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## From Lombard Street to Avenida Paulista: Foreign Exchange Liquidity Easing in Brazil in Response to the Global Shock of 2008–09

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Walker, and Yosuke Yasui*

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**Abstract**

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The provision of *foreign exchange* liquidity by emerging market central banks during the global shock of 2008–09 departs from the *domestic liquidity* lender of last resort role described by Bagehot in his classic “Lombard Street.” This paper documents and analyzes the foreign exchange liquidity providing measures of the Banco Central do Brasil (BCB) in response to varied market stresses. These measures appear to have reduced the relative onshore cost of dollar liquidity on impact and seemed to stabilize market expectations of exchange rate volatility. The results suggest that foreign exchange liquidity easing operations may become a standard central bank tool.

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## I. INTRODUCTION

The emergency injection of dollar liquidity by emerging market central banks is one of the policy innovations of the 2008–09 global financial crisis. Emerging market country banks and corporations dependent on external funding were especially hard hit by the drying up of global dollar liquidity.<sup>2</sup> In response, at least 19 emerging market central banks introduced special facilities to provide foreign exchange liquidity (Table 1). A closely related innovation was the provision by the U.S. Federal Reserve Bank (Fed) and other advanced country central banks of their currencies to emerging market central banks in need of foreign exchange.

The dollar liquidity injections differ qualitatively from the standard domestic lender of last resort (LOLR)—as famously described by Bagehot in “Lombard Street.” In contrast to domestic LOLR, central banks cannot issue foreign currency and are constrained by the level of international reserves. Further, the emergency provision of foreign exchange by emerging market central banks is usually for the benefit of corporations, rather than banks, the standard focus of domestic LOLR operations. The dollar liquidity injections also differ from standard foreign exchange market intervention because they are not aimed at influencing the exchange rate *per se*.

This paper assesses the effectiveness of the foreign exchange liquidity providing measures of the Banco Central do Brasil (BCB), an especially interesting case. Foreign exchange liquidity is actively traded in the advanced financial markets of Brazil (whose major players are mostly domiciled on Avenida Paulista in São Paulo). The BCB has a well-established record of price and exchange rate stability since adopting full-fledged inflation targeting in 1999, has in the past taken innovative approaches to foreign exchange operations, and operates transparently. The cutoff of dollar funding lines to Brazilian corporations and banks in September and October 2008, led the BCB to introduce an array of foreign exchange liquidity easing measures in response to stresses in different markets. At the same time, the BCB agreed to a currency swap arrangement with the Fed meant to assuage concerns about the continued availability of dollars.

This paper also contributes to the exchange rate intervention literature. The analysis here takes advantage of the intervention data reported by the BCB to gauge the impact of conventional spot intervention, and of the foreign exchange liquidity easing measures, on the level and implied volatility of the exchange rate.

The main empirical result is that the BCB measures reduced on impact the relative cost of onshore dollar financing—a market proxy for foreign exchange liquidity. Announcement

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<sup>2</sup> See Baba and others (2009) and McGuire and von Goetz (2009).

effects are estimated to be bigger than those of the interventions themselves. The announcement of the foreign exchange swap with the Fed had the biggest empirical effect. The level and implied volatility of the spot exchange rate are also estimated to have been positively affected by the foreign exchange easing measures, implying that those measures stabilized the exchange rate, in addition to easing dollar liquidity. The apparent effectiveness of the BCB's foreign exchange liquidity easing measures suggests that they may become a standard central bank tool and thus warrant further analysis.

The rest of the paper is organized as follows. The next section reviews the background of the Brazilian measures and section III puts the foreign exchange easing measures into the general policy context. The empirical analysis is reported and discussed in section IV, and section V provides closing thoughts on the broader policy implications. The annexes elaborate on the asset prices used in the analysis, provide detailed information on the foreign exchange measures of the BCB during the period September 2008 to May 2009, list the relevant quotes from "Lombard Street," describe the data used in the regressions, and report unit root tests.

**Table 1. Medium and Large Emerging Market Economies, Number of Central Bank Foreign Exchange Liquidity Easing Measures, 2008–09**

|             |   |              |   |
|-------------|---|--------------|---|
| India       | 8 | Peru         | 3 |
| Korea       | 8 | Ukraine      | 2 |
| Chile       | 7 | South Africa | 1 |
| Turkey      | 6 | Hong Kong    | 1 |
| Hungary     | 5 | Vietnam      | 1 |
| Indonesia   | 4 | Poland       | 1 |
| Philippines | 4 | Romania      | 1 |
| Argentina   | 4 | Russia       | 1 |
| Serbia      | 3 | Mexico       | 1 |

Source: Ishi, Stone and Yehoue (2009).

Note: These measures encompass: new foreign exchange providing facilities; easier terms and the widening of counterparties on existing foreign exchange facilities; the relaxation of foreign exchange liquidity limits; and the easing of the reserve requirement framework of bank foreign exchange liabilities. Extensions of existing facilities are counted as a new measure.

## II. BACKGROUND FOR BRAZIL

Financial markets in Brazil are well-developed. Bond and equity markets are broad and deep, and the derivatives exchange—the Bolsa Mercadorias e Futuros (BMF)—is among the world's largest. Interest rate and currency futures and many other securities trade actively over a wide range of maturities. Both banks and nonfinancial firms make extensive use of the market for hedging and for maturity and currency transformation. Over-the-counter trading

of forwards, options, and other structures within Brazil is also active, as well as offshore trading in nondeliverable forwards on the *real* and other products. Brazil's sophisticated derivatives markets evolved in response to high domestic inflation, interest rate variability, and reliance on dollar funding.

The implied onshore dollar interest rate, or *cupom cambial*, plays a unique role in Brazil and affords a good market indicator of foreign exchange liquidity tightness (Annex 1). Contracts in the dollar interest rate were once traded directly on the exchange; today, most dollar rate positions are established by trading in currency and dollar interest rate futures. The implied dollar interest rate is the sum of the domestic currency interest rate and the rate of expected currency depreciation calculated from the difference between the spot and forward exchange rates.<sup>3</sup> The implied dollar interest rate is not necessarily equal to the U.S. domestic dollar interest rate, and at times has diverged considerably from it. The reasons for this divergence, which can be viewed as a departure from the covered interest parity condition, are discussed in Annex 1. Since the onset of the financial crisis, implied onshore dollar interest rates have become a major indicator of dollar funding pressures, not only in Brazil, but in other major emerging markets such as Korea and Turkey.

Brazil's advanced financial markets have facilitated sophisticated responses of the BCB to external shocks. Like most central banks, the BCB has at times engaged in spot intervention, particularly during periods of capital outflows, such as in 1998–99 and again in 2002.<sup>4,5</sup> Spot reserves sales were substantial, at 30 percent or more of outstanding pre-crisis reserves, during both of these episodes. The BCB has also maintained a forward position on the BMF since before 1998 and used operations in dollar futures in response to market pressures.

The buildup of foreign exchange vulnerabilities on corporate balance sheets was one of the major reasons for the foreign exchange liquidity operations of the BCB. Brazilian firms had total dollar debt of about \$120 billion, equivalent to about 8 percent of GDP, as of September 2008. Many export firms depended on short-term trade lines of credit, totaling an

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<sup>3</sup> Although the currency futures market in Brazil is nondeliverable (all trades are settled in *reais* and not in dollars) it is used for synthetic dollar borrowing operations. A Brazilian firm could, for example, take out a 3-month loan in *reais*, convert the proceeds to dollars in the spot market, and purchase *reais* forward in the futures market. At maturity, the firm would buy back the *reais* in the spot market to repay the original loan, with the settlement of the futures contract covering any currency fluctuation.

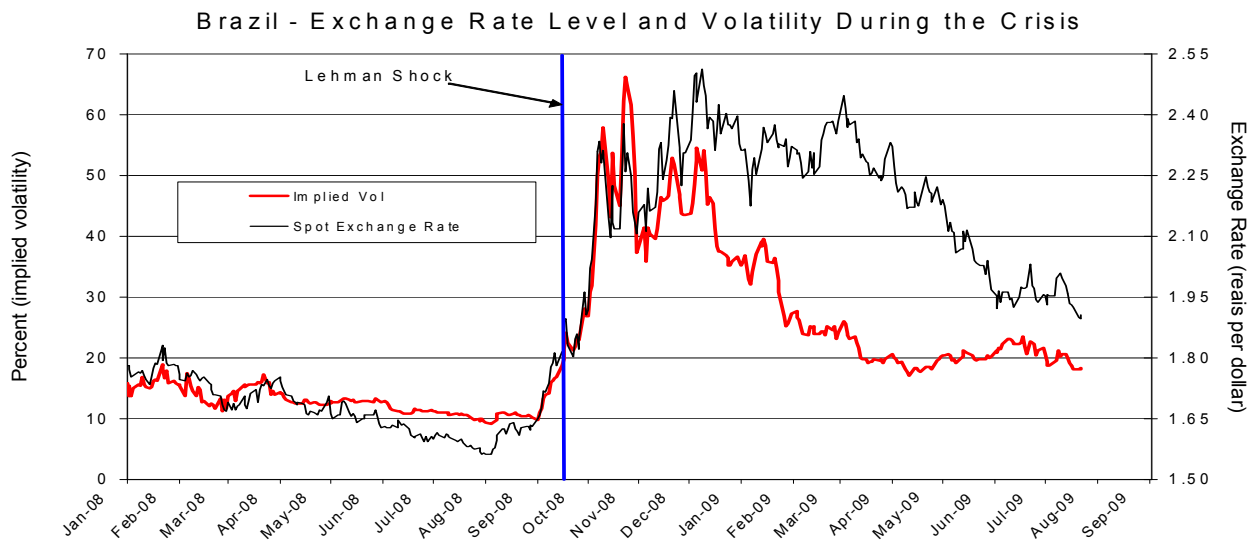
<sup>4</sup> Stone and others (2009) document the role of the exchange rate for inflation targeting emerging market countries; see also Ho and McCauley (2003).

<sup>5</sup> In 2002, foreign exchange liquidity tightened sharply in response to the presidential election, the Argentine crisis, and the tightening of U.S. credit markets (implied dollar funding rates moved sharply higher, well above domestic U.S. dollar interest rates) (BCB, 2002). In response, the BCB auctioned \$1.4 billion of reserves tied to export credit, sold \$5.9 billion spot and \$1.8 billion of external credit line auctions, and undertook futures interventions.

average of \$40–50 billion at any given time. Further, some firms undertook speculative (“overhedged”) foreign exchange derivatives strategies premised on realizing gains from the interest rate differential in favor of the *real* and from further appreciation of the currency.<sup>6</sup> The overall exposure of Brazilian firms to currency derivatives was estimated at up to \$50 billion.

Brazil’s financial markets were hard hit by the global liquidity squeeze that began in September 2008. Brazil’s *real*, which had been appreciating in nominal terms for more than five years, depreciated by 35 percent against the dollar in less than two months as foreign capital exited domestic fixed income and equity markets (Chart 1). Brazilian external credit spreads more than doubled. The volatility of Brazilian asset prices, gauged in both implied and historical terms, increased more than five-fold. And the difference between the domestic cost of dollar funding and the dollar LIBOR increased from about 1 percent to more than 6 percent at the peak of the crisis (Chart 2).

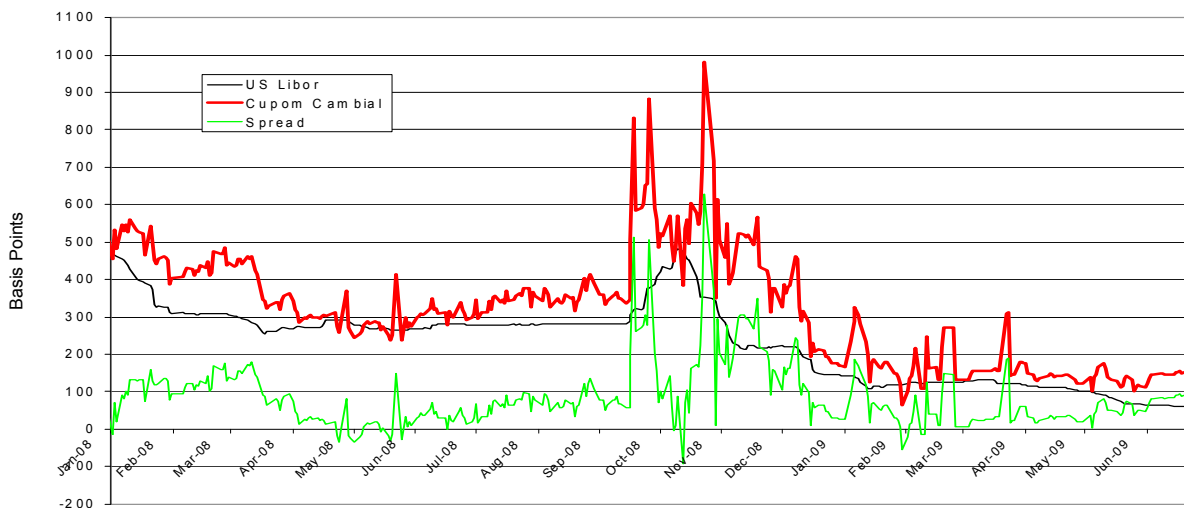
**Chart 1**



<sup>6</sup> Typically, an exporter would receive an at-the-money call option that would pay when the local currency appreciated, in exchange for which it would write one or more out-of-the-money put options on the currency.

Chart 2

Cupom Cambial and Libor



These shocks quickly carried over into the corporate sector. Many of the corporate dollar debtors were suddenly unable to obtain the funds to roll over their obligations or to fund new activities, as lines of credit from foreign lenders were cut. Three large exporters acknowledged extensive losses, totaling as much as \$10 billion, on currency positions during the post-Lehman market turbulence.<sup>7</sup>

To restore confidence and alleviate the dollar shortage, the BCB implemented the following measures, which are the focus of the empirical work (see Annex 2 for more detail):

- The BCB initiated *spot market* dollar sales, beginning in early October. However, spot sales did not meet the BCB's objectives of addressing the foreign exchange liquidity squeeze while minimizing outright loss of reserves. While there was not a large increase in demand for holding dollar-denominated assets indefinitely—which would be met by spot sales—local demand for temporary dollar financing ratcheted up as a result of the global liquidity squeeze. Thus, spot sales, at less than \$10 billion of the \$208 billion pre-crisis reserves stock, were quite limited compared to reserves outstanding and to previous episodes of exchange rate pressure.
- Beginning in September, the BCB sold *foreign exchange swaps at auction* to help compensate for the loss of dollar export credit lines. Each swap consisted of two legs. In the first leg, the BCB exchanged dollars for *reais*. In the forward leg, this transaction was reversed, with the BCB buying back the dollars against the *reais*. The effect of this transaction in the marketplace was to reduce the interest rate cost to

<sup>7</sup> These companies are Aracruz (a paper products company), Sadia (poultry exporter), and Votorantim (conglomerate).



dollar debtors of taking out a synthetic dollar loan within the window of the swap maturity.<sup>8</sup> These swaps were sold from September 19 to January 29, and totaled about \$11 billion. However, some of the sales were to replace maturing lines (the term of the swaps varied from 30 to 180 days) so that the largest amount outstanding at any one time was \$6.2 billion.<sup>9</sup>

- The BCB sold *dollar futures* directly, in the BMF futures market, mainly to facilitate the unwinding of the speculative positions taken by the overhedged corporations. The forward market intervention was substantial, totaling a cumulative \$34 billion from September 15, 2008 to the end of the year, bringing the BCB's net forward position from \$22 billion to \$-12 billion. An interesting feature of the futures market transaction is that it is the opposite of the forward leg of the foreign exchange swap measure, in that the BCB was selling dollars in the forward market rather than buying them back. However, the two measures were aimed at addressing two distinct market phenomena. While the swaps auctions were a response to the overall dollar liquidity shortage, the sale of dollar futures was largely directed at easing pressure on Brazilian export firms holding short dollar derivatives positions that they needed to unwind.
- In October the BCB instituted a program to *lend dollars (again at auction) against dollar-denominated collateral*. Eligible collateral consisted of A-rated-or-better dollar-denominated bonds, and, significantly, export-funding contracts. Banks were eligible to repo export-funding contracts signed by exporters with the BCB. Repo auctions were conducted ten times between October 6 and January 14, for a total of about \$11 billion.
- The BCB announced in December that it would make available up to \$10 billion in *dollar funding to Brazilian firms with external dollar debt*. By the time the first auction was conducted in April 2009, however, the markets had improved and demand had waned, so that the BCB eventually auctioned only about \$2 billion through this facility.

The BCB also took a number of domestic liquidity easing measures. These included substantial relaxations in reserve requirements, easing of collateral requirements for access to BCB domestic liquidity facilities, and other measures to facilitate credit flow. The domestic policy interest rate was not reduced until January 2009. The domestic easing measures can be

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<sup>8</sup> The foreign exchange swap reduced the “*cupom cambial*” implied dollar interest rate attached to borrowing in reais, swapping the proceeds for dollars, and then swapping the dollars back again to repay the original loan in reais.

<sup>9</sup> This operation, like the two dollar lending operations (4<sup>th</sup> and 5<sup>th</sup> bullet points), resulted in an immediate drain on reserves. However, this loss was reversed at the maturity of the swap or of the loan in question (see Annex II for more details). In addition, during the term of the operation, the BCB held dollar or local currency collateral, which potentially helped to enhance its market credibility.

seen as partly sterilizing foreign exchange easing measures, since the shock was external rather than domestic. Lending in domestic currency to firms in dire need of foreign exchange would have been of limited help because they would have had to convert the proceeds into dollars at a depreciated exchange rate, or swap for dollars using a forward market that had become much less liquid.

### III. POLICY CONTEXT

This section puts foreign exchange liquidity easing measures into sharper relief by contrasting them with the rest of the central bank policy framework. As noted earlier, at least nineteen emerging market central banks introduced some form of foreign exchange liquidity easing measure after September 2008. A discussion of how foreign exchange liquidity easing by emerging market central banks relates to the rest of the monetary framework can help shed some light on how to assess of these novel measures as well as their broader policy implications. The BCB serves as the main focus of comparison because its provision of foreign exchange liquidity was comprehensive, systematic and well documented. There appear to be overlaps with at least three other types of central bank operations, some of which are especially germane to emerging market countries. Cross-central bank currency swap agreements are considered here as well.

#### **Domestic LOLR<sup>10</sup>**

Foreign exchange liquidity easing measures overlap with standard domestic currency LOLR. “Lombard Street” is the touchstone for discussion of the terms of LOLR, although it is not always applicable to today.<sup>11</sup> So what is old and what is new is discerned here by comparing foreign exchange liquidity provision of central banks with Bagehot’s description of them (see Annex 3), updated to modern times.

Controllability of the reserves backing up liquidity provision is the main structural difference between foreign exchange liquidity easing and domestic LOLR. Central banks today can issue domestic currency reserves held at the central bank and thus control domestic liquidity provision. In contrast, foreign exchange liquidity easing requires actual or potential access to foreign currency which, of course, cannot be created by the national central bank. The central bank has immediate access to its international reserves, but these are finite (especially during a crisis) and it may or may not be able to tap financing from reserve currency central banks.

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<sup>10</sup> The literature on the different set of LOLR challenges faced by emerging market countries compared to advanced countries is limited. Calvo (2006) stresses that the vulnerability of emerging market countries to sudden stops and dollarization puts them at a disadvantage in providing domestic currency LOLR facilities.

<sup>11</sup> Madigan (2009) and Turner (2009) compare recent unconventional measures of the Fed and the Bank of England with Bagehot.

However, Bagehot dealt with a gold standard regime where reserves (in the form of gold and government and other securities and notes) were less than fully backed, which means domestic LOLR at that time was in some ways more akin to today's emerging market foreign exchange liquidity easing than to modern domestic LOLR.

The other elements of comparison pertain to the parameters of liquidity easing:

- Counterparty—Most domestic LOLR goes to banks because they are the natural central bank counterparties, although non-bank financial institutions occasionally gain access in some countries. Similarly, in Bagehot's time, banks were the counterparties for LOLR. However, Bagehot did explicitly express the view that in a panic central banks should provide liquidity to corporations. The recent foreign exchange liquidity provision by emerging market central banks, while still done using banks as counterparties, was in some cases to relieve market stresses that arose in the form of foreign exchange shortages for nonfinancial corporations, as well as for banks.<sup>12</sup>
- Timing—According to Bagehot, the central bank should lend at the immediate onset of systemic liquidity pressures rather than wait, and this is the typical approach of central banks today. The BCB began its special foreign exchange liquidity providing operations within a week after the failure of Lehman Brothers. Likewise, most emerging market central banks responded quickly to market pressures.
- Market stress and confidence—A main objective of domestic LOLR support as articulated by Bagehot is to prevent concerns over stressed banks broadening into a general loss of confidence in the currency. Foreign exchange easing by emerging economy central banks is addressed at alleviating local foreign exchange *liquidity* strains and need not be concerned about a general loss of confidence in the *value* of the foreign currency.
- Instruments—The instruments used by the Bank of England as analyzed by Bagehot were bill rediscounts and government security sales; today, domestic LOLR can be in the form of market operations or other short-term usually collateralized instruments. The BCB used derivatives to offset foreign exchange liquidity strains. As noted earlier, derivatives such as swaps and futures can be used to meet temporary liquidity needs and their effect on reserves is not permanent.

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<sup>12</sup>Oliveira and Novaes (2005) find evidence that the BCB found it expedient to provide foreign exchange liquidity directly to corporations during the episodes of foreign exchange market instability in 1999 and 2002.

- **Magnitude**—Bagehot believed that the central bank should not act cautiously but should provide the amount needed to restore confidence. Provision of foreign exchange, however, is limited by availability. In the case of Brazil, the BCB used instruments that allowed it to meet foreign currency demand while limiting the impact on reserves and without tapping the Fed swap line.
- **Collateral**—The standard description of good practice LOLR includes lending to “illiquid but solvent institutions” although distinguishing between the two is often exceedingly difficult in a crisis. Bagehot called for a relaxation of collateral standards if needed to help ensure the injection of sufficient liquidity. The term BCB foreign exchange provision was collateralized, as was that of most other central banks.
- **Interest rate**—Bagehot is often misunderstood as favoring LOLR financing at high interest rates, but in “Lombard Street” he says that high rates are for a “foreign drain” or outflow of gold reserves; he did not take an explicit view on interest rates for liquidity provision in response to domestic shocks. For emerging market countries in 2008, the foreign exchange liquidity shocks were certainly external, and foreign reserves were scarce. However, since external shocks prompt a safe haven demand for foreign currency there is no need for the central bank to raise interest rates to stem a loss of confidence. Indeed, the BCB generally made foreign exchange liquidity available at a market-determined price.
- **Transparency**—One of Bagehot’s intentions in writing “Lombard Street” was to make the case that explicit recognition by the Bank of England of its LOLR role would help maintain confidence in times of stress. The BCB was clear in its role as provider of foreign exchange liquidity, while some other emerging market central banks were less transparent.<sup>13</sup>

### **Foreign exchange market intervention**

The key difference here is that foreign exchange liquidity operations are aimed at providing *liquidity* in the event of a market breakdown, whereas spot foreign exchange intervention is intended to influence the level, rate of change, or volatility of the *exchange rate* (Calvo, 2006).<sup>14</sup> Of course, the line is very thin, especially when it comes to the use of derivatives, which some central banks appear to use to influence the exchange rate. Almost

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<sup>13</sup> de Mendonça and Filho (2008) found that increased transparency of the BCB has been associated with faster adjustment of market expectations of key asset prices.

<sup>14</sup> In making this distinction, Calvo (2006) is of the view that foreign exchange LOLR follows from an information advantage of the central bank which makes it worthwhile to circumvent the foreign exchange market and providing liquidity directly to key institutions that are important for overall economic activity.

all emerging market central banks, including the BCB, undertook standard foreign exchange market intervention during late 2008 and early 2009 to smooth exchange rate volatility.

### **Recent unconventional measures**

Foreign exchange liquidity operations also overlaps with some of the recent unconventional measures undertaken mostly by large advanced country central banks. First, several central banks have injected domestic liquidity at maturities beyond the very short-term<sup>15</sup> and have broadened counterparties; foreign exchange easing operations also are of a longer maturity than standard central bank operations, and are directed at a wider range of counterparties. Second, some foreign exchange easing measures are similar to credit easing if the maturity of directed support is relatively long and if the central bank is exposed to credit risk.<sup>16</sup> This can be the case if the central bank is locked into a long-term loan, and if the collateral is not sufficient to cover the credit risk.

### **Cross-central bank provision of foreign exchange**

The cross-central bank provision of foreign exchange is perhaps the newest aspect of the central bank policy response to the 2008–09 crisis (Obstfeld and others, 2009).<sup>17</sup> Consideration of the emergency cross-border provision of liquidity—or international LOLR—has focused on multilateral institutions (Fischer, 1999). In contrast, as discussed below, the crisis of 2008–09 was marked by the provision of foreign exchange liquidity from reserve currency central banks to the central banks of countries facing acute foreign exchange liquidity shortages. There seem to be few well-documented precedents for these measures. The cross border central bank provision of foreign exchange differs markedly from classical LOLR in that liquidity is supplied through an official institution rather than via the market or directly to the end-user. The injection of foreign exchange via central bank currency swaps is money-creating in the absence of sterilization.

## **IV. EMPIRICAL ANALYSIS**

The central empirical question is whether the BCB's measures were effective in meeting the demand for foreign exchange liquidity and relieving pressure in the dollar lending market. The secondary question is how the BCB's foreign exchange operations altered the level and volatility of the exchange rate. The effects of announcements and of the measures themselves

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<sup>15</sup> For example, the ECB has issued large amounts of liquidity at a maturity of one year.

<sup>16</sup> Credit easing is defined generally in Bernanke (2009), and addressed in the emerging market context in Ishi, Stone and Yehoue (2009).

<sup>17</sup> The Fed undertook currency swap arrangements with 14 central banks, [only the Bank of Korea and the ECB drew on the arrangements].

are gauged separately. The analysis is facilitated by the sophistication of Brazil's financial markets, the range of foreign exchange measures undertaken by the BCB in 2008–09, the transparency of the BCB and the availability of market and intervention data.

The two main groups of policy variables are:

- *Announcement* dummy variables equal to 1 on days that the BCB announces a new foreign exchange liquidity easing policy measure or extension of the measure and 0 otherwise. They are: futures intervention (Oct 23, 2008); dollar funding to Brazilian firms (Dec 11, 2008); U.S. dollar lending for export finance (Oct 17, 2008); the swap line with the U.S. Federal Reserve (Oct 29, 2008) and its extensions (Feb 3, 2009 and June 25, 2009).
- *Intervention* variables are the amounts of the BCB's daily interventions for each of the five measures described in the previous section. The foreign exchange swap auctions, U.S. dollar lending for export financing, and dollar funding to Brazilian firms are included on the day of the auction.

The estimation interval is from January 2, 2007 to June 26, 2009 based on data availability.<sup>18</sup> Weekends, holidays, and non-transaction days are excluded. During these periods, all of the above variables except for the policy variables were estimated to be  $I(1)$  processes according to unit root tests (Annex 5). Thus, first differences of them are used in the regressions. In addition, to address simultaneity bias, one-day lags of each independent variable except for the two sets of policy variables are used. Since financial markets in Brazil close earlier than those in New York, the BCB's announcements and interventions are followed by other market prices mainly set at the closing time in New York.

### **The level of the exchange rate**

The first set of results follows the standard approach to assessing the consequences of foreign exchange intervention on the behavior of the spot exchange rate (Sarno and Taylor, 2001).<sup>19</sup> While the main focus of this paper is on foreign exchange liquidity rather than the exchange rate, the consequences for the exchange rate of the varied foreign exchange measures of the

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<sup>18</sup> The data are detailed in Annex 4.

<sup>19</sup> Foreign exchange intervention is viewed as generally operating through at least one of three channels: the signaling channel, under which intervention alters the market's expectations about future fundamentals based on an information advantage on the part of the central bank; the portfolio balance channel works when the foreign exchange sales/purchases of the central banks effects a change in the relative supply of domestic versus foreign currency assets and causes a portfolio reallocation that changes their relative price; and the order flow channel is based on how order flows affect price formation.

BCB during 2008–09 are of interest in their own right because they were implemented in a crisis situation, and because data availability and the clear policy intentions facilitate empirical assessment.<sup>20</sup>

The following specification is used here:

$$\Delta Y_t^j = a + b_1 \text{Announcement}_t + b_2 \text{Intervention}_t + b_{3i}(L)\Delta \text{SPREAD}_{t-i} + b_{4i}(L)\Delta \text{STOCK}_{t-i} + b_{5i}(L)\Delta \text{SP500}_{t-i} + b_{6i}(L)\Delta \text{COMMODITY}_{t-i} + c_i(L)\Delta Y_{t-i}^j + \varepsilon_t$$

where  $\Delta Y_t^j$ , the dependent variable, is the logarithmic change in the spot exchange rate (Brazilian real per U.S. dollar).<sup>21</sup> Macroeconomic (“fundamental”) control variables comprise changes in the U.S.-Brazil short-term interest rate spreads, log changes in domestic stock market prices, logarithmic changes in the US stock market prices, and logarithmic changes in commodity price indices. The other controls are  $\Delta \text{SPREAD}_t$ , the logarithmic change in the spread between US short-term interest rate and Brazilian short-term interest rate (expected positive sign);  $\Delta \text{STOCK}$ , the logarithmic change in the Bovespa index (expected negative sign);  $\Delta \text{SP500}$  is the logarithmic change in the U.S. Standard and Poor’s 500 index (expected negative sign); and  $\Delta \text{COMMODITY}_t$  is the logarithmic change in the commodity price index, (expected negative sign). A negative parameter estimate means the explanatory variable appreciates the exchange rate.

The estimation results suggest that the announcements have a bigger effect on the exchange rate than do the actual interventions (Table 2). The estimated parameters for all of the BCB’s announcements except the dollar export financing are negative and statistically significant. With regard to the interventions themselves, the coefficient of the spot market intervention is statistically significant and of the expected sign, but the magnitude is not large (a sale of \$1 billion appreciates the spot exchange rate by 0.3–0.4 percent). The coefficients on the

<sup>20</sup> The empirical literature on the impact of emerging country central bank intervention on the spot exchange rate has yielded mixed results. Disyatat and Galati (2007) employed daily data and official statistics on central bank intervention by the Czech National Bank to conclude that intervention has a limited impact on the spot exchange rate. Tapia and Tokman (2004) found that the signaling channel was important in Chile. Egert and Komarek (2005, 2006) show that from 1997 to mid-1998, koruna purchases were fairly ineffective, though from mid-1998 to 2002, koruna sales were effective in smoothing the path of the exchange rate. Galati and Melick (2002) point out that the portfolio balance channel is potentially more effective in a smaller, less developed financial market where the scale of the central bank’s intervention capacity is comparatively large. The signaling channel may be weaker in most emerging market countries because central banks have a shorter track record and relatively less credibility (c.f. Domac and Mendoza (2002) for Mexico and Turkey). Thus, effective signaling for emerging markets may require larger interventions (Canales-Kriljenko, Pereira Guimarães and Karacadag, 2003).

<sup>21</sup> The data are described in more detail in Annex 4.

foreign exchange market liquidity operations are statistically insignificant, consistent with the operations' objective of targeting dollar liquidity shortfalls rather than the exchange rate. Equation 5 is for the period since August 9, 2007, when BNP Paribas announced the freeze on investment fund redemptions. This change of the sample periods does not meaningfully alter the coefficient estimates.

**Table 2. Estimates of the Effect of the BCB's Announcements and Interventions on the Spot Rate**

|  |   | Dependent Variable: Spot rate |                |                   |                |                   |                |                   |                |                   |     |
|--|---|-------------------------------|----------------|-------------------|----------------|-------------------|----------------|-------------------|----------------|-------------------|-----|
| Period from                                  |   | 1/2/2007                      | 1/2/2007       | 1/2/2007          | 1/2/2007       | 1/2/2007          | 1/2/2007       | 1/2/2007          | 1/2/2007       | 8/9/2007          |     |
| to   |   | 6/26/2009                     | 6/26/2009      | 6/26/2009         | 6/26/2009      | 6/26/2009         | 6/26/2009      | 6/26/2009         | 6/26/2009      | 6/26/2009         |     |
| Observations                                 |   | 622                           | 622            | 622               | 622            | 622               | 622            | 622               | 622            | 472               |     |
|  |   | (eq1)                         | (eq2)          | (eq3)             | (eq3)          | (eq4)             | (eq4)          | (eq4)             | (eq4)          | (eq5)             |     |
| BCB's announcement on F/X operations         |   |                               |                |                   |                |                   |                |                   |                |                   |     |
| ①  | BCB's announcement on dollar lending (10/17/2008)               | -0.009<br>(0.058)             | *<br>(0.499)   | -0.004<br>(0.499) |                | -0.002<br>(0.761) |                | -0.010<br>(0.001) | ***            | -0.008<br>(0.067) | *   |
| ②  | BCB's announcement on futures market intervention (10/23/2008)  | -0.047<br>(0.000)             | ***<br>(0.000) | -0.046<br>(0.000) | ***<br>(0.000) | -0.047<br>(0.000) | ***<br>(0.000) | -0.046<br>(0.000) | ***<br>(0.000) | -0.046<br>(0.000) | *** |
| ③  | Swap line with US Fed (10/29/2008)                              | -0.017<br>(0.000)             | ***<br>(0.000) | -0.015<br>(0.004) | ***<br>(0.004) | -0.015<br>(0.019) | **<br>(0.000)  | -0.018<br>(0.000) | ***<br>(0.000) | -0.017<br>(0.001) | *** |
| ④  | BCB's announcement on non-trade-based dollar loans (12/11/2008) | -0.037<br>(0.000)             | ***<br>(0.000) | -0.038<br>(0.000) | ***<br>(0.000) | -0.036<br>(0.000) | ***<br>(0.000) | -0.037<br>(0.000) | ***<br>(0.000) | -0.038<br>(0.000) | *** |
| ⑤  | 1st Extension on the swap line with US Fed (2/3/2009)           | -0.004<br>(0.001)             | ***<br>(0.001) | -0.003<br>(0.041) | **<br>(0.041)  | -0.003<br>(0.005) | ***<br>(0.005) | -0.004<br>(0.000) | ***<br>(0.000) | -0.004<br>(0.004) | *** |
| ⑥  | 2nd Extension on the swap line with US Fed (6/25/2009)          | -0.014<br>(0.000)             | ***<br>(0.000) | -0.015<br>(0.000) | ***<br>(0.000) | -0.014<br>(0.000) | ***<br>(0.000) | -0.016<br>(0.000) | ***<br>(0.000) | -0.015<br>(0.000) | *** |
| Types of BCB's F/X operations                |   |                               |                |                   |                |                   |                |                   |                |                   |     |
| ①  | Spot market intervention  | -0.003<br>(0.019)             | **<br>(0.030)  | -0.002<br>(0.030) | **<br>(0.031)  | -0.003<br>(0.031) | **<br>(0.031)  | -0.003<br>(0.015) | **<br>(0.015)  | -0.004<br>(0.032) | **  |
| ②  | Futures market intervention                                     | 0.001<br>(0.583)              |                | 0.001<br>(0.495)  |                | 0.001<br>(0.533)  |                | 0.001<br>(0.584)  |                | 0.001<br>(0.701)  |     |
| ③  | F/X swap auctions   | 0.003<br>(0.146)              |                | 0.002<br>(0.815)  |                | 0.002<br>(0.822)  |                | 0.003<br>(0.805)  |                | 0.003<br>(0.725)  |     |
| ④  | Dollar lending  | 0.007<br>(0.109)              |                | 0.007<br>(0.182)  |                | 0.007<br>(0.165)  |                | 0.007<br>(0.158)  |                | 0.006<br>(0.182)  |     |
| ⑤  | Non-trade-based dollar loans                                    | -0.021<br>(0.112)             |                | -0.021<br>(0.108) |                | -0.022<br>(0.102) |                | -0.019<br>(0.082) |                | -0.021<br>(0.123) |     |
| Control Variables                            |   |                               |                |                   |                |                   |                |                   |                |                   |     |
|  | ΔSPREAD (-1)  | 0.006                         |                | 0.006             |                | 0.006             |                |                   |                | 0.006             |     |
|  | ΔSPREAD (-2)  |                               |                |                   |                | 0.001             |                |                   |                |                   |     |
|  | ΔSTOCK (-1)   | 0.017                         |                | 0.074             |                | 0.017             |                |                   |                | 0.019             |     |
|  | ΔSTOCK (-2)   |                               |                |                   |                | 0.058             |                |                   |                |                   |     |
|  | ΔSP500 (-1)   |                               |                | -0.108            |                |                   |                |                   |                |                   |     |
|  | ΔSP500 (-2)   |                               |                |                   |                |                   |                |                   |                |                   |     |
|  | ΔCRB (-1)   |                               |                | -0.001            |                |                   |                |                   |                |                   |     |
|  | ΔCRB (-2)   |                               |                |                   |                |                   |                |                   |                |                   |     |
|  | ΔRaw Sugar Price (-1)   | -0.019                        |                |                   |                | -0.035            | *              |                   |                | -0.023            |     |
|  | ΔRaw Sugar Price (-2)   |                               |                |                   |                | -0.027            |                |                   |                |                   |     |
|  | ΔSpot rate (-1)   | -0.069                        |                | -0.087            |                | -0.078            |                | -0.081            |                | -0.072            |     |
|  | ΔSpot rate (-2)   |                               |                |                   |                | -0.005            |                | 0.234             |                |                   |     |
| Adjusted-R square                            |   | 0.047                         |                | 0.053             |                | 0.054             |                | 0.043             |                | 0.050             |     |
| Schwarz information criterion                |   | -5.568                        |                | -5.566            |                | -5.539            |                | -5.591            |                | -5.311            |     |
| Breusch-Godfrey LM test (F stat, a lag of 1) |   | 2.117                         |                | 1.467             |                | 0.280             |                | 1.341             |                | 2.895             | *   |
| Breusch-Pagan-Godfrey test (F stat)          |   | 5.476                         | ***            | 7.004             | ***            | 4.380             | ***            | 7.284             | ***            | 4.017             | *** |

Notes: 1. P-values are reported in parentheses, ( ), on the basis of White heteroskedasticity-consistent standard errors for eq1-4, or on the basis of Newey-West HAC standard errors for eq5.

2. \*\*\*, \*\*, and \* denotes significance at the one, five, and ten percent levels.



### The implied volatility of the exchange rate

The next set of results is for the influence of the BCB's measures on the implied volatility of the exchange rate (Table 3). Implied volatility can be interpreted as a simple estimate of the dispersion of the market's subjective probability distribution and is often used, including by central banks, as a predictor of future price developments.<sup>22</sup> For Brazil, de Andrade and Tabak (2001) concluded that currency options traded on the BMF embed information over and above that from past returns and can therefore inform expectations about future exchange rate volatility over the life of the contract. This paper uses a daily series of implied volatility derived from the actively traded options on the BMF for the exchange rate calculated by Bloomberg.

The few studies that have analyzed foreign exchange interventions and implied volatility have attained mixed results. Rogers and Siklos (2003) show that interventions effectively reduced implied volatility in the case of the Reserve Bank of Australia, but not in the case of the Bank of Canada. Other studies on advanced countries have concluded that intervention increased implied volatility.

The specification here follows that of Rogers and Siklos (2003) and is essentially the same as for the spot exchange rate. Here, the expected sign for  $\Delta SPREAD_t$  is ambiguous, while those for  $\Delta STOCK$  and  $\Delta SP500$  and  $\Delta COMMODITY_t$  are negative if market participants' uncertainty about the economy declines with an improvement in fundamentals.

The results suggest that during a period of extreme uncertainty—as late 2008 and early 2009 certainly was—the announcement of new central bank foreign exchange measures can assuage market expectations of prospective exchange rate volatility (Table 3). The announcements of the swap line with the Fed and non-trade-based dollar loans are estimated to have reduced implied volatility by 6 to 9 percent. However, the coefficient of the announcement on futures market intervention is positive (greater volatility) and statistically significant. The coefficients on the actual interventions are not statistically significant. Among the control variables, only the coefficient of  $\Delta STOCK$  is negative and statistically significant, and only in equations 1, 3, and 5.

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<sup>22</sup> The implied volatility is obtained from the Black-Scholes formula by computing the volatility value that equates the Black-Scholes price with the market price.

**Table 3. Estimates of the Effect of the BCB's Announcements and Interventions on the Implied Volatility**

| Dependent Variable: Implied volatility                            |              |                       |                       |                       |                       |                       |           |           |           |           |
|---|--------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------|-----------|-----------|-----------|
|   | Period Start | 1/2/2007              | 1/2/2007              | 1/2/2007              | 1/2/2007              | 8/9/2007              |           |           |           |           |
|   | Period End   | 6/26/2009             | 6/26/2009             | 6/26/2009             | 6/26/2009             | 6/26/2009             | 6/26/2009 | 6/26/2009 | 6/26/2009 | 6/26/2009 |
|   | Observations | 622                   | 622                   | 622                   | 622                   | 622                   | 622       | 472       |           |           |
|   |              | (eq1)                 | (eq2)                 | (eq3)                 | (eq4)                 | (eq5)                 |           |           |           |           |
| BCB's announcement on F/X operations                              |              |                       |                       |                       |                       |                       |           |           |           |           |
| ① BCB's announcement on dollar lending (10/17/2008)               |              | -0.064 ***<br>(0.000) | -0.054 ***<br>(0.000) | -0.050 **<br>(0.010)  | -0.064 ***<br>(0.000) | -0.063 ***<br>(0.000) |           |           |           |           |
| ② BCB's announcement on futures market intervention (10/23/2008)  |              | 0.051 **<br>(0.017)   | 0.052 **<br>(0.014)   | 0.054 ***<br>(0.007)  | 0.063 ***<br>(0.002)  | 0.048 **<br>(0.045)   |           |           |           |           |
| ③ Swap line with US Fed (10/29/2008)                              |              | -0.060 ***<br>(0.000) | -0.057 ***<br>(0.000) | -0.069 ***<br>(0.000) | -0.087 ***<br>(0.000) | -0.062 ***<br>(0.000) |           |           |           |           |
| ④ BCB's announcement on non-trade-based dollar loans (12/11/2008) |              | -0.072 ***<br>(0.000) | -0.073 ***<br>(0.000) | -0.068 ***<br>(0.000) | -0.075 ***<br>(0.000) | -0.073 ***<br>(0.000) |           |           |           |           |
| ⑤ 1st Extension on the swap line with US Fed (2/3/2009)           |              | -0.023 ***<br>(0.000) | -0.022 ***<br>(0.000) | -0.021 ***<br>(0.000) | -0.021 ***<br>(0.000) | -0.023 ***<br>(0.000) |           |           |           |           |
| ⑥ 2nd Extension on the swap line with US Fed (6/25/2009)          |              | -0.013 ***<br>(0.000) | -0.013 ***<br>(0.000) | -0.011 ***<br>(0.000) | -0.014 ***<br>(0.000) | -0.014 ***<br>(0.000) |           |           |           |           |
| Types of BCB's F/X operations                                     |              |                       |                       |                       |                       |                       |           |           |           |           |
| ① Spot market intervention  |              | -0.008 **<br>(0.041)  | -0.007 **<br>(0.046)  | -0.008 *<br>(0.063)   | -0.008 **<br>(0.040)  | -0.009 *<br>(0.058)   |           |           |           |           |
| ② Futures market intervention                                     |              | -0.001<br>(0.695)     | -0.001<br>(0.740)     | -0.001<br>(0.738)     | -0.001<br>(0.777)     | -0.001<br>(0.801)     |           |           |           |           |
| ③ F/X swap auctions   |              | 0.002<br>(0.948)      | 0.002<br>(0.962)      | 0.001<br>(0.970)      | 0.004<br>(0.916)      | 0.002<br>(0.964)      |           |           |           |           |
| ④ Dollar lending  |              | 0.003<br>(0.756)      | 0.003<br>(0.762)      | 0.003<br>(0.746)      | 0.003<br>(0.714)      | 0.003<br>(0.766)      |           |           |           |           |
| ⑤ Non-trade-based dollar loans                                    |              | -0.005<br>(0.433)     | -0.006<br>(0.401)     | -0.005<br>(0.450)     | -0.006<br>(0.424)     | -0.007<br>(0.317)     |           |           |           |           |
| Control Variables   |              |                       |                       |                       |                       |                       |           |           |           |           |
| ΔSPREAD(-1)   |              | 0.012                 | 0.012                 | 0.012                 |                       | 0.015                 |           |           |           |           |
| ΔSPREAD(-2)   |              |                       |                       | -0.004                |                       |                       |           |           |           |           |
| ΔSTOCK(-1)  |              | -0.191 **             | -0.094                | -0.182 *              |                       | -0.170 *              |           |           |           |           |
| ΔSTOCK(-2)  |              |                       |                       | 0.007                 |                       |                       |           |           |           |           |
| ΔSP500(-1)  |              |                       | -0.171                |                       |                       |                       |           |           |           |           |
| ΔSP500(-2)  |              |                       |                       |                       |                       |                       |           |           |           |           |
| ΔCRB(-1)  |              |                       | 0.003                 |                       |                       |                       |           |           |           |           |
| ΔCRB(-2)  |              |                       |                       |                       |                       |                       |           |           |           |           |
| ΔRaw Sugar Price (-1)   |              | -0.036                |                       | -0.055                |                       | -0.020                |           |           |           |           |
| ΔRaw Sugar Price (-2)   |              |                       |                       | -0.054                |                       |                       |           |           |           |           |
| ΔImplied volatility(-1)   |              | 0.101                 | 0.099                 | 0.115                 | 0.154                 | 0.128                 |           |           |           |           |
| ΔImplied volatility(-2)   |              |                       |                       | -0.075                |                       |                       |           |           |           |           |
| Adjusted-R square   |              | 0.059                 | 0.060                 | 0.061                 | 0.047                 | 0.073                 |           |           |           |           |
| Schwarz information criterion                                     |              | -3.497                | -3.489                | -3.462                | -3.510                | -3.369                |           |           |           |           |
| Breusch-Godfrey LM test (F stat, a lag of 1)                      |              | 0.454                 | 0.560                 | 3.839 *               | 2.037                 | 0.079                 |           |           |           |           |
| Breusch-Pagan-Godfrey test (F stat)                               |              | 5.432 ***             | 5.236 ***             | 5.064 ***             | 6.533 ***             | 4.432 ***             |           |           |           |           |

Notes: 1. P-values are reported in parentheses, ( ), on the basis of White heteroskedasticity-consistent standard errors for eq1,eq2,eq4 and eq5, or on the basis of Newey-West HAC standard errors for eq3.

2. \*\*\*, \*\*, and \* denotes significance at the one, five, and ten percent levels.

## The basis spread

The main empirical results of this paper are for the effects of the BCB's foreign exchange liquidity easing measures on the basis spread—the difference between the *cupom cambial* and U.S. dollar LIBOR. The *cupom cambial* is:

$$i_{\$implied} = i_{Brazil} + (e-f)/e,$$

where  $e$  is the real/dollar exchange rate,  $f$  is the 90-day forward exchange rate, and  $i_{Brazil}$  is the local 90-day treasury-bill rate. The basis spread is:

$$BasisSpread_t = i_{\$implied} - i_{\$LIBOR}.$$

This spread captures the relative dollar funding cost faced by Brazilian firms and therefore is a good market-based measure of local dollar liquidity. This paper appears to be the first to empirically assess the effectiveness of emerging market central bank foreign exchange liquidity easing measures on this indicator.

The empirical basis spread literature is quite small and Baba and Packer (2008) is the most relevant for this paper. Baba and Packer model the spread between euro area U.S.-euro dollar swap-implied rates and the LIBOR rates as determined by credit and liquidity risk factors. Credit risk is captured by the difference in counterparty risks of U.S. and euro area banks as proxied by CDS spread differences. Applying the EGARCH (exponential generalized autoregressive conditional heteroskedasticity) model (Nelson, 1991) to the level and volatility of the basis spread, they find that the ECB's dollar term funding auctions were effective in reducing the volatility of the basis spread but not the level.

The empirical model used here is similar to that of Baba and Packer (2008):

Mean equation:

$$BasisSpread_t = a + b_1 Announcement_t + b_2 Intervention_t + b_3 CounterpartyRisk_t \\ + \sum BasisSpread_{t-i} + \varepsilon_t \\ \varepsilon_t \sim N(0, \sigma_t^2)$$

Variance equation:

$$\ln(\sigma_t^2) = \alpha + \beta(|\varepsilon_{t-1}|/\sigma_{t-1} - \sqrt{2/\pi}) + \gamma\varepsilon_{t-1}/\sigma_{t-1} + \eta \ln(\sigma_{t-1}^2) + \lambda_1 Announcement_t + \lambda_2 Intervention_t$$

In the mean equation,  $BasisSpread_t$  is the spread between three-month *cupom cambial* and three-month U.S. dollar LIBOR rate (hereafter, three-month basis spread against LIBOR<sup>23</sup>). Weekends, holidays, and non-transaction days are excluded.

The announcement and intervention policy variables are the same as in the two previous empirical estimates.  $CounterpartyRisk_t$  is the counterparty risk between Brazilian banks and U.S. banks; since CDS spreads or other credit risk proxies are not available for Brazilian banks, the sovereign EMBI spread for Brazil is used. Lags of the basis spread in the mean equation are included, given indications of an autoregressive component. The error term of the mean equation is assumed to be distributed normally, with the variance ( $\sigma^2$ ) of the error term depending on its own lagged values and the realized errors as well as the policy and control variables. The extent to which the variability of returns may increase with negative returns is indicated by  $\gamma$ .<sup>24</sup> Volatility persistence can be measured by  $\eta$ .  $\lambda_1$  and  $\lambda_2$  are the coefficients of the BCB's announcements and its operations, respectively. All of the variables except for EMBI spreads of Brazil are I(0) processes as indicated by unit root tests<sup>25</sup> during the period of the study. In particular, the basis spread is found to be a stationary process with a constant. Thus, a constant term is included in the mean equation. Since the EMBI spread for Brazil is estimated as an I(1) process, its first difference is used in the equation. A negative sign on the coefficients means the explanatory variable reduces the mean or volatility of the basis spread. All of the measures, with one exception, would be expected to reduce mean or volatility of the basis spread. The exception is the futures dollar sale, because this reduces the expected value of the dollar and thus could be expected to increase the implied dollar interest rate (Annex 1) and have a positive estimated coefficient.

The estimation results are striking in that for most of the measures both the announcements and operations lower the mean of the basis spread (Table 4). The biggest effect is for the announcement on the swap line with the Fed, which reduced the basis by more than 300 basis points across all the specifications. Also significant are the announcements of futures and exporter loan facilities, and the second extension of the Fed's swap line. The announcement of the futures operations has the expected positive sign. The positive dollar lending announcement coefficient is the opposite of what is expected.

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<sup>23</sup> The three-month basis spread against OIS (Overnight Index Swap) (in place of LIBOR) was also checked. This measure is preferable in theory, as the LIBOR rate incorporated a large credit risk component during the crisis, while OIS is generally regarded as a approximation of the risk-free rate. The results, shown in Annex 5, are not substantially different from those obtained from using a three-month basis spread against LIBOR rate.

<sup>24</sup> This is sometimes referred to as the "leverage" effect.

<sup>25</sup> The unit root tests are reported in Annex 4.

For the variance of the basis spread, the second equation, the announcements are generally more effective than the interventions themselves in reducing volatility. Again, the announcement on the swap line with the Fed had the biggest stabilizing effect, but almost all of the other announcement coefficients are negative as expected. The effects of the interventions are mixed.

### **Caveats**

The estimates of all three equations may be affected by simultaneity problems, despite the use of daily data. Many interventions are aimed at addressing intraday price developments, of the type that may not be captured in the daily data. For example, the central bank may intervene in the futures or dollar loan market in response to a sudden increase in dollar spreads during morning trading. Such an intervention could have the desired effect of bringing down dollar spreads, but if the closing spread from that day's trading is higher than that of the previous day, the impact of the intervention would not appear in the regression. This problem would be reduced or eliminated if data were available on prices immediately before specific interventions.

The empirical analysis is by no means a complete picture of success of the policy measures. The regressions offer only a partial picture because they gauge the immediate market response to announcements, as opposed to their lasting macroeconomic consequences. Still, during a crisis, when confidence is low, the announcement impact can be an important motivation for policy measures compared to normal circumstances. Further, short-term market responses to policy announcements can be expected to capture market expectations of their longer term success.

**Table 4. Estimates of the Effect of the BCB's Announcements and Interventions on Basis Spread**

Dependent Variable: **Basis spread against Libor**

|  | Mean equation                     |                                       |                                       |                                       |                                       |                                       |                                       |       |                     |       |                     |       |
|--|-----------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|-------|---------------------|-------|---------------------|-------|
|  | Period from<br>to<br>Observations | 2007/1/2<br>2009/6/26<br>567<br>(eq1) | 2007/1/2<br>2009/6/26<br>566<br>(eq2) | 2007/1/2<br>2009/6/26<br>567<br>(eq3) | 2007/8/9<br>2009/6/26<br>419<br>(eq4) | 2007/8/9<br>2009/6/26<br>419<br>(eq5) | 2007/8/9<br>2009/6/26<br>419<br>(eq6) |       |                     |       |                     |       |
| BCB's announcement on F/X operations                                 |                                   |                                       |                                       |                                       |                                       |                                       |                                       |       |                     |       |                     |       |
| ① BCB's announcement on dollar lending<br>(10/17/2008)               | 107.949<br>(0.000)                | ***                                   | 96.879<br>(0.000)                     | ***                                   | 101.696<br>(0.000)                    | ***                                   | 92.110<br>(0.000)                     | ***   | 95.679<br>(0.000)   | ***   | 90.839<br>(0.000)   | ***   |
| ② BCB's announcement on futures market intervention<br>(10/23/2008)  | 179.585<br>(0.015)                | **                                    | 153.700<br>(0.000)                    | ***                                   | 160.310<br>(0.000)                    | ***                                   | 149.021<br>(0.000)                    | ***   | 152.390<br>(0.000)  | ***   | 154.623<br>(0.000)  | ***   |
| ③ Swap line with US Fed<br>(10/29/2008)                              | -316.810<br>(0.000)               | ***                                   | -327.607<br>(0.000)                   | ***                                   | -324.436<br>(0.000)                   | ***                                   | -315.631<br>(0.000)                   | ***   | -331.035<br>(0.000) | ***   | -337.412<br>(0.000) | ***   |
| ④ BCB's announcement on non-trade-based dollar loans<br>(12/11/2008) | -34.409<br>(0.002)                | ***                                   | -46.918<br>(0.000)                    | ***                                   | -44.237<br>(0.000)                    | ***                                   | -38.012<br>(0.000)                    | ***   | -45.480<br>(0.000)  | ***   | -47.803<br>(0.000)  | ***   |
| ⑤ 1st Extension on the swap line with US Fed<br>(2/3/2009)           | 41.407<br>(0.122)                 |                                       | 11.729<br>(0.000)                     | ***                                   | 10.981<br>(0.000)                     | ***                                   | 11.036<br>(0.016)                     | **    | 10.053<br>(0.001)   | ***   | 5.971<br>(0.099)    | *     |
| ⑥ 2nd Extension on the swap line with US Fed<br>(6/25/2009)          | 3.753<br>(0.901)                  |                                       | -19.770<br>(0.000)                    | ***                                   | -19.431<br>(0.000)                    | ***                                   | -13.997<br>(0.221)                    |       | -19.729<br>(0.000)  | ***   | -20.118<br>(0.000)  | ***   |
| Types of BCB's F/X operations  |                                   |                                       |                                       |                                       |                                       |                                       |                                       |       |                     |       |                     |       |
| ① Spot market intervention   | -6.342<br>(0.000)                 | ***                                   | -4.556<br>(0.022)                     | **                                    | -6.820<br>(0.001)                     | ***                                   | -2.652<br>(0.413)                     |       | -1.565<br>(0.642)   |       | -4.402<br>(0.179)   |       |
| ② Futures market intervention  | 4.793<br>(0.001)                  | ***                                   | 5.576<br>(0.000)                      | ***                                   | 4.766<br>(0.003)                      | ***                                   | 7.378<br>(0.001)                      | ***   | 5.239<br>(0.036)    | **    | 7.519<br>(0.005)    | ***   |
| ③ F/X Swap Auctions  | -86.570<br>(0.000)                | ***                                   | -76.381<br>(0.000)                    | ***                                   | -76.524<br>(0.000)                    | ***                                   | -52.148<br>(0.001)                    | ***   | -60.151<br>(0.000)  | ***   | -49.716<br>(0.002)  | ***   |
| ④ Dollar lending   | -27.808<br>(0.245)                |                                       | -4.683<br>(0.826)                     |                                       | -13.893<br>(0.481)                    |                                       | -12.405<br>(0.501)                    |       | -13.715<br>(0.508)  |       | -6.829<br>(0.752)   |       |
| ⑤ Non-trade-based dollar loans                                       | -323.588<br>(0.000)               | ***                                   | -311.609<br>(0.000)                   | ***                                   | -326.476<br>(0.000)                   | ***                                   | -321.317<br>(0.000)                   | ***   | -314.574<br>(0.000) | ***   | -314.229<br>(0.000) | ***   |
| Basis spread <sub>t-1</sub>  | 0.692<br>(0.000)                  | ***                                   | 0.675<br>(0.000)                      | ***                                   | 0.689<br>(0.000)                      | ***                                   | 0.684<br>(0.000)                      | ***   | 0.673<br>(0.000)    | ***   | 0.672<br>(0.000)    | ***   |
| Basis spread <sub>t-2</sub>  | 0.104<br>(0.000)                  | ***                                   | 0.079<br>(0.002)                      | ***                                   | 0.101<br>(0.000)                      | ***                                   | 0.098<br>(0.000)                      | ***   | 0.065<br>(0.071)    | *     | 0.068<br>(0.054)    | *     |
| Basis spread <sub>t-3</sub>  |                                   |                                       | 0.042<br>(0.028)                      | **                                    |                                       |                                       |                                       |       | 0.059<br>(0.024)    | **    | 0.042<br>(0.133)    |       |
| ΔEMBI Spread   |                                   |                                       |                                       |                                       | -0.202<br>(0.001)                     | ***                                   |                                       |       |                     |       | -0.264<br>(0.002)   | ***   |
| Constant   | 18.153<br>(0.000)                 | ***                                   | 18.886<br>(0.000)                     | ***                                   | 18.990<br>(0.000)                     | ***                                   | 20.842<br>(0.000)                     | ***   | 19.377<br>(0.000)   | ***   | 20.555<br>(0.000)   | ***   |
| Variance equation  |                                   |                                       |                                       |                                       |                                       |                                       |                                       |       |                     |       |                     |       |
| α  | 5.821<br>(0.000)                  | ***                                   | 6.508<br>(0.000)                      | ***                                   | 6.794<br>(0.000)                      | ***                                   | 6.683<br>(0.000)                      | ***   | 6.406<br>(0.000)    | ***   | 7.013<br>(0.000)    | ***   |
| β  | 0.919<br>(0.000)                  | ***                                   | 0.799<br>(0.000)                      | ***                                   | 0.740<br>(0.000)                      | ***                                   | 0.716<br>(0.000)                      | ***   | 0.751<br>(0.000)    | ***   | 0.656<br>(0.000)    | ***   |
| γ  | 0.110<br>(0.126)                  |                                       | 0.189<br>(0.004)                      | ***                                   | 0.151<br>(0.017)                      | **                                    | 0.326<br>(0.000)                      | ***   | 0.352<br>(0.000)    | ***   | 0.259<br>(0.000)    | ***   |
| η  | 0.074<br>(0.001)                  | ***                                   | -0.011<br>(0.709)                     |                                       | -0.046<br>(0.156)                     |                                       | 0.012<br>(0.725)                      |       | 0.049<br>(0.226)    |       | -0.027<br>(0.634)   |       |
| BCB's announcement on F/X operations                                 |                                   |                                       |                                       |                                       |                                       |                                       |                                       |       |                     |       |                     |       |
| ① BCB's announcement on dollar lending<br>(10/17/2008)               | -3.380<br>(0.826)                 |                                       | -11.592<br>(0.000)                    | ***                                   | -4.293<br>(0.648)                     |                                       | -11.129<br>(0.000)                    | ***   | -15.882<br>(0.001)  | ***   | -12.702<br>(0.000)  | ***   |
| ② BCB's announcement on futures market intervention<br>(10/23/2008)  | -5.711<br>(0.423)                 |                                       | -19.479<br>(0.000)                    | ***                                   | -24.665<br>(0.000)                    | ***                                   | -16.817<br>(0.000)                    | ***   | -17.060<br>(0.006)  | ***   | -18.443<br>(0.000)  | ***   |
| ③ Swap line with US Fed<br>(10/29/2008)                              | -15.472<br>(0.018)                | **                                    | -22.459<br>(0.001)                    | ***                                   | -21.090<br>(0.000)                    | ***                                   | -21.810<br>(0.000)                    | ***   | -20.491<br>(0.001)  | ***   | -17.167<br>(0.001)  | ***   |
| ④ BCB's announcement on non-trade-based dollar loans<br>(12/11/2008) | -3.833<br>(0.759)                 |                                       | -11.836<br>(0.000)                    | ***                                   | -13.420<br>(0.000)                    | ***                                   | -4.349<br>(0.848)                     |       | -11.225<br>(0.000)  | ***   | -12.266<br>(0.000)  | ***   |
| ⑤ 1st Extension on the swap line with US Fed<br>(2/3/2009)           | 0.165<br>(0.980)                  |                                       | -8.646<br>(0.000)                     | ***                                   | -8.768<br>(0.000)                     | ***                                   | -7.846<br>(0.000)                     | ***   | -9.120<br>(0.000)   | ***   | -9.982<br>(0.000)   | ***   |
| ⑥ 2nd Extension on the swap line with US Fed<br>(6/25/2009)          | -0.099<br>(0.987)                 |                                       | -6.165<br>(0.004)                     | ***                                   | -9.000<br>(0.000)                     | ***                                   | -3.309<br>(0.746)                     |       | -9.121<br>(0.000)   | ***   | -10.004<br>(0.000)  | ***   |
| Types of BCB's F/X operations  |                                   |                                       |                                       |                                       |                                       |                                       |                                       |       |                     |       |                     |       |
| ① Spot market intervention   | 0.001<br>(0.990)                  |                                       | -0.027<br>(0.725)                     |                                       | 0.041<br>(0.603)                      |                                       | -0.243<br>(0.003)                     | ***   | -0.276<br>(0.001)   | ***   | -0.227<br>(0.009)   | ***   |
| ② Futures market intervention  | 0.639<br>(0.000)                  | ***                                   | 0.619<br>(0.000)                      | ***                                   | 0.669<br>(0.000)                      | ***                                   | 0.540<br>(0.001)                      | ***   | 0.527<br>(0.001)    | ***   | 0.607<br>(0.000)    | ***   |
| ③ F/X Swap Auctions  | 2.302<br>(0.000)                  | ***                                   | 1.634<br>(0.000)                      | ***                                   | 1.690<br>(0.000)                      | ***                                   | 1.256<br>(0.000)                      | ***   | 1.151<br>(0.000)    | ***   | 1.137<br>(0.000)    | ***   |
| ④ Dollar lending   | 0.694<br>(0.429)                  |                                       | 0.656<br>(0.367)                      |                                       | 0.584<br>(0.459)                      |                                       | 0.426<br>(0.597)                      |       | 0.513<br>(0.542)    |       | 0.325<br>(0.693)    |       |
| ⑤ Non-trade-based dollar loans                                       | -17.900<br>(0.334)                |                                       | -16.624<br>(0.000)                    | ***                                   | -14.818<br>(0.000)                    | ***                                   | -17.878<br>(0.288)                    |       | -2.970<br>(0.501)   |       | -16.610<br>(0.000)  | ***   |
| Adjusted-R square  |                                   | 0.570                                 |                                       | 0.581                                 |                                       | 0.580                                 |                                       | 0.581 |                     | 0.578 |                     | 0.584 |

Notes: 1. p-values are in parentheses, ( ).

2. \*\*\*, \*\*, and \* denotes significance at the one, five, and ten percent levels.

## V. CLOSING THOUGHTS

The main conclusion of this paper is that the foreign exchange easing measures undertaken by the BCB during 2008–09 seemed to have alleviated the various market stresses arising from local dollar liquidity shortage, at least on impact. The announcements and to a lesser extent the interventions themselves reduced the relative cost of onshore dollar financing. The varied foreign exchange operations also appeared to have stabilized market expectations of exchange rate volatility. The positive effects of the announcements of the currency swap facility between the Fed and BCB across the three regressions strongly suggest that this arrangement helped boost confidence.

Of course, these results may not hold for all central banks in all circumstances. The apparent effectiveness of the foreign exchange measures of the BCB can be attributed to the sophistication of the financial markets in Brazil which allowed the effective use of derivatives. The BCB also was perceived as having a successful track record during previous episodes of exchange rate instability, and has earned credibility since the adoption of inflation targeting.

Still, the provision of foreign exchange liquidity under conditions of stress may well become a standard policy tool and thus the less well understood aspects warrant further thinking. Why do the announcement effects on prices and expectations seem to outweigh the actual implementation effects, as suggested by the empirical results? Under what conditions should derivatives, as opposed to spot sales, be used to supply foreign exchange liquidity? How should central banks be held accountable for the effectiveness of foreign exchange liquidity provision? Is there a place for cross-central bank liquidity arrangements? Does the role of derivatives in facilitating foreign exchange liquidity provision by the BCB strengthen the general case for developing sophisticated financial markets in emerging market countries?

In some respects, Avenida Paulista today may not be so far from the Lombard Street of the 19<sup>th</sup> century. Financial globalization now necessitates the provision of foreign exchange liquidity, in addition to domestic LOLR. The approaches of Bagehot in domestic LOLR and the BCB in foreign exchange liquidity provision are similar in that both are designed to inject large amounts of liquidity via a wider set of counterparties and with limited control over availability. However, the foreign exchange liquidity providing central bank of today can utilize derivatives that reduce its dependence on reserves and seem to provide a helpful announcement effect. Thus, financial globalization entails a new type of liquidity shock—the sudden shutdown of foreign currency financing—but also offers a new set of tools for helping central banks to deal with it.

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## Annex I. *Cupom Cambial* and Basis Spreads

The *cupom cambial* represents the dollar interest rate implied from the domestic local currency interest rate in Brazil, the spot exchange rate, and currency futures prices. If, for example, the one-year interest rate in Brazil is 15 percent, the spot exchange rate is 2 *reais* to the dollar, and the one-year forward exchange rate is 2.2 *reais* to the dollar, then the implied onshore dollar interest rate is 5 percent. That 5 percent is equal to the 15 percent interest rate in Brazilian *reais* minus the 10 percent depreciation of the real against the dollar that is priced into the forward contract.<sup>26</sup> Under conditions of covered interest parity, this implied dollar interest rate would be equal to the prevailing one-year domestic interest rate in the U.S. In practice, however, this is rarely the case. The onshore dollar interest rate in Brazil and in most other countries is often higher than the dollar interest rate in the U.S.—sometimes much higher.

Why is this difference not arbitrated away?<sup>27</sup> In an emerging market, credit and liquidity factors play a role, so that a high onshore implied dollar interest rate may reflect the credit risk priced in by the market in lending to a foreign counterparty. Liquidity factors, which may be supposed to result from a scarcity of funds, are sometimes distinguished from credit factors, and can also work to limit arbitrage. Thus – returning to the example in the first paragraph – a financial institution could in theory borrow dollars at 3 percent in the U.S., convert these funds into *reais* at the spot exchange rate, invest the proceeds at 15 percent in the Brazilian market, and at the same time purchase dollar futures to cover its obligation to repay the original loan. This trade would yield a 2 percent return free of currency risk. However, there is typically no institution in a position to conduct the arbitrage. Brazilian banks are not able to borrow at 3 percent in the U.S. market, and large global banks have to consider credit risk and balance sheet costs in making such a trade.

This difference between the onshore dollar interest rate and the domestic rate in the U.S. is known as the basis spread.<sup>28</sup> Such spreads tend to be low—often very close to zero—for G7 currencies for which there is continuous and effective arbitrage. However, during the financial crisis, basis spreads even for yen-dollar and euro-dollar spiked as high as

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<sup>26</sup> This is approximately true when interest rates are low; there is a second-order term that becomes more important as interest rates become higher.

<sup>27</sup> The difference could be arbitrated by borrowing the relatively cheap currency (i.e., cheap in the forward market) and changing the proceeds in the spot market to purchase a bond in the more expensive currency. At the same time, the arbitrageur would buy a forward in (or swap into) the cheaper currency.

<sup>28</sup> There is often a question about which U.S. interest rate to use as a reference. Prior to the global financial crisis the LIBOR interbank rate was usually taken as the standard. However, this became an unreliable gauge during the crisis, so that the market standard has become futures on the Fed funds rate (OIS rates).

1 percent.<sup>29</sup> Some emerging market basis spreads moved out to 10 percent or more during this period. In addition to the credit and liquidity considerations cited above, other factors likely to affect basis spreads are spot and forward intervention by central banks, currency market pressures and volatility, and capital controls.

In a market with limited liquidity, spot and forward interventions have opposite effects on the implied dollar interest rate (*cupom cambial*) and the basis spread. To see why, consider the interest parity relationship:  $i_{\$ \text{implied}} = i_{\text{Brazil}} + (e-f)/e$ , where  $e$  is the spot exchange rate in *reais* per dollar, and  $f$  is the forward rate. A spot intervention to sell dollars and buy *reais* will reduce  $E$  (the number of *reais* per dollar), thereby reducing the right-hand side and the implied dollar interest rate. But a forward intervention to sell dollars and buy *reais* will reduce  $F$  and increase the right-hand side. By bidding down the value of the dollar in the forward market, the latter type of intervention reduces the implied rate of dollar appreciation and thereby increases the implied dollar interest rate. Finally, a combined type of operation known as a foreign exchange swap consists of selling dollars in the spot market and buying them back in the forward market.<sup>30</sup> As described, this type of operation should be especially effective in reducing the *cupom cambial* as it affects both the spot and the forward legs of the interest parity relationship.

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<sup>29</sup> Gârleanu and Pedersen (2009) posit a theoretical model of basis spreads as a deviation from the law of one price explained by risk averse investors facing constraints on the amount of derivatives they can hold and risk tolerant investors facing margin limits in times of stress.

<sup>30</sup> Or buying dollars spot and selling them forward. Use of foreign exchange swaps is not limited to central banks – these are widely traded by private market participants.

## Annex II. Foreign Exchange Measures of the Banco Central do Brasil, September 2008–May 2009

| <b>Spot market intervention</b> |   |
|---------------------------------|---|
| Modality                        | Cash sales of foreign exchange into the foreign exchange market   |
| Market stress                   | Reflects drying up of forward dollar market which compelled corporations to turn to spot market for foreign exchange needs. |
| Objective                       | Smooth exchange rate volatility and alleviate short-term foreign exchange pressure.   |
| BCB counterparties              | The 17 institutions authorized as foreign exchange dealers.   |
| Collateral                      | None.   |
| Form of intervention            | Regular spot multiple price foreign exchange auctions.  |
| Frequency of intervention       | Daily to weekly.  |
| Gross sales 1/                  | \$14.5 billion.   |
| Conventionality                 | Standard foreign exchange intervention.   |
| Balance sheet impact            | Reduces foreign reserves.   |
| BCB communication               | Governor de Campos Meirelles speech of March 2009.  |

| <b>Futures market intervention [swaps] 2/</b> |   |
|---|---|
| Modality                                      | Forward sales of foreign exchange in the market.  |
| Objective                                     | Provide forward dollar liquidity to alleviate pressure on corporations ahead of them unwinding hedging positions.   |
| Market stress                                 | Drying up of forward dollar market and vulnerability of corporate balance sheets.   |
| BCB counterparties                            | All financial institutions authorized to operate in the Brazilian foreign exchange market.  |
| Maturities                                    | 26–672 days.  |
| Announcements                                 | Oct 23, 2008: BCB announces a ratcheting up of foreign intervention.  |
| Form of intervention                          | BCB conducts transaction as market player.  |
| Frequency of intervention                     | Daily to weekly (Sales will be made according to the liquidity needs of the market).  |
| Gross sales 1/                                | \$34 billion.   |
| Conventionality                               | Unconventional in that the explicit objective is to influence foreign exchange liquidity of nonfinancial corporations, and that foreign exchange impact is automatically unwound. |
| Balance sheet impact                          | No immediate impact; at maturity reduces foreign reserves.  |
| BCB communication                             | Governor de Campos Meirelles speech of March 2009, the BCB's press release on Oct. 23, 2008.  |

| <b>Foreign exchange swaps auctions [repos] 2/</b> |  |
|---|--|
| Modality  | Spot leg: BCB auctions dollars in exchange for reais<br>forward leg: BCB receives dollars in exchange for reais  |
| Objective   | Increase availability and reduce the cost of foreign exchange for Brazilian corporations and banks over the term of the swap, and stem depreciation in the short-run.  |
| Market stress                                     | Drying up of term external dollar financing.   |
| BCB counterparties                                | All financial institutions authorized to operate in the Brazilian foreign exchange market.   |
| Collateral  | Local currency serves as collateral.   |
| Maturities  | 30-180 days.   |
| Announcements                                     | None.  |
| Dates of intervention                             | Sep. 19, 2008, Sep. 26, 2008, Oct. 7, 2008, Oct. 15, 2008, Oct. 16, 2008, Oct. 27, 2008, Oct. 30, 2008, Nov. 19, 2008, Dec. 17, 2008, Dec. 30, 2008, Jan. 5, 2009, Jan. 13, 2009, Jan. 29, 2009, March 30, 2009, April 16, 2009, and April 29, 2009. |
| Gross sales 1/                                    | \$11.8 billion.  |
| Conventionality                                   | Conventional in that BCB counterparties are foreign exchange market participants and limited credit risk for BCB. Unconventional in that the explicit objective is to influence foreign exchange liquidity of nonfinancial corporations.             |
| Balance sheet impact                              | Reduces foreign reserves at impact, but reduction is reversed at maturity.   |
| BCB communication                                 | Governor de Campos Meirelles speech of March 2009.   |

| <b>Dollar lending (Dollar loans for exporters) [export financing, ACCs]2/</b> |  |
|---|--|
| Modality  | BCB provides dollar financing to financial institutions, who on-lend to exporters.   |
| Objective   | Provide dollar financing for exporters   |
| Market stress   | Drying up of term external and domestic dollar financing for exporters.  |
| BCB counterparties  | All financial institutions authorized to operate in the Brazilian foreign exchange market may have access to foreign currency loans available via auctions by BCB.   |
| Collateral  | Sovereign bonds in U.S. dollars issued by Brazil or other country, provided they are rated A or above, and advances on foreign exchange contracts (ACE) or export contracts (ACC) transactions.  |
| Maturities  | One to six months.   |
| Announcements   | Oct 16, 2008: announced by news.<br>Oct 17, 2008: officially announced by the BCB.   |
| Form of intervention  | Auctions: Oct. 20, 2008, Nov. 5, 2008, Nov. 13, 2008, Nov. 18, 2008, Dec. 3, 2008, Jan. 14, 2009, Feb. 11, 2009, and March 12, 2009.   |
| Gross sales 1/  | \$12.6 billion.  |
| Conventionality   | Conventional liquidity easing in the sense that meant to address liquidity shock;<br>Unconventional in that the explicit objective is to influence foreign exchange liquidity of nonfinancial corporations, and the relatively long maturities imply an element of credit easing with a degree of credit risk. |
| Balance sheet impact  | Reduces foreign reserves at impact, but reduction is reversed at maturity.   |
| BCB communication   | Governor de Campos Meirelles speeches of March 2009, the BCB's press releases on Oct. 17, 2008 and on Nov. 4, 2008, AE Brazil-Financial and Corporate News service on Oct. 16, 2008.   |

| <b>Non-trade-based dollar loans (for rolling over external debt of Brazilian corporations)</b> |   |
|--|---|
| Modality   | BCB provides dollar financing to financial institutions, who on-lend to targeted Brazilian corporations with loan payments falling due over a pre-specified period.   |
| Objective  | Ensure dollar availability for private-sector short-term foreign debts.   |
| Market stress  | Drying up of term external and domestic dollar financing for Brazilian corporations.  |
| BCB counterparties   | Banks authorized to operate in foreign currency transactions, these banks' foreign subsidiaries, financial institutions abroad owned by these banks operating in Brazil, and foreign financial institutions with an AA risk rating. (source: AE Brazil-Financial and Corporate News Service). |
| Collateral   | ACC, ACE and others.  |
| Maturities   | 30–387 days.  |
| Announcements  | Dec 11, 2008: announced by news [up to up \$10 billion].<br>Feb 4, 2009: announced by news [up to \$20 billion].<br>Note: According to news source, BCB will release the money on specific dates such as Feb. 27, 2009, March 13, 2009, and March 27, 2009.                                   |
| Form of intervention   | Auctions: April 3, 2009, May 4, 2009<br>Note: The loans will be offered exclusively to Brazilian companies with debts due between Oct. 2008 and Dec. 2009.  |
| Gross sales 1/   | \$2.1 billion   |
| Conventionality  | Unconventional in that the foreign exchange market is circumvented and the intended counterparties are nonfinancial corporations. Liquidity easing in the sense that meant to address liquidity shock; credit easing in sense that relatively long maturities.                                |
| Balance sheet impact   | Reduces foreign reserves at impact, but reduction is reversed at maturity.  |
| BCB communication  | Governor de Campos Meirelles speeches of January and March 2009, AE Brazil-Financial and Corporate News service on Dec. 11, 2008.   |

1/ From Sep 19, 2008 to May 5, 2009.

2/ BCB terminology is in brackets [ ].



### Annex III. Quotes from “Lombard Street”

Bagehot’s “Lombard Street” serves as the touchstone for consideration of LOLR policies; for example, Madigan (2009) and Tucker (2009) discuss how the recent unconventional measures of the Fed and Bank of England square with Bagehot. The views ascribed to Bagehot in section IV are based on the below direct quotes from “Lombard Street”:

Timing— “If possible, that alarm is best met by enabling those persons to pay their creditors to the very moment. For this purpose only a little money is wanted. If that alarm is not so met, it aggravates into a panic,”

Volume— “we must keep a great store of ready money always available, and advance out of it very freely in periods of panic, and in times of incipient alarm” and “whatever bank or banks keep the ultimate banking reserve of the country must lend that reserve most freely in time of apprehension”.

Collateral— “The only safe plan for the Bank is the brave plan, to lend in a panic on every kind of current security, or every sort on which money is ordinarily and usually lent. This policy may not save the Bank; but if it do not, nothing will save it.”

Counterparty— “They [central banks] must lend to merchants, to minor bankers, to 'this man and that man,' whenever the security is good.”

Interest rate—[domestic shock]: “the best way for the bank or banks who have the custody of the bank reserve to deal with a drain arising from internal discredit, is to lend freely.”; [external shock]: “We must look first to the foreign drain, and raise the rate of interest as high as may be necessary.”

Transparency—“There should be a *clear understanding* between the Bank and the public that, since the Bank hold out ultimate banking reserve, they will recognise and act on the obligations which this implies; that they will replenish it in times of foreign demand as fully, and Lend it in times of internal panic as freely and readily, as plain principles of banking require.” [Emphasis added]

### Annex IV. Data Description

| Variable   | Definitions and Sources   |
|--|---|
| Spot exchange rate   | Brazilian real per U.S. dollar. We use the logarithmic change in the regression.<br>Source: Bloomberg.  |
| Implied volatility   | Implied volatility calculated by both put and call option prices of which maturity is three months. We use the logarithmic change in the regression.<br>Source: Bloomberg.  |
| Announcement   | Dummy variables which is equal to 1 on the BCB's policy announcement date and 0 otherwise. The variables are comprised of five variables: The BCB's announcements on U.S. dollar lending for export finance (Oct 17, 2008), on futures intervention (Oct 23, 2008), on swap line with U.S. Federal reserves (Oct 29, 2008), on non-trade-based dollar loans (Dec 11, 2008), on the first extension on the swap line (Fed 3, 2009), and on the second extension on the swap line (June 25, 2009).<br>Source: The BCB's press release and news sources.   |
| Intervention   | The actual amounts of the BCB's interventions, which consist of five measures: spot market intervention, futures market intervention, foreign exchange swap auctions, U.S. dollar lending for export financing, and non-trade-based U.S. dollar loans.<br>Since the data of the spot market intervention are not available, we use changes in the international reserves in the liquidity concept, not cash concept which includes repurchase agreement and futures as a proxy of the intervention<br>The dates related to foreign exchange swap auctions, U.S. dollar lending for export financing, and non-trade-based U.S. dollar loans are set at the auction dates, not the settlement dates because the market prices tend to reflect the intervention at the auction dates. The unit is one U.S. billion dollar. |
| $\Delta$ SPREAD  | Change in the spread between U.S. short-term interest rate and Brazilian short-term interest rate. As a U.S. short-term interest rate, we use the daily effective federal funds rate, a weighted average of rates on trades through New York brokers. As a short-term interest rate in Brazil, we use the SELIC interest rate, the interest rate for overnight interbank loans.<br>Source: Datastream.  |
| $\Delta$ STOCK   | Logarithmic change in the Bovespa index, which is a total return index weighted by traded volume and is comprised of the most liquid stocks traded on the Sao Paulo Stock Exchange.<br>Source: Bloomberg.   |
| $\Delta$ SP500   | Logarithmic changes in the Standard and Poor's 500 index.<br>Source: Bloomberg.   |
| $\Delta$ COMMODITY<br>1) $\Delta$ CRB<br>2) $\Delta$ Raw Sugar Price | Logarithmic change in a certain commodity price index. We use either $\Delta$ CRB or $\Delta$ Raw Sugar Price as a proxy of the commodity price index. $\Delta$ CRB is logarithmic change in the commodity futures prices index produced by the Commodity Research Bureau. $\Delta$ Raw Sugar Price is logarithmic change in Brazilian raw sugar price index.<br>Source: Bloomberg and Datastream.  |
| Basis spread against US dollar LIBOR rate                            | Difference between three-month <i>cupom cambial</i> and three-month U.S. dollar LIBOR rate. Since LIBOR rate is a reference rate at 11:00a.m. in London and <i>cupom cambial</i> is a rate at 5:00 p.m. in New York, we use the difference: [ <i>cupon cambial</i> at date t] - [U.S. dollar LIBOR rate at t+1]. We omit the missing values.<br>Source: Bloomberg and British Bankers Association.  |
| Basis spread against OIS spread                                      | Difference between three-month <i>cupom cambial</i> and three-month U.S. dollar OIS rate. We omit the missing values.<br>Source: Bloomberg.   |
| EMBI spread in Brazil  | Difference between the yield on a dollar-denominated bond issued by the Brazilian government and a corresponding one issued by the U.S. Treasury. We use this spread as a proxy of the counterparty risk of Brazilian financial institutions.<br>Source: JP Morgan .  |

## Annex V. Unit Root Tests

| Spot rate              |         |         | Implied Volatility          |         |          |
|------------------------|---------|---------|-----------------------------|---------|----------|
| ADF                    | Const   | Trend   | ADF                         | Const   | Trend    |
| t-value                | t-value | t-value | t-value                     | t-value | t-value  |
| -1.74                  | 1.39    | 0.99    | -2.19                       | 0.39    | 1.41     |
| -1.56                  | 1.50    | none    | -1.69                       | 1.69 *  | none     |
| -0.45                  | none    | none    | -0.61                       | none    | none     |
| $\Delta$ Spot rate     |         |         | $\Delta$ Implied Volatility |         |          |
| ADF                    | Const   | Trend   | ADF                         | Const   | Trend    |
| t-value                | t-value | t-value | t-value                     | t-value | t-value  |
| -27.01 ***             | -0.70   | 0.69    | -12.30 ***                  | 0.56    | -0.29    |
| -27.01 ***             | -0.20   | none    | -12.30 ***                  | 0.62    | none     |
| -27.03 ***             | none    | none    | -12.29 ***                  | none    | none     |
| Risk Reversal          |         |         | SPREAD                      |         |          |
| ADF                    | Const   | Trend   | ADF                         | Const   | Trend    |
| t-value                | t-value | t-value | t-value                     | t-value | t-value  |
| -1.36                  | 0.03    | 0.77    | -0.18                       | -0.55   | 0.36     |
| -1.12                  | 1.13    | none    | -0.77                       | -0.83   | none     |
| -0.59                  | none    | none    | 0.15                        | none    | none     |
| $\Delta$ Risk Reversal |         |         | $\Delta$ SPREAD             |         |          |
| ADF                    | Const   | Trend   | ADF                         | Const   | Trend    |
| t-value                | t-value | t-value | t-value                     | t-value | t-value  |
| -22.27 ***             | 0.37    | -0.09   | -16.62 ***                  | -0.89   | 0.83     |
| -22.28 ***             | 0.60    | none    | -16.60 ***                  | -0.35   | none     |
| -22.29 ***             | none    | none    | -16.61 ***                  | none    | none     |
| STOCK                  |         |         | SP500                       |         |          |
| ADF                    | Const   | Trend   | ADF                         | Const   | Trend    |
| t-value                | t-value | t-value | t-value                     | t-value | t-value  |
| -1.89                  | 1.91 *  | -0.93   | -2.05                       | 2.05 ** | -2.15 ** |
| -1.71                  | 1.71 *  | none    | -0.37                       | 0.33    | none     |
| 0.09                   | none    | none    | -1.26                       | none    | none     |
| $\Delta$ STOCK         |         |         | $\Delta$ SP500              |         |          |
| ADF                    | Const   | Trend   | ADF                         | Const   | Trend    |
| t-value                | t-value | t-value | t-value                     | t-value | t-value  |
| -26.16                 | 0.53    | -0.52   | -21.63 ***                  | 0.03    | -0.76    |
| -26.17 ***             | 0.16    | none    | -21.62 ***                  | -1.25   | none     |
| -26.19 ***             | none    | none    | -21.58 ***                  | none    | none     |

Note 1: All variables were tested using Augmented Dickey-Fuller test. The number of lags were chosen based on Schwarz information criterion.

2: The estimated period is from 1/2/2007 to 7/8/2009.

3: \*\*\*, \*\*, and \* denotes significance at the one, five, and ten percent levels.

| CRB          |         |         | 3-month Basis Spread against OIS          |          |         |
|--------------|---------|---------|---|----------|---------|
| ADF          | Const   | Trend   | ADF                                       | Const    | Trend   |
| t-value      | t-value | t-value | t-value                                   | t-value  | t-value |
| -1.08        | 1.13    | -1.68 * | -3.81 **                                  | 2.13 **  | 1.04    |
| -0.41        | 0.38    | none    | -3.69 ***                                 | 3.21 *** | none    |
| -0.72        | none    | none    | -1.58                                     | none     | none    |
| $\Delta$ CRB |         |         | $\Delta$ 3-month Basis Spread against OIS |          |         |
| ADF          | Const   | Trend   | ADF                                       | Const    | Trend   |
| t-value      | t-value | t-value | t-value                                   | t-value  | t-value |
| -26.58 ***   | 1.02    | -1.56   | -17.41 ***                                | 0.53     | -0.52   |
| -26.51 ***   | -0.67   | none    | -17.42 ***                                | 0.16     | none    |
| -26.51 ***   | none    | none    | -17.43 ***                                | none     | none    |

| 3-month Libor-OIS Spread          |         |         | EMBI Spread          |         |         |
|-----------------------------------|---------|---------|----------------------|---------|---------|
| ADF                               | Const   | Trend   | ADF                  | Const   | Trend   |
| t-value                           | t-value | t-value | t-value              | t-value | t-value |
| -2.49                             | 0.67    | 1.01    | -2.66                | 1.95 *  | 1.85 *  |
| -2.36                             | 1.81 *  | none    | -1.91                | 1.85 *  | none    |
| -1.51                             | none    | none    | -0.50                | none    | none    |
| $\Delta$ 3-month Libor-OIS Spread |         |         | $\Delta$ EMBI Spread |         |         |
| ADF                               | Const   | Trend   | ADF                  | Const   | Trend   |
| t-value                           | t-value | t-value | t-value              | t-value | t-value |
| -10.24 ***                        | 0.67    | -0.72   | -20.32 ***           | 0.27    | -0.18   |
| -7.38 ***                         | 0.07    | none    | -20.33 ***           | 0.23    | none    |
| -7.39 ***                         | none    | none    | -20.35 ***           | none    | none    |

| 3-month Basis Spread against Libor          |          |         |
|---|----------|---------|
| ADF   | Const    | Trend   |
| t-value                                     | t-value  | t-value |
| -5.93 ***                                   | 3.65 *** | -0.06   |
| -5.94 ***                                   | 5.02 *** | none    |
| -2.75 ***                                   | none     | none    |
| $\Delta$ 3-month Basis Spread against Libor |          |         |
| ADF   | Const    | Trend   |
| t-value                                     | t-value  | t-value |
| -17.34 ***                                  | 0.23     | -0.17   |
| -17.36 ***                                  | 0.17     | none    |
| -17.37 ***                                  | none     | none    |

Note 1: All variables were tested using Augmented Dickey-Fuller test. The number of lags were chosen based on Schwarz information criterion.

2: The estimated period is from 1/2/2007 to 7/8/2009.

3: \*\*\*, \*\*, and \* denotes significance at the one, five, and ten percent levels.