Order Flow and Exchange Rate Dynamics in Brazil

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Abstract

The paper presents results of empirical tests with hybrid nominal exchange rate models for the Brazilian foreign exchange market, using macroeconomic and market microstructure variables. The basic model was originally proposed and tested in the German (DM/US$) and the Japanese (¥/US$) foreign exchange markets by Evans and Lyons (2002). We applied the model to the Brazilian foreign exchange market (R$/US$) and obtained significant and correctly signaled coefficients, but the regressions showed low R^2s, suggesting the omission of relevant variable(s). The inclusion of an additional variable representing a country-risk premium results significant and increases R^2. Estimation by GARCH further improves previous results obtained by OLS. The upshot indicates that the route proposed by Evans and Lyons is a promising explanation for the R$/US$ exchange rate, but it seems the model specification needs further improvement.

Key words: exchange rate, market microstructure, country risk, order flow, Brazil

1. Introduction

Economic theories about exchange rates have been in crisis since the 80´s, when some economists pointed out that existing macroeconomic models developed to explain exchange-rate determination were empirical failures, with explanatory power close to zero (Meese and Rogoff, 1983; Meese, 1990). Those diagnostics were never convincingly rejected or explained and it keeps exerting a pessimistic effect on the empirical modeling of exchange rates in particular, and on international finance in general (Frankel and Rose, 1994).

It seems that the solution for such problems is not trivial. Some researchers concluded that the most critical determinants of exchange-rate volatility are not macroeconomic in nature (Flood and Rose, 1995). However, if the exchange rate is not determined by macroeconomic variables such as interest rates, money supply and trade balances, what determines it? Two alternatives have attracted attention in the academic area. The first one assumes that the determinants of exchange rates include extraneous variables. Such variables are typically modeled as rational speculative bubbles (Blanchard, 1979; Dornbusch, 1982; Meese, 1986; Evans, 1986). However, various authors have argued that the speculative bubble is not convincing (Flood and Hodrick, 1990; Evans and Lyons, 2002).

The second alternative was to incorporate the irrational behavior of economic agents. For example, exchange rates would be partially determined by avoidable errors in the formation of expectations (Dominguez,1986; Frankel and Froot, 1987; Hau, 1998). However, this route has also not very well received in the academic area (Evans and Lyons, 1999).

Following a third path, Evans and Lyons (2002) introduce a new proposal, amplifying the traditional macroeconomic analysis by inserting a variable from market microstructure finance. Market microstructure is defined as the "processes and the outcomes of exchanging assets under explicit negotiation rules" (O'Hara, 1995). This way, Evans and Lyons (2002) created a new class of models, based on market microstructure finance, which include variables that the macroeconomic models omit. The most important of these variables is the order flow. This is defined as the net balance of orders initiated by buyers and sellers in the foreign exchange market, being, thus, a measure of the net pressure of demand for a foreign currency. Order flow

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is a strong price determinant in such models since it transmits information that is consolidated by the foreign exchange markets. This information include all that is related to the realization of demands under uncertainty conditions (diverging interpretation of news, demand chocks for hedging, demand chocks for liquidity, etc).

The theoretical foundations for the utilization of market microstructure in the determination of exchange rates proposed by Evans and Lyons (2002) are discussed in detail in Lyons (2001). Evans and Lyons' (2002) hybrid model shows how the order flow affects price (exchange rate) determination by consolidating information. The authors report that their model explains more than 60% of the daily changes in the log of the exchange rate between the Deustche Mark and the US dollar (DM/US$) and more than 40% of the daily variations of the log of the exchange rate between the Yen and the US$ dollar (¥/US$). They also claim that their analysis bridges the gap between previous work on market microstructure, which utilize data transaction by transaction, and the macroeconomic studies utilizing monthly data.

The main purpose of this paper is to test empirically the Evans and Lyons' (2002) model in the Brazilian foreign exchange market context. This means to test that model for the exchange rate between the Brazilian currency (Real) and the US dollar (R$/US$). A secondary objective is to test alternative specifications that might add explanatory power to the original model. More specifically, we tested a model that includes a variable from the international finance field: country risk.

A foreign exchange market is the abstract environment were exchange rate transactions are carried out amongst authorized agents (banks, dealers, tourism agencies, hotels), and between these and their clients. In Brazil, the foreign exchange market is divided into two segments - the "free market" and the "floating market" - both regulated by the Brazilian Central Bank. The exchange rate reported by the Brazilian Central Bank is the average rate considering these two markets. Since January 15, 1999, the Brazilian foreign exchange market, which had the exchange rate fixed by the Brazilian Central Bank (currency peg), begun to operate in a floating exchange-rate regime, after a speculative attack against the Real (Eicheingreen and Rose, 2001; Perry and Lederman, 1999). Detailed information on the Brazilian foreign exchange market can be found at the Brazilian Central Bank's internet page (Banco Central do Brasil, 2004).

The paper is organized as follows: Section 2 brings a summary of extant theories and models striving to explain exchange-rate determination; Section 3 presents previous empirical findings; Section 4 describes the methods used; Section 5 gives the empirical results and comparisons with previous work; and Section 6 provides the conclusion.

2. Theoretical Background

Various types of models express the main theories on the determination of exchange rates: the flexible price model, the sticky price model, the portfolio balance model, and the monetary interest-rate differential model. There are a number of surveys on the extant theories and models, which make it unnecessary to discuss these in detail here (Eaton and Turnovsky, 1983; Macdonald and Taylor, 1992; Frankel and Rose, 1994; Isard, 1995; Taylor, 1995).

The flexible-price monetary model stands on the hypotheses of purchasing power parity (PPP) and of the existence of stable demands for currencies in the domestic and foreign economies. However, the naive flexible-price monetary approach does not fit well to the observed data, since it assumes the PPP in its continuous form. Under these conditions, the real exchange rate cannot vary, by definition. An attempt to rehabilitate the monetary model led to the development of a second generation of monetary models (Dornbusch, 1976). This is the sticky-price model, which accepts deviations in both the nominal and the real exchange rates with respect to the PPP equilibrium levels, provided that the volatile variables in the system –

interest rates and exchange rates – compensate for the low mobility of the other variables, especially the price of goods.

On a different stream, the portfolio shifts model has in common with flexible-price and sticky-price models, the fact that the exchange rate level is determined, at least in the short run, by supply and demand in the financial assets market. However, the exchange rate is a primary determinant of the balance of payments current account. A surplus in the current account represents an increase in the domestic stock of foreign assets, which in turn affects the wealth level, which in turn affects the level of the demand for assets, which feeds back into the exchange rate. Therefore, the portfolio equilibrium model is essentially a dynamic model of exchange-rate adjustment.

The monetary models of interest-rate differentials are based on the covered interest parity (CIP) or on the uncovered interest parity (UIP) hypotheses. The CIP hypothesis sustains that the difference between the future exchange rate and the current exchange rate is equal to the difference between the internal interest rate and the external interest rate. On the other hand, the UIP hypothesis proposes that the expected future exchange rate covers this difference.

The general conclusion stemming from the extant literature is that the CIP holds as a valid assumption for the exchange rate short-term movements, but the same is not true for the UIP. This conclusion is connected to the so-called "forward premium puzzle", referring to the fact that the empirical studies show that the future exchange rate does not reflect correctly the expected future exchange rate (Lewis, 1995; Bansal and Dahquist, 2000; Flood and Rose, 2002). It is not clear yet the extent to which the empirical failure of the UIP is caused by econometric problems.

As the result of attempts to solve the empirical difficulties of the traditional models, Evans and Lyons propose a model based on portfolio shifts. The model can be expressed by:

$$\Delta P_t = \Delta m_t + \lambda \Delta x_t , \tag{1}$$

where ΔP is the exchange rate change, Δm are innovations concerning macroeconomic information (e.g., interest rate changes), λ is a positive constant, Δx is the order flow, and the subscript t refers to time. The variable x is the accumulated order flow.

Two modifications must be made in equation (1) with estimation purposes. Firstly, the public information increment Δm is defined as the change in the interest rate differential (foreign minus internal domestic rate), i.e. $\Delta m = \Delta(i - i^*)$, plus a white-noise random term, where i is the nominal interest rate associated to the foreign currency and i^* is the nominal interest rate associated to the local currency. Although Δm could also be a function of other macroeconomic fundamentals, the interest rate differential is privileged for it is the main engine of exchange rate variations in macroeconomic models, and also because it is a variable with available daily data. Secondly, the dependent variable is replaced by the change in the log of the spot exchange rate, Δp. With this replacement, the specification becomes comparable to the standard macroeconomic models, taking the form:

$$\Delta p_t = \alpha \cdot \Delta(i_t - i_t^*) + \beta \cdot \Delta x_t + e_t \tag{2}$$

where Δp is the change in the log of the spot exchange rate, $\Delta(i - i^*)$ is the change in the interest rate differential, Δx is the order flow, α and β are regression parameters, and $e \sim N(0, \sigma^2)$ is the error term.

The coefficient α is expected to be positive, based on the sticky-price monetary model, since an increase in the foreign interest rate i requires an immediate appreciation of the foreign currency, i.e. an increase in the exchange rate, to compensate for the its depreciation caused by the uncovered interest parity. The coefficient β is also expected to have a positive signal, indicating that net purchases of the foreign currency (positive Δx_t) result in a higher price of the foreign currency in terms of the local currency.

Under the null hypothesis of the Evans and Lyons' (2002) model, causality runs strictly from the order flow to price (exchange rate), i.e., the order flow is exogenous. Hence, under the null, the estimation of the model by OLS is not subject to simultaneity bias (Lyons, 2001).

An important aspect to be pointed out is that, in general, the theoretical models, including Evans e Lyons' (2002), con sider that investors are risk neutral, so that risk premia are rarely included in these models. However, the poor performance of some exchange-rate models could be attributed to the omission of relevant variables such as risk factors (Macdonald and Taylor, 1992).

3. Previous Empirical Evidence

There is a large number of empirical studies on nominal exchange rates (Cumby, 1988; Thornton, 1989; Christensen, 2000; Fullerton and Calderón, 2001, Karamé, Patureau, and Sopraseith, 2002; Chinn and Meredith, 2002; Cheung, Chinn and Pascual, 2003; Engel and West, 2003). One point in common in these studies is that the models tested perform well during some time periods such as the interwar period (1919-1939) and, to some extent, during the first international experience phase with floating rates (1973-1978), but they provide poor explanations for the behavior of the main exchange rates during the more recent phase of floating exchange-rate regimes.

The Evans and Lyons' (2002) hybrid model, takes into account elements from the market microstructure finance and present more significant results, both in terms of the significance and signals of coefficients, as well as R^2. The main empirical results obtained by Evans and Lyons (2002) for the DM/US$ and ¥/US$ rates are presented in Section 5, together with our results, for the sake of comparison. The data utilized by Evans and Lyons (2002) refer to DM/US$ and ¥/US$ transactions captured in the Reuters Dealing 2000-1 system between 5/1/96 and 8/31/96. It is important to stress that, in their study, order flow is based on the number of foreign exchange transactions and their signal, and not on the money volume of transactions. A purchase order is accounted as +1, whereas a selling order is accounted as (−1). Their variables were measured as follows: the spot rate change (DM/US$ or ¥/US$), Δp_t, is the change in the log of the purchase exchange rate; the daily order flow, Δx_t, is the difference between the number of transactions initiated by buyers and the number of transactions initiated by sellers (in thousands). The change in the interest rate differential, $\Delta(i - i^*)$, was calculated using the US daily (overnight) interest rate and the equivalent rates in Germany and Japan, all expressed on an annual basis. The source of these data is DataStream.

4. Methods

In the study we attempted to verify if the results obtained by Evans and Lyons (2002) for the DM/US$ and ¥/US$ exchange rates apply to the Brazilian foreign exchange market, i.e. to the R$/US$ exchange rate. Hence, the first model tested is the one presented in Section 2 as equation (2), with the following adaptations. The dependent variable is the daily change in the natural log of the closing purchase quote on the R$/US$ exchange rate The interest-rate differential is the difference between the US daily (overnight) interest rate and the daily interest rate in Brazil, both expressed on an annual basis. The model estimation was carried out by OLS, such as in Evans and Lyons. As mentioned in Section 2, under the model's null hypothesis, order flow is exogenous, which allows for OLS estimation free from simultaneity bias.

A major difference between the present study and that of Evans and Lyons (2002) is in the order flow, Δx_t, which here is the balance of foreign currency exchange transactions in monetary terms, whereas in that study, order flow is based on the quantity of foreign exchange transactions. There are two reasons why we adopted the transactions monetary flow instead of the number of transactions. Firstly, it seems more logical that the transaction money volumes are more relevant as a measure of the demand and supply pressures for foreign currency than the number of orders, although Evans and Lyons do not recognize this. Secondly, data on daily monetary sales and purchases of US dollar are available in Brazil, whereas those on the number of transactions are not.

At this point, it is necessary to return to the risk issue. As already mentioned, the traditional exchange rate models adopt, in general, the hypothesis that economic agents are risk neutral, so that risk related variables are not included in those models. However, the derivation of the UIP from the CIP shows that, if investors are risk averse, it is necessary to take into account the premium that compensates investors for the risk of holding assets in foreign currency (Meredith and Chinn, 1998).

Given capital mobility, the local interest rates must be equal to the foreign interest rate plus two-risk premia. The first risk premium compensates the investor for the depreciation of the Real, and it is measured by the future dollar market. The second risk compensates the investor for the risk of government debt moratorium, capital controls, and other movements that may affect the return in US dollar of the investment. The first risk premium is denominated exchange-rate risk; the second, country risk. By decomposing the Brazilian interest rate in such a manner, it can be seen that the two risks, exchange-rate risk and country risk, move together upwards and downwards. The interest-rate risk translates into the fact that the two risks go up together in foreign credit rationing situations, causing stagnation and exchange rate depreciation. Developed economies practice counter-cyclical monetary policies, so that interest rates fall in recession periods, mitigating the loss of product and employment. In Brazil, the monetary authorities cannot adopt such measures, as both risks go up during crises (Garcia, 2002).

Consequently, we decided to amplify Evans and Lyons' (2002) model, incorporating to it a variable associated to country risk. This model is expressed by

$$\Delta p_t = \Delta(i_t^* - i_t) + \Delta x_t + \Delta r_t + e_t \tag{3}$$

where Δr_t is the daily change in the country risk premium, proxied by the spread of the C-Bond, the main security tied to the Brazilian foreign debt. It was assumed that since country risk is associated to the market's perception regarding the country's political and economic situation, it is an exogenous variable.

The sample utilized includes daily data (workdays) for the period from 01/01/2001 to 05/30/2002. Data on the R$/US$ exchange rate (daily closing purchase quote), on the daily foreign currency transactions in US dollars, and on the daily interest rate in Brazil are available at the Brazilian Central Bank's Internet site (Banco Central do Brazil, 2004). The daily money volume of transactions includes both the free market and the floating market as well. Data on the daily US interest rate are available in the Internet's Federal Reserve System site (Federal Reserve System, 2004).

5. Results

The results of four different model specifications tested in this study are reported in the four first lines of Table 1 and the equivalent results in Evans and Lyons (2002), in the subsequent lines.

The coefficient estimates are presented together with their respective standard errors. The R^2 coefficients are also shown for each specification as well as the p-values for the Breusch-Godfrey Lagrande Multiplier test (Godfrey, 1988) for residual autocorrelation and for the LM

Engle test (Engle, 1982) for ARCH effects, for the sake of comparison with those obtained by Evans and Lyons (2002).

Specifications I, II, III, and IV, which refer to the current study, as well as specifications I and II from Evans and Lyons (2002), have shown evidence of heteroscedasticity (ARCH effects). Besides, our specification II showed signs of first and fifth order autocorrelation. The test for fifth order autocorrelation aims at capturing eventual one-week lagged effects. For this reason, the standard errors of specifications I, III e IV were computed, utilizing White's heteroscedasticity-consistent covariance matrix (White, 1980). The standard errors of specification II was computed utilizing the Newey-West covariance matrix, which is consistent with autocorrelation and heteroscedasticity (Newey and West, 1987).

Comparing our specification I with the corresponding Evans and Lyons's (2002) specification [E&L(I)], it can be seen that the coefficients of both studies are significant at 5% and have signals according to theory. However, the R^2 obtained in our study (0.06) is quite low and not comparable to those obtained by those authors (0.64 and 0.46).

Our specification IV, which includes the country risk premium, does not have a correspondence in Evans and Lyons (2002), since they did not test this variable. This specification is clearly superior to specification I and shows that the change in country risk premium is strongly significant. Although the R^2 associated to this specification is still low (0.16), it is quite superior to our other specifications. Specifications II and III have the purpose of showing that univariate tests considering individually either the interest rate differential or the order flow yield statistically inferior results and should be discarded.

Table 1: Results from current study compared with Evans and Lyons' (2002)

Specification	Exchange rate	Independent Variables			R^2	Autocor-relation	Heterosce-dasticity
		$\Delta(i - i^*)$	Δx	Δr			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I	R$/US$	0.70	9.77		0.06	0.12	0.02
		(0.29)	(2.87)			0.62	0.00
II	R$/US$		9.79		0.04	0.03	0.00
			(2.89)			0.75	0.00
III	R$/US$	0.70			0.02	0.07	0.00
		(0.30)				0.48	0.00
IV	R$/US$	0.52	7.58	0.13	0.16	0.95	0.00
		(0.28)	(2.82)	(0.02)		0.99	0.00
E & L (I)	DM/US$	0.51	2.14		0.64	0.77	0.07
		(0.26)	(0.29)			0.40	0.02
E & L (II)	DM/US$		2.15		0.63	0.73	0.05
			(0.29)			0.45	0.03
E & L (III)	DM/US$	0.62			0.01	0.78	0.92
		(0.77)				0.77	0.99
E & L (I)	¥/US$	2.47	2.86		0.46	0.06	0.92
		(0.92)	(0.36)			0.44	0.74
E & L (II)	¥/US$		2.61		0.40	0.19	0.60
			(0.36)			0.33	0.83
E & L (III)	¥/US$	0.57			0.00	0.85	0.13
		(1.20)				0.81	0.67

Figures between brackets are standard errors. Column 7 shows the p-values of the Breusch-Godfrey test for autocorrelation (1^{st} order on top and 5^{th} order below). Column 8 shows the p-values of the Engle ARCH test (1^{st} order on top and 5^{th} order below). In all specifications, the intercept was not significant.

It is important to stress that since the Engle test indicated the presence of ARCH effects, it would be appropriate to estimate the models using ARCH/GARCH regression methods instead of OLS, although Evans and Lyons (2002) have not done this. Hence, we decided to re-estimate the most significant specification (IV), using ARCH/GARCH methodology. The result was:

$$\Delta p_t = \underset{(2.43)}{0.001} + \underset{(2.86)}{0.403}\Delta(i_t - i_t^*) + \underset{(2.66)}{5.731}\Delta x_t + \underset{(9.89)}{0.132}\Delta r_t \tag{4}$$

$$\sigma_t^2 = 0.000002 + \underset{(1.36)}{0.199}\, \underset{(3.05)}{e_{t-1}^2} + \underset{(13.64)}{0.794}\sigma_{t-1}^2 \tag{5}$$

$$R^2 = 0.200; \quad DW = 1.901; \quad F = 10.633; \quad \text{P-value}(F) = 0.0000 \cdot$$

These results show that the mean equation (4), which explains the exchange rate behavior and the variance equation (5), which explains the exchange rate volatility, have statistically relevant coefficients and that the ARCH (e_{t-1}^2) and GARCH (σ_{t-1}^2) components are significant. The figures between brackets are the z statistics, which show that parameters are significant at 1%, except for the constant in the variance equation. The R^2 obtained is higher than that obtained by OLS (0.16).

It was also found that the results utilizing ΔP_t instead of Δp_t (change in the exchange rate instead of change in the logs) produce similar results, both in terms of R^2, and in terms of significance of coefficients, such as reported by Evans and Lyons (2002).

Finally, it is worthwhile to report the result of the additional statistical tests performed. The augmented Dickey-Fuller test (Dickey and Fuller, 1979) resulted in the rejection of the null hypothesis of existence of unit roots for all series, which means that all series are stationary within the period. The Bera-Jarque (Bera and Jarque, 1981) test resulted in the rejection of the null of normality of the residuals in all regressions, which however does not harm the robustness of the regressions, having in mind the Central Limit Theorem and the sufficiently large sample size.

6. Conclusion

This study confirms the relevance of order flow for the determination of the exchange rate such as demonstrated by Evans and Lyons (2002). It should be kept in mind though that in this study order flow is the daily balance of purchase and sale monetary transactions of US dollars in the Brazilian foreign exchange market, whereas in Evans and Lyons (2002), order flow is the daily balance of sale and purchase orders of US dollars in Germany and Japan, respectively.

The coefficient signals obtained in the regressions are correct vis-à-vis the relevant theory. The order flow coefficient has the right signal and it is significant. The positive signal indicates that net US dollar purchases result in a higher price of the dollar in terms of the Brazilian currency. The main macroeconomic fundament – the interest rate differential – has the correct signal and it is significant. The positive signal comes from the fixed-price monetary model, where a increase in the foreign interest rate (US dollar) requires an instant appreciation of this currency, i.e. an increase in the R$/US$ rate to compensate for the dollar depreciation caused by the uncovered interest parity.

Our results show that the Evans and Lyons' (2002) model, when applied to the Brazilian foreign exchange market present satisfactory results, regarding the significance and signals of the coefficients. However, the R^2 coefficients obtained are much lower than those reported by those authors are. There are a number of reasons to explain this. Firstly, our proxy for order flow might be incapable of fully capturing the effects of this variable on the dependent variable. Secondly, it might be that in the Brazilian market there are relevant variables, which are not included in those authors' specifications. In fact, the inc lusion in our model of a variable representing a country-risk premium, the daily change in the C-Bond spread, has shown that this variable is even more significant than the others, besides producing a higher R^2, although still low as compared to those reported by Evans and Lyons (2002). The estimation of this model by GARCH is superior to OLS estimation and improved the results obtained by the latter method.

Summing up, the results suggest that the Evans and Lyons' (2002) model, when tested in the Brazilian foreign exchange market, produces results in the right direction, mainly when the estimation allows for autoregressive conditional heteroscedasticity in the residuals, although the goodness of fit (R^2) obtained is still low. One possible explanation for this is that the foreign exchange market in an emerging country like Brazil might have idiosyncrasies that are not present in developed country foreignn exchange markets, such as those tested by Evans and Lyons (Germany and Japan). This might demand different model specifications with additional variables, such as a country-risk premium, tested in this study, and possibly other variables, yet to be tested.

7. References

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