

UNDERSTANDING EXCHANGE-RATE DYNAMICS:  
A SESSION IN MEMORY OF RUDI DORNBUSCH<sup>†</sup>

## A Scapegoat Model of Exchange-Rate Fluctuations

By PHILIPPE BACCHETTA AND ERIC VAN WINCOOP\*

There is a peculiar mismatch between explanations given by market analysts for observed exchange-rate fluctuations and the academic consensus about exchange rates. The academic consensus, based on the seminal work of Richard A. Meese and Kenneth Rogoff (1983) and subsequent literature, is that macroeconomic variables have little explanatory power for exchange rates in the short to medium run. On the other hand, market analysts often point to particular macroeconomic developments in accounting for exchange rates. For example, the large depreciation of the euro relative to the dollar subsequent to its inauguration in January 1999 was blamed on the strong growth performance of the U.S. economy relative to the European economy. More recently the appreciation of the euro relative to the dollar has been blamed on the large U.S. current-account deficit.<sup>1</sup> That practitioners regularly change the weight they attach to different macroeconomic indicators is widely reported in the financial press. It has also been confirmed by Yin-Wong Cheung and Menzie Chinn (2001), who surveyed U.S. foreign-exchange traders.

<sup>†</sup> *Discussants:* Olivier Jeanne, International Monetary Fund; Mark W. Watson, Princeton University; Richard K. Lyons, University of California–Berkeley.

\* Bacchetta: Study Center Gerzensee, 3115 Gerzensee, Switzerland, University of Lausanne, and CEPR; van Wincoop: Department of Economics, University of Virginia, Charlottesville, VA 22904, and NBER. We thank Olivier Jeanne and Elmer Mertens for comments on a previous draft.

<sup>1</sup> For example, in the *Financial Times* of 1 December 2003, one can read: “The dollar’s latest stumble ... came despite optimistic economic data from the US. But analysts said the movement of the US currency was no longer driven by growth fundamentals. All the focus is on the deficit now ... .”

The varying weight that traders give to different macroeconomic indicators may explain why formal models of exchange rates have found so little explanatory power of macro variables. In contrast to existing models, the relationship between macro variables and the exchange rate appears to be highly unstable. Cheung et al. (2002) find that some models, with certain macro variables, do well in some periods but not in others.

One explanation for this parameter instability is a scapegoat story: some variable is given an “excessive” weight during some period. The exchange rate may change for reasons that have nothing to do with observed macro fundamentals, for example, due to unobserved liquidity trades. As the market rationally searches for an explanation for the observed exchange-rate change, it may attribute it to some observed macro indicator. This macro indicator then becomes a natural scapegoat and influences trading strategies. Over time, different observed variables can be taken as scapegoats, so that the weights attributed to macro variables change.

In this paper we formalize this scapegoat story in the context of a simple rational-expectations model. The model illustrates how a variable can become a scapegoat and illuminates the implications for the exchange rate. The basic mechanism behind this scapegoat story is that there is “confusion” in the market about the true source of exchange-rate fluctuations. This happens because investors have different views about the importance of various observed macro variables. We model this heterogeneity with investors receiving different private signals about some structural parameters. Investors therefore do not know whether an exchange-rate fluctuation can be explained by unobserved fundamentals, such as liquidity

trades, or by a larger-than-expected weight to certain observed macro fundamentals. In such an environment it is natural to blame the variables one can observe (i.e., the macro fundamentals).

Although models with investor heterogeneity are common in the finance literature, they have not often been used to analyze the foreign-exchange market. In related work (Bacchetta and van Wincoop, 2003), we develop a fully dynamic macroeconomic model of exchange-rate determination where investors have different information about future macroeconomic variables. We show that such a framework can lead to a disconnect between observed macro fundamentals and exchange rates in the short to medium run, but a closer relationship in the long-run. In that paper it is assumed that all investors know the model and its parameters. In contrast, here we assume that investors are incompletely, and heterogeneously, informed about some parameters and therefore about the importance of various macro indicators.

**I. A Model with Heterogeneous Beliefs**

Our starting point is the standard monetary model of exchange-rate determination. It contains three equations. The first is a purchasing-power-parity equation:  $p_t = p_t^* + s_t$ , where  $s_t$  is the log of the nominal exchange rate. The second is a money-demand equation:  $m_t - p_t = y_t - \alpha i_t$  (and foreign analogue). The third is an interest-arbitrage equation:

$$(1) \quad \bar{E}_t(s_{t+1}) - s_t = i_t - i_t^* + \gamma b_t \sigma_t^2.$$

Here  $\bar{E}_t$  denotes the average expectation of individual investors, and  $\sigma_t^2$  is the conditional variance of next period's exchange rate;  $b_t$  is the unobserved net supply of foreign currency based on nonspeculative trade (such as liquidity trades) and has a normal distribution  $\mathcal{N}(0, \sigma_b^2)$ . This interest-parity equation can be derived from a standard portfolio-choice model with constant absolute risk-aversion  $\gamma$ . We refer the reader to Olivier Jeanne and Andrew K. Rose (2002) and Bacchetta and van Wincoop (2003) for formal derivations.

As usual, (1) is solved forward after substituting the purchasing-power-parity and money-demand equations, leading to an expression

equating the current exchange rate to the present value of expected future fundamentals. In our context, however, we are dealing with average instead of single expectations. In Bacchetta and van Wincoop (2003) we show that this implies that the law of iterated expectations may not hold and that the exchange rate may depend on higher-order expectations as in John Maynard Keynes's (1936) beauty-contest paradigm (average expectations of average expectations, and so on). While the presence of higher-order expectations has interesting implications for asset-price behavior in general (see Franklin Allen et al., 2003; Bacchetta and van Wincoop, 2004), we abstract from them in this short paper by assuming that information heterogeneity lasts only one period.

We assume that starting at date 2 investors have common information about future output levels and money supplies. To keep things simple we assume that  $\bar{E}_2(m_t) = \bar{E}_2(y_t) = 0$  for  $t > 2$  and that the foreign money supply and output level are zero at all times. Since  $\bar{E}_1(b_t) = 0$  for  $t > 2$ , we have  $\bar{E}_1(s_t) = 0$  for  $t > 2$  (ruling out bubbles). Then,

$$(2) \quad s_1 = \frac{1}{1 + \alpha} (m_1 - y_1) + \frac{\alpha}{(1 + \alpha)^2} \bar{E}_1(m_2 - y_2) - \frac{\alpha}{1 + \alpha} \gamma \sigma_1^2 b_1.$$

The exchange rate depends on current and expected future macro fundamentals minus a risk-premium term that depends on liquidity trade. Investors need to forecast money and output at time 2. We assume the following autoregressive structure (applying only at time 2):

$$(3) \quad m_2 - \bar{m} = \rho_m (m_1 - \bar{m}) + \varepsilon_2^m \\ y_2 - \bar{y} = \rho_y (y_1 - \bar{y}) + \varepsilon_2^y$$

with  $0 < \rho_j < 1$  and  $\varepsilon_2^j \sim \mathcal{N}(0, \sigma_j^2)$ ,  $j = m, y$ . The persistence coefficients  $\rho_m$  and  $\rho_y$  are key elements of the model. The larger is  $\rho_m$ , the

bigger is the impact of the current money supply on the exchange rate, and similarly for output. However, investors do not know the persistence coefficients and only receive private signals about them:

$$\begin{aligned} v_m^i &= \rho_m + \varepsilon_m^i & \varepsilon_m^i &\sim \mathcal{N}(0, \sigma_v^2) \\ v_y^i &= \rho_y + \varepsilon_y^i & \varepsilon_y^i &\sim \mathcal{N}(0, \sigma_v^2). \end{aligned}$$

We assume that errors in the private signals average to zero across all investors. We can plug the expectation derived from (3) into (2) to get

$$(4) \quad s_1 = q_1 + \tilde{\alpha}(m_1 - \bar{m})\bar{E}_1(\rho_m) - \tilde{\alpha}(y_1 - \bar{y})\bar{E}_1(\rho_y) - \frac{\alpha}{1 + \alpha} \gamma \sigma_1^2 b_1$$

where  $\tilde{\alpha} \equiv \alpha/(1 + \alpha)^2$  and

$$q_1 \equiv \frac{1}{1 + \alpha} (m_1 - y_1) + \tilde{\alpha}(\bar{m} - \bar{y}).$$

Equation (4) shows that the exchange rate depends in a straightforward manner on the observable variables  $m_1$  and  $y_1$  as well as on the unobservable  $b_1$ . Moreover, it depends on the average expectations of the persistence coefficients,  $\bar{E}_1(\rho_m)$  and  $\bar{E}_1(\rho_y)$ . With heterogeneous information, individual investors do not know these average expectations and cannot disentangle shocks to  $b_1$  from shocks to  $\bar{E}_1(\rho_m)$  and  $\bar{E}_1(\rho_y)$ . This difficulty in the inference process can lead to rational confusion, which in turn can lead to attributing the wrong weight to fundamental variables.

## II. Finding a Scapegoat

The equilibrium exchange rate can be solved with a simple signal-extraction procedure. Based on (4), we first conjecture that the exchange rate takes the form

$$(5) \quad s_1 = q_1 + \tilde{\alpha}\rho_m(m_1 - \bar{m}) - \tilde{\alpha}\rho_y(y_1 - \bar{y}) - \lambda b_1$$

for some positive  $\lambda$ . The exchange rate depends linearly on the unknown persistence coefficients

$\rho_m$  and  $\rho_y$ , and it therefore provides a public signal of these parameters. It is therefore optimal for individual investors to use both their private signals and the exchange rate as bases for estimating  $\rho_m$  and  $\rho_y$ . We now describe the inference process and the solution for the exchange rate in the case where  $y_1 = \bar{y}$ , so that investors are only interested in estimating  $\rho_m$ . The more general case can be found in a Technical Appendix (available from the authors upon request).

From (5), investors can use an adjusted exchange-rate signal that is normally distributed:

$$\frac{s_1 - q_1}{\tilde{\alpha}(m_1 - \bar{m})}.$$

Since the private signal is also normal, the optimal inference of  $\rho_m$  is a linear combination of the two signals. Aggregating the expectations of  $\rho_m$  over individuals, we get the following:<sup>2</sup>

$$(6) \quad \bar{E}(\rho_m) = \delta_v \rho_m + (1 - \delta_v) \frac{s_1 - q_1}{\tilde{\alpha}(m_1 - \bar{m})}$$

where  $0 < \delta_v < 1$  depends on the (endogenous) relative precision of private and public signals,

$$\delta_v = \frac{1/\sigma_v^2}{(1/\sigma_v^2) + [\tilde{\alpha}^2(m_1 - \bar{m})^2/\lambda^2\sigma_b^2]}.$$

A crucial element in the analysis is that the expectation of  $\rho_m$  depends on the value of the exchange rate. Using (5), one can substitute  $s_1$  to obtain

$$(7) \quad \bar{E}(\rho_m) = \rho_m - k(m_1 - \bar{m})b_1$$

where

$$k = \frac{(1 - \delta_v)\lambda}{\tilde{\alpha}(m_1 - \bar{m})^2} > 0.$$

It is easily verified that the conjectured equation

<sup>2</sup> Here we use the fact that summing over the signals  $v_m^i$  gives  $\rho_m$ .

(5) is confirmed if one substitutes (7) into (4), with

$$\lambda = \frac{\alpha}{1 + \alpha} \gamma \sigma_1^2 / \delta_v.$$

Equation (7) illustrates how an observed macroeconomic variable can become a scapegoat. Investors know that the equilibrium exchange rate takes the form (5). While they know the functional form, they do not know the persistence  $\rho_m$  and liquidity trades  $b_1$ . When an investor sees that the exchange rate is higher than expected based on the private signal of persistence, there can be only two explanations: either unobserved liquidity sales have reduced  $b_1$  or the persistence coefficient differs from the private signal. In the case where money supply is large, so that  $m_1 - \bar{m}$  is large, a high exchange rate can then be explained by a large persistence coefficient. The reason is that more persistence leads to a bigger expected second-period money supply when the money supply is above its mean in period 1.

Now assume that the high level of the exchange rate is actually caused by liquidity trades. It then becomes rational to make money the scapegoat when the money supply is unusually large. Even if investors do not believe that the high money supply will be so persistent based on their private information, they will each believe that others have private signals indicating that money supply is persistent. The scapegoat is captured by (7), which shows that the expected persistence rises when  $b_1 < 0$  and  $m_1 - \bar{m} > 0$ .

The rational confusion that leads to making money the scapegoat is market-wide. Based on private information alone the average expectation of  $\rho_m$  is equal to  $\rho_m$ . However, when  $b_1 < 0$  and  $m_1 - \bar{m} > 0$  investors systematically, and incorrectly, believe that  $\rho_m$  is larger than it actually is. They all believe that others must have information indicating that  $\rho_m$  is very large, even if no investor actually has such information.

Output can similarly become a scapegoat. The Technical Appendix (available from the authors upon request) shows that if  $y_1 \neq \bar{y}$  we have  $\bar{E}(\rho_y) = \rho_y + \bar{k}(y_1 - \bar{y})b_1$ . If the exchange rate is high due to liquidity trades and output is

below its mean ( $y_1 - \bar{y} < 0$ ), investors revise upward their expectation of  $\rho_y$ , and output becomes a scapegoat. The larger the deviations from the mean, the more likely it is that one of the macro variables will be blamed.

### III. The Scapegoat Effect on Exchange Rates

When a macroeconomic variable becomes a scapegoat, it has a much larger impact on the exchange rate than otherwise due to confusion with liquidity trade. In this regard an important role is played by the parameter

$$\lambda = \frac{\alpha}{1 + \alpha} \gamma \sigma_1^2 / \delta_v$$

that multiplies liquidity trade in the equilibrium exchange rate. This coefficient is larger than in the risk-premium term in (2) or (4) because  $\delta_v < 1$ . This implies that the impact of  $b_1$  is amplified with heterogeneous information.<sup>3</sup> More important in our context, it is easy to check that  $\lambda$  depends positively on  $(m_1 - \bar{m})^2$ . In other words,  $\partial\lambda/\partial(m_1 - \bar{m})^2 > 0$ . If the deviation of money from its mean is large, there is more rational confusion that leads to a bigger amplification of the impact of liquidity trade on the exchange rate.

The impact of current money supply on the exchange rate is found by differentiating (5):

$$(8) \quad \frac{\partial s_1}{\partial m_1} = \frac{1}{1 + \alpha} + \bar{\alpha}\rho_m - \nu(m_1 - \bar{m})b_1$$

where  $\nu = 2\partial\lambda/\partial(m_1 - \bar{m})^2 > 0$ . The impact of  $m_1$  therefore depends on  $b_1$ . For example, if  $m_1 > \bar{m}$ , a negative  $b_1$  increases the impact of  $m_1$ .

With no liquidity shocks, the derivative of the exchange rate with respect to money would be only  $1/(1 + \alpha) + \bar{\alpha}\rho_m$ , the same as it would be under perfect foresight. A similar impact obtains if money supply is close to its normal level  $\bar{m}$ . It is the interplay between the unobserved liquidity trades and the unusual size of the money supply that delivers the scapegoat effect

<sup>3</sup> This amplification of shocks is similar to the one discussed in detail in Bacchetta and van Wincoop (2003).

and its increased weight in the equilibrium exchange rate.

The derivative in (8) is not known to market participants since  $\rho_m$  is unknown. One can compute the average expectation of (8), by using (5)–(7) (see the Technical Appendix [available from the authors upon request] for details). This gives

$$(9) \quad \bar{E} \frac{\partial s_1}{\partial m_1} = \frac{1}{1 + \alpha} + \bar{\alpha} \rho_m - (\nu \delta_v + \bar{\alpha} k)(m_1 - \bar{m}) b_1.$$

Clearly, the same reasoning applies to the perceived impact of  $m_1$  on  $s_1$  as to the actual impact. The reason is that  $\rho_m$  is expected to be larger than it actually is when  $m_1$  is large and  $b_1$  is negative.

We conclude this section with two remarks. First, it is worth noting that, when the impact of money on the exchange rate is large as a result of the scapegoat effect, the impact of liquidity trade is also magnified. The rational confusion raises the impact of both money shocks and liquidity trades. Second, we have focused on the case where macro variables have increased weight. The opposite can also occur, for example, when the exchange rate is high due to a negative  $b_1$  and the money supply is below normal. On average, macro variables have the correct weight because, on average,  $b_1 = 0$ . However, this average weight may be small, so that observed macro variables do not consistently contribute much to observed exchange-rate volatility.

#### IV. Conclusion

In this short paper we have developed a simple model to illuminate some implications of information dispersion for the importance of macroeconomic variables in the equilibrium exchange rate. We have shown that, when unobserved speculative trades are responsible for an exchange-rate depreciation, an unusually high money supply can easily be made the scapegoat. We introduced only two macro fundamentals, money supply and output, but in reality one can

have a large number of such macro indicators. When a macro fundamental becomes a scapegoat, its impact on the exchange rate can be much larger than otherwise.

While the model we adopted here is close to static in nature in order to keep things simple, future work should naturally focus on a more dynamic model with information heterogeneity of the sort described here. This can account for phenomena such as parameter instability and changing weight given by investors to different macro indicators.

#### REFERENCES

- Allen, Franklin; Morris, Stephen and Shin, Hyun Song.** “Beauty Contests and Iterated Expectations in Asset Markets.” Mimeo, Yale University, 2003.
- Bacchetta, Philippe and van Wincoop, Eric.** “Can Information Heterogeneity Explain the Exchange Rate Determination Puzzle?” National Bureau of Economic Research (Cambridge, MA) Working Paper No. 9498, February 2003.
- \_\_\_\_\_. “Higher Order Expectations in Asset Pricing.” Mimeo, University of Virginia, 2004.
- Cheung, Yin-Wong and Chinn, Menzie David.** “Currency Traders and Exchange Rate Dynamics: A Survey of the US Market.” *Journal of International Money and Finance*, August 2001, 20(4), pp. 439–71.
- Cheung, Yin-Wong; Chinn, Menzie David and Pascual, Antonio G.** “Empirical Exchange Rate Models of the Nineties: Are they Fit to Survive?” National Bureau of Economic Research (Cambridge, MA) Working Paper No. 9393, December 2002.
- Jeanne, Olivier and Rose, Andrew K.** “Noise Trading and Exchange Rate Regimes.” *Quarterly Journal of Economics*, May 2002, 117(2), pp. 537–69.
- Keynes, John Maynard.** *The general theory of employment, interest and money*. London: MacMillan, 1936.
- Meese, Richard A. and Rogoff, Kenneth.** “Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?” *Journal of International Economics*, February 1983, 14(1–2), pp. 345–73.