho_{t+1}) \quad (10)\end{aligned}$$

where $\mathrm{E}_t^j(\rho_{t+1})$ and $\mathrm{Var}_t^j(\rho_{t+1})$ are the expected value and conditional variance of the excess return on peso bonds as evaluated by trader j at period t, and $\mathrm{E}_t(\rho_{t+1})$ and $\mathrm{Var}_t(\rho_{t+1})$ are their mathematical counterparts.

Noise traders, by way of contrast, have imperfect knowledge of the determinants of the exchange rate. We adopt the (standard) assumption that noise traders perceive the second moment of returns correctly, but allow their perception of first-moments to be affected by noise that is unrelated to economic fundamentals; that is, they have irrationally volatile expectations.[6] The noise is common across traders; there is no private information in the model. Formally we assume that for $j > N_i$:

$$\begin{aligned} \mathrm{E}_t^j(\rho_{t+1}) &= \overline{\rho} + \nu_t \quad (11)\\ \mathrm{Var}_t^j(\rho_{t+1}) &= \mathrm{Var}_t(\rho_{t+1}) \quad (12)\end{aligned}$$

where $\overline{\rho}$ is the unconditional mean of the excess return (or average risk premium) and the noise term ν_t is a stochastic i.i.d. normal shock common across j and uncorrelated with m_t and ϵ_t. We interpret the noise term as a fad which is wide-spread but non-fundamental. Unlike De Long *et al.* (1990), our noise traders do not make systematic errors in their prediction of excess returns.

We link the size of noise traders' errors to economic uncertainty by assuming that the variance of the noise is proportional to the true unconditional variance of the exchange rate:

$$\mathrm{Var}(\nu) = \lambda\ \mathrm{Var}(e), \quad (13)$$

where λ is a positive coefficient.[7]

Traders also differ with respect to their entry costs. This heterogeneity can be rationalized in a number of ways. It may reflect the fact that some

[6]For evidence of bias in exchange rate expectations, see Frankel and Froot (1987).

[7]Assuming that $\mathrm{Var}(\nu)$ is constant is implausible; it would imply, for example, that noise traders expect the exchange rate to be stochastic when it is in fact constant.

traders inherit a larger stock of knowledge on the domestic economy and so can afford to invest less in the acquisition of information. For the sake of the analysis we assume that the cost of entry is equal to zero for informed investors, but may be positive for noise traders—that is, informed investors have a native ability to process the relevant information costlessly, while it is costly for noise traders to acquire the non-noisy component of their information. The assumption that informed investors bear no entry cost, which could be relaxed, simplifies the analysis, and allows us to focus on the entry decision of *noise* traders.

Without loss of generality we order noise traders by increasing entry cost:

$$c_j = 0 \quad \text{for } j \leq N_i \tag{14}$$

$$c_j \geq 0. \quad \text{increasing with } j \text{ for } j > N_i. \tag{15}$$

We also assume that the entry cost of noise traders is not too small:

$$\forall j > N_i, \quad c_j > \frac{1}{2a} \log(1+\lambda). \tag{16}$$

2.3 Equilibrium

An equilibrium in this model consists of stochastic processes for the exchange rate $\{e_t\}$, the risk premium $\{\rho_t\}$, and individual traders' decision rules $\{\delta_t^j\}$ and $\{b_t^j\}$, such that at each period t, δ_t^j satisfies the entry condition (5), b_t^j is the solution to the optimal portfolio allocation problem (6), and the market for domestic currency bonds is in equilibrium:

$$\overline{B} = \sum_{j=1,\ldots,N} \delta_t^j \, b_t^j. \tag{17}$$

This equilibrium appears to be difficult to determine, since it involves entry decisions by a set of heterogeneous agents in a stochastic environment. However, we exploit the assumption that the shocks are independently and identically distributed, which suggests that the set of equilibrium individual decision rules takes a simple stable form.

We solve the model with a "guess-and-verify" technique, first postulating its properties, then checking that they are satisfied. We conjecture that:

(i) the fluctuations of the exchange rate are identically and independently distributed around an average level $\overline{e}$;

(ii) all informed traders, and a constant number of noise traders, n, enter the peso bonds market at each period.

We characterize the equilibrium by proceeding in two steps. First, we determine the equilibrium exchange rate, taking the number of noise traders in the domestic market as given. We then endogenize the number of noise traders by using the no-entry condition.

2.4 Analysis with an Exogenous Number of Noise Traders

In equilibrium the domestic interest rate and the risk premium are identically and independently distributed around average values that we denote $\overline{\imath}$ and $\overline{\rho}$ respectively. The *average* risk premium is equal to the average difference between the domestic and foreign nominal interest rates:

$$\overline{\rho} = \overline{\imath} - i^*, \tag{18}$$

which, taking the expectation of equation (4), implies:

$$\overline{e} = \overline{m} - m^* + \alpha\overline{\rho}. \tag{19}$$

A rise in $\overline{e}$ corresponds to a depreciation of the domestic currency. Equation (19) says that a higher average interest rate differential, by decreasing the demand for domestic money relative to foreign money, leads to depreciation of the domestic currency.

The risk premium is determined by equilibrium in the market for peso-denominated bonds. If the excess return on these bonds is normally distributed (which is true in equilibrium, as we show below), it is well-known that maximizing (6) is equivalent to maximizing the mean-variance objective function:

$$\mathrm{E}_t^j(W_{t+1}^j) - \frac{a}{2}\mathrm{Var}_t^j(W_{t+1}^j), \tag{20}$$

and the demand for bonds denominated in peso by an individual trader is given by:

$$b_t^j = \frac{\mathrm{E}_t^j(\rho_{t+1})}{a\mathrm{Var}_t^j(\rho_{t+1})}. \tag{21}$$

The equality of demand and supply in the peso bonds market implies:

$$\begin{aligned} \overline{B} &= N_i \frac{\mathrm{E}_t(\rho_{t+1})}{a\mathrm{Var}_t(\rho_{t+1})} + n\frac{\overline{\rho} + \nu_t}{a\mathrm{Var}_t(\rho_{t+1})} \\ &= \frac{N_i \mathrm{E}_t(\rho_{t+1}) + n(\overline{\rho} + \nu_t)}{a\mathrm{Var}(e)}, \end{aligned} \tag{22}$$

where n is the number of noise traders investing in the peso bonds market. Taking the expectation of (22) at $t-1$ then gives an expression for the average risk premium:

$$\overline{\rho} = a\frac{\overline{B}}{N_i + n}\mathrm{Var}(e). \tag{23}$$

The average risk premium is increasing with the variance of the exchange rate, the coefficient of absolute risk aversion and the quantity of bonds per trader. We can then derive the equilibrium exchange rate and interest rate by substituting the definition of ρ_{t+1} into (22) and using (4) to substitute out the interest rate differential, which gives:

$$e_t - \overline{e} = \frac{1}{1+\alpha}\left(m_t - \overline{m} + \epsilon_t - \alpha\frac{n}{N_i}\nu_t\right). \tag{24}$$

This expression confirms that the fluctuations of the exchange rate are i.i.d. normal in equilibrium.

Taking the variance of (24) and using (13) to substitute out the variance of the noise allows us to close the characterization of equilibrium with an expression for exchange rate variability:[8]

$$\mathrm{Var}(e) = \frac{\mathrm{Var}(m+\epsilon)}{(1+\alpha)^2 - \lambda\alpha^2(n/N_i)^2}. \tag{25}$$

The variance of the exchange rate depends on both fundamentals and noise. The fundamental component appears in the numerator of the fraction in equation (25). The novelty in this model is the noise component, which appears in the denominator. An exogenous increase in the number of noise traders unambiguously increases the variance of the exchange rate, which

[8]Note that this expression yields a positive value for the variance of the exchange rate for all $n \leq N_n$ iff $\sqrt{\lambda} < (1+\alpha)N_i/(\alpha N_n)$, a condition that we assume is satisfied hereafter.

tends to raise the risk premium. On the other hand, it also increases the total number of traders demanding peso bonds, which lowers the risk premium (see equation (23)). *That is, noise traders have two counter-acting roles in our model; they both a) create risk and b) share risk.* As a result, the impact of the extra noise traders on the equilibrium risk premium is non-monotonic. The ambiguous effect of noise trading on the risk premium is portrayed in Figure 1. This ambiguity, and the fact that the risk premium can be increasing with the number of noise traders, lie at the heart of our model.[9]

2.5 Endogenous Entry

We now endogenize the composition of the pool of active traders.

The entry decision for informed traders is trivial: they bear no entry cost and always enter the peso bonds market in equilibrium. However, a noise trader enters only if the benefit of diversifying her portfolio into peso bonds exceeds her cost of entry. We show in the appendix that for trader j this condition takes the form:

$$\mathrm{GB}(\overline{\rho}, \mathrm{Var}(e)) \geq c_j \tag{26}$$

where GB($\overline{\rho}$,Var(e)), the gross benefit of entry for noise traders, is given by:

$$\mathrm{GB}(\overline{\rho}, \mathrm{Var}(e)) = \frac{1}{2a(1+\lambda)} \frac{\overline{\rho}^2}{\mathrm{Var}(e)} + \frac{1}{2a} \log(1+\lambda). \tag{27}$$

The partial derivatives of equation (27) have an intuitive interpretation. The benefit of entry, as assessed by noise traders, is increasing with the risk premium and decreasing with exchange rate variability.[10] But in equilibrium both the risk premium and the variance of the exchange rate are functions of the number of noise traders that enter the peso bond market; this can be seen in equations (23) and (25). This circularity, as we now show, can generate multiple equilibria.

The multiplicity of equilibria is illustrated in Figure 2, which shows the benefit and cost of entry for the marginal noise trader. The benefit depends

[9]Figures 1-3 were obtained for the following values of the parameters: $\alpha = 1$, $a = 4$, $\lambda = 3$, $N_i = N_n = \overline{B} = 100$, and $c_j = 0.3$ for all noise traders. The fundamental variance, $Var(m + \epsilon)$, was set to 1 in figure 1 and to 1.5 in figure 2.

[10]The benefit of entry as perceived by noise traders is different from the average realized benefit because noise traders' expectations are imperfectly rational.

on the number of noise traders already in the peso bonds market, n, as well as the impact that these noise traders have on exchange rate variability and the risk premium, Var(e) and $\overline{\rho}$. There are two stable equilibria, corresponding to points A and C (point B is unstable).[11] Point A corresponds to an equilibrium with low exchange rate volatility and a low risk premium. Here, the domestic market does not offer noise traders a large enough gain to induce many of them to enter. But there is another equilibrium at point C, which corresponds to a high volatility, high risk premium equilibrium. In this equilibrium, more noise traders are attracted to the peso bonds market by the high risk premium *that they themselves generate by entering the market.* Thus, our model can generate different levels of exchange rate volatility for the same level of macroeconomic volatility.

The following proposition states how the set of equilibria depends on the level of fundamental variance.

Proposition 1 . *For high levels of fundamental variance, $Var(m+\epsilon)$, there is one unique equilibrium, in which all noise traders enter the peso bonds market. For low levels of fundamental variance there is also a unique equilibrium, in which no noise traders enters the peso bonds market. For intermediate levels of fundamental variance, the number of noise traders is a non-linear function of fundamental variance, and multiple equilibria (with low and high entry by noise traders) can coexist.*

Proof. Increasing the fundamental variance shifts upwards the curve (GB) in figure 2. For high levels of fundamental variance the curve (GB) is everywhere above the (C) curve, so that there is one unique equilibrium in which all noise traders enter the domestic market. For small levels of fundamental variance the curve (GB) is close to the horizontal line $GB = \log(1+\lambda)/2a$, which is everywhere below the (C) curve because of assumption (16). Hence there is a unique equilibrium with no entry. For intermediate levels of fundamental variance, the number of entrants is not necessarily uniquely determined, as illustrated in figure 2. **Q.E.D.**

[11]Figure 2 is constructed under the assumption that all noise traders have the same entry cost. In general, the cost curve is upward sloping and there could be more than two stable equilibria.

Multiple equilibria thus typically arise for intermediate levels of fundamental variance. This is illustrated in figure 3, which portrays the relationship between the variance of fundamentals and exchange rate volatility under the same calibration as in figure 2. The lower branch corresponds to equilibria in which noise traders do not enter the domestic market (or only a small number of them do); the higher branch corresponds to equilibria with entry; and the branch in the middle to unstable equilibria. For intermediate values of the fundamental variance, $\mathrm{Var}(m + \epsilon)$, there is a "zone of multiplicity" with two equilibria. One equilibrium has low exchange rate volatility and limited entry of noise traders; the many noise traders who are present in the other make the exchange rate more volatile.

Under a pure float, hence, there is no simple relationship between the volatility of fundamentals and the exchange rate. Two countries with similar fundamentals may exhibit radically different levels of exchange rate volatility. In the high volatility equilibrium, exchange rate volatility is "excessive" in the sense that it is higher than the level that can be ascribed to the traditional macroeconomic fundamentals. We next scrutinize how this excessive volatility can be eliminated by policy.

2.6 Policy Implications

Exploring the implications of our model for the design of monetary policy requires explicit consideration of the domestic government's objectives. In order to keep the model as simple as possible, we assume that the government attempts to minimize a loss function defined as a weighted average of the variance in the domestic price level and the variance in the domestic nominal interest rate:[12]

$$L \equiv \omega Var(p) + (1 - \omega) Var(i). \tag{28}$$

This loss function captures the idea that the government attempts to smooth the interest rate and to stabilize the domestic price level. Parameter $\omega \in (0, 1)$ reflects the importance of price stability relative to interest rate stability. Substituting out e_t and m_t from equation (24) using (1) and (3) gives a

[12] One could take any other pair of variables, provided that the relationship between them involves noise as well as the fundamental shock to PPP, like in equation (29) below.

relationship between the two variables that appear in the government's loss function:

$$(p_t - \overline{p}) + (i_t - \overline{\imath}) = -\left(\epsilon_t + \frac{n}{N_i}\nu_t\right) \tag{29}$$

The loss function (28) describes the policy objectives, not the policy regime. We compare two types of regime in what follows: "pure floating", and "stable exchange rates". In a pure floating regime the government takes the amount of noise in the foreign exchange market as given. In a stable exchange rate regime the government attempts to control the amount of noise by announcing an upper bound on exchange rate volatility. As we argue below, our definition of stable exchange rate regimes is flexible enough to encompass a wide spectrum of exchange rate regimes, from managed floating to perfectly fixed pegs.

Under a pure float the domestic government minimizes its loss function subject to (29), taking n as given. The government's problem can be written:

$$(P) \quad \begin{cases} \min . L = \omega \mathrm{Var}(e) + (1-\omega)\mathrm{Var}(i) \\ (p_t - \overline{p}) + (i_t - \overline{\imath}) = z_t \end{cases} .$$

where the composite external shock z_t is given by:

$$z_t \equiv -\left(\epsilon_t + \frac{n}{N_i}\nu_t\right). \tag{30}$$

The composite external shock is the sum of two components: an exogenous fundamental component (the shock to PPP) and an endogenous non-fundamental component (noise). Because the problem is linear-quadratic we know that the solution to problem (P) is proportional to z_t. Using the method of undetermined coefficients, one finds:

$$p_t - \overline{p} = (1-\omega) z_t \tag{31}$$

$$i_t - \overline{\imath} = \omega z_t. \tag{32}$$

These equations describe how the monetary authorities funnel external shocks into the domestic price level and the interest rate. Unsurprisingly, the domestic country will let more of the volatility go into the price level if it cares less about price stability (ω is lower).

The number of noise traders in the domestic bonds market results, as before, from the no entry condition. The gross benefit of entry is still given by expression (27) and the variance of the exchange rate is obtained by taking the variance of:

$$e_t = p_t + \epsilon_t = \overline{p} + \omega\epsilon_t - (1-\omega)(n/N_i)\nu_t. \tag{33}$$

Using $\text{Var}(\nu) = \lambda\text{Var}(e)$ to substitute out the variance of noise then gives:

$$\text{Var}(e) = \frac{\omega^2}{1-\lambda(1-\omega)^2(n/N_i)^2}\text{Var}(\epsilon). \tag{34}$$

This equation is similar to equation (25). The variance of the exchange rate is proportional to the variance of the shock in PPP, and increasing with the number of noise traders. It follows that the results in Proposition 1 remain valid: in particular there may be multiple equilibria with low and high entry by noise traders when $\text{Var}(\epsilon)$ takes intermediate values. The low volatility equilibrium clearly dominates the high volatility equilibrium, since in the latter the exchange rate and the interest rate are *both* more volatile.

By contrast with a pure float, we define a "stable exchange rate regime" as a commitment by the domestic authorities to maintain the variance of the exchange rate below a preannounced bound v. With a stable exchange rate regime, thus, the optimization problem of the domestic monetary authorities becomes:

$$(P') \quad \begin{cases} \min. L = \omega\text{Var}(e) + (1-\omega)\text{Var}(i) \\ (p_t - \overline{p}) + (i_t - \overline{\imath}) = z_t \\ Var(e) \leq v \end{cases}$$

This definition encompasses a wide variety of exchange rate regimes, including pure floats when v goes to infinity. If v is large the limit on exchange rate variance is not binding as long as the number of noise traders in the foreign exchange market is not too large. The difference between regime *(P)* and regime *(P')*, then, is that while in the former the government has a policy of "benign" neglect with respect to noise in the foreign exchange market, in the latter it promises to prevent exchange rate variance from increasing *should a large number of noise traders choose to enter*. This promise to "lean against the noise" does not have to be fulfilled as long as the level of noise trading remains moderate, so that the exchange rate would behave in the same way as under a pure floating in normal times. This regime can be interpreted as a managed float or wide target zones such as the ones envisioned in the Plaza-Louvre strategy. Smaller values of v correspond to harder commitments to exchange rate stability. The limit $v = 0$ corresponds to a perfectly fixed peg.

Our definition of a stable exchange rate regime is consistent with Svensson's (1994) definition of exchange rate bands. It is different from Krugman's (1991) definition of target zones since it does not constrain the exchange rate to remain at all times in a band with well-defined edges. As Svensson (1994) argues, defining exchange rate bands in terms of variance is a good approximation to the actual working of target zones. Moreover this keeps the monetary policy problem linear-quadratic, and so much easier to manipulate. Svensson interprets parameter v as the "width" of the band.

An objective of exchange rate stability can reduce the domestic government's loss, in spite of the fact that it *adds* a constraint to the government's problem, *by decreasing the level of noise* in the foreign exchange market. When the constraint on exchange rate variance is binding the gross benefit of entry for noise traders is given by equation (23) and (27) with $\text{Var}(e) = v$, i.e.:

$$GB = \frac{a\overline{B}^2}{2(1+\lambda)} \frac{v}{(N_i + n)^2} + \frac{1}{2a} \log(1+\lambda). \qquad (35)$$

This is unambiguously decreasing with the number of entrants n. The reason is that the entry of noise traders no longer increases the variance of the exchange rate (since the government transfers the additional volatility to the domestic price level and the interest rate) and decreases the risk premium because of the risk-sharing effect. The gross benefit of entry is also strictly decreasing with the bound v, so that if the constraint on exchange rate variance is binding:

$$\frac{\partial n}{\partial v} > 0. \qquad (36)$$

Increasing the width of the exchange rate band increases the number of noise traders who enter the domestic market in equilibrium.

As we now show, a stable exchange rate regime can benefit the government in two different ways. First, it can remove bad equilibria.

Proposition 2 . *Suppose that under a pure float there are two equilibria* *with differing levels of exchange rate variance. A stable exchange rate regime can pin down the economy on the equilibrium with low exchange rate variance.*

Proof. Denote by $\mathrm{Var}(e)^L_{float}$, $\mathrm{Var}(e)^H_{float}$, and n^L_{float}, n^H_{float} the levels of exchange rate variance and number of noise traders that prevail in the bad and good equilibrium under floating respectively. Assume that the government adopts a bound on exchange rate variance which lies between these levels:

$$\mathrm{Var}(e)^L_{float} < v < \mathrm{Var}(e)^H_{float}. \tag{37}$$

Then by equation (34) there is a number of noise traders between n^L_{float} and n^H_{float}, above which the variance constraint is binding. Denoting this number by $\overline{n}_v$, then for $n > \overline{n}_v$ the gross benefit of entry for noise traders is decreasing with n (see (35)). Hence in Figure 2 the (GB) curve is decreasing for $n > \overline{n}_v$, and the bad equilibrium disappears. **Q.E.D.**

This proposition states the possibility of a "free lunch" of exchange rate volatility. If the economy is in a bad equilibrium with many noise traders, adopting an objective of exchange rate stability allows the country to get closer to both its objectives *simultaneously*, i.e., reduce the variance of the price level *and* that of the interest rate at the same time. Although the stable exchange rate commitment constrains the monetary policy response function *out of equilibrium*, there is no observable sacrifice of monetary autonomy *in equilibrium*—on the contrary, since the level of noise is lower. The mere promise that the authorities will react to the entry of noise traders, if it is believed, suffices to keep noise traders away and thereby delivers lower exchange rate volatility.

The optimality of a stable exchange rate regime is not limited to the case where floating involves multiple equilibria. When the equilibrium is unique exchange rate stability involves an effective loss of monetary autonomy, but the latter might be dominated by the benefit in terms of reduced noise. As the following proposition shows, the benefit of exchange rate stability easily dominates the loss of monetary autonomy in our model.

Proposition 3 . *If a pure float involves the entry of some (but not all) noise traders, the domestic government can strictly reduce its loss function by adopting an objective of exchange rate stability.*

Proof. Let us denote by $\text{Var}(e)_{float}$ and n_{float} the exchange rate variance and the number of noise traders in the pure float equilibrium. We treat n_{float} as a continuous variable and assume that some but all noise traders are present ($0 < n_{float} < N_n$). The marginal entrant, thus, is indifferent between entering the domestic market and staying out.

As we now show, the government's loss function is strictly reduced if v is set at values slightly lower than $\text{Var}(e)_{float}$. For these values the variance constraint $\text{Var}(e) \leq v$ is binding, so that $\partial n/\partial v > 0$. Denoting by $L^*(v, n)$ the minimand of problem *(P')*, we have:

$$\frac{dL^*(v,n)}{dv} = \frac{\partial L^*}{\partial v} + \frac{\partial L^*}{\partial n}\frac{\partial n}{\partial v}. \tag{38}$$

The first term is the Lagrange multiplier for the exchange rate variance constraint; it is equal to zero for $v = \text{Var}(e)_{float}$, and close to zero for values of v slightly below $\text{Var}(e)_{float}$. The second term is strictly positive because $\partial L^*/\partial n > 0$, and $\partial n/\partial v > 0$. **Q.E.D.**

That is, *it is optimal to adopt an objective of exchange rate stability as soon as a pure float attracts noise traders.* The intuition behind this result is the following. A stable exchange rate regime has two effects. First, it increases the government's loss function by shifting policy away from the optimum at a given number of noise traders—the classical "loss of monetary autonomy" effect. Second, it decreases the level of noise to which the economy is exposed. If the exchange rate variance is marginally below the level that would prevail under a pure float, the loss of monetary autonomy is of the second order; it is dominated by the decrease in noise. Hence there always exists a stable exchange rate regime that dominates floating.

Our model has been kept highly stylized; it abstracts from country size, non-traded goods, and the nominal frictions that make exchange rate policy decisions non-trivial. Still, our main result—that reducing exchange rate volatility may not involve any sacrifice in terms of monetary autonomy—should remain valid in more complex models. This violates Mundell's "Incompatible Trinity" of fixed exchange rates, monetary autonomy and capital mobility. A threat by the monetary authority (to react if noise traders enter) changes the composition of the market. By discouraging the entry of noise traders, the market is steered to a low volatility equilibrium where intervention is unnecessary. Words speak loudly enough that actions are unnecessary.

3 Empirics

The primary purpose of this paper is to provide a theoretical framework for the policymakers' view of fixed exchange rate regimes as shelters against speculative noise. Another question is the extent to which the policymakers' view, and our model, are corroborated by the empirical evidence. As our introductory discussion of the literature shows, there is a large body of evidence suggesting the presence of non-fundamental influences in foreign exchange markets. This literature is certainly broadly consistent with our approach. Unfortunately, it focuses almost exclusively on floating exchange rates, and is thus of limited value to us. Our objective in this section of the paper is to provide more direct evidence in favor of our model.

We look at features of foreign exchange markets for which our model makes predictions that contrast sharply with those of macroeconomic models: market expectations (which we examine both directly and indirectly), and trading volume. The choice of these variables is not original—they are used in many papers on the micro-structure of foreign exchange markets (Lyons, 2000)—but they have not been examined across exchange rate regimes. Our model predicts increased forecast dispersion, greater UIP deviations, and higher volume during floating exchange rate regimes. While data limitations hamper our ability to test the model directly, we now test (and confirm!) as many of these predictions as the data allow us.

3.1 Forecast Dispersion

The notion of heterogeneous expectations is alien to the macrofundamental-based approach to exchange rates. If all market participants form perfectly rational forecasts on the basis of the same macroeconomic information, there should be a single market forecast. This forecast could be volatile over time, but there should be only one forecast at a given point in time. In the world described by macro-fundamental based models, there would be little need for *surveys* of market expectations. In the real world, however, costly resources are spent to produce market surveys that show considerable heterogeneity in expectations. Using such survey evidence Frankel and Froot (1987,1990) and Cheung *et al.* (2000) provide direct evidence of considerable forecast heterogeneity (though not across exchange rate regimes).

Our model predicts that market expectations should be more noisy under floating exchange rates. As a measure of noise we take the heterogeneity (or dispersion) in market forecasts. The question we ask in this sub-section is: "Are fixed exchange rates associated with reduced forecast dispersion?" We use data taken from the *Financial Times Currency Forecaster* which provides "consensus" forecasts for rates which are expected to prevail six months in the future. This data set is available monthly (with gaps) for thirteen different (dollar) exchange rates from 1996 through 1999.[13] More importantly for us, the data set also includes the "High Forecast" and the "Low Forecast".[14] We define forecast dispersion as the difference, in percentage points, between the higher and the lower forecast.

Is there any association in the data between forecast dispersion and the exchange rate regime? In the data set, we have 118 observations for fixed exchange rate regimes, a number of which were attacked either successfully (e.g., the Korean Won, the Brazalian real) or unsuccessfully (e.g., the Hong Kong dollar) in the sample. We also have 337 observations of floating exchange rates. Table 1 reports the results of an OLS regression of forecast dispersion on a dummy variable characterizing the nature of the exchange rate regime. As can be seen in the table, fixed exchange rate regimes have much lower forecast dispersion; the point estimate from the column at the extreme left of the table indicates that the difference is 5.3%, a difference which is both economically and statistically significant. This column uses a country's stated exchange rate policy to construct the fixed exchange rate dummy variable.[15]

Of course not all officially fixed exchange rates are credibly fixed. In the next column to the right, we use a dummy variable which is unity only if the country is formally fixed and if the markets consensus forecast is within 2% of the actual spot rate, a situation we refer to as a "credible fix". As

[13]The currencies are: Japanese yen, German mark (euro from Feb. 1999 onwards), Pound sterling, Canadian dollar, Argentine peso, Mexican peso, Brazilian real, Hong Kong dollar, Singapore dollar, Taiwan dollar, Korean won, Malaysian ringgit, Philippine peso, all vis a vis the American dollar. It has been checked and corrected for transcription errors and is available at Rose's website.

[14]In July 1997, the high forecast switched from being the highest single forecast to the average of the strongest five forecasts, and *mutatis mutandis* for the low forecast.

[15]Stated policy seems to correspond to actual policy in our sample; the volatility of exchange rate changes for floaters was three times that of fixers, a difference that is statistically significant at conventional levels (since the test for equality of standard deviations for exchange rate changes is F(329,111)=28.3).

expected, credible fixes have even less forecast dispersion than the aggregate of all fixes, though (as the third column shows), non-credible fixes are still associated with significantly lower forecast dispersion. The last three columns of the table add a control for actual exchange rate volatility (that is, the country-specific standard deviation of the percentage change in the spot rate). This is an important control variable since high forecast dispersion may in principle simply reflect high exchange rate volatility. But, as the table clearly indicates, the nature of the exchange rate regime still matters once the effects of exchange rate volatility are controlled for. Both non-credible and credible fixes are associated with lower forecast dispersion in economically and statistically significant amounts. This is true despite the positive relationship between actual exchange rate volatility and forecast dispersion.

[Insert Table 1]

In sum, our model predicts that floating exchange rates should be associated with greater forecast dispersion because of the presence of noise traders. This prediction is strongly and intuitively verified in the data.

3.2 Uncovered Interest Parity

The risk premium in our model leads us naturally to tests of uncovered interest parity (UIP). It is well-known that tests of UIP are grossly rejected in the data; Lewis (1995) provides a thorough survey. Yet virtually all the evidence reviewed by Lewis stems from floating exchange rate regimes. Our model makes a strong prediction about deviations from UIP in different exchange rate regimes. As we now show, our model indicates that deviations from UIP should be smaller during fixed exchange rate regimes than for floating rates.[16]

UIP is typically tested by regressing the *ex post* change in the exchange rate on the interest rate differential and a constant:

$$\Delta e_{t+1} = \beta_0 + \beta_1 (i_t - i_t^*) + \eta_{t+1} \tag{39}$$

[16]Mark and Wu (1998) also analyze deviations from UIP using a noise trader model, but for floating rate regimes.

where $\eta_{t+1}$is a forecast error realized at t+1 which is orthogonal to information available at time t. In our model the regressand and regressor are given by

$$\Delta e_{t+1} = \frac{m_{t+1} - m_t}{1+\alpha} - \frac{\alpha}{1+\alpha}\frac{n}{N_i}(\nu_{t+1} - \nu_t) \tag{40}$$

$$i_t - i^* = \overline{\rho} - \frac{m_t - \overline{m}}{1+\alpha} - \frac{1}{1+\alpha}\frac{n}{N_i}\nu_t \tag{41}$$

(where the shock to PPP, ϵ has been set to zero for the sake of simplicity). The asymptotic OLS estimate for the coefficient of the interest rate differential is given by

$$\hat{\beta}_1 = \frac{\mathrm{Cov}(\Delta e_{t+1}, i_t - i^*)}{\mathrm{Var}(i - i^*)} = \frac{\mathrm{Var}(m) - \alpha(n/N_i)^2\mathrm{Var}(\nu)}{\mathrm{Var}(m) + (n/N_i)^2\mathrm{Var}(\nu)}. \tag{42}$$

This coefficient is equal to one in the absence of noise traders ($n = 0$), as predicted by UIP. From a theoretical viewpoint, the coefficient is decreasing with the number of noise traders. It may even fall to negative values with sufficiently intense noise trading (most empirical studies have estimated it to be negative). Thus if fixed exchange rate regimes are associated with less noise trading (as posited above), $\hat{\beta}_1$ should be higher for fixed exchange rate regimes than for floating rate regimes.

This is in fact precisely what Flood and Rose (1996) found. Using high-frequency data from the European Monetary System of fixed exchange rate regimes, they find a typical estimate of $\hat{\beta}_1$ to be about .6, although it is negative when they apply the same techniques to comparable floating exchange rate data. To our knowledge, this is the only study that compares deviations from UIP across exchange rate regimes.[17]

[17] Flood and Rose conclude: "Explanations of the forward discount bias which emphasize heterogeneous beliefs and trading strategies on foreign exchange markets (either by central banks or by traders who are not fully rational) which are regime-dependent seem particularly plausible to us. These may stem from either a risk-premium or systematic forecast errors which vary by exchange rate regime."

3.3 Trading Volume

One of the most well-known puzzles with the foreign exchange markets is the huge volume of trade.[18] The Bank for International Settlements collects data on a wide range of foreign exchange trading every three years and continues to show dramatic growth in foreign exchange volume, which is now estimated to surpass $1.5 trillion daily. From the perspective of a macroeconomic model, the size of this volume is another mystery. In the standard macro model, volume in the foreign exchange market should be related to trade volume in goods and services. Portfolio adjustments generate no forex trade since the price of assets adjusts instantaneously to the no-trade level. In our model, by contrast, trade volume is generated by heterogeneity in expectations and is higher with floating exchange rates. Do trading volumes vary across exchange rate regimes in the data in the way predicted by the model?

An approach to this question is to use the BIS data set. These data are broken down into only a few bilateral markets, only for trades involving either the dollar or DM, and even then for only for the most recent few surveys. Thus, we are unable to perform a regression analysis. Still, there is some evidence that floating exchange rates are associated with larger volumes. The 1992 survey shows that of the top thirteen foreign exchange markets, only two were for fixed exchange rate regimes. This result is confirmed in more recent surveys, which shows that the vast majority of foreign exchange transactions occur between floating exchange rate regimes. The table below shows the average daily foreign exchange volumes for the most important currency pairs in the world. The data are collected in April; 1995 and 1998 data are shown in the first two columns. Virtually all the heavily-traded markets are floating exchange rates; the rare exceptions are highlighted in bold. For comparison, the third column of the table shows average daily bilateral merchandise trade in 1995 (annual exports plus imports, divided by 250), extracted from the *World Trade Data Bank*. Note that in 1995 the DM/French Franc exchange rate ranked third in goods and services trade volume but only ninth in foreign exchange volume. In April 1998, a few months before the introduction of the euro, the DM/French Franc exchange rate had disappeared from the top thirteen foreign exchange markets.

[18] Evans and Lyons (1999) show that the "order flow" variable which lies at the heart of most micro-structure models is an important determinant of exchange rate movements.

[Insert Table 2]

3.4 Summary

The literature suggests that exchange rates are substantively affected by non-fundamental influences, such as the noise traders that we have modelled above. While it is difficult to directly test our model, we have provided several pieces of evidence which are consistent with our theory: (i) floating exchange rate regimes are associated with more noise (higher forecast dispersion) than their fixed counterparts; (ii) the deviations from UIP are smaller in fixed exchange rate regimes than under floating; (iii) volume on foreign exchange markets is higher in floating exchange rate regimes. While we view these pieces of evidence as preliminary, we hope that they, together with our model, are sufficiently plausible to spur others to continue work in the area. We also note that much more complicated *macroeconomic* models, are even *less* capable of rationalizing the facts.[19]

4 Conclusion

In this paper we have presented a model which rationalizes an important benefit of (credible) fixed exchange rate regimes—according to policymakers—as well as some stylized facts. Our model introduces noise traders, who create exchange rate volatility if they choose to enter the domestic bonds market in order to diversify their portfolios. Noise traders benefit from holding bonds, but pay a cost from entering the markets while also creating undesirable exchange rate volatility.

For a range of fundamental macroeconomic volatility, our model generates multiple equilibria under floating; noise traders can either be present

[19] It is, to our knowledge, both well-known and uncontroversial that macroeconomic models cannot rationalize the phenomenon with which we are concerned. To a first approximation, countries with fixed exchange rates have less volatile exchange rates than floating countries, but macro-economies which are equally volatile. This result stretches back at least as far as Mussa's (1986) work on nominal and real exchange rate variability across exchange rate regimes. Baxter and Stockman (1989) extended Mussa's work on exchange rates to other macroeconomic variables, and Flood and Rose (1995,1999) provide further consistent evidence using model-based approaches.

or absent from the markets. If they are present, they generate exchange rate volatility. But there is another equilibrium with less noise trading and with a more stable exchange rate. With a stable exchange rate regime, the policy authorities can coordinate activity to this equilibrium. In fact, an appropriate exchange rate regime can lower exchange rate volatility without any macroeconomic cost at all. *Exchange rate policy works by affecting the composition of the foreign exchange market, not simply by the traditional mechanism of subordinating monetary policy to an exchange rate target.*

There are at least three directions in which we would like to see the model extended. First, the normative analysis of exchange rate regimes could be enriched by introducing non-traded goods and nominal stickiness. Second, one could give more rigorous microeconomic underpinnings to the macroeconomic part of the model along the lines of the "New Open Macroeconomics" developed by Obstfeld and Rogoff (1996). Although we do not see reasons why the essential properties of the model would be altered by the explicit consideration of intertemporally optimizing agents—which would significantly complicate the model—it would be reassuring to have a version of the model where the macroeconomy has more microfoundations. Adding goods markets may also enable us to understand better the persistence nature of exchange rate shocks. Third, the issue of *credibility* could be incorporated to the analysis. Imperfectly credible currency pegs could attract noise traders for the same reason as very volatile currencies—because the risk premium is high—potentially shifting the balance of costs and benefits towards floating.

It would also be interesting to study other ways of endogenizing the deviations from rational expectations. For example, noise could be endogenized at the level of the trader rather than at the level of the traders' population. We could assume that each trader can reduce the noise component in her expectations by investing in information and analysis—instead of endogenizing noise as the result of the entry by noise traders who are intrinsically noisy, as we do here. The distinction would seem to be important in a *global* normative analysis of exchange rate regimes. In our model, a fixed exchange rate regime keeps noise trading away from the domestic currency perhaps at the expense of the third countries to which noise traders go. The analysis would be different if the *global* quantity of noise were itself endogenous to the global exchange rate system.

To conclude, we acknowledge that our micro-structural model of exchange rate volatility is stylized and unable to capture many aspects of reality. Although there is qualitative and anecdotal evidence in favor of our approach, providing direct empirical support for our model is made difficult by data limitations. A test of our model, literally interpreted, would require disaggregated data on trading activity and the identity of traders across a number of exchange rate regimes: such data simply do not exist to our knowledge. We have offered, instead, what we think are convincing pieces of evidence in support of a somewhat broader interpretation of the model. Jointly, we think of these pieces of evidence as corroboration of our model, and a strong encouragement, to us and other researchers, to develop new data sets. More definitive tests await better data.

TABLES

Table 1. Forecast dispersion and exchange rate regimes.

Dependent variable: exchange rate forecast dispersion (percent)

Explanatory Variables						
Fixed Exchange Rate Dummy	-5.27		-2.60	-6.35		-6.01
	(.52)		(.63)	(.52)		(1.15)
Credibly Fixed Rate Dummy		-7.40	-5.18		-6.69	-.57
		(.54)	(.73)		(.51)	(1.33)
Exchange Rate Volatility				1.23	.49	1.17
				(.16)	(.17)	(.24)
R^2	.17	.20	.22	.30	.22	.30

Regressand is High-Low forecast, expressed in percentage. Robust standard errors in parentheses; constants not displayed. Number of Observations = 455.

Table 2. Trade volumes in the foreign exchange and goods and services markets.

Currency pair	Foreign exchange		Merchandise Trade
	April 1995	April 1998	1995
US$/DM	254	291	.3
US$/Yen	242	267	.7
US$/other EMS	104	176	
US$/Pound Sterling	78	118	.2
US$/Swiss Franc	61	79	.2
US$/French Franc	60	58	.1
DM/Other EMS	**38**	**35**	
US$/Canadian $	38	50	1.1
DM/French Franc	**34**		.4
US$/Australian $	29	42	.1
DM/Yen	24	24	.1
DM/Pound Sterling	21	31	.3
DM/Swiss Franc	18	18	.2
All Pairs	1137	1442	

Average daily billions of US$. Extracted from Table B-4 of the 1998 BIS' *Central Bank Survey of Foreign Exchange and Derivatives Market Activity.* Data on Goods and Services come from the World Trade Data Bank.

APPENDIX

This appendix derives the net benefit of entering the domestic market for noise traders (equation (27)). Let us consider the entry decision of noise trader j at time t. Without entry, trader j's expected utility is given by:

$$\mathrm{E}^j_{t-1}\left(U^j_t|\delta^j_t=0\right)=-\exp\left(-a(1+i^*)W\right), \tag{43}$$

while under entry it is given by:

$$\mathrm{E}^j_{t-1}\left(U^j_t|\delta^j_t=1\right)=-\exp\left(-a(1+i^*)W\right)\mathrm{E}^j_{t-1}\left(\max_{b^j_t}E^j_t\left(\exp(-ab^j_t\rho_{t+1}+ac_j\right)\right) \tag{44}$$

At the time of her entry decision, noise trader j does not know what her expectation of the excess return will be after entry. However she knows that this expectation will be given by $\mathrm{E}^j_t(\rho_{t+1})=\overline{\rho}+\nu_t$, where ν_t is normally distributed, and that the innovation in ρ_{t+1} at $t+1$ will be normally distributed with variance Var(e). In other terms, at the time of entry the excess return ρ_{t+1} is expected by the noise trader to be of the form $\overline{\rho}+\nu_t+\eta_{t+1}$ with $\nu_t\sim N(0,\mathrm{Var}(\nu))$ and $\eta_{t+1}\sim N(0,\mathrm{Var}(e))$. Using $b^j_t=(\overline{\rho}+\nu_t)/(a\mathrm{Var}(e))$, it follows from the comparison of expressions (43) and (44) that:

$$\delta^j_t=1\Longleftrightarrow E_{t-1}\left(\exp\left(-\frac{(\overline{\rho}+\nu_t)}{\mathrm{Var}(e)}(\overline{\rho}+\nu_t+\eta_{t+1})+ac_j\right)\right)<1. \tag{45}$$

In order to compute this expression we use the following lemma.

Lemma. If x is normally distributed with mean zero and variance σ^2, and μ_0, μ_1 and μ_2 are scalars (with $\mu_2>-1/(2\sigma^2)$) then:

$$E\left(\exp\left(-(\mu_0+\mu_1x+\mu_2x^2)\right)\right)=\frac{1}{\sqrt{1+2\mu_2\sigma^2}}\exp\left(-\mu_0+\frac{\mu_1^2\sigma^2}{2(1+2\mu_2\sigma^2)}\right) \tag{46}$$

Proof. To alleviate notations we denote by I the l.h.s. of (46), and define $\kappa\equiv\mu_1\sigma^2/(1+2\mu_2\sigma^2)$. Using the decomposition:

$$\mu_0 + \mu_1 x + \left(\mu_2 + \frac{1}{2\sigma^2}\right) x^2 = \frac{\mu_1}{2\kappa}(x+\kappa)^2 + \mu_0 - \frac{\mu_1 \kappa}{2}, \tag{47}$$

one has:

$$\begin{aligned} I &= \int_{-\infty}^{+\infty} \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\left(\mu_0 + \mu_1 x + \left(\mu_2 + \frac{1}{2\sigma^2}\right) x^2\right)\right) dx \\ &= \exp\left(-\mu_0 + \frac{\mu_1 \kappa}{2}\right) \frac{1}{\sqrt{2\pi}\sigma} \int_{-\infty}^{+\infty} \exp\left(-\frac{\mu_1}{2\kappa}\left(x+\kappa\right)^2\right) dx \\ &= \exp\left(-\mu_0 + \frac{\mu_1 \kappa}{2}\right) \frac{1}{\sqrt{2\pi}\sigma} \sqrt{2\pi} \sqrt{\frac{\kappa}{\mu_1}}. \end{aligned}$$

which gives the expression in the lemma (the integral on the r.h.s. of the second equation is computed as the integral of a normal law). **Q.E.D.**

In equation (45) the expectation is taken over two stochastic variables: ν_t and η_{t+1}. Since these variables are independent we can compute the expectation by applying the lemma two each variable successively. We first compute the expectation conditional on ν_t (taking $x = \eta_{t+1}$, $\mu_0 = (\overline{\rho} + \nu_t)^2/\mathrm{Var}(e) - ac_j$, $\mu_1 = (\overline{\rho} + \nu_t)/\mathrm{Var}(e)$, $\mu_2 = 0$ and $\sigma^2 = \mathrm{Var}(e)$). We then compute the expectation over ν_t using the same method. This allows us to rewrite the condition in (45) as:

$$\sqrt{\frac{\mathrm{Var}(e)}{\mathrm{Var}(\nu) + \mathrm{Var}(e)}} \exp\left(-\frac{\overline{\rho}^2}{2(\mathrm{Var}(\nu) + \mathrm{Var}(e))} + ac_j\right) < 1 \tag{48}$$

Taking the logarithm of this expression and using the identity $\mathrm{Var}(\nu) = \lambda \mathrm{Var}(e)$ to substitute out the variance of noise then gives (26)-(27).

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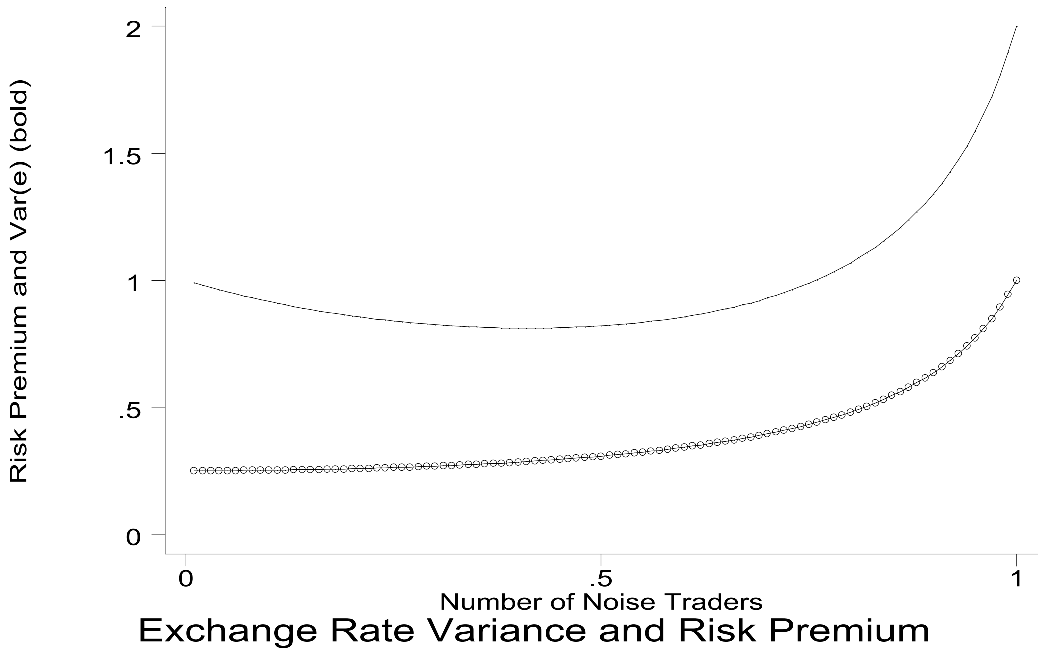

Figure 1: Exchang Rate Variance and Risk Premium

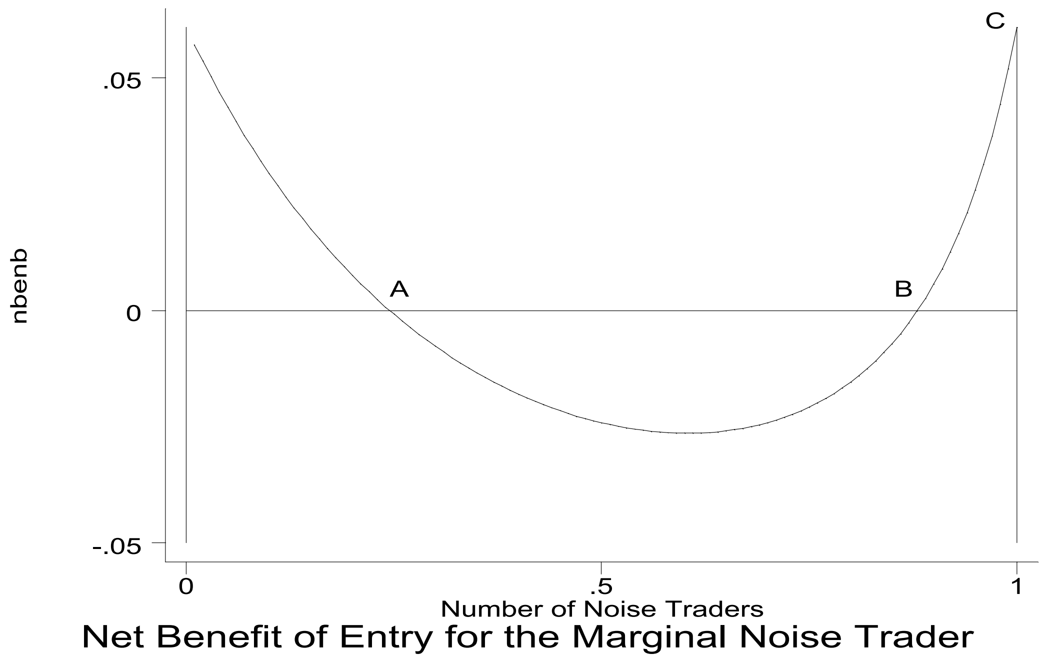

Figure 2: Cost and Benefit of Entry for the Marginal Noise Trader

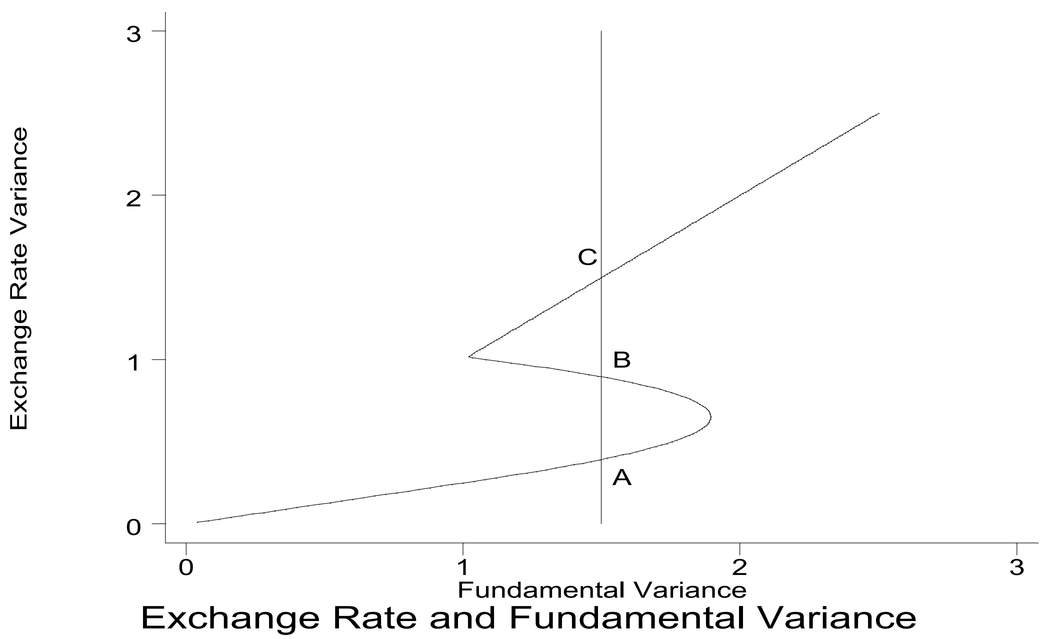

Figure 3: Fundamental Variance and Exchange Rate Variance