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# Order Flow in the South: Anatomy of the Brazilian FX Market\*

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## Abstract

This paper analyses one of the main pillars of Brazil's newly found economic resilience: a maturing FX market providing support to its managed floating exchange rate regime. I develop a microstructure model suitable to describe the Brazilian FX market, an emerging economy frequently subjected to sudden stops in capital flows. The model introduces two major changes relative to previous microstructure models. First, dealers may decide to hold overnight positions in the FX market if they find it profitable to do so. Second, customers' demand for foreign exchange is a function of macroeconomic fundamentals, including contemporaneous feedback from exchange rate movements. The main predictions of the model are supported by a unique data set, covering all transactions between dealers and customers from the official Brazilian FX market from July 1, 1999 to June 30, 2003 (a time period in which Brazil suffered two severe external liquidity shocks).

Keywords: Microstructure, Exchange Rates, Dealers, Liquidity, Central Bank Intervention.

JEL Codes: F31, F41, G15.

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# 1 Introduction

Generations have come to know Brazil as the country of the future. However, its perpetual struggle with economic disorders – monetary instability, fiscal imbalances, and Balance of Payments crisis, to name a few – rendered the impression that such a future would never arrive. Some felt Brazil was bound to be the country of the future forever. Now that skepticism looks misplaced, as Brazil’s fast recovery from the global financial crisis of 2008 and solid growth rates in its aftermath have changed the mind of many pessimists. The view that Brazil is finally unleashing its full potential is becoming widespread. According to forecasts from the International Monetary Fund, published in the September 2011 edition of the World Economic Outlook, Brazil is likely to become the world’s fifth-largest economy in 2016, overtaking Italy, the United Kingdom, and France.

One of the main pillars of Brazil’s newly found economic resilience relies on its managed floating exchange rate regime. Particularly, this study will support the view that the Brazilian economy’s future ability to absorb and recover from upcoming liquidity shocks hinges upon the well-fuctioning of its maturing FX market, which provides essential support to the managed floating system. When Brazil formally adopted an official inflation target as its monetary policy strategy in July 1999, the unpleasant task of absorbing external shocks was assumed by the exchange rate. The global financial crisis of 2008 is a good example of a severe liquidity shortage imposed on the Brazilian FX market. As global fundamentals worsened, end-user customers’ pressure to buy foreign currency rapidly amounted. On one hand, rising risk aversion coupled with foreign investors’ need to offset losses in their head offices led to massive outflows from financial customers. On the other hand, as demand for Brazilian commodity-based exports dwindled, foreign exchange liquidity usually provided by commercial flows slumped. Consequently, the Brazilian *real* depreciated by more than 60% between August 1 and December 5, 2008. After the initial depreciation, the exchange rate remained highly volatile for a couple of additional months but, as figure 1 reveals, by the end of the first quarter of 2009 it was already converging back towards pre-crisis levels.

[Insert Figure 1 about here]

In this paper, I analyze some specific characteristics of the Brazilian FX market, with special attention to the interaction between customers, dealers, and the central bank. First, it is important to note that in terms of trading volume the Brazilian FX market is smaller than the FX markets of the main currency pairs. Therefore, it is unreasonable to expect customers' imbalances to be resolved within a trading day. This implies that part of end-users' excess demand for foreign currency in a trading day has to be supplied by domestic dealers. In other words, domestic dealers from the Brazilian FX market do not simply behave as intermediaries, matching buyers and sellers while the market is open, and ending the trading day with zero balances. Dealers do hold overnight foreign exchange positions and, naturally, require an additional premium to bear the overnight risk (which takes the form of a price change). Second, although domestic dealers provide short-term liquidity to the Brazilian FX market, they are not a long-term solution. Changes in the price of foreign currency will keep amounting, reflecting changes in dealers' overnight positions, until the non-dealer sector is finally induced to provide the required liquidity. For instance, "stabilizing speculators" would decrease their demand for foreign currency if they believed that its price was too expensive. Third, the rebalancing of the FX market after a liquidity shock rarely occurs in an orderly fashion. Consequently, the Central Bank of Brazil (BCB) frequently steps in, intervening in the Brazilian FX market in such a way that, ideally, only the exchange rate short-run volatility is affected, but not its long-run trend.

Motivated by the observations above, this paper develops a microstructure model more suitable to describe the Brazilian FX market. The model introduces two major changes relative to previous microstructure models:

a. Dealers' foreign holdings at the end of each trading day are not exogenously set (to zero, for example): they may decide to hold overnight positions in the FX market if they find it profitable to do so;

b. Customer flow is not simply the realization of a random variable: the model moves towards a general equilibrium approach in which customers' demand for foreign exchange is influenced by macroeconomic fundamentals, including contemporaneous effects from exchange

rate movements (which, for example, capture feedback trading arising from “stabilizing speculators” or central bank interventions).

After solving the model, I find empirical evidence supporting its main predictions using a unique data set, covering all transactions between dealers and customers from the official Brazilian FX market from July 1, 1999 to June 30, 2003. Interestingly, the global financial crisis of 2008 was not the first major test the floating exchange rate regime had to endure. As a matter of fact, the resilience displayed by the Brazilian FX market in this recent crisis may be attributed, in great part, to learning experiences acquired from previous sudden stops in capital flows that the floating exchange rate regime had to face during its early years. Figure 2 presents the evolution of the exchange rate during the sample period studied by this paper. In 2001, the US dot-com bubble burst, the September 11 attacks, the financial contagion from the Argentinean crisis, and the Brazilian energy shortage forced the Brazilian *real* to depreciate by 40% from February 19 to September 21. Then, the Brazilian electoral uncertainty in 2002 imposed another severe liquidity shortage, which resulted in a depreciation of the Brazilian *real* of more than 70% between April 11 and October 10.

**[Insert Figure 2 about here]**

Employing a Structural VAR approach, which explores information regarding the type of customer who is trading against the dealer, I find empirical evidence that dealers from the Brazilian FX market do charge a premium to provide overnight liquidity. Specifically, in order to meet a US\$ 100 million customer order flow, dealers increase the price of foreign currency by approximately 0.35%. Moreover, I also find evidence of customer feedback trading: a 1% depreciation of the Brazilian *real* decreases financial flows by US\$ 68 million and commercial flows by US\$ 47 million. Finally, estimation output suggests that the BCB tends to sell foreign currency to dealers when the exchange rate is depreciating (leaning-against-the-wind) or when there is a positive excess demand for foreign exchange from financial customers (liquidity provision): a 1% depreciation of the Brazilian *real* is associated with a US\$ 23 million sale from the central bank to dealers; and a US\$ 100 million financial customer flow is associated with a US\$ 23 million sale from the central bank to dealers.

The behavior of nominal exchange rates has been a major challenge to explain since Meese and Rogoff (1983) documented that a naïve random walk would outperform a variety of macro models in terms of out-of-sample forecast.<sup>1</sup> In a seminal paper, Evans and Lyons (2002) moved away from models that relied solely on macroeconomic fundamentals and introduced order flow as a key determinant of exchange rates dynamics. Empirical evidence supporting microstructure models, both in-sample (see Evans and Lyons, 2002) and out-of-sample (see Evans and Lyons, 2005, and Rime et al, 2010), stimulated many subsequent studies reinforcing the importance of order flows (see Osler, 2008, and Sager and Taylor, 2008, for surveys). A couple of recent papers have explored the specific characteristics of emerging markets: see Duffuor et al. (2011), Disyatat and Galati (2007), Frommel et al (2010), and Onur (2008) for analysis of the Czech, Hungarian, Ghanaian, and Israeli FX markets, respectively. This paper also relates to Bjonnes et al (2005), Fan and Lyons (2003), and Froot and Ramadorai (2005) on their focus on end-user customer flows.

The rest of this paper is organized as follows. Section 2 develops the model. Section 3 presents the dataset and some of its characteristics. Section 4 estimates the two-way effects between exchange rates and customer flows. Section 5 concludes.

## 2 FX Market Model

### 2.1 Description

In this section, I describe the interaction between customers and dealers in the FX market of a small emerging economy. The trading model that I use has some key features from Lyons (1997): there are only two trading rounds, with customer-dealer transactions being limited to the first round; trading is simultaneous (i.e., all demand schedules have to be submitted at the same time); and trading with multiple partners is feasible. However, my model departs from Lyons (1997) and other exchange rate microstructure models such as Evans and Lyons (2002) in some ways. First, it is a competitive rational expectations equilibrium model: dealers can condition their orders on market clearing prices. Also, dealers receive an additional

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<sup>1</sup>More recently, Cheung et al (2005) reinforced this result by testing a wider set of exchange rate models.

signal prior to the second round, after the first round is concluded. This signal captures one characteristic of the inter-dealer trade in the FX market: the readjustment of dealers' desired foreign exchange holdings before markets close using all new information which was collected while markets were open.

The model also presents two important improvements relative to previous microstructure models. First, customer flow,  $X_t$ , is not simply the realization of a random variable. Instead, this type of flow is a function of the exchange rate and other macroeconomic fundamentals. Let  $s_t$  be the (log of the) amount of domestic currency necessary to purchase one unit of foreign currency in period  $t$  and let  $F_t$  be a vector of macroeconomic fundamentals which also affect customer flow, such as domestic and foreign interest rates or the country sovereign risk premium. Customer flow is, then, described by the following expression:

$$X_t = \kappa_0 + \kappa_1 s_t + \kappa_2 F_t \tag{1}$$

in which  $\kappa_1 < 0$  denotes that customers' demand for foreign currency decreases as its price increases.

The second important improvement is that dealers' foreign exchange holdings at the end of each trading day are not exogenously set (to zero, for example): dealers may optimally decide to hold overnight positions in the FX market, with the desired amount being determined by profit maximization. This implies that dealers play a dual role in the model: first as intermediaries, matching buyers and sellers within a trading day; and second as speculators, whose profits arise from the overnight payoff on their foreign exchange holdings (the sum of interest rate differential and overnight depreciation rate).

There is an overlapping generation of a continuum of identical dealers in the FX market. Each dealer within its generation is indexed by  $i \in [0, 1]$  and "lives" for two periods. Young dealers are responsible for supplying the excess demand of customers in a given period  $t$ . Let  $Q_t$  be the market-wide level of FX inventory held by dealers in period  $t$ . Since a positive

customer flow means that there is a positive excess demand for FX, we can write:

$$Q_t = Q_{t-1} - X_t \quad (2)$$

In each period  $t$ , trading occurs in two rounds. In the first round, each young dealer  $i$  trades with old dealers and with its customers at the first round equilibrium price  $s_{t,1}$ . In the second and final trading round, each dealer  $i$  readjusts its foreign exchange inventory by trading with other dealers. In the first round of the following trading day,  $t + 1$ , young dealer of generation  $t$  sells its positions, collects its profits, and exits the FX market. Let  $Q_{t,1}^i$  and  $Q_{t,2}^i$  be the foreign exchange holdings of dealer  $i$  after the first and the second trading rounds respectively. The dealer's profit function can be written as:

$$\Pi_t^i = Q_{t,1}^i (s_{t,2} - s_{t,1}) + Q_{t,2}^i (s_{t+1,1} + \bar{V} - s_{t,2}) \quad (3)$$

The first part of the profit function of dealer  $i$  from generation  $t$  is given by its first round holdings (the amount purchased from old dealers and from its customers) multiplied by the change in the equilibrium exchange rate between the first and the second trading rounds,  $s_{t,2} - s_{t,1}$ . The second part is the payoff that it receives from its overnight foreign exchange holdings. This payoff is composed by the change in the exchange rate equilibrium price between the second round of period  $t$  and the first round of period  $t + 1$ ,  $s_{t+1,1} - s_{t,2}$ , plus the constant overnight dividend  $\bar{V}$  paid by the FX from period  $t$  to  $t + 1$ . To simplify the calculations, we will assume from now on that  $\bar{V} = 0$ . All dealers maximize identical negative exponential utility defined over its profits, with constant absolute coefficient of risk aversion  $\theta$ .

The market clearing condition imposes that the total amount of foreign exchange held by young dealers at the end of the first round equals the total amount of foreign exchange sold by old dealers exiting the market, subtracted by the total demand from customers:

$$\int_0^1 Q_{t,1}^i di = Q_{t-1} - X_t \quad (4)$$

Since dealers only trade with other dealers in the second and final round, the total amount of



foreign exchange held overnight by dealers has to equal the total amount of foreign exchange at the end of the first round:

$$\int_0^1 Q_{t,2}^i di = Q_t \quad (5)$$

Finally, the information structure is as follows. The realization of macroeconomic fundamentals  $F_t \sim N(\bar{F}, \sigma_F^2)$  is known before the market opens. Customers perfectly observe  $F_t$  and decide how much foreign currency they need to exchange in the first round. After the first and before the second trading rounds, each dealer receives new information, in the form of a common signal. The signal,  $F_t^c = F_{t+1} + \varepsilon_t^i$ , with  $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$ , is correlated to the following period's macroeconomic fundamentals and will affect the following period's customer flow.

## 2.2 Solution

Let  $E_{t,j}(\cdot)$  and  $Var_{t,j}(\cdot)$  be the expectation and the variance of a random variable conditional on all information available in round  $j$  of period  $t$ , respectively. Given that conditional on all information available at the first round,  $s_{t,2}$  is normally distributed, and conditional on all information available at the second round,  $s_{t+1,1}$  is also normally distributed, dealer  $i$  optimal foreign exchange holdings in each trading round will be given by:

$$Q_{t,1}^i = \frac{E_{t,1}(s_{t,2}) - s_{t,1}}{\theta Var_{t,1}(s_{t,2})} \quad (6)$$

$$Q_{t,2}^i = \frac{E_{t,2}(s_{t+1,1}) + \bar{V} - s_{t,2}}{\theta Var_{t,2}(s_{t+1,1})} \quad (7)$$

**Proposition 1** *There are rational expectations equilibrium exchange rates for trading round 1 and trading round 2 within the class of functions of the form:*

$$s_{t,1} = \alpha_0 + \alpha_1 Q_{t-1} + \alpha_2 F_t \quad (8)$$

$$s_{t,2} = \beta_0 + \beta_1 Q_t + \beta_2 F_t^c \quad (9)$$

These prices are given by:

$$\alpha_0 = \beta_0 = -\kappa_0/\kappa_1 \quad (10)$$

$$\alpha_1 = \frac{\theta\kappa_2^2\sigma_F^2 + \kappa_1}{\theta\kappa_1\kappa_2^2\sigma_F^2} \quad (11)$$

$$\alpha_2 = -\frac{\theta\kappa_2^2\sigma_F^2 + \kappa_1}{\theta\kappa_1\kappa_2\sigma_F^2} \quad (12)$$

$$\beta_1 = -\frac{\beta_2}{\kappa_2\rho_F} - \theta\frac{\beta_2^2\sigma_\varepsilon^2}{\rho_F} \quad (13)$$

$$\beta_2 = -\frac{\theta\kappa_2^2\sigma_F^2 + \kappa_1}{\theta\kappa_1\kappa_2(\sigma_F^2 + \sigma_\varepsilon^2)} \quad (14)$$

**Proof.** See appendix 2. ■

**Corollary 1** *The change in the exchange rate between the end of period  $t - 1$  and the end of period  $t$  can be written as:*

$$\Delta s_{t,2} = \beta_1 X_t + \beta_2 \Delta F_t^c \quad (15)$$

with  $\beta_1 < 0$  and  $\beta_2 > 0$  if the following condition is verified:

$$|\kappa_1| < \theta\kappa_2^2\sigma_F^2 \quad (16)$$

**Proof.** Equation (15) follows directly from equation (9) and equation (2). Also, since  $\kappa_1 < 0$  and  $\kappa_2 > 0$ , equation (14) implies that  $\beta_2 > 0$  if condition (16) is satisfied. Finally, if  $\beta_2 > 0$ , then from equation (13) it is necessarily the case that  $\beta_1 < 0$ . ■

Keeping in mind that the exchange rate is defined as the amount of domestic currency necessary to purchase one unit of foreign currency,  $\beta_1 < 0$  and  $\beta_2 > 0$  implies that the exchange rate depreciates if there is pressure from customers to purchase foreign currency from dealers ( $X_t > 0$ ) or if the signal received by dealers indicates an increase in future customer demand ( $\Delta F_t^c > 0$  could be interpreted, for example, as a signal from rating agencies that sovereign bonds might be downgraded). One final comment should be made about the condition that limits the sensitivity of customer flow to exchange rate changes. Imagine an exogenous shock that increases customer flow by  $\bar{X}$ . Given equation (15), this excess demand will depreciate the

exchange rate. If  $\kappa_1$  is negative, the exchange rate depreciation will feedback into the customer flow by reducing it. However, if the magnitude of the feedback effect is too large, the decrease in customer flow could be strong enough to generate a negative customer flow larger than the initial shock  $\overline{X}$ , which would lead to a subsequent appreciation of the exchange rate even larger in magnitude than the original depreciation. Equation (16) rules out this possibility.

## 3 Dataset

### 3.1 Description

The dataset used in this paper contains all customer flows between domestic dealers and three types of counterparties in the official Brazilian FX market: commercial customers (whose demand for foreign exchange is generated by a trade in goods with non-residents), financial customers (whose demand for foreign exchange is generated by a trade in assets with non-residents), and the central bank. The data is aggregated by each type of counterparty on a daily basis, spanning a total period of four years, from July 1, 1999 to June 30, 2003.

The dataset was obtained from SISBACEN, an electronic system of collection, storage, and exchange of information that connects the BCB and all other agents operating in a Brazilian financial market, including the FX market. The BCB closely monitors all activities involving capital flows. For instance, it requires all dealers operating in the Brazilian FX market to input into the SISBACEN information about the characteristics of each of their transactions in that market on a daily basis. These characteristics include the price, the volume, the type of counterparty – another dealer, the central bank, or a customer – and, if the counterparty is a customer, the nature of the underlying economic transaction which generated the demand for foreign exchange. The detailed information input by dealers into the SISBACEN is only observed by the BCB. After considerable delay, some summary data aggregated in a lower time frequency is released to dealers through the SISBACEN.

The Brazilian FX market is a decentralized multiple dealer market. Trading between dealers and commercial and financial customers occurs in the retail FX market. This market is also called the “primary” market, since its net transactions affect the country’s aggregate

inventory of foreign currency. Trading between dealers and the central bank does not affect the country's inventory, since both agents are domestic, but does affect the dealers' market-wide inventory level. Interdealer trading does not affect the country nor the market-wide inventory. When trading with customers, dealers do not behave as market makers, that is, they are not required to quote firm bid-ask prices at which they are ready to buy or sell foreign currency at any time while the market is open. They may condition their quote on whether the customer wants to buy or sell, and also on the size of the transaction. Customers, in order to trade foreign exchange with dealers, need to have proper justification – they have to show documentation with respect to the underlying economic transaction with a non-resident which is generating the need to exchange foreign currency. Since customers (and their underlying economic activities) are the agents who initiate the transaction with dealers, each transaction is attributed a positive or negative sign according to their point of view. This means that if customer flow is positive, it represents pressure from customers to buy foreign exchange or, equivalently, pressure on dealers to sell. The same procedure will be taken with the transactions between dealers and the central bank. It is the BCB who initiates the transactions with dealers. Therefore a positive intervention flow represents pressure from the central bank to buy foreign exchange from dealers or, equivalently, pressure from dealers to sell. All flows are measured in US\$ billions.

The dataset also includes the following pre-determined variables: the foreign interest rate, the domestic interest rate, and a measure of the Brazilian sovereign risk premium, all three in first difference. The foreign interest rate is the daily annualized Fed Funds rate, the domestic interest rate is the daily annualized Selic rate, and the risk premium is measured as the spread of the C-Bond (the most liquid Brazilian Brady bond in the sample period) over the Treasury, measured in annualized rates, so a 1% risk premium is equivalent to a 100 basis-point spread of the yield of the C-bond over a Treasury bill of equivalent maturity. Table 1 presents summary statistics.

**[Insert Table 1 about here]**

### 3.2 Endogeneity and Overnight Liquidity

Figure 2 displays the relationship between the exchange rate, defined as the Brazilian *real* price of one US dollar, and the cumulative customer order flow in Brazil (cumulative customer order flow in a date  $t$  is defined as the sum of all customer flows between date 0 and date  $t$ ). Two features are noteworthy:

a. Correlation between the cumulative customer flow and the exchange rate is negative (and significant at the 1% level).

b. Market-wide customer flow each day does not net to zero, implying that dealers from the Brazilian FX market do not simply behave as intermediaries, matching buyers and sellers during the day. If, for example, at the end of a given day there are more buyers than sellers, the dealers may supply the extra overnight liquidity.

The negative correlation between cumulative customer flow and the exchange rate found in the sample is indicative of the presence of “feedback trading” in the Brazilian FX market: as the domestic currency slowly depreciates, customers’ demand for foreign currency slowly decreases as a result, for example, of smaller imports and higher exports. This is the opposite of what is reported by Evans and Lyons (2002) and Fan and Lyons (2003), who find a positive correlation between order flows and the exchange rate and interpret it as evidence of pressure to buy foreign currency increasing the price charged by dealers.<sup>2</sup>

Two additional empirical exercises provide more formal evidence on the presence of endogeneity between customer flows and the exchange rate. Table 2 reveals that bivariate Granger causality tests reject the null hypothesis that exchange rate movements do not Granger cause commercial nor financial flows at the 1% significance level. The null hypothesis that exchange rate movements do not Granger cause intervention flows is also rejected, but at the 10% significance level. These results differ from Killeen et al (2006), which find no evidence of Granger causality running from the french franc/deutsch mark exchange rate to the interdealer order

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<sup>2</sup>Evans and Lyons (2002) find a strong positive correlation at the daily frequency between the exchange rate and interdealer order flow for the deutsche mark/dollar and yen/dollar markets and Fan and Lyons (2003) find a positive correlation at the monthly frequency between the exchange rate and customer order flow for the euro/dollar and yen/dollar markets.

flow of the same market.<sup>3</sup>

**[Insert Table 2 about here]**

Table 3 provides estimation output of single equation OLS regressions using the first difference of the log of the exchange rate as the dependent variable and the total customer flow from the retail market as a regressor.<sup>4</sup> The estimated coefficient is either negative and significant at the 1% significance level if no controls are included, or not significant at the 5% significance level if the pre-determined variables are included as additional controls. What does this result mean? Does it mean that the demand for foreign currency in the retail FX market decreases as a result of an increase in its price, or that pressure to buy in the retail FX market does not increase the price of foreign currency? Most likely, the coefficients from the OLS regressions have no economic interpretation since they are probably biased towards zero due to the presence of endogeneity.

**[Insert Table 3 about here]**

We have also noticed from figure 1 that customer flows from the retail market do not net to zero at the market-wide level at the daily frequency. In other words, dealers are providing liquidity overnight, by absorbing the change in the country’s foreign exchange inventory generated by customers’ underlying economic transactions (in goods and assets) with non-residents. If dealers find it optimal to do so, then we should expect them to be making profits from overnight liquidity provision. We calculate these “speculative” profits using the methodology described in Hau (2001), which gauges whether on average the price of foreign currency

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<sup>3</sup>However, we must bear in mind that these results are only an indication of the presence of endogeneity since Granger causality measures precedence and informational content rather than contemporaneous reverse causality in the sense of “feedback trading”.

<sup>4</sup>Note that this regression is comparable to Evans and Lyons (2002), even though their dependent variable is interdealer order flow and not customer order flow. In their model, interdealer order flow should be a multiple of the customer initiated transactions. Since in our dataset the transactions between dealers and customers were initiated by the customers, we should expect a similar result from their paper: a positive and significant coefficient indicating that pressure to buy increases the price of foreign currency.

goes up (profits) or down (losses) when dealers hold more foreign currency than usual.<sup>5,6</sup> The result reveals that for each dollar that dealers supplied overnight, they made a daily profit of 0.035%, or a 9.3% annualized profit rate.

## 4 Empirical Evidence

### 4.1 Estimation Strategy

Hasbrouck (1991) suggests that trades and quote revisions can be modeled from an econometric perspective as a system characterized by auto- and cross-correlations of a very general nature. Under his framework, the information impact of a trade is formally defined as the impact on prices resulting from the unexpected component of the trade. A vector autoregression (VAR) is the primary statistical technique employed to identify trade innovations. My estimation strategy will follow a Hasbrouck-style analysis.

Let  $y_t$  be the vector of endogenous variables, including the daily change in the (log of the) spot exchange rate,  $\Delta s_t$ , the financial customer flow,  $X_t^F$ , the commercial customer flow,  $X_t^C$ , and the central bank intervention flow,  $X_t^I$ :

$$y_t = \begin{bmatrix} \Delta s_t & X_t^F & X_t^C & X_t^I \end{bmatrix}' \quad (17)$$

Also, let  $Z_t$  be the vector of pre-determined macroeconomic variables, including the first differences of the domestic interest rate,  $\Delta r_t$ , the foreign interest rate,  $\Delta r_t^*$ , and the sovereign risk premium,  $\Delta \vartheta_t$ :

$$Z_t = \begin{bmatrix} \Delta r_t & \Delta r_t^* & \Delta \vartheta_t \end{bmatrix}' \quad (18)$$

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<sup>5</sup>These are not the only source of the dealers' profits. One component of the dealers' profits in the FX market comes from its role as an intermediation, by matching a buyer with a seller and profiting from the bid-ask spread. Another important source of profits comes from the dividends "paid" by the foreign currency (the interest rate differential). We are interested at the FX dealers "speculation" profits, that is, the profits that arise only from the change in the price of the asset he is trading.

<sup>6</sup>Let  $X_t$  be the daily customer flow. Now imagine that there is a representative dealer through the sample period, so that the daily market wide customer flow equals the change on its daily holdings of FX. Define  $Q_t = -\sum_{t=1}^T X_t$  as his inventory of FX. Let  $\bar{Q} = \frac{1}{T} \sum_{t=1}^T Q_t$  be the long run average inventory and  $\tilde{Q}_t = Q_t - \bar{Q}$  be the daily deviation of the representative dealer from its long run average. Finally, let  $s_t$  be the exchange rate. The total profit of the representative dealer is given by  $\Pi = \sum_{n=1}^T \tilde{Q}_t \Delta s_{t+1}$ .

I will estimate the following Structural VAR:

$$A_0 y_t = \sum_{p=1}^P A_p y_{t-p} + B_0 Z_t + \sum_{q=1}^Q B_q D_{q,t} + \varepsilon_t \quad (19)$$

in which  $D_{q,t}$ ,  $q = 1, \dots, Q$ , is a set of dummy variables which includes controls for each day of the week and each month of the year, and  $\varepsilon_t$  is a normally distributed vector of structural innovations, with zero mean and diagonal covariance matrix  $\Sigma_\varepsilon$ .

Of special interest to the microstructure approach to exchange rates literature is the effect of unexpected shocks on dealers' overnight foreign exchange positions,  $Q_t$ , on exchange rate dynamics. Since our data captures the whole market, the daily change on dealers' FX holdings is given by

$$\Delta Q_t = - (X_t^F + X_t^C + X_t^I) \quad (20)$$

which suggests the following restriction on the  $A_0$  matrix:  $\alpha_{12}^0 = \alpha_{13}^0 = \alpha_{14}^0$ . A second set of restrictions is based on the idea that financial and commercial flows do not affect each other contemporaneously,  $\alpha_{23}^0 = \alpha_{32}^0 = 0$ , nor are they affected by the central bank intervention flow,  $\alpha_{24}^0 = \alpha_{34}^0 = 0$ . This does not mean that commercial and financial flows are not correlated with each other, nor with the central bank intervention flow at the daily frequency. Indeed, common sources of shocks may affect all three types of flows simultaneously, such as changes in the exchange rate, interest rate differential, sovereign risk premium, and also past shocks to the endogenous variables. However, once we control for these potential sources of common shocks, the amount of foreign currency demanded because of the trade in goods with non-residents should not be a direct function of the amount of foreign currency demanded because of the trade in assets with non-residents. While the former should be related to the marginal utility of foreign goods, the latter should be a function of the present discounted value of the future dividends that foreign assets pay and some measure of risk aversion. These two sets of



restrictions imply the following format for the matrix of contemporaneous relations:

$$A_0 = \begin{bmatrix} 1 & \alpha_{12}^0 & \alpha_{12}^0 & \alpha_{12}^0 \\ \alpha_{21}^0 & 1 & 0 & 0 \\ \alpha_{31}^0 & 0 & 1 & 0 \\ \alpha_{41}^0 & \alpha_{42}^0 & \alpha_{43}^0 & 1 \end{bmatrix} \quad (21)$$

## 4.2 Estimation Output

Table 4 reports estimation output of the reduced form of a VAR(2) described by equation (19).<sup>7</sup> Based on the residuals of the VAR(2), I estimate the matrix of contemporaneous relations  $A_0$  in equation (21). Panel A in table 5 shows that all estimated coefficients are significant at the 1% level, with the exception of one: the behavior of commercial customers does not seem to affect central bank interventions. Therefore, I re-estimate the matrix of contemporaneous relations  $A_0$ , but setting an additional restriction,  $\alpha_{43}^0 = 0$ , to equation (21), which turns the system into an over-identified one.

[Insert Tables 4 and 5 about here]

The following equations describe the endogenous relationships implied by the over-identified system. All coefficients are significant at the 1% significance level (see panel B in table 5 for standard errors):

$$\Delta s_t = 0.035 (X_t^F + X_t^C + X_t^{CB}) + e_{1t} \quad (22)$$

$$X_t^F = -6.85 \Delta s_t + e_{2t} \quad (23)$$

$$X_t^C = -4.68 \Delta s_t + e_{3t} \quad (24)$$

$$X_t^I = -2.29 \Delta s_t - 0.23 X_t^F + e_{4t} \quad (25)$$

There are several lessons which can be learned from the contemporaneous relationships presented above. First, dealers from the Brazilian FX market charge a 0.35% premium to

<sup>7</sup>The Akaike information criterion, the lag length exclusion test on the endogenous variables, and the test for serial correlation in the residuals all suggest that two lags of the dependent variables should be included in the VAR. The Schwarz information criterion is the only test statistic that suggests a lag length of one.

provide US\$ 100 million of overnight foreign exchange liquidity. Second, a 1% appreciation increases financial customers' demand for foreign exchange by US\$ 68 million. Third, a 1% appreciation increases commercial customers' demand for foreign exchange by US\$ 47 million. Interestingly, these two coefficients are negative, suggesting that “feedback trading” in the Brazilian FX market is stabilizing. Fourth, the central bank tends to sell foreign currency to dealers when the exchange rate is depreciating or when there is excess demand for liquidity from financial customers. While the former indicates a “leaning-against-the-wind” type of reaction, the latter is evidence of the BCB’s “liquidity provision” role in the FX market. Estimated coefficients tell us that a 1% depreciation is associated with a US\$ 23 million sell from the central bank to dealers and that a US\$ 100 million financial customer flow is associated with a US\$ 23 million sell from the central bank to dealers. Finally, the p-value associated to the Wald test of overidentifying restrictions is 0.501, suggesting that we cannot reject the null hypothesis that all restrictions imposed on the matrix of contemporaneous relations  $A_0$  are valid.

## 5 Conclusion

This paper develops and estimates a microstructure model which more appropriately describes the Brazilian FX market. Detailed analysis of Brazil’s maturing FX market helps understand the reason why Brazil’s managed exchange rate flexibility remains a pillar of economic resilience. The model introduces two major changes relative to previous microstructure models. First, dealers may decide to hold overnight positions in the FX market, if they find it profitable to do so. Second, customers’ demand for foreign exchange is a function of macroeconomic fundamentals, including contemporaneous feedback from exchange rate movements. The paper also presents empirical evidence supporting the main predictions of the model using a unique data set, covering all transactions between dealers and customers from the Brazilian official FX market from July 1, 1999 to June 30, 2003 (a time period in which Brazil suffered two sudden stops). Among the main results, I find that dealers from the Brazilian FX market charge a 0.35% premium to provide US\$ 100 million of overnight foreign exchange liquid-

ity. I also find empirical evidence of customers' "stabilizing" feedback trading, and of BCB's "leaning-against-the-wind" and "liquidity provision" behavior.

It is worthy to compare the estimated slope of the Brazilian FX market liquidity supply curve with Evans and Lyons' (2002) estimate that a US\$ 1 billion net dollar purchase increases the deutsche mark price of a US dollar by 0.54%. Although both estimates are not directly comparable, since I use customer flow and Evans and Lyons (2002) use inter-dealer order flow, a couple of reasons might explain why order flow in the Brazilian FX market has a price impact approximately five times greater than in the deutsche mark/dollar market. First, because the Brazilian FX market is considerably smaller, both in terms of volume and liquidity, it should be more difficult for a dealer to rebalance its portfolio. Therefore, it is natural for the price impact of a trade to be larger in the smaller and less liquid market. Second, the exchange rate in an emerging economy is much more volatile than in a developed economy, and the riskier the asset, the larger the price change required for a risk averse agent to hold it.

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## A Proof of Proposition 1

To find the first and second trading rounds REE exchange rates, start with the following price conjectures:

$$s_{t,1} = \alpha_0 + \alpha_1 Q_{t-1} + \alpha_2 F_t \quad (26)$$

$$s_{t,2} = \beta_0 + \beta_1 Q_t + \beta_2 F_t^c \quad (27)$$

Recall that optimal FX holdings of dealer  $i$  in each trading round are given by:

$$Q_{t,1}^i = \frac{E_{t,1}(s_{t,2}) - s_{t,1}}{\theta \text{Var}_{t,1}(s_{t,2})} \quad (28)$$

$$Q_{t,2}^i = \frac{E_{t,2}(s_{t+1,1}) + \bar{V} - s_{t,2}}{\theta \text{Var}_{t,2}(s_{t+1,1})} \quad (29)$$

and the market clearing conditions impose:

$$\int_0^1 Q_{t,1}^i di = Q_{t-1} - X_t \quad (30)$$

$$\int_0^1 Q_{t,2}^i di = Q_t \quad (31)$$

Given the price conjectures we can write the expectation of the second round exchange rate conditional on information available only up to the first round as:

$$\begin{aligned} E_{t,1}(s_{t,2}) &= \beta_0 + \beta_1 Q_t + \beta_2 E_{t,1}(F_t^c) \\ &= \beta_0 + \beta_1 (Q_{t-1} + X_{i,t}) + \beta_2 \bar{F} \\ &= \beta_0 + \beta_1 (Q_{t-1} + \kappa_0 + \kappa_1 s_{t,1} + \kappa_2 F_t) + \beta_2 \bar{F} \end{aligned} \quad (32)$$

and the variance of the second round exchange rate conditional on the same information set as:

$$Var_{t,1}(s_{t,2}) = \beta_2^2 Var_{t,1}(F_t^c) = \beta_2^2 (\sigma_F^2 + \sigma_\varepsilon^2) \quad (33)$$

Assuming for simplification that  $\bar{F} = 0$ , plugging the conditional expectation and the conditional variance into each bank  $i$  optimal first round customer flow demand given by equation (28) and imposing the market clearing condition given by equation (30), we arrive at:

$$s_{t,1} = \frac{\beta_0 + [\beta_1 - \theta\beta_2^2 (\sigma_F^2 + \sigma_\varepsilon^2)] (Q_{t-1} - \kappa_0 - \kappa_2 F_t)}{1 + [\beta_1 - \theta\beta_2^2 (\sigma_F^2 + \sigma_\varepsilon^2)] \kappa_1} \quad (34)$$

By comparing the above equation to the price conjecture for  $s_{t,1}$  in equation (26), we can write  $\alpha_0$ ,  $\alpha_1$  and  $\alpha_2$  as functions of  $\beta_0$ ,  $\beta_1$ ,  $\beta_2$  and other structural parameters:

$$\alpha_0 = \frac{\beta_0 - [\beta_1 - \theta\beta_2^2 (\sigma_F^2 + \sigma_\varepsilon^2)] \kappa_0}{1 + [\beta_1 - \theta\beta_2^2 (\sigma_F^2 + \sigma_\varepsilon^2)] \kappa_1} \quad (35)$$

$$\alpha_1 = \frac{\beta_1 - \theta\beta_2^2 (\sigma_F^2 + \sigma_\varepsilon^2)}{1 + [\beta_1 - \theta\beta_2^2 (\sigma_F^2 + \sigma_\varepsilon^2)] \kappa_1} \quad (36)$$

$$\alpha_2 = \frac{-[\beta_1 - \theta\beta_2^2 (\sigma_F^2 + \sigma_\varepsilon^2)] \kappa_2}{1 + [\beta_1 - \theta\beta_2^2 (\sigma_F^2 + \sigma_\varepsilon^2)] \kappa_1} \quad (37)$$

In the second round, banks can update their beliefs about the realizations of the future macroeconomic fundamentals  $F_{t+1}$  using the common signal  $F_t^c$ . Given  $F_{t+1} \sim N(0, \sigma_F^2)$ , we can apply the projection theorem to reach the following expressions:

$$E(F_{t+1}/F_t^c) = \frac{\sigma_F^2}{\sigma_F^2 + \sigma_\varepsilon^2} F_t^c = \rho_F F_t^c \quad (38)$$

$$Var(F_{t+1}/F_t^c) = \frac{\sigma_F^2 \sigma_\varepsilon^2}{\sigma_F^2 + \sigma_\varepsilon^2} = \rho_F \sigma_\varepsilon^2 \quad (39)$$

Using the above expressions to calculate bank  $i$  period  $t$  second round expectations of

period  $t + 1$  first round equilibrium exchange rate we get:

$$\begin{aligned} E_{t,2}(s_{t+1,1} + V_t) &= \alpha_0 + \alpha_1 Q_t + \alpha_2 E_{t,2}(F_{t+1}) + E_{t,2}(V_t) \\ &= \alpha_0 + \alpha_1 Q_t + \alpha_2 \rho_F F_t^c + \bar{V} \end{aligned} \quad (40)$$

$$Var_{t,2}(s_{t+1,1} + V_t) = \alpha_2^2 Var_{t,2}(F_t) = \alpha_2^2 \rho_F \sigma_\varepsilon^2 \quad (41)$$

Assuming for simplification that  $\bar{V} = 0$ , plugging the conditional expectation and variance into each bank  $i$  second round optimal foreign currency demand given by equation (29) and imposing the market clearing condition given by equation (31), we arrive at:

$$s_{t,2} = \alpha_0 + (\alpha_1 - \theta \alpha_2^2 \rho_F \sigma_\varepsilon^2) Q_t + \alpha_2 \rho_F F_t^c \quad (42)$$

By comparing the above equation to the price conjecture for  $s_{t,2}$  in equation (27), we can write  $\beta_0$ ,  $\beta_1$  and  $\beta_2$  as functions of  $\alpha_0$ ,  $\alpha_1$ ,  $\alpha_2$  and other structural parameters:

$$\beta_0 = \alpha_0 \quad (43)$$

$$\beta_1 = \alpha_1 - \theta \alpha_2^2 \rho_F \sigma_\varepsilon^2 \quad (44)$$

$$\beta_2 = \alpha_2 \rho_F \quad (45)$$

Combine equations (43) and (35) to find  $\alpha_0$  and  $\beta_0$ . Also, combining equations (36) and (37) gives us:

$$\alpha_2 = -\alpha_1 \kappa_2 \quad (46)$$

Use equations (44), (45) and (46) to write  $\alpha_1$ ,  $\alpha_2$  and  $\beta_1$  as functions of  $\beta_2$ . Then plug these expression into equation (36) and solve for  $\beta_2$ .

*Table 1: Summary statistics*

<b>Variables</b>	<b>Mean</b>	<b>Mean(Absolute)</b>	<b>Minimum</b>	<b>Maximum</b>	<b>Std. Dev.</b>
Depreciation rate	0.0005	0.0075	-0.0893	0.0487	0.0108
Financial flow	0.0404	0.1325	-2.6260	1.1379	0.2064
Commercial flow	-0.0577	0.0829	-0.5848	0.2984	0.0955
Intervention flow					
All data (1003 obs.)	-0.0126	0.0218	-0.6646	2.0401	-0.1053
Non-zero (236 obs.)	-0.0537	0.4673	-0.6646	2.0401	-0.2122
$\Delta$ (Selic interest rate)	0.0000	0.0004	-0.0141	0.0300	0.0018
$\Delta$ (Fed funds interest rate)	0.0000	0.0008	-0.0112	0.0144	0.0014
$\Delta$ (Risk premium)	0.0000	0.0022	-0.0220	0.0234	0.0037

Summary statistics of daily data from July 1, 1999 until June 30, 2003. Financial and commercial customer flows and intervention flows are measured in US\$ billions. Other variables measured in rates. A positive financial or commercial customer flow indicates that the customer purchased US dollars from dealers in the Brazilian FX market. A positive intervention flow indicates that the central bank purchased US dollars from dealers in the Brazilian FX market. Exchange rate is defined as the domestic price for one US dollar. The foreign interest rate is the daily annualized rate of the Fed Funds rate. The domestic interest rate is the daily annualized rate of the Brazilian Selic rate. The risk premium is the spread of the C-Bond (the most liquid Brazilian Brady bond in the sample period) over the Treasury, measured in annualized rates, so a 1% risk premium is equivalent to a 100 basis-points spread of the yield of the C-bond in % a.a. over the yield of a Treasury bill with the same maturity, also in % a.a.

*Table 2: Bivariate Granger causality tests*

<b>Variable 1</b>	<b>Variable 2</b>	<b>p-value</b>
Depreciation rate	Commercial customer flow	0.8%
Commercial customer flow	Depreciation rate	1.0%
Depreciation rate	Financial customer flow	0.5%
Financial customer flow	Depreciation rate	94.9%
Depreciation rate	Central bank intervention flow	6.3%
Central bank intervention flow	Depreciation rate	80.0%

Granger causality tests based on bivariate regressions using daily data from July 1, 1999 until June 30, 2003. The lag length of each bivariate VAR is based on the Schwarz information criterion. Null hypothesis is variable 1 does not Granger cause variable 2. Probability of rejection is reported under p-value.



*Table 3: Single equation OLS regressions*

Regressor	Equation	
	Depreciation rate <sub>t</sub>	Depreciation rate <sub>t</sub>
Customer flow <sub>t</sub>	0.005*** (0.002)	0.002 (0.002)
Domestic interest rate <sub>t</sub>	- -	-0.129 (0.122)
Foreign interest rate <sub>t</sub>	- -	0.075 (0.194)
Sovereign risk premium <sub>t</sub>	- -	1.316*** (0.140)
R <sup>2</sup>	0.01%	20.93%

Coefficients estimated by OLS using daily data from July 1, 1999 until June 30, 2003. Coefficients associated with constant omitted from the table. Newey-West standard errors in parenthesis. The symbols ‘\*’, ‘\*\*’, and ‘\*\*\*’ denote that the individual coefficient is statistically significant at the 10%, 5%, and 1% significance level, respectively.

Table 4: VAR(2) estimation output

Regressor	Equation			
	Depreciation rate <sub>t</sub>	Financial flow <sub>t</sub>	Commercial flow <sub>t</sub>	Intervention flow <sub>t</sub>
Depreciation rate <sub>t-1</sub>	0.107*** (0.034)	-0.986 (0.636)	-0.421 (0.285)	0.448 (0.337)
Depreciation rate <sub>t-2</sub>	-0.190*** (0.034)	-0.900 (0.636)	-0.490* (0.285)	0.064 (0.337)
Financial flow <sub>t-1</sub>	0.000 (0.002)	0.063* (0.037)	-0.015 (0.017)	0.017 (0.020)
Financial flow <sub>t-2</sub>	0.001 (0.002)	0.032 (0.037)	-0.019 (0.017)	-0.009 (0.020)
Commercial flow <sub>t-1</sub>	0.013*** (0.004)	-0.149* (0.077)	0.227*** (0.035)	0.008 (0.041)
Commercial flow <sub>t-2</sub>	-0.001 (0.004)	0.057 (0.078)	0.078** (0.035)	-0.032 (0.041)
Intervention flow <sub>t-1</sub>	-0.004 (0.004)	-0.068 (0.070)	0.000 (0.032)	0.033 (0.037)
Intervention flow <sub>t-2</sub>	-0.003 (0.004)	0.097 (0.070)	-0.002 (0.031)	0.009 (0.037)
Domestic interest rate <sub>t</sub>	-0.050*** (0.014)	-0.041 (0.272)	-0.016 (0.122)	-0.293** (0.144)
Foreign interest rate <sub>t</sub>	0.029 (0.027)	1.171** (0.500)	-0.183 (0.224)	-0.589** (0.265)
Sovereign risk premium <sub>t</sub>	0.054*** (0.014)	-0.774*** (0.270)	0.442*** (0.121)	0.428*** (0.143)
R <sup>2</sup>	11.8%	14.1%	19.4%	7.4%

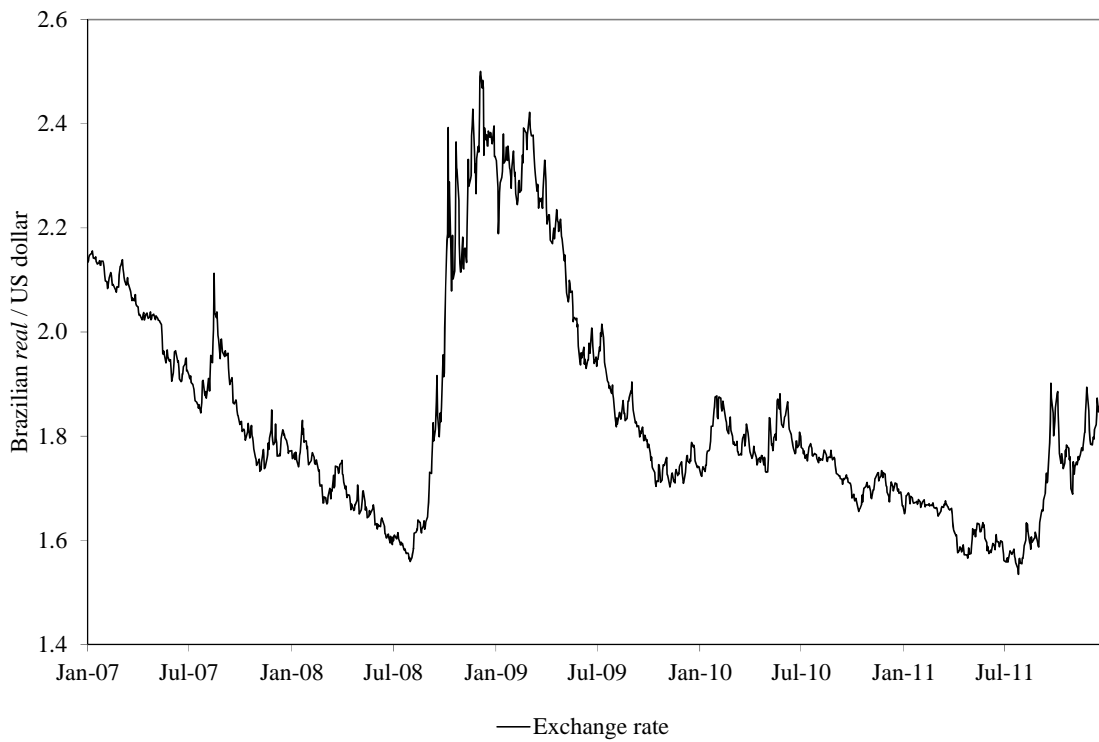
Estimation output of the VAR specified by equation (34) with 2 lags. Coefficients estimated by OLS using daily data from July 1, 1999 until June 30, 2003. Coefficients associated with constant and dummy variables omitted from the table. Standard errors in parenthesis. The symbols ‘\*’, ‘\*\*’, and ‘\*\*\*’ denote that the individual coefficient is statistically significant at the 10%, 5%, and 1% significance level, respectively.

Table 5: Matrix of contemporaneous relations estimation output

<b>Panel A</b>	Depreciation rate <sub>t</sub>	Financial flow <sub>t</sub>	Commercial flow <sub>t</sub>	Intervention flow <sub>t</sub>
Depreciation rate <sub>t</sub>	1	-0.038***	-0.038***	-0.038***
	-	(0.009)	(0.009)	(0.009)
Financial flow <sub>t</sub>	7.332***	1	0	0
	(1.765)	-	-	-
Commercial flow <sub>t</sub>	4.787***	0	1	0
	(0.354)	-	-	-
Intervention flow <sub>t</sub>	2.291***	0.221***	-0.028	1
	(0.379)	(0.022)	(0.041)	-
<b>Panel B</b>	Depreciation rate <sub>t</sub>	Financial flow <sub>t</sub>	Commercial flow <sub>t</sub>	Intervention flow <sub>t</sub>
Depreciation rate <sub>t</sub>	1	-0.035***	-0.035***	-0.035***
	-	(0.008)	(0.008)	(0.008)
Financial flow <sub>t</sub>	6.848***	1	0	0
	(1.679)	-	-	-
Commercial flow <sub>t</sub>	4.680***	0	1	0
	(0.327)	-	-	-
Intervention flow <sub>t</sub>	2.289***	0.227***	0	1
	(0.396)	(0.021)	-	-
LR test for over-identification:			0.452	
			(0.501)	

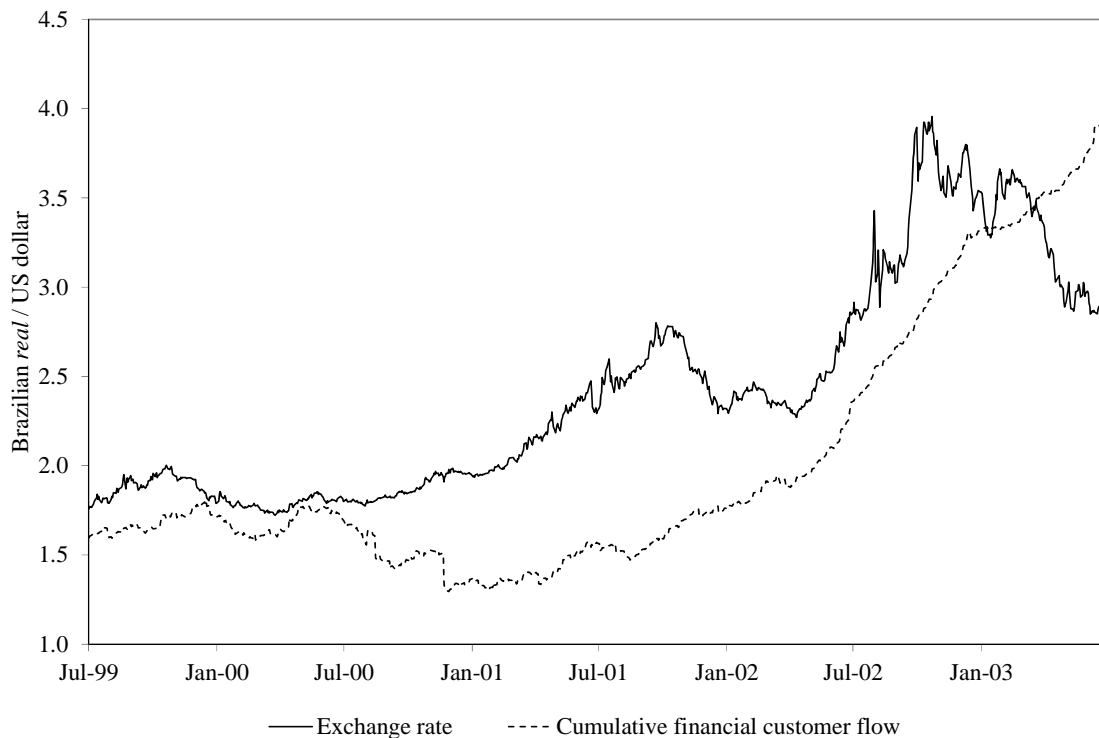
Structural factorization based on VAR(2) estimates presented in table 4. Entries on the table without standard errors mean that the coefficient was constrained to that value. The symbols ‘\*’, ‘\*\*\*’, and ‘\*\*\*\*’ denote that the individual coefficient is statistically significant at the 10%, 5%, and 1% significance level, respectively.

Figure 1: Daily exchange rate



Daily data from January 2, 2007 until December 30, 2011. Exchange rate is defined as Brazilian *real* price of one US dollar.

Figure 2: Cumulative customer flow from retail FX market and exchange rate



Daily data from July 1, 1999 until June 30, 2003. Cumulative customer flow from the retail market includes commercial and financial flows. Cumulative customer order flow in a date  $t$  is the sum of all customer flows between date 0 (July 1, 1999) and date  $t$ . Positive (negative) customer flow indicates that customers purchased (sold) US dollars from (to) dealers in the Brazilian FX market. Exchange rate is defined as Brazilian *real* price of one US dollar.