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and Benjamin Miranda Tabak

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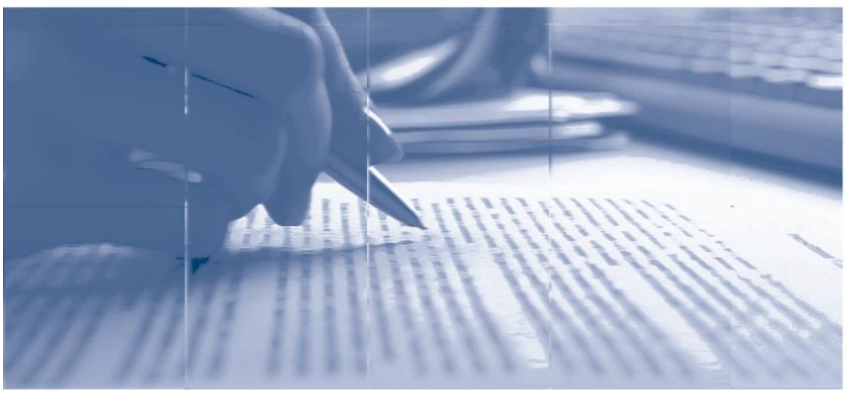

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Banking Systemic Risk, Foreign Funding, Exchange Rate Exposure and Carry Trade: is there a relation?*

Bruno Freitas Boynard de Vasconcelos**

Benjamin Miranda Tabak***

Abstract

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We study what is the systemic impact of banks' foreign funding and what are the determinants of this flow of international money. With that, we intend to establish a relation between banks' foreign funding, carry trade, exchange rate exposure and banking system risk which is novel in the literature. We used an unique data for Brazilian banks exchange rate transactions combined with other micro and macro data. Our results indicate that banks improve its credit portfolio, free from regulatory investment, in periods when banks get foreign funding. Those results and future analysis and extensions of this work may better quantify this effect and serve as a basis for policy makers in terms of analysis of macroprudential policies.

Keywords: exchange rate exposure, carry trade, balanced Panel SUR, balanced 3SLS panel.

JEL Classification: C33, C58, G15, G11, G12

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1. Introduction

We discuss the impact of Brazilian banks' foreign funding on banking system risk and the determinants of this funding flow, which was used to finance carry trade between 2001 and 2011, a remarkable period for carry trade attractiveness in Brazil. Carry trade, as defined in this paper, is when banks obtain foreign money to invest in their domestic activities. We base our arguments on the banks' accounting information and *FX contracts* to describe their strategy[1]. Our approach is different from that used in the literature in terms of database detail, model design, definitions and channel dynamics and coverage. Our databases for the Brazilian banking system allow us to explore details in the relations between the banks' asset allocations and their foreign funding. The issues raised by this paper are relevant, because since the carry trade has been debated internationally over recent decades, and during the highlighted period, Brazil was an important destination for foreign investments.

The currency carry trade is a financial transaction in which an investor borrows money in a low interest-currency (funding currency) and invests it in a higher rate currency (investing currency). The profit from this investment is the interest rate differential discounted by the exchange rate variation. The carry trade's risk is related to the movements of the exchange rate between the two currencies.

The Japanese yen is usually cited as a funding currency for the carry trade, as Japan held the lowest interest rates in the world for more than a decade. Another currency used as a source for carry trade activity is the Swiss franc. Moreover, the US dollar, which was known and used as a source currency for some time, has been used as investment currency. Other commonly cited currencies as a target for the carry trade are the Australian dollar and the New Zealand dollar[2]. Recently, Brazil and South Africa have been highlighted as attractive destinations for carry trade money.

The carry trade's most traditional impact is on countries' exchange rates. However, we have a different focus. This paper address the subject of foreign funding in a context of financial management in the banking system. We discuss the systemic risk impacts for the banking sector and the factors that drive banks' foreign funding flows. We test two channels through which banks' foreign funding can affect or influence banking system risk. The first is the *direct impact* on banking financial structure risk through banks' asset allocation. The second is what we call *indirect impact*, which is the effect on the banks' exchange rate exposure or the risk related to foreign currency movements. We also examine the effects of the subprime crisis on banks' behavior and how it affects the banks' foreign funding dynamics.

We emphasize in this paper that foreign funding deserves special attention in relation to domestic funding for several reasons. First, unlike domestic funding, the flow of foreign funding is subject to factors beyond the control of national policy makers, such as the situation and liquidity in international markets, the risk aversion of foreign investors and the exchange rate. These factors are related to what we here call the *direct effect*. It is also important to mention that a greater share of foreign funding in the banks' balance

[1] Any agent that wishes to bring money to Brazil needs what we call an FX contract to exchange the currencies. More information will be detailed in topic 3. Data Description.
[2] See Galati et al. (2007) which develop in more details this subject.

increases the risk of banks' exposure to foreign currency. These aspects are relevant even after taking into account the regulatory limits for financial transactions related to exchange rate variations.[3]

Our estimates do not ignore that a link between foreign funding, exchange rate exposure (ERE) and banking system risk exists and can be established with temporal adjustments between funding and investment. Our results indicate that banks improve their credit portfolio, free from regulatory investment, during periods when they obtain foreign funding. Accordingly, the share of foreign funding in the stock of banks' liabilities, rather than the flow, can be associated with their exchange rate exposure (ERE) and the risk in the banking system. Those results and future analysis and extensions of this work may better quantify this effect and serve as a basis for policy makers in terms of the analysis of macro-prudential policies.

This paper contributes to the literature because it relates banks' foreign funding, the carry trade, exchange rate exposure and banking system risk. This paper address the carry trade using a different approach from what is seen in the related literature; it also uses a unique dataset.

2. Related Literature

Carry trade strategy has important effects on a country's economy and exchange rate stability. Many of these effects were recorded in the literature over history. More recently, in this last decade, these potential impacts have received special attention from central bankers and policy makers because the world experienced a period of low currency volatility and persistent interest rate differentials. These two conditions, according to Anzuini and Fornari (2012), create an attractive environment for the carry trade. The carry trade exists when there are profitable opportunities from interest rate differentials and acceptable exchange rate risk.

The literature highlighted that the most common impact of the carry trade is on currency exchange rate stability in order to respect the uncovered interest rate parity (UIP). The UIP demands appreciation in the funding currency and depreciation in the high-interest rate currency until the profit from this operation reaches zero. Despite the theory, the literature has long showed opposing empirical evidence in the international market (Fama (1984), Engel (1996), Baillie and Bollerslev (2000), Burnside et al. (2009)). This violation of the UIP is known as the *forward premium puzzle* and is the reason for carry trade profitability. The persistence through history of the forward risk premium has several explanations (Burnside et al. (2006), Lustig and Verdelhan (2007), Du (2013)). Notwithstanding, others effects from carry trade movements on exchange rates have been revealed in the literature, for example, a destabilizing exchange rate effect (Plantin and Shin (2011)) or currency shock (Brunnermeier et al. (2008)).

Beyond effects on exchange rates, the carry trade has been identified as a source of low quality credit growth or asset bubbles in investment economies. The movement known as

[3]Despite this discussion, the authors highlight that the Central Bank of Brazil charges a punitive capital requirement to banks' foreing exchange rate exposure, which inhibits high levels of this in order to prevent exposure from impacting the stability of the banking system.

the Yen Carry Trade was cited as one of the feeds for the US low quality credit subprime bubble (Hattori and Shin (2009), Brunnermeier (2009)) and the Australian housing price bubble.

Although also susceptible to risk from unanticipated exchange rate movements, banks' exchange rate exposure (ERE) is not mentioned in the literature as being related to their carry trade. Exchange rate exposure is defined in the literature as the banks' market value sensitivity to FX market movements (Adler and Dumas (1980, 1984)). This relation between exchange rate exposure and the carry trade or the banks' foreign funding is somewhat difficult to see in a first approach. That is because ERE is related to the banks' unhedged position or mismatches in the foreign currency hedged position. On the other hand, banks' foreign funding could be used both in a unhedged position (completely vulnerable to exchange rate risk) or in a hedged one. This second type of transaction occurs when, for example, banks hedge the *FX risk* using FX future market contracts and use the foreign funding money, converted to domestic currency, to invest in their assets. Banks' accountancy unhedged position are not systemically significant if the banks are subject to risk exposure limits defined by their supervisory authorities. However, even the position classified as hedged is not FX risk free from exchange rate movements[4]. Therefore, it is possible to suppose that if a bank improves its foreign funding, its exchange rate exposure, measured as its sensibility to FX movements and not the accountancy unhedged position, would also be affected.

Here we introduce some considerations about the carry trade. By the strict definition, according to which the risk of this financial transaction is the exchange rate variation between the currencies involved, the carry trade would be made in unhedged operations and would be related to ERE. However, if there is exchange rate risk in hedged operations with foreign currency (the risk of the hedge - accounting or economic - not being perfect, if it exists, is very small due to the regulatory requirements from CBB), you could also define every operation including foreign funding for banks' investment in domestic operations as carry trade. In this case, the carry trade is related to a bank's foreign funding. Either way, we consider the carry trade conditional to Brazilian idiosyncratic exchange risk, and not global exchange risk as argued by Menkhoff et al. (2012a).

With that, if a bank improves its foreign funding to take advantage of the international interest rate differential, a feasible banking system impact exists through credit bubbles and foreign currency exposure. If this impact exists and presents a systemic risk to the banking system due foreign funding flows, it is important to study banks' foreign funding determinants.

Both the carry trade and the exchange rate exposure literature focus on some type of asset pricing model approach. The literature related to the carry trade uses asset pricing models to asses carry trade pay-off and discuss the role of risk factors in explaining its return (Clarida et al. (2009), Burnside et al. (2010), Burnside (2011), Lustig et al. (2011), Menkhoff et al. (2012a)). The Exchange rate exposure literature, however, focuses on explaining banks' market value measures (equity or cash flow approach) through movements in the exchange rate market (Choi and Elyasiani (1997), Alvarez et al. (2009), Wong et al.

[4]In the case of Brazil, according to CBB Circular 3082/02 rule, those operations for which the market value compensation is between 80% and 125% are hedged operations in the Brazilian Banking System. This definition means that even hedged positions allow some, even small, speculation.

(2009), Chi et al. (2010)). The primary concern of both areas is to test if the relation holds in data.

When we turn our attention to why agents seek funding in the international market to obtain interest rate differentials between two economies, we need to look to a broader set of literature. The literature mention several determinants behind the international flow of money such as an unexpected component of series (Menkhoff et al. (2012a)), exchange rate volatility (Bekaert (1994, 1995), Bekaert (1995), Menkhoff et al. (2012a)), market stress (Melvina and Taylor (2009)) and liquidity (Acharya and Pedersen (2005), Brunnermeier et al. (2008), Brunnermeier and Pedersen (2009), Menkhoff et al. (2012a)). In a last example, the determinants of banks' foreign funding can be related to the risk and return duality.

2.1. Related works

This work uses an approach based on bank balance sheets and exchange rate contract information. A few works in the literature explore, at least superficially, similar information. Gagnon and Chaboud (2007) analyze Japanese bank balance sheet long and short positions on foreign and domestic currency, with the objective of studying evidence of the yen carry trade. The authors found it difficult to draw conclusions because it was not possible to obtain direct information about the carry trade in the data. For example, if banks' positions include operations related to exporters and importers or other investors, this money is subjected to other demand factors different from those that affect bank portfolio management and, consequently, a carry trade strategy. Balance sheet information also shows limited information if not matched with the derivatives market.

Galati et al. (2007) discuss several issues related to carry trade activity and the international flow of money between 2002 and 2007. The authors argue that is difficult to track the carry trade using balance sheet information due to the impossibility of obtaining enough detail in the data to isolate the desired effects.

Hattori and Shin (2009) study US and Japanese banks' balance sheets to conclude that the Japanese yen was used as funding source for US credit growth before the episodes of 2007 and 2008. These authors show that a relationship exists between yen outflow from Japan and movements in US banks', hedge funds' and other financial intermediaries' balance sheets. Further, they argue that the US credit bubble and the appreciation of the yen against the US dollar are connected.

Anzuini and Fornari (2012) broach issues related to our second objective: the determinants of banks' foreign funding. They examine the effect of shocks in the interest rate differential on carry trade activity. Their primary results are related to the importance of the long-term horizon in investors' strategies. This statement is consistent with many works that argue that long-term factors are essential for banks' ERE.

All of these papers related to the carry trade literature agree that it is difficult to track carry trade operations and that the data provide limited information on the subject. Otherwise, in other works that focus on banks' balance sheet information, the line of research papers that explain and study the forward premium puzzle through the asset pricing approach, do not elucidate the many interesting questions adressed in this paper such as the systemic importance of banks' foreign funding, effects and dynamics. The ERE literature does not mention or associate banks' sensibility to foreign currency with their foreign funding or carry trade. This carelessness regarding this link is feasible given the rigor of countries banks' supervision on this subject.

Our econometric approach and database, which uses some balance sheet information as its primary source, allow us to treat banks' foreign funding in a broader way than is seen in the literature. This database allows us to split the data into the flow of money, by period and by final user of that money (if is a bank or another agent with the bank acting as an intermediary). These data are more informative about the subject than the usual end of period position provided in banks' balance sheets. We also propose an econometric approach to analyze the data and not just describe its behavior.

Our paper uses a model-free approach, which is different from the research line such as Du (2013), which uses a general equilibrium approach.

3. Data description

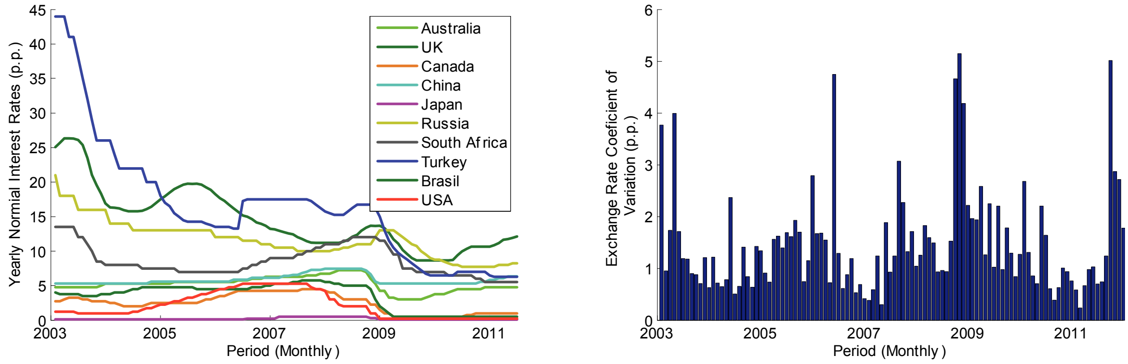
We use data from different sources in this paper on a quarterly time basis. There are four primary databases for Brazilian banking micro data: the banking accountancy database (COSIF), the banks' credit database from Circular 2.957/02 (C2957), the banks' paid domestic funding databases from CETIP and the Central Bank of Brazil (CBB) exchange rate contracts database (ERC)[5]. Except for CETIP, the others micro databases are held by CBB. COSIF is a monthly database, while ERE, C2957 and CETIP are on a daily basis. Other database sources used for the macro economic variables are Bloomberg, IBGE, FED and CBB macro data.

3.1. Brazilian Banks Foreign Funding

Over the last 15 years, in Brazil, except for a few brief periods, volatility was at moderate levels and nominal interest rates are in a high level, as compared to international standards (Figure (1)). This situation made Brazil a potential opportunity for investment currency in the carry trade international flow of money.

[5]ERC is a short name for the database used in this work but not a commonly used name in the Central Bank of Brazil. The same is true for C2957. COSIF, however, is the official short name for the Brazilian accountancy financial institution system, and CETIP (Central de Custodia e de Liquidacao Financeira) is a Brazilian central securities depository for banks' domestic debts.

Figure 1. Brazilian interest rates and fx volatility in the last decade



(a) World Norminal Interest Rates

(b) Brazilian Exchange Rate CV

NOTE: These figures shows the two characteristics highlighted by Anzuini and Fornari (2011) as essential for the carry trade that were present in the Brazilian economy over the last decade. These characteristics are (i) a persistent international interest rate differential and (ii) a low exchange rate risk.

Banks act as intermediaries in financial transactions involving foreign and domestic currencies. Among the market agents that banks intermediate in these transactions, we can highlight importers, exporters and foreign investors. These cases are not interesting for the purposes of this paper because we focus on only one agent (banks), for which we have detailed data and which we believe to exhibit more dynamic behavior related to international market transactions. We focus on banks' self-owned transactions and positions in foreign currencies, that is, when Brazilian banks are not the intermediary but the final user of the money.

Brazilian banks self-owned foreign funding ($F_{b,t}^{ff}$) was calculated using ERC and COSIF information. Self-owned foreign funding is a flow variable. Table (1) summarizes the components of the foreign funding variable. Banks can obtain foreign funding ($F_{b,t}^{ff}$) through Loans and Bonds for a short- and long-term horizon. We define banks' foreign funding as the sum of all these financial instruments. All of the variables here were measured over assets, and the table shows the results in terms of pecentage points (pp). For our sample, according to Table (1), long terms funds were used, on average, more than short-term ones.

Figure (2) shows the growth index for Brazilian banks' foreign funding over assets using quarterly data. This index presents the cumulative dynamics for national private and foreign control ownership banks. The figure does not describe the banks' foreign funding stock, but the net flow accumulation over a base of 100 points. The index is given by

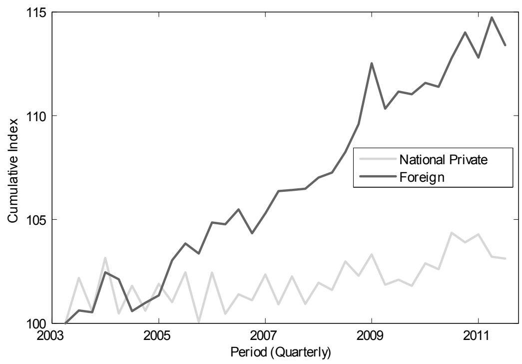
$$Index_t = \sum_{t=1}^{T} \left(Index_{t-1} + \frac{F_t^{ff}}{A_t} \right) \tag{1}$$

Table 1
Brazilian Banks foreign fund descriptive statistics

Variable		Observation	Mean (pp)	Std.Dev. (pp)	Source [1]
(+) Bonds	Short Term	704	-0.007	0.313	ERC
(+)	Long Term	704	0.091	0.661	ERC
(+) Loans	Short Term	704	0.037	1.023	ERC
(+)	Long Term	704	0.091	0.821	ERC
(+)	Special Lines [2]	704	-0.061	3.100	COSIF
Foreign	Funding ($F_{b,t}^{ff}$)	704	0.147	3.395	

NOTE: The table summarizes the banks' foreign funding ($F_{b,t}^{ff}$) components and data. We calculated banks' $F_{b,t}^{ff}$ as the sum, in each quarter, of banks' foreign loans and bonds (short and long term). Mean and Std.Dev. (Standard.Deviation) values are measured in percentage points (pp). [1] The databases used in this table are held by CBB. [2] International loans special lines are short term money avaliable to Brazilian banks from international banks and use a different recording procedure from ERC.

Figure 2. Foreign Funding over Assets average Index by banks control ownership



NOTE: This figure shows a growth index for Brazilian banks' foreign funding over assets ($F_{b,t}^{ff}$) using quarterly data.

where $t = 1$ is the 3^{rd} quarter of 2003, and T is the 4^{th} quarter of 2011, the last period in the sample. The index includes the 2003 second quarter, when $t = 0$, as $Index_0 = 100$. When we examine the dynamic of these operations, as expected, we see that Brazilian banks improving its foreign funding based against assets, due to the mentioned attractiveness of the Brazilian economy (Figure (2)).

Furthermore, the figure draws attention to the importance of considering the difference between global banks and local banks, as argued by Cetorelli and Goldberg (2012). However, we will not explore this question because we choose to simplify the analysis and focus on other aspects.

Beyond the concern regarding the final destination of foreign funding money, it is interesting to look at where this money came from. If Brazil is an investment currency, what are the funding currencies? Our data show that Brazilian banks' foreign funding after 2003 primarily uses three currencies: the US dollar, the Euro and the Japanese yen. Table (2) shows that during this entire period, the most important overseas market for

Brazilian bank funding is US. Notwithstanding, before the beginning of the subprime crisis in 2007, Brazilian banks obtained substantial money from the Japanese market. After 2010, when the effects of the Lehman Brothers crisis over the Brazilian economy were no longer significant, it was possible to notice a huge improvement in US dollar funding.

Table 2
Brazilian Banks' Foreign Funding by currency (BRL billion)

Period	Currencies	Banks Foreign Funding Currencies ($F_{b,t}^{ff}$)				Others Banks Funding	
		Loans		Bonds			
		Short Term	Long Term	Short Term	Long Term	IDI	Portfolio
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
2003.1 to	EUR	0.28	0.00	-0.00	-0.40	-0.00	0.04
2007.2	JPY	-0.90	3.24	3.24	-0.00	-0.00	0.00
	USD	6.81	2.64	0.86	0.78	0.78	13.2
2007.3 to	EUR	-0,00	0.14	0.00	-0.30	0.27	0.19
2008.2	JPY	-0.50	0.87	-0.60	0.94	0.00	0.00
	USD	-3.90	2.45	1.60	3.47	1.08	3.86
2008.3 to	EUR	0.38	-0.00	-0.00	0.02	0.12	-0.00
2009.4	JPY	-1.70	-0.80	-4.00	-2.70	0.07	0.70
	USD	2.39	0.39	-0.30	-2.10	0.54	0.76
2010.1 to	EUR	-0.70	2.00	0.00	0.76	0.21	-0.90
2011.2	JPY	-0.10	-1.70	0.05	-0.01	0.00	-0.00
	USD	9.18	22.30	2.10	25.00	2.07	-0.30

NOTE: This table describes Brazilian banks' funding sources in international markets. We used the ERC database on a quarterly basis. We aggregate, in each quarter, the total FX contract by currency (b). The table shows the average of the quarters within each period interval (a). In addition to $F_{b,t}^{ff}$ ERC components ((c), (d), (e) and (f)), we include two other variables: (g) international direct investment (IDI) and (h) international investment in portfolios (Portfolio).

3.2. Bank Balance Sheets

The bank balance sheet micro data used in this paper is divided in three groups: (i) Assets, (ii) Liabilities and (iii) Returns. We summarize all bank balance sheet descriptive data in Table (3).

3.2.1. Bank Assets

Between these three groups, after banks' foreign funding as described in the last section, the most important for this paper is bank assets. Banks can invest their funding in different assets. We will group these assets into three major groups: Risk Free Bonds (B_t^{rf}), Risky Bonds (B_t^r) and Credit (C_t). Risk Free Bonds (B_t^{rf}) and Risky Bonds (B_t^r) are assets that belong to the banks' self-owned portfolio; we therefore do not consider assets held by banks but those that are related or that belong to banks' customers.

Bank assets classified as risk free bonds (B_t^{rf}) are not only "bonds" but are all financial securities, including funds, considered to be risk free. Risky bonds (B_t^r) are also defined with a similar grouping. Credit (C_t) is the banks' credit portfolio free from regulatory investment. We also include banks' Non Performing Loans (NPL) within the asset analysis.

3.2.2. Bank Liabilities, Return and others micro data

Beyond banks' foreign funding ($F_{b,t}^{ff}$), as described in topic 3.1., we also used domestic paid deposits ($F_{b,t}^h$) as bank liabilities. Bank asset returns and liabilities cost ($r_{b,t}^c$ and $r_{b,t}^h$)

and are also part of the set of variables related to bank balance sheet information. A final variable is the Basel Capital Requirement over assets ($pr_{b,t}$), which we use to control for general risk exposure related to regulatory requirements.

Table 3
Brazilian Banks microdata descriptive statistic

Group	Variable	Var Code	Observation	Mean	StD	Base
Asset	Risk free bonds over assets	$B^{rf}_{b,t}$	704	8.46	8.74	COSIF
	Risky bonds over assets	$B^{r}_{b,t}$	704	2.54	6.18	COSIF
	Credit over assets	$C_{b,t}$	704	39.14	24.28	C2957
	NPL over total credit	$NPL_{b,t}$	704	3.40	12.78	COSIF
Funding	Paid domestic funding *	$F^{h,r}_{b,t}$	704	16.52	12.78	CETIP
	Foreign funding *	$F^{ff}_{b,t}$	704	0.15	3.40	ERC
Returns/Costs	Loans return	$r^{c}_{b,t}$	704	11.79	3.40	COSIF
	Domestic funding cost	$r^{h,r}_{b,t}$	704	13.89	3.61	COSIF
Risk Exposure	Capital Requirement	$pr_{b,t}$	704	16.62	11.76	COSIF

NOTE: This table presents the descriptive statistics for bank micro data. Variables with a "" represent flow variables over stock variables. All others are stock variables over stock variables.*

3.3. Macroeconomic Variables

Macroeconomic variables plays an important role in the estimations if this paper. We use data from Central Bank of Brazil, US Federal Reserve, Brazilian Geography Statistic Institute (IBGE) and Bloomberg database, which are summarized in the Table (4).

3.4. FX risk Variables

We used three variables as measures of risk in the exchange rate market (*FX market*). We expect that unanticipated movements in the *FX market* impact bank profits that have some ERE. Therefore, we define variables to capture these unexpected shocks or that are correlated to this information to use as market risk factors.

- *coefficient of variation* (δ^1_t): using spot FX daily data, we estimate the FX CV for each quarter. This variable aims to quantify the uncertainty and volatility in the FX rate;
- *FX forecast error over* ΔFX (δ^2_t): for this factor, we assume that there is no risk premium in the FX future contracts. Moreover, we assume that the rates in these contracts are

Table 4
Macroeconomic descriptive statistic table

Variable	Observations	Mean	Std.Dev.	Source	Comments
$Selic_t$	32	13.88	3.75	CBB	Quarterly Brazilian interest rate (SELIC) in anual basis. Measured in percentual points (pp)
r^{FED}_t	32	2.17	1.97	FED	Quarterly US Fed rates in anual basis. Measured in percentual points (pp)
$I.Liq_t$	32	0.21	0.74	Bloomberg	Bloomberg International Liquidity index
VIX_t	32	20.43	9.95	Bloomberg	Chicago Board Options Exchange Market Volatility Index
CDS^{BR}_t	32	253.25	197.52	Bloomberg	Brazilian Credit Default Swap as a mean of monthly index.
GDP^{BR}_t	32	1371.85	440.73	IBGE	Brazilian quarterly GDP (USD thousand).- 1995 price

NOTE: This table presents a table with descripitive statistics about macroeconomic data used in this paper.

future expected exchange rates or market forecast rates conditional on the information available on the contract day:

$$\delta_t^2 = \left[\sum_{i=1}^{T_q} \left(\frac{fx_i^{t+3} - fx_{i,t+3}}{fx_{i,t+3} - fx_i} \right) \left(\frac{1}{T_q} \right) \right] \tag{2}$$

Each quarter has T_q days, fx_i^{t+3} is the FX future contract for 3 months ahead made on day i, $fx_{i,t+3}$ is the daily FX spot rate 3 months ahead from day i and fx_i is the FX spot rate on day i. We highlight that the future contract exchange rates (fx_t^{t+n}) are quite similar to those in the CBB market expectations survey. This result supports the hypothesis that the rate of exchange rate future contracts would be a good proxy for market expected forward rates;

- *risk premium* (δ_t^3): unlike δ_t^2, we suppose that the exchange rate (fx_t) follows a random walk and, according to UIP, we have that the *risk premium* (δ_t^3) in each FX future contract is

$$\delta_t^3 = \left[\sum_{i=1}^{T_q} \left(fx_t^{i,t+3} - fx_i \right) \left(\frac{1}{T_q} \right) \right] \tag{3}$$

These three variables capture different risk components in the FX market. δ_t^1 is a measure of volatility and uncertainty. Variable δ_t^2 sees if the FX forecast error $\left(fx_i^{t+3} - fx_{i,t+3}\right)$ occurs in the same direction as the observed change in the spot FX rate ($fx_{i,t+3} - fx_i$). This variable holds information about the relationship between surprises in banks' short and long positions. Factor δ_t^3 obtains the risk in the FX market that agents are asking in the FX future market.

3.5. Sample

Our sample consists of 22 banks that (i) had significant own foreign funding between 2003 and 2011 and (ii) full information for all variables used here (to obtain a balanced panel data). Significant own foreign funding is defined as those banks for with more than 2/3 of the $F_{b,t}^{ff}$ series is different from 0. These criteria provide a panel data structure with 704 observations distributed along 32 periods on a quarterly time basis. After these elimination criteria, 32% of our sample is foreign owned banks.

Table 5
Brazilian Banks Balance Sheet micro data descriptive statistics

Ownership	Banks	Observations
National	15	480
Foreign	7	224
Total	22	704

NOTE: This table summarizes the Brazilian banks' ownership distribution of the data in our sample used in the equation system (12) estimation. We only used a balanced panel data set for banks that have significant $F_{b,t}^{ff}$ in the period analyzed.

4. Econometric Specification

We organized the econometric specification and the estimators to address the objectives and questions of this paper. This paper has three primary questions: (i) the systemic importance of foreign funding for the Brazilian banking system; (ii) the determinants of the banks' foreign funding flow and (iii) the role of the Lehman Brothers crisis in these concerns. Based on these questions, we expect to discuss the relationship between banking system risk, foreign funding, the carry trade and exchange rate exposure.

To elucidate these issues, we define three basic transmission channels from an exchange rate shock to banking system risk: (I) direct investment in risky assets through banks' portfolio management, (II) improving the NPL and (III) affecting the banks' exchange rate exposure. The paper uses a model-free approach with three blocks of equations that we name: (a) Asset Allocation, (b) Funding Diversification and (c) Exchange Rate Exposure. Blocks (a) and (c) are related to question (i), and block (b) is related to question (ii). We discuss question (iii) using the results of estimations of blocks (a) and (b) . From now on, we refer to these channels, in short, as follows:

- *direct effect*: channels I and II using block of equations (a);
- *indirect effect*: channel III using block of equations (c);

The topics of this section summarize the equations and the estimation definition to cover the three primary objectives of the paper. Topic 4.1. relates to the objective of testing and quantifying the impact of a bank's ERE on banking system risk (objective (i)). In this topic, section 4.1.1. describes the block of equations (a), and section 4.1.2. describes the block of equations (c). Section 4.1.3. discusses a formal test to the carry trade, and Section 4.1.4. makes a theoretical link that justifies the approach described in topics 4.1.2. and 4.1.3. Topic 4.2. relates to the objective of identifying the determinants of the banks' carry trade or foreign funding flows, which is block of equations (b).

4.1. Asset Allocation

We assume that banks have three base assets: risk free bonds ($B_{b,t}^{rf}$), risky bonds ($B_{b,t}^{r}$) and credit ($C_{b,t}$). We suppose that bank assets in the balance sheet can be divided into these three assets. We will add a fourth, Non performing loans ($NPL_{b,t}$), which is in fact, part of banks' credit portfolios ($C_{b,t}$). Let bank assets be

$$A_{b,t} = [B^{rf}_{b,t}, B^{r}_{b,t}, C_{b,t}, NPL_{b,t}] \tag{4}$$

where $A_{b,t}$ is the vector of bank assets for each bank b in time t. From now on, every variable or coefficient without a superscript specification refers to a vector for all mentioned j assets.

On the other side of the balance sheet, banks have, here, two liabilities: domestic paid deposits ($F^{h}_{b,t}$) and foreign funding ($F^{ff}_{b,t}$). The vector of bank b's liabilities in time t ($L_{b,t}$) is

$$L_{b,t} = [F^{h}_{b,t}, F^{ff}_{b,t}] \tag{5}$$

With that, we obtain the bank's budget constraint in this framework given by:

$$B^{rf}_{b,t} + B^{r}_{b,t} + C_{b,t} = F^{h}_{b,t} + F^{ff}_{b,t} + \varepsilon^{BUD}_{b,t} \tag{6}$$

where $NPL_{b,t}$ is part of $C_{b,t}$ and $\varepsilon^{BUD}_{b,t}$ is a variable that includes all other bank balance sheet components not included in those variables highlighted. These are related, on the asset side, to those bonds held by banks but owned by banks' clients, for example. On the liabilities side, these are related to banks' equities, non-paid deposits and other types of funding that are not of interest for this study. Walras' law applies to this balance sheet constraint through the variable $\varepsilon^{BUD}_{b,t}$, which will not be modeled.

In our first approach, each bank asset $A^{j}_{b,t}$ observed in the bank balance sheets, is an equilibrium between supply and demand in the asset market. Accordingly, our econometric specification controls for both effects. Each asset j is a function of market returns ($R^{j}_{b,t}$), risk ($\sigma^{j}_{b,t}$) and lagged bank funding ($L_{b,t-1}$). Each equation has an other set of variables that defines or affects its equilibrium ($X^{j}_{b,t}$). Later, we will include a structural component (contemporaneous transmission channel). Equation system (7) resumes and presents this concept:

$$\begin{array}{lclllllll}
B^{rf}_{b,t} & = & b^{rf}_{0} & +b^{rf}_{r}R_{b,t} & +b^{rf}_{\sigma}\sigma_{b,t} & +b^{rf}_{L}L_{b,t-1} & +b^{rf}_{X}X_{b,t} & +\varepsilon^{rf}_{b,t} \\
B^{r}_{b,t} & = & b^{r}_{0} & +b^{r}_{r}R_{b,t} & +b^{r}_{\sigma}\sigma_{b,t} & +b^{r}_{L}L_{b,t-1} & +b^{r}_{X}X^{r}_{b,t} & +\varepsilon^{r}_{b,t} \\
C_{b,t} & = & b^{c}_{0} & +b^{c}_{r}R_{b,t} & +b^{c}_{\sigma}\sigma_{b,t} & +b^{c}_{L}L_{b,t-1} & +b^{c}_{X}, X^{c}_{b,t} & +\varepsilon^{c}_{b,t} \\
NPL_{b,t} & = & b^{npl}_{0} & +b^{npl}_{r}R_{b,t} & +b^{npl}_{\sigma}\sigma_{b,t} & +b^{npl}_{L}L_{b,t-1} & +b^{npl}_{X}X^{npl}_{b,t} & +\varepsilon^{npl}_{b,t}
\end{array} \tag{7}$$

The errors ($\varepsilon_{b,t}$) in equation system (7) are assumed to have common components among the asset equilibrium specifications that describe factors related to asset allocation strategy. With that, the error vector ($\varepsilon_{b,t}$) contains the banks' idiosyncratic strategic components, which means that these errors are correlated among bank assets ($E[\varepsilon^{i}_{b,t}, \varepsilon^{j}_{b,h}] = \sigma_{i,j}$) if $t = h$ and 0 otherwise, whith means that the errors variance covariance matrix is not diagonal.

For a direct link between banks' foreign funding and banking system risk to exist in this equation without contemporaneous transmission, $F^{ff}_{b,t-1}$ must be significant to explain banks' risky asset dynamics. In equation system (7) that means that the effect of banks' foreign funding for risky assets ($B^{r}_{b,t}$, $C_{b,t}$ and $NPL_{b,t}$) is positive ($b^{r}_{L,ff}$, $b^{c}_{L,ff}$ or $b^{npl}_{L,ff}$ are

> 0). Here, we call this effect the *direct impact* of banks' foreign funding on banks' asset allocation, and it is block of equations (a) in our framework. One can broadly think of excessive attractive funding as capital flow in the Parlour et al. (2012) model or the excess liquidity effect of Acharya and Naqvi (2012).

4.2. Exchange Rate Exposure

Asides from the direct impact on risky assets, the inflow of overseas money can influence banks' exposure risk to foreign currency, through unhedged positions or mismatches in the hedged position. This risk is given by banks' exchange rates exposure (ERE) and is generally measured in the literature as banks' market value (equity or cash flow) sensibility to exchange rate movements.

According to Wong et al. (2009), this approach is preferred over an accountancy measure of banks' ERE. In the latter, ERE is defined as the mismatch between assets and liabilities (cosidering derivative positions) denominated in foreign currency. This approach is prefered is because the accounting definition of ERE is more restricted and the impact of exchange rate shocks extrapolate unhedged positions in foreign currency.

We model banks' ERE, block of equations (c), in two ways: ERE_t and ERE_b. The first (equation (8)) assumes that ERE is constant, on average, among cross sectional banks and varies over time (ERE_t):

$$D.RoA_{b,t}= \beta^{cons}+ \left(\beta^0 + \beta^{ff} F^{ff}_{b,t} + \sum_{t=1}^{T} \theta_t \beta^t\right) D.\delta_t + \beta^R R_{b,t}+\varepsilon_{b,t} \qquad (8)$$

where $RoA_{b,t}$ is the return over assets of bank b in time t, β^{cons} is its intercept and θ_t is a dummy for each period t. δ_t is a measure of risk, or surprises, in the FX market that would affect banks' RoA if the ERE is supported by the data. The δ_t measures were described in section 3.4..

Exchange rate exposure that is fixed among banks (cross section) but varies along time ($ERE_t = \left(\beta_0 + \beta^{ff} F^{ff}_{b,t} + \theta_t \beta^t\right)$) for each period t exists in the banking system if:

$$\left(\beta_0 + \beta^{ff} F^{ff}_{b,t} + \theta_t \beta^t\right) \neq 0 \text{ for any } t.$$

We included in equation (8) a matrix $R_{b,t}$ of different banks' asset returns to clean the equation residuals from other assets returns that would affect banks' $RoA_{b,t}$.

In the second case (equation (9)), we estimate an equation, again model-free and just using the definition, where the ERE vary among banks and are constant over time and for each bank (ERE_b), also following a panel-data structure:

$$D.RoA_{b,t}= \alpha^{cons}+ \left(\alpha^0 + \alpha^{ff} F^{ff}_{b,t} + \sum_{b=1}^{B} \tau_b \alpha^b\right) D.\delta_t + \alpha^R R_{b,t}+\varsigma_{b,t} \qquad (9)$$

where τ_b is a dummy for each bank, and in this model, the ERE for each bank b is, $ERE_b = \left(\alpha_0 + \alpha^{ff} F^{ff}_{b,t} + \tau_b \alpha^b\right)$. In this case the ERE exist for any bank b, constant over time, if

$\left(\alpha_0 + \alpha^{ff} F_{b,t}^{ff} + \tau_b \alpha^b\right) \neq 0$ for any b.

Equations (9) and (8) refer to block of equations (c). Both ERE (ERE_t and ERE_b) depend on banks' foreign funding ($F_{b,t}^{ff}$). If β^{ff} or α^{ff} are $\neq 0$, then banks' foreign funding ($F_{b,t}^{ff}$) affects banks' ERE and RoA. This link is a very important into this paper's framework because, as described in section 4.4., it is possible to relate banks' RoA movements with banks' default probability.

4.3. Carry Trade

To test the hypothesis that banks do carry trade, we check the impact of banks' foreign funding over banks' ERE. If increases in banks' foreign funding also raise banks' profit sensibility to exchange rates shocks, independently of the accountancy issue, banks would be assuming higher risk. If banks are assuming higher risk, then they would be using foreign funding in financial transactions with exchange rate risk, which means that banks are conducting carry trades.

If this relationship can not be established, then banks do economic hedge and foreign funding does not impact banks' profit.

4.4. Banks' probability of default and exchange rate exposure

Several papers have highlighted banks' exchange rate exposure (ERE) as not being systemically important considering current regulatory standards. This is due to central banks concerns about this subject as mentioned in the Basel Accords (1988, 2004, 2010).

The risk impact of banks' ERE is usually measured as the banks' potential loss in response to movements in exchange rates. Notwithstanding, here we measure the systemic risk of banks' ERE through their probability of default ($PD_{b,t}$). Let the Z-Score (Boyd and Graham (1986), Hannan and Hanweck (1988), Boyd et al. (1993)) as be measure of banking default probability:

$$Z_{b,t} = \left[\frac{RoA_{b,t} - EoA_{b,t}}{\sigma_{b,t}^{RoA}}\right] \tag{10}$$

where $RoA_{b,t}$ is bank b's Return on Assets in time t, $EoA_{b,t}$ is bank b's Equity over Assets and $\sigma_{b,t}^{RoA}$ is the standard error of bank b's RoA at time t. $Z_{b,t}$ is a normalized variable that measures banks' insolvency or the distance to insolvency. This variable sees whether a bank's profits are volatile enough to the point of compromising all equity ($EoA_{b,t}$) in the event of loss.

We assume that the ERE do not have a clear effect on $\sigma_{b,t}^{RoA}$ or $EoA_{b,t}$. With that, in equation $Z_{b,t}$, unexpected movements in the FX market (δ_t) has an effect only in $RoA_{b,t}$.

If ERE influences the banks' $RoA_{b,t}$ (through equations (8) and (9)), then the link between ERE and banks' PD is straight. This statement ensures the relationship between banks' systemic risk and the *indirect effect* channel (using (10)). If the banks' foreign funding ($F_{b,t}^{ff}$) influence their banks' ERE, then banks do conduct carry trade and the link with the banks' probability of default and banking system stability is through the indirect channel.

4.5. Banks' foreign funding flow determinants

The drivers of foreign funding ($F^{ff}_{b,t}$) are considered within the banks' liabilities ($L_{b,t}$) system of equations.

To assemble the structure of these equations, we consider the factors related to the financial dichotomy of risk and return. We also include factors related to the demand for funding to finance the banks' assets.

Thus, the first aspect when considering in the attractiveness of different funding is the interest rates for the banks' assets and liabilities. The rates and returns vector ($R_{b,t}$) aims to evaluate the complementary and substitution effect for each funding option with other components on the balance sheet. In addition to returns, finance theory emphasizes the role of risk in investors' decision-making. The variable that controls market risk and agents' risk aversion is σ_t. Another important aspect to consider in a banks' funding structure is the dynamics of an asset's demand for funding. Vector $A_{b,t-1}$ includes the assets of banks and their variations.

The system of bank funding or liability equations, without the structural component, is given by:

$$\begin{array}{lcllllll} F^h_{b,t} & = & b^h_0 & +b^h_r R_{b,t} & +b^h_\sigma \sigma_{b,t} & +b^h_A A_{b,t-1} & +b^h_X X_{b,t} & +\varepsilon^h_{b,t} \\ F^{ff}_{b,t} & = & b^{ff}_0 & +b^{ff}_r R_{b,t} & +b^{ff}_\sigma \sigma_{b,t} & +b^{ff}_A A_{b,t-1} & +b^{ff}_X X_{b,t} & +\varepsilon^{ff}_{b,t} \end{array} \tag{11}$$

This framework follows a similar structure to equation system (7) and defines several sources for bank funding fluctuations and equilibrium positions.

4.6. Estimation

First, we combine equation system (7) and equation system (11) into only one system for which we expect a contemporaneous, but not temporal, correlation in equation errors. Second, we add a structural component (contemporaneous transmission channel) to the system, assuming some identification assumptions. This system relates equations and errors from the Asset Allocation system (block (a) - eq system (7)) and the Funding Diversification system (block (b) - eq system (11)). The error correlation between equations in the structural model (12) is justified by common strategic components in the asset and liability interrelationships and also by the relationship between the assets and the liabilities.

Thus, we define the structural model that explains the assets and funding allocations of banks:

$$BY_{b,t} = CZ_{b,t} + DL_{b,t-1} + \varepsilon_{b,t} \tag{12}$$

where $Y_{b,t}$ is the vector of endogenous variables from banks' balance sheets [$B^{rf}_{b,t}$, $B^r_{b,t}$, $C_{b,t}$, $NPL_{b,t}$, $F^h_{b,t}$, $F^{ff}_{b,t}$]. $Z_{b,t}$ is the matrix of exogenous variables described in equation systems (7) and (11)[$R_{b,t}$, $\sigma_{b,t}$, $X_{b,t}$]. $L_{b,t-1}$ is the vector of one period lagged funding variables and $\varepsilon_{b,t}$ is the vector of equations' (7) and (11) residuals such that $\varepsilon_{b,t}$=[$\varepsilon^{rf}_{b,t}$, $\varepsilon^r_{b,t}$, $\varepsilon^c_{b,t}$, $\varepsilon^{npl}_{b,t}$, $\varepsilon^{h,r}_{b,t}$, $\varepsilon^{ff}_{b,t}$].

The problem in estimating the system of equations (12) is imposing constraints on the coefficient matrices B and C so that the equations are exactly identified.

Accordingly, to address the identification problem in this work, we make the following assumptions, which imply restrictions on the coefficient matrix B:

(i) *assets are exogenous to domestic paid funding*: we assume that banks define their need for funding in accordance with the assets' investment opportunities of investment;

(ii) *risky assets are exogenous to risk free assets*: thus, we assume that banks define their asset portfolios by first selecting (setting) the loan portfolio ($C_{b,t}$) and risky bonds ($B^{rf}_{b,t}$), and then the risk-free bonds ($B^{rf}_{b,t}$) to manage their liquidity and meet the supervisory authority legal requirements;

Aside from these, we specifically tested two hypotheses about banks' foreign funding ($F^{ff}_{b,t}$):

(iii') $F^{ff}_{b,t}$ *exogenous to the assets*: regardless of the funding need, given the investment opportunities (asset), banks use this funding for other factors (such as banks' funding average cost strategy or opportunity when it is available) that are difficult to model and that are related to transaction complexity;

(iii") $F^{ff}_{b,t}$ *endogenous to the assets*: assets define the need for domestic and foreign bank funding;

Thus, B is a lower triangular matrix, following a Cholesky decomposition structure in accordance with assumptions (i) and (ii) and the hypotheses to be tested in (iii). This hypotheses strucuture is defined in two vectors of endogenous variables ($Y_{b,t}$).

$$(iii') : Y'_{b,t} = [F^{ff}_{b,t}, C_{b,t}, NPL_{b,t}, B^{r}_{b,t}, B^{rf}_{b,t}, F^{h}_{b,t}] \tag{13}$$

$$(iii'') : Y''_{b,t} = [C_{b,t}, NPL_{b,t}, B^{r}_{b,t}, B^{rf}_{b,t}, F^{ff}_{b,t}, F^{h}_{b,t}] \tag{14}$$

where the vectors (13) and (14) are ordered from the most exogenous variable to the most endogenous.

Additionally, we estimate a parsimonious version of the structural model (12), where we focus on the most important endogenous variables on bank balance sheet for our objectives. With that, we reduce the number of equations in the system and the coefficients to be estimated. This smaller system, identified by an "*" in the endogenous variables vector and, following the previous structure, consists of

$$(iii'^{*}) : Y'^{*}_{b,t} = [F^{ff}_{b,t}, C_{b,t}, B^{rf}_{b,t},] \tag{15}$$

$$(iii''^{*}) : Y''^{*}_{b,t} = [C_{b,t}, B^{rf}_{b,t}, F^{ff}_{b,t}] \tag{16}$$

We use Zelner's 3SLS for the structural model (12) in a panel structure and SUR to estimate equation systems (7) and (11). The estimations are completed by the equations related with ERE ((9) and (8)). These equations used Driscoll and Kraay (1998) robust errors for general forms of heteroskedasticity, autocorrelation and bank cross correlations.

The panels are estimated, first, using bank fixed effects where the equations were differentiated. Then, we test the relevance of bank fixed effects against an estimation using a likelihood-ratio test to obtain benefits with more degrees of freedom, which we expected to be preferred once we used first-difference estimator.

4.7. Variables Description

The variables used in the estimations are summarized in definitions (17) to (20). In these definitions, the first vector shows the variables as described in the *Econometric Specification* (topics 4.1 to 4.5 above). The second uses the variables codes in the estimation tables (Apendix I). The third described how the variables used in the estimations are calculated. The observed series used are identified by a bar over the characters

We begin with the description of the variables for the structural model (12). First we show the left hand of system (12). These are the endogenous variables ($Y_{b,t}$), which are composed of bank Assets (4) and Liabilities (5):

$$\begin{bmatrix} B^{rf}_{b,t} \\ B^{r}_{b,t} \\ C_{b,t} \\ NPL_{b,t} \\ F^{h,r}_{b,t} \\ F^{ff}_{b,t} \end{bmatrix} = \begin{bmatrix} d.B^{rf}_{b,t} \\ d.B^{r}_{b,t} \\ d.C_{b,t} \\ d.NPL_{b,t} \\ d.F^{h,r}_{b,t} \\ d.F^{h,ff}_{b,t} \end{bmatrix} = \begin{bmatrix} \left[\overline{B}^{rf}_{b,t} - \overline{B}^{rf}_{b,t-1}\right] /TA_{b,t} \\ \left[\overline{B}^{r}_{b,t} - \overline{B}^{r}_{b,t-1}\right] /TA_{b,t} \\ \left[\overline{C}_{b,t} - \overline{C}_{b,t-1}\right] /TA_{b,t} \\ \left[\overline{NPL}_{b,t} - \overline{NPL}_{b,t-1}\right] /C^{total}_{b,t} \\ \left[\overline{F}^{h,r}_{b,t}\right] /TA_{b,t} \\ \left[\overline{F}^{ff}_{b,t}\right] /TA_{b,t} \end{bmatrix} \tag{17}$$

Asset variables ($\overline{B}^{rf}_{b,t}, \overline{B}^{r}_{b,t}, \overline{C}_{b,t}, \overline{NPL}_{b,t}$) are stock variables, which is why we took the first difference to use the net flow. Domestic paid deposits ($\overline{F}^{h}_{b,t}$) and foreign funding ($\overline{F}^{ff}_{b,t}$) are flow variables. All of the variables here are calculated over bank total assets ($TA_{b,t}$).

The explanatory variables in the structural model (12) - matrix $Z_{b,t}$ - are, as described previsiously price/return variables ($R_{b,t}$), risk variables (σ_t) and a set of complementary variables ($X_{b,t}$). We show these variables in vectors (18) to (20).

The price/return set of variables ($R_{b,t}$) are composed of asset and liabilitiy related rates. We split these rates into base components.

$$R_{b,t} = \begin{bmatrix} d.Selic_t \\ d.FED_t \\ d.r^{c,spr}_{b,t} \\ d.r^{h}_{b,t} \end{bmatrix} = \begin{bmatrix} \overline{Selic}_t - \overline{Selic}_{t-1} \\ \overline{FED}_t - \overline{FED}_{t-1} \\ \left(\overline{r}^{c}_{b,t} - \overline{Selic}_t\right) - \left(\overline{r}^{c}_{b,t-1} - \overline{Selic}_{t-1}\right) \\ \left(\overline{r}^{h}_{b,t} - \overline{Selic}_t\right) - \left(\overline{r}^{h}_{b,t-1} - \overline{Selic}_{t-1}\right) \end{bmatrix} \tag{18}$$

The risk variables set ($\sigma_{b,t}$) is composed of macroeconomic variables, which are constant in the cross section and vary over time. Here, we are not including the *FX risk market* variables (δ) once we assume that these variables are not part of bank assets and funding risky management but represent shocks in the *FX market*.

$$\sigma_{b,t} = \begin{bmatrix} d.VIX_t \\ d.CDS_t \\ d.I.Liq_t \end{bmatrix} = \begin{bmatrix} \ln(\overline{VIX}_t) - \ln(\overline{VIX}_{t-1}) \\ \ln(\overline{CDS}_t^{BR}) - \ln(\overline{CDS}_{t-1}^{BR}) \\ \overline{I.Liq}_t - \overline{I.Liq}_t \end{bmatrix} \quad (19)$$

The group of "General Controls" ($X_{b,t}$) include the log difference of Brazilian GDP, as described in the Table (3.3) and $pr_{b,t}$, described in table (3.2.2).

$$X_{b,t} = \begin{bmatrix} d.pr_{b,t} \\ d.GDP_t \end{bmatrix} = \begin{bmatrix} pr_{b,t} - pr_{b,t-1} \\ \overline{GDP}_t^{BR} - \overline{GDP}_{t-1}^{BR} \end{bmatrix} \quad (20)$$

The last set of variables are b_0. The intercept changes during the crises period.

$$b_0 = \begin{bmatrix} crise_t \\ +\ b_0 \end{bmatrix} \quad (21)$$

where $crise_t$ is a dummy to identify the most critical period of the 2008 crisis.

4.8. Endogeneity, error structure and econometric issues

Our estimations and results are based on the structural model (12), the systems of equations (7) and (11) and equations (8) and (9), for which we used a 3SLS and SUR approach, assuming that the residuals variance-covariance matrices are not diagonal.

For equations (8) and (9), we use Driscoll and Kraay (1998) robust errors, and we lagged the $R_{b,t}$ bank specific variables (that change in the cross section) to control for endogeneity.

We compare difference in difference panels with fixed effects and with pooled estimations. For this purpose, we use a likelihood ratio test. We expect to have more degrees of freedom without the need to estimate panel fixed effects.

5. Results

Our results compare eight diferent specifications combining the results of the structural model (12) and the systems of equations (7) and (11). These specifications are as follows:

- *specification (a)*: balanced 3SLS panel estimation of structural model (12) in its parsimonious specification with $F_{b,t}^{ff}$ endogenous ($Y_{b,t}^{''*}$ - described in (15)) and with fixed effects;
- *specification (b)*: balanced 3SLS panel estimation of structural model (12) in its parsimonious specification with $F_{b,t}^{ff}$ endogenous ($Y_{b,t}^{''*}$ - described in (15)) with pooled specification;

- *specification (c)*: balanced 3SLS panel estimation of structural model (12) in its extended specification with $F^{ff}_{b,t}$ endogenous ($Y''_{b,t}$ - described in (13)) with pooled estimation;
- *specification (d)*: balanced 3SLS panel estimation of structural model (12) in its parsimonious specification with $F^{ff}_{b,t}$ exogenous ($Y'^{*}_{b,t}$ - described in (16)) and with fixed effects;
- *specification (e)*: balanced 3SLS panel estimation of structural model (12) in its parsimonious specification with $F^{ff}_{b,t}$ exogenous ($Y'^{*}_{b,t}$ - described in (16)) with pooled estimation;
- *specification (f)*: balanced 3SLS panel estimation of structural model (12) in its extended specification with $F^{ff}_{b,t}$ exogenous ($Y'_{b,t}$ - described in (14)) with pooled specification;
- *specification (g)*: balanced panel SUR estimation of the combination of system of equations (7) and (11) with fixed effects;
- *specification (h)*: balanced panel SUR estimation of the combination of system of equations (7) and (11) with pooled estimation;

Table 6
Likelihood - ratio test for banks' fixed effect significance

TEST	Likelihood-Ratio	Significance-level
Test1	89.86	0.01
Test2	95.83	0.00
Test2	1006.08	0.00

NOTE: This table summarizes the results for the likelihood-ratio test with H_0: constrained model (pooled estimation) is significant. Test1 compares specifications (a) and (b), Test2 compares specifications (d) and (e) and Test3 compare specifications (g) and (h).

The test has a null hypothesis that the fixed effects (unrestricted model) are not relevant. Thus, for $F^{ff}_{b,t}$ being endogenous (*Test1* - specifications (a) and (b)), for $F^{ff}_{b,t}$ being exogenous (*Test2* - specifications (d) and (e)) and for the combination of equation systems in specifications (g) and (h) (*Test3*), we verified that we can use pooled estimation, and we therefore expect to have more degrees of freedom in our estimations.

Table (7) shows general information about the estimatons for specifications (a) to (h). We include the *AIC* and *BIC* information criteria to obtain some information to compare the specifications. We therefore highlight two key aspects, or evidence, indicated by the results shown in the table: (i) when we compare the specifications with pooled estimations and those with fixed effects, we see that pooled estimations have a better fit with the data; (ii) specifications with $F^{ff}_{b,t}$ being exogenous are preferable to those with $F^{ff}_{b,t}$ being endogenous.

Table 7
General information about panel estimations

Information	Specification							
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Observations	704	704	704	704	704	704	704	704
Parameters	108	42	84	111	45	90	84	216
AIC	13001.4	12971.32	27906.72	12738.32	12932.42	27641.08	27153.47	27906.72
BIC	13479.86	13162.7	28289.49	13230.45	13132.92	28046.63	28110.4	28289.49

NOTE: This table present general informarion about the specifications (a) to (h) estimations.

5.1. What is the systemic risk and impact of Brazilian banks' foreign funding?

We test banks' foreign funding ($F_{b,t}^{ff}$) impact on Brazilian banking systemic risk using two channels: (i) *direct effect*, which is when a bank assumes a risky position in its portfolio allocation or deteriorates its credit portfolio quality (structural model (12) and the system of equations (7)), and (ii) *indirect effect*, when a bank affects its ERE through its foreign funding adjustments (equation (8) and equation (9)).

5.1.1. Direct Effect - Banks Asset Allocation Improvement Trough Foreign Funding

Here we adress whether changes in banks' foreign funding flow can explain a riskier bank asset allocation.

We therefore focus on the role of funding ($F_{b,t}^{h}$, $F_{b,t}^{ff}$ and $F_{b,t-1}^{ff}$) in the asset equations in the structural model (12) and in the system of equations (7). However, as we assume here that $F_{b,t}^{h}$ is the most endogenous variable in all specifications, it will not be an explanatory variable in any estimation. Furthermore, specifications (g) and (h) do not use any funding as an explanatory variable to avoid the dynamic component in the $F_{b,t}^{ff}$ equation.

Table (8) summarizes the results of Table (12) to Table (19) of Annex I.

According to Table (8), we found a significant relationship between an increase in banks' foreign funding ($F_{b,t}^{ff}$) and an increase in its credit portfolio free from regulatory investment ($C_{b,t}$). In fact, we found that an international funding transaction of 1% of a bank's total assets implies an increase, on average, proportionally greater in its credit portfolio over total assets.

Furthermore, we emphasize that this result was observed, among the considered assets, only for $C_{b,t}$. These findings refute the argument that because of complexity of these transactions, in periods where it was made, there would be a general increase in almost all bank assets. That is, given the occasional growth in liabilities ($F_{b,t}^{ff}$), banks would automatically invest this money in various assets (according to the opportunity).

We also emphasize that the results of the table (8) did not support the hypothesis that banks would make a significant funding in a given period and then would best allocate that resource over time in its assets - $F_{b,t-1}^{ff}$ is not statistically significant for explaining asset variations in t. However, we do not rule out this hypothesis. The problem would be to (i) further specify the model to exactly answer this question and (ii) find one average standard behavior to establish a statistically significant coefficient.

Table 8
Banks Funding as explanatory variable for banks' assets in different model specification

Variable[1] (Funding)	Equation[2] (Asset)	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
					Specification				
Foreign	$d.B^{rf}_{b,t}$				1.04	0.886	−0.41		
($d.F^{ff}_{b,t}$)					(0.60)	(0.64)	(0.74)		
	$d.B^{r}_{b,t}$						0.54		
							(0.78)		
	$d.C_{b,t}$				2.03***	1.74***	1.74***		
					(0.01)	(0.02)	(0.02)		
	$d.NPL_{b,t}$						−0.52		
							(0.62)		
Lagged Foreign	$d.B^{rf}_{b,t}$	−0.09	−0.02	0.05					
($d.F^{ff}_{b,t-1}$)		(0.54)	(0.87)	(0.94)					
	$d.B^{r}_{b,t}$			0.26					
				(0.48)					
	$d.C_{b,t}$	−0.01	0.02	0.02					
		(0.81)	(0.80)	(0.80)					
	$d.NPL_{b,t}$			0.04					
				(0.54)					

p-value in parentheses
*** p<0.01, ** p<0.05, * p<0.1

NOTE: This table summarizes the results for bank funding ($F^{h}_{b,t}$ and $F^{ff}_{b,t}$) in the structural model (12) and in the system of equations' (7) estimations for different specifications. Full estimation results are described in tables (12) to (19). We organized equation results in rows and the system estimations (tables) in columns. [1] *The first column refers to the funding variable as an explanatory variable in the estimations and the second column* [2] *is the endogenous asset variables.*

5.1.2. Indirect Effect - Exchange rate exposure and banks' probability of default

The impact of banks' foreign funding on banks' probability of default is through banks' profits as described in section 4.4.. The here called *indirect impact* is seen in equations (8) and (9). The estimated impact of banks' foreign funding ($F^{ff}_{b,t}$) on banks' profit sensibility to the forex market (ERE) is shown in Table (5.1.2).

We test three risk factors for the FX market (δ^1_t, δ^2_t and δ^3_t) to verify two conditions: (i) variations in the FX risk generate variations in the banks' profits (existence of ERE) and (ii) the increase of banking transactions using foreign money affects this sensitivity ($F^{ff}_{b,t}$ affects banks' ERE, which means that banks use its funding for carry trade).

Our findings indicate that we can identify banks' ERE both in the cross sectional dimension (ERE_b - equation (9)) and in the temporal dimension (ERE_t - equation (8)).

If we consider the number of statistically significant coefficients as a criteria for choosing the best model, then our results indicate that the temporal effect outweighs the cross sectional effect ($n\ \beta^{t,sig} > n\ \alpha^{b,sig}$). While it is possible to identify some banks' ERE_b, ERE_t is statistically significant proportionally more often. Thus, we can argue that exchange rate exposure is more likely to "*change jointly, between banks, over time given changes in the economic scenario*" than that "*banks have an individual, distinct and relatively constant ERE strategy, on average, over time*".

We also found that it was possible to better measure ERE using FX market risk measurements related to prediction errors (δ^2_t) or risk premiums (δ^3_t). In other words, we found better information contained in the exchange futures contracts.

Notwithstanding, we found no significant relationship between banks' foreign funding

Table 9
Brazilian Banks' ERE in equation (8) and (9)

$VARIABLE$	$ERE_t - eq(8)$ $d.RoA_{b,t}$ (1)	$d.RoA_{b,t}$ (2)	$d.RoA_{b,t}$ (3)	$VARIABLE$	$ERE_b - eq(9)$ $d.RoA_{b,t}$ (1)	$d.RoA_{b,t}$ (2)	$d.RoA_{b,t}$ (3)
δ_t	δ_t^1	δ_t^2	δ_t^3	δ_t	δ_t^1	δ_t^2	δ_t^3
β^0	-0.00	-0.07^{***}	0.00^{***}	α^0	0.00	-0.00	0.00^{***}
	(0.23)	(0.00)	(0.00)		(0.51)	(0.80)	(0.00)
β^{ff}	-0.00	-0.00	0.00	α^{ff}	-0.00	-0.00	0.00
	(0.33)	(0.53)	(0.65)		(0.14)	(0.49)	(0.87)
$n\ \beta^t$	32	32	32	$n\ \alpha^b$	20	20	20
$n\ \beta^{t,sig}$	25	28	26	$n\ \alpha^{b,sig}$	2	2	3
$avg\ \beta^{t,sig}$	-0.00	-0.00	-0.00	$avg\ \alpha^{t,sig}$	-0.00	-0.00	-0.00
$std\ \beta^{t,sig}$	0.01	0.09	0.00	$std\ \alpha^{t,sig}$	0.00	0.00	0.00
N	704	704	704		704	704	704
$Groups$	21	21	21		21	21	21

NOTE: This table summarizes the results for the banks' ERE_t varying over time but fixed in the cross section (equation (8)) and banks' ERE_b varying over banks but fixed over time (equation (9)). In the first group of variables, we show the base betas for banks' ERE: β^0/α^0 and β^{ff}/α^{ff}. The second group of variables summarizes the results for the $\sum_{t=1}^{T}\theta_t\beta^t$ term in equation (8) and the results for the $\sum_{b=1}^{B}\tau_b\alpha^b$ term in equation (9). Where $n\ \beta^t$ and $n\ \alpha^b$ are the total number of time and banks betas estimated. The $n\ \beta^{t,sig}$ and $n\ \alpha^{b,sig}$ are the total significant time betas and alphas, respectively. $avg\ \beta^{t,sig}$ is the average $(\beta^0 + \beta^{t,sig})$, in the estimation and $std\ \beta^{t,sig}$ is the standard deviation of $(\beta^0 + \beta^{t,sig})$ with the same logic for the alphas.

and banks' ERE_t (β^{ff}) or ERE_b (α^{ff}). We therefore reject the hypothesis that banks are not hedging (accounting and economic) their foreign funding $(F_{b,t}^{ff})$. Thus, if all foreign funding of banks is hedged, we can not argue that banks in Brazil between 2003 and 2011, have done carry trade.

5.2. *What are the determinants of banks' foreign funding?*

To identify the determinants of banks' funding diversification strategies, we examine the structural model (12) and the system of equations (11). We bring together the results of different specifications into three groups of results: prices / returns, risk and the funding demand for asset investments.

When we examine Table (5.2), we see that we have little success in our estimations for returns, for risk, for asset funding demand.

This result raises three primally possibilities: (i) the equations are badly specified, (ii) some variables should be better worked (measurement error) or (iii) such operations are difficult to model because they are subject to some dynamic factors in banking (their attractiveness does not closely follow the economic environment) or because they are related to transaction operational issues[6].

Results show that the estimates for bank assets are good explanatory variables in banks' foreign funding equation. This results highlights hypothesis (i), where we could think that there are a relevant lag between market attractiveness and realization of the transaction itself.

[6]As described by Menkhoff et al. (2012b)

Table 10
Determinants of banks funding - price

	VARIABLE	Specification							
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Return	Selic ($d.Selic_t$)	−1.99	−6.94		0.73	0.073	0.073	0.073	0.073
		(0.77)	(0.91)		(0.50)	(0.51)	(0.51)	(0.51)	(0.51)
	FED rates ($d.r_t^{FED}$)	−34.5	−118	−10.9	−0.39	−0.39	−0.39	−0.39	−0.39
		(0.64)	(0.89)	(0.88)	(0.35)	(0.36)	(0.36)	(0.36)	(0.36)
	Loans rate Spread ($d.r_{b,t}^{c,spr}$)	1.26	4.50		−0.02	−0.02	−0.02	−0.02	−0.02
		(0.62)	(0.90)		(0.59)	(0.57)	(0.57)	(0.57)	(0.57)
	Domestic paid deposit cost ($d.r_{b,t}^{h,r}$)	−12.6	−42.3	−6.63	−0.25	−0.23	−0.23	−0.23	−0.23
		(0.65)	(0.90)	(0.79)	(0.20)	(0.23)	(0.23)	(0.23)	(0.23)
Risk	VIX ($d.VIX_t$)	0.67	2.29	0.40	0.24	0.024	0.024	0.024	0.024
		(0.61)	(0.89)	(0.83)	(0.11)	(0.12)	(0.12)	(0.12)	(0.12)
	Brazilian CDS $\left(d.CDS_t^{BR}\right)$				−0.00	−0.00	−0.00	−0.00	−0.00
					(0.32)	(0.32)	(0.32)	(0.32)	(0.32)
	International Liquidity ($d.I.Liq_t$)	−42.4	−1.44	−29.5	−0.79	0.79	−0.79	−0.79	−0.79
		(0.63)	(0.89)	(0.86)	(0.53)	(0.53)	(0.53)	(0.53)	(0.53)
Assets	Risk Free Bonds $\left(B_{b,t}^{rf}\right)$	−5.48	−21.9	−7.39					
		(0.60)	(0.88)	(0.81)					
	Risky Bonds $\left(B_{b,t}^{r}\right)$			3.12					
				(0.53)					
	Credit ($C_{b,t}$)	−13.1	−45.6	−4.09					
		(0.64)	(0.89)	(0.76)					
	Non Perform Loans ($NPL_{b,t}$)			−8.60					
				(0.86)					

p-value in parentheses
*** p<0.01, ** p<0.05, * p<0.1

NOTE: This table summarizes the results for funding (i) prices/rates ($R_{b,t}$), (ii) risk measures (σ_t) and asset demands for funding ($A_{b,t}$).

5.3. *How did the Lehman Brothers 2008 crisis affect Brazilian banks foreign funding dynamics?*

The international financial stress of 2008 had different effects on Brazilian banks' assets and liabilities. We include this effect in our estimations using a dummy that modifies the intercepts of our estimations. In addition to modeling an intercept dummy, one could think of interactions with other variables to verify the effect of the crisis on the different variable slopes.

However, due to an excess of coefficients already estimated, we choose a simpler approach here.

The results, in Table (5.3), show that this dummy is not significant. We understand this result as consequence of the effect of the crisis effect could already be controlled in the others macroeconomic variables.

Table 11
Effect of 2008 crises over banks asset allocation and funding diversification

Equation	Specification							
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Risk Free Bonds ($d.B_t^{rf}$)	−1.48	−1.40	−1.16	−0.05	−0.18	0.38	0.79	0.79
	(0.78)	(0.79)	(0.87)	(0.96)	(0.91)	(0.89)	(0.44)	(0.44)
Risky Bonds ($d.B_t^r$)			−2.72			2.18	−1.42	−1.42
			(0.58)			(0.41)	(0.18)	(0.34)
Credit ($d.C_t$)	−1.12	−1.09	−1.09	−0.45	−0.53	−0.53	−1.11	−1.11
	(0.21)	(0.25)	(0.25)	(0.73)	(0.67)	(0.67)	(0.21)	(0.25)
Non Perform-Loans ($d.NPL_{b,t}$)			−0.47			−0.32	−0.29	−0.29
			(0.57)			(0.72)	(0.69)	(0.69)
Domestic paid Fundind ($d.F_{b,t}^{h,r}$)			−5.06			2.19	−0.44	−0.44
			(0.82)			(0.80)	(0.81)	(0.81)
Foreign Fund ($d.F_{b,t}^{ff}$)	−10.77	−33.4	2.87	−0.32	−0.32	−0.32	−0.32	−0.32
	(0.74)	(0.90)	(0.84)	(0.50)	(0.51)	(0.51)	(0.51)	(0.51)

p-value in parentheses
*** p<0.01, ** p<0.05, * p<0.1

NOTE: This table summarizes the results of the Lehman Brothers crisis dummy in the structural model (12), and the system of equations (7) and (11). The system equations are in the table rows and the different specifications are in the columns. The estimation results in the table refer to the crisis dummy only ($crise_t$).

6. Conclusion

Brazil, between 2001 and 2012, has mantained a high interest rate relative to the rest of the world and a low exchange rate volatility. These characteristics have brought Brazil a significant inflow of international money over the last decade. This money is used by different agents, such as foreign investors, hedge funds and banks that trade with international currency. We focus on a specific agent that uses this funding, Brazilian banks.

We attempted to answer three questions: (i) What is the systemic risk and impact of Brazilian banks' foreign funding? (ii) What are the determinants of bank foreign funding?, (iii) How did the 2008 crisis affect these dynamics? With these questions, we expected to establish relationships between banks' exchange rate exposure, foreign funding, the carry trade and banking system risk.

The data show that there has been an increase in the share of bank foreign funding to bank total assets since 2003. This result means that Brazilian banks have increased the use of their funding in the composition of its total funding. We also saw that most of the incoming and outgoing fund money in Brazil is through contracts in US dollars, despite a strong drive for the euro and the Japanese yen, especially before the 2008 crisis.

We develop a theoretical background using a model-free approach based on two structures of econometric equations. On one hand, we have a system of Assets and Liabilities for the equations with correlated errors. This system includes different relationships and control various aspects of banks financial dynamics. On the other hand we define equations to study the impact of foreign exchange risk on bank profits. With this equation structure, we expect to relate exchange rate shocks and risk of the banking system to answer the above questions. This relationship has two transmission channels, the so-called direct and indirect effects.

Specifically, we found a significant link between an increase in banks' foreign funding and an increase in banks' credit portfolios free from the required investment. This result reinforces the thesis of a direct transmission channel.

Thus, we believe it is possible to argue that the increase in banks' foreign funding in Brazil between 2003 and 2011 was related to a riskier position in bank assets. It is important to emphasize two aspects related to this result. First, this result does not consider that this type of transaction involves significant systemic risk for the Brazilian banking system, because we use a small portion of bank activity in our estimations. Second, we do not relate these results to noncompliance to the risk exposure legal limits defined by the CBB supervision authority.

With regard to the indirect channel, through banks' foreign exchange rate exposure, we could not establish a direct link between the variation in the banks' foreign funding and variations in the sensitivity of banks' profits to shocks in the foreign exchange market. Thus, we can not argue that banks in Brazil were involved in the carry trade over the considered period.

We also note that we can argue that exchange rate exposure is more likely to "*change jointly, between banks, over time given changes in the economic scenario*" than that "*banks have an individual, distinct and relatively constant ERE strategy, on average, over time*".

With regard to foreign funding determinants, our results indicate that these are possibly related to operational issues in preceding periods because, given the complexity, funding decisions are made with some lag.

Finally, and as previously argued, we emphasize that we find evidence that the decision to use foreign funding is an exogenous demand for funding by bank assets.

We used significant restrictions on the data series to obtain its interest component. We also applied restrictions so that the database contained enough observations in all series. These are interesting but strong assumptions. Due to these restrictions, there were two problems. First, the analysis tried to explain a very specific component of the series with other specific components of other series. Banking activity goes beyond the series used, and this undermines the explanatory power of the models. Therefore, because of the second-mentioned constraint, retreating many observations of the base. Few banks in the Brazilian banking system had frequent observations and could be included in all series. Therefore, many observations had zero value for a given variable describing a market. The existence of these zeros undermined the estimates. Many filters have also been used to remove gaps within the database.

Thus we believe that the theoretical framework is valid, but adjustments in the temporal relationships between funding and investment must be made to better analyze the effects and transmission channels described in the paper. Once scope of the the work is broadened other extensions focusing on particular aspects can be considered. For example, one can think about separating the direct and indirect effects and studying them in more detail.

It is worth noting that this work uses a first difference estimator. This approach can be more complicate than model using level variables. Therefore, we believe that would be interesting extend the analyzes between ERE, Foreign Funding and Banking System Risk using level variables.

We also note the importance of exploring the differences between global and local banks, as argued by Cetorelli and Goldberg (2012). An emphasis on differences in banks size would be interesting (Berger and Bouwman (2013) and Huizinga and Laeven (2012) for example). Some usual controls could also have positive impacts on the estimations (Chang et al. (2013)).

Given all of the arguments presented above, the paper presents innovations in relation to the literature in several aspects, including the methodology, and database. We contribute to the literature with the developed concepts and, the results for the temporal and variable level or flow relationships, further, the work itself opens up possibilities for several other research lines.

The relationship between banks' exchange rate exposure and the probability of default can be further extended and exploited.

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7. ANNEX I - Structural Model (12) and the system of equations (7) and (11) Results

This Annex present the complete estimations of structural model (12), and the system of equations (7) and (11) . The tables follows the specifications descriptions in section.

Table 12
3SLS panel estimation with fixed effects and $F_{b,t}^{ff}$ endogenous

	VARIABLE	$d.C_{b,t}$	$d.B_{b,t}^{rf}$	$d.F_{b,t}^{ff}$
Returns/	$d.r_{b,t-1}^{h,spr}$	$-1.03***$	-1.84	-12.6
Rates		(0.00)	(0.68)	(0.65)
	$d.r_{b,t}^{loans}$	0.066	0.206	1.264
		(0.43)	(0.54)	(0.62)
	$d.r_{t}^{FED}$	$-2.46***$	-5.19	-34.5
		(0.00)	(0.64)	(0.64)
	$d.Selic_t$	-0.28	-0.25	-1.99
		(0.16)	(0.81)	(0.77)
Risk	$d.CDS_t$	0.008		
		(0.61)		
	$d.VIX_t$	0.035	0.103	0.669
		(0.21)	(0.58)	(0.61)
	$d.l.Liq_t$	-2.57	-6.73	-42.4
		(0.26)	(0.59)	(0.63)
Lagged	$d.F_{b,t-1}^{ff}$	-0.01	-0.09	
Funding		(0.81)	(0.54)	
Structural	$d.C_{b,t}$		-1.98	-13.1
Models			(0.64)	(0.64)
	$d.B_{b,t}^{rf}$			-5.48
				(0.60)
General	$d.GDP_t$	0.086	0.148	1.035
controls		(0.21)	(0.66)	(0.65)
	$d.pr_{b,t}$	$-0.27***$	-0.39	-2.89
		(0.00)	(0.74)	(0.69)
	$crise_t$	-1.12	-1.48	-10.7
		(0.21)	(0.78)	(0.74)
	cons	1.103	8.781	51.01
		(0.43)	(0.12)	(0.56)

P-valueinparentheses
***p<0.01,**p<0.05,*p<0.01

NOTE: This tables present the estimations of structural model (12) with fixed effects using 3SLS and with banks' $F_{b,t}^{ff}$ endogenous to banks' assets investment decision (especification (a)). We omit the fixed effects and the seasonality controls. In the comlumns are the system's equations with the dependent variable identified in the columns' labels. In the rows are the variables used as explanatory variables to the system estimation.

Table 13
3SLS pooled panel estimation and $F_{b,t}^{ff}$ endogenous

	VARIABLE	$d.C_{b,t}$	$d.B_{b,t}^{rf}$	$d.F_{b,t}^{ff}$
Returns/	$d.r_{b,t-1}^{h,spr}$	$-1.02***$	-1.81	-42.3
Rates		(0.00)	(0.69)	(0.89)
	$d.r_{b,t}^{loans}$	0.062	0.199	4.489
		(0.48)	(0.55)	(0.89)
	$d.r_{t}^{FED}$	$-2.43***$	-5.11	$-118.$
		(0.00)	(0.66)	(0.89)
	$d.Selic_t$	-0.29	-0.28	-6.84
		(0.16)	(0.81)	(0.91)
Risk	$d.CDS_t$	0.008		
		(0.62)		
	$d.VIX_t$	0.034	0.099	2.287
		(0.26)	(0.59)	(0.89)
	$d.l.Liq_t$	-2.40	-6.37	$-144.$
		(0.33)	(0.61)	(0.89)
Lagged	$d.F_{b,t-1}^{ff}$	0.017	-0.02	
Funding		(0.80)	(0.87)	
Structural	$d.C_{b,t}$		-1.97	-45.6
Models			(0.65)	(0.89)
	$d.B_{b,t}^{rf}$			-21.9
				(0.88)
General	$d.GDP_t$	0.091	0.156	3.664
controls		(0.21)	(0.67)	(0.89)
	$d.pr_{b,t}$	$-0.23***$	-0.31	-7.50
		(0.00)	(0.76)	(0.90)
	$crise_t$	-1.09	-1.40	-33.4
		(0.25)	(0.79)	(0.90)
	cons	$1.925*$	10.40	232.9
		(0.06)	(0.24)	(0.88)

P-valueinparentheses
***p<0.01,**p<0.05,*p<0.01

NOTE: This tables present the pooled estimations of structural model (12) using 3SLS and with banks' $F_{b,t}^{ff}$ endogenous to banks' assets investment decision (especification (b)). We omit the seasonality controls. In the comlumns are the system's equations with the dependent variable identified in the columns' labels. In the rows are the variables used as explanatory variables to the system estimation.

Table 14

3SLS pooled panel estimation and $F^{ff}_{b,t}$ endogenous of full system

	VARIABLE	$d.C_{b,t}$	$d.NPL_{b,t}$	$d.B^{r}_{b,t}$	$d.B^{rf}_{b,t}$	$d.F^{ff}_{b,t}$	$d.F^{h}_{b,t}$
Returns/	$d.r^{h,spr}_{b,t-1}$	$-1.02***$	$-0.57*$	-1.51	-1.65	-6.93	4.568
Rates		(0.00)	(0.09)	(0.74)	(0.58)	(0.79)	(0.74)
	$d.r^{loans}_{b,t}$	0.062	-0.05	-0.12			
		(0.48)	(0.46)	(0.81)			
	$d.r^{FED}_{t}$	$-2.43***$	-1.24	-6.45	-4.93	-10.9	-4.31
		(0.00)	(0.18)	(0.56)	(0.75)	(0.88)	(0.74)
	$d.Selic_t$	-0.29	-0.18	-0.56	-0.28		
		(0.16)	(0.37)	(0.67)	(0.82)		
Risk	$d.CDS_t$	0.008	0.006				
		(0.62)	(0.65)				
	$d.VIX_t$	0.034	0.017	0.080	0.095	0.400	-0.13
		(0.26)	(0.51)	(0.67)	(0.60)	(0.83)	(0.76)
	$d.l.Liq_t$	-2.40	-2.33	-9.91	-8.63	-29.5	
		(0.33)	(0.26)	(0.63)	(0.70)	(0.86)	
Lagged	$d.F^{ff}_{b,t-1}$	0.017	0.035	0.256	0.049		-2.71
Funding		(0.80)	(0.54)	(0.48)	(0.94)		(0.50)
Structural	$d.C_{b,t}$		-0.17	-0.42	-0.99	-4.09	2.663
Models			(0.52)	(0.78)	(0.40)	(0.76)	(0.78)
	$d.NPL_{b,t}$			-3.29	-2.22	-8.60	5.264
				(0.68)	(0.73)	(0.86)	(0.60)
	$d.B^{r}_{b,t}$				-0.15	3.118	-4.66
					(0.96)	(0.53)	(0.76)
	$d.B^{rf}_{b,t}$					-7.39	3.843
						(0.81)	(0.79)
	$d.F^{ff}_{b,t}$						6.599
							(0.52)
General	$d.GDP_t$	0.091	-0.03	-0.26	-0.06	0.185	-0.72
controls		(0.21)	(0.60)	(0.55)	(0.91)	(0.93)	(0.78)
	$d.pr_{b,t}$	$-0.23***$				0.476	
		(0.00)				(0.91)	
	$crise_t$	-1.09	-0.47	-2.72	-1.16	2.868	-5.06
		(0.25)	(0.57)	(0.58)	(0.87)	(0.84)	(0.82)
	$cons$	$1.925*$	0.712	0.753	$9.140**$	64.15	-23.3
		(0.06)	(0.46)	(0.90)	(0.01)	(0.79)	(0.85)

P-valueinparentheses

***p<0.01,**p<0.05,*p<0.01

NOTE: This tables present the pooled estimations of structural model (12) using 3SLS and with banks' $F^{ff}_{b,t}$ endogenous to banks' assets investment decision (especification (c)). We omit the seasonality controls. In the comlumns are the system's equations with the dependent variable identified in the columns' labels. In the rows are the variables used as explanatory variables to the system estimation.

Table 15
3SLS panel estimation with fixed effects and $F^{ff}_{b,t}$ exogenous

	VARIABLE	$d.F^{ff}_{b,t}$	$d.C_{b,t}$	$d.B^{rf}_{b,t}$
Returns/ Rates	$d.r^{h,spr}_{b,t-1}$	−0.25	−0.50	−0.61
		(0.20)	(0.31)	(0.39)
	$d.r^{loans}_{b,t}$	−0.02	0.116	0.172
		(0.59)	(0.35)	(0.31)
	$d.r^{FED}_{t}$	−0.39	−1.65	−2.51
		(0.35)	(0.16)	(0.30)
	$d.Selic_t$	0.073	−0.43	−0.07
		(0.50)	(0.14)	(0.86)
Risk	$d.CDS_t$	−0.00	0.025	
		(0.32)	(0.28)	
	$d.VIX_t$	0.024	−0.01	0.043
		(0.11)	(0.74)	(0.30)
	$d.l.Liq_t$	−0.79	−0.92	−3.35
		(0.53)	(0.78)	(0.38)
Structural Models	$d.F^{ff}_{b,t}$		2.029 ∗ ∗	1.041
			(0.01)	(0.60)
	$d.C_{b,t}$			−1.06
				(0.28)
General controls	$d.GDP_t$	−0.00	0.103	0.081
		(0.83)	(0.30)	(0.49)
	$d.pr_{b,t}$	−0.13 ∗ ∗∗		
		(0.00)		
	$crise_t$	−0.32	−0.45	−0.05
		(0.50)	(0.73)	(0.96)
	$cons$	1.283∗	−1.52	6.291 ∗ ∗
		(0.09)	(0.49)	(0.01)

P-valueinparentheses
***p<0.01,**p<0.05,*p<0.01

NOTE: This tables present the estimations of structural model (12) with fixed effects using 3SLS and with banks' $F^{ff}_{b,t}$ exogenous to banks' assets investment decision (especification (d)). We omit the fixed effects and seasonality controls. In the comlumns are the system's equations with the dependent variable identified in the columns' labels. In the rows are the variables used as explanatory variables to the system estimation.

Table 16
3SLS pooled panel estimation and $F^{ff}_{b,t}$ exogenous

	VARIABLE	$d.F^{ff}_{b,t}$	$d.C_{b,t}$	$d.B^{rf}_{b,t}$
Returns/ Rates	$d.r^{h,spr}_{b,t-1}$	−0.23	−0.60	−0.74
		(0.23)	(0.20)	(0.38)
	$d.r^{loans}_{b,t}$	−0.02	0.107	0.169
		(0.57)	(0.36)	(0.34)
	$d.r^{FED}_{t}$	−0.39	−1.74	−2.72
		(0.36)	(0.11)	(0.32)
	$d.Selic_t$	0.073	−0.42	−0.09
		(0.51)	(0.12)	(0.82)
Risk	$d.CDS_t$	−0.00	0.023	
		(0.32)	(0.29)	
	$d.VIX_t$	0.024	−0.00	0.048
		(0.12)	(0.83)	(0.28)
	$d.l.Liq_t$	−0.79	−1.06	−3.56
		(0.53)	(0.74)	(0.38)
Structural Models	$d.F^{ff}_{b,t}$		1.737 ∗ ∗	0.886
			(0.02)	(0.64)
	$d.C_{b,t}$			−1.14
				(0.30)
General controls	$d.GDP_t$	−0.00	0.104	0.089
		(0.83)	(0.27)	(0.49)
	$d.pr_{b,t}$	−0.13 ∗ ∗∗		
		(0.00)		
	$crise_t$	−0.32	−0.53	−0.18
		(0.51)	(0.67)	(0.91)
	$cons$	1.412 ∗ ∗∗	−0.49	7.459 ∗ ∗∗
		(0.00)	(0.76)	(0.00)

P-valueinparentheses
***p<0.01,**p<0.05,*p<0.01

NOTE: This tables present the pooled estimations of structural model (12) using 3SLS and with banks' $F^{ff}_{b,t}$ exogenous to banks' assets investment decision (especification (e)). We omit the fixed effects and seasonality controls. In the comlumns are the system's equations with the dependent variable identified in the columns' labels. In the rows are the variables used as explanatory variables to the system estimation.

Table 17
3SLS pooled panel estimation and $F^{ff}_{b,t}$ exogenous of full system

	VARIABLE	$d.F^{ff}_{b,t}$	$d.C_{b,t}$	$d.NPL_{b,t}$	$d.B^{r}_{b,t}$	$d.B^{rf}_{b,t}$	$d.F^{h}_{b,t}$
Returns/	$d.r^{h,spr}_{b,t-1}$	−0.23	−0.60	−0.39	−0.73	−1.10	−0.38
Rates		(0.23)	(0.20)	(0.39)	(0.70)	(0.30)	(0.94)
	$d.r^{loans}_{b,t}$	−0.02	0.107	−0.08			
		(0.57)	(0.36)	(0.36)			
	$d.r^{FED}_{t}$	−0.39	−1.74	−0.70	−4.86	−1.46	−2.63
		(0.36)	(0.11)	(0.64)	(0.33)	(0.75)	(0.63)
	$d.Selic_t$	0.073	−0.42	−0.05	−0.37		
		(0.51)	(0.12)	(0.82)	(0.57)		
Risk	$d.CDS_t$	−0.00	0.023				
		(0.32)	(0.29)				
	$d.VIX_t$	0.024	−0.00	0.020	0.050	0.060	−0.00
		(0.12)	(0.83)	(0.42)	(0.56)	(0.40)	(0.96)
	$d.l.Liq_t$	−0.79	−1.06	−2.07	−6.73	−3.93	
		(0.53)	(0.74)	(0.35)	(0.44)	(0.64)	
Structural	$d.F^{ff}_{b,t}$		1.737 ∗ ∗	−0.52	0.544	−0.41	5.247
Models			(0.02)	(0.62)	(0.78)	(0.74)	(0.16)
	$d.C_{b,t}$			0.127	−0.41	−0.67	−1.03
				(0.83)	(0.74)	(0.29)	(0.80)
	$d.NPL_{b,t}$				−1.62	−1.04	2.606
					(0.55)	(0.61)	(0.45)
	$d.B^{r}_{b,t}$					0.538	0.622
						(0.69)	(0.91)
	$d.B^{rf}_{b,t}$						−0.51
							(0.92)
General	$d.GDP_t$	−0.00	0.104	−0.06	−0.18	0.055	0.245
controls		(0.83)	(0.27)	(0.33)	(0.35)	(0.85)	(0.81)
	$d.pr_{b,t}$	−0.13 ∗ ∗∗					
		(0.00)					
	$crise_t$	−0.32	−0.53	−0.32	−2.18	0.365	2.194
		(0.51)	(0.67)	(0.72)	(0.41)	(0.89)	(0.80)
	cons	1.412 ∗ ∗∗	−0.49	0.924	−0.24	9.365 ∗ ∗∗	14.98
		(0.00)	(0.76)	(0.36)	(0.94)	(0.00)	(0.76)

P-valueinparentheses
***p<0.01,**p<0.05,*p<0.01

NOTE: This tables present the pooled estimations of the system of equations (7) using 3SLS and with banks' $F^{ff}_{b,t}$ exogenous to banks' assets investment decision (especification (f)). We omit the fixed effects and seasonality controls. In the comlumns are the system's equations with the dependent variable identified in the columns' labels. In the rows are the variables used as explanatory variables to the system estimation.

Table 18
SUR panel estimation with fixed effect

	VARIABLE	$d.C_{b,t}$	$d.B^{r}_{b,t}$	$d.B^{rf}_{b,t}$	$d.F^{ff}_{b,t}$	$d.F^{h}_{b,t}$	$d.NPL_{b,t}$
Returns/	$d.r^{h,spr}_{b,t-1}$	−1.03 ∗ ∗∗	0.055	0.222	−0.23	−1.60 ∗ ∗	−0.39
Rates		(0.00)	(0.90)	(0.59)	(0.23)	(0.04)	(0.19)
	$d.r^{loans}_{b,t}$	0.066	0.045	0.075	−0.02	−0.37 ∗ ∗	−0.06
		(0.43)	(0.65)	(0.43)	(0.57)	(0.03)	(0.34)
	$d.r^{FED}_{t}$	−2.46 ∗ ∗∗	−2.71 ∗ ∗∗	−0.29	−0.39	−5.87 ∗ ∗∗	−0.80
		(0.00)	(0.00)	(0.74)	(0.36)	(0.00)	(0.22)
	$d.Selic_t$	−0.28	−0.04	0.307	0.073	0.191	−0.13
		(0.16)	(0.84)	(0.18)	(0.51)	(0.65)	(0.43)
Risk	$d.CDS_t$	0.007	−0.01	−0.01	−0.00	−0.04	0.005
		(0.62)	(0.41)	(0.33)	(0.32)	(0.22)	(0.67)
	$d.VIX_t$	0.035	0.029	0.031	0.024	0.119∗	0.011
		(0.22)	(0.40)	(0.33)	(0.12)	(0.05)	(0.63)
	$d.l.Liq_t$	−2.54	−2.80	−1.46	−0.79	−7.84	−1.97
		(0.27)	(0.31)	(0.57)	(0.53)	(0.11)	(0.31)
General	$d.GDP_t$	0.087	−0.13	−0.02	−0.00	−0.10	−0.05
controls		(0.20)	(0.10)	(0.79)	(0.83)	(0.47)	(0.35)
	$d.pr_{b,t}$	−0.27 ∗ ∗∗	0.035	0.150∗	−0.13 ∗ ∗∗	−0.45 ∗ ∗∗	0.040
		(0.00)	(0.68)	(0.07)	(0.00)	(0.00)	(0.51)
	$crise_t$	−1.11	−1.42	0.794	−0.32	−0.44	−0.29
		(0.21)	(0.18)	(0.44)	(0.51)	(0.81)	(0.69)
	cons	1.076	5.901 ∗ ∗∗	6.477 ∗ ∗∗	1.412 ∗ ∗∗	17.53 ∗ ∗∗	0.433
		(0.44)	(0.00)	(0)	(0.00)	(0)	(0.58)

P-valueinparentheses
***p<0.01,**p<0.05,*p<0.01

NOTE: This tables present the estimations of the system of equations (7) and (11) with fixed effects using SUR (especification (h)). We omit the fixed effects and seasonality controls. In the comlumns are the system's equations with the dependent variable identified in the columns' labels. In the rows are the variables used as explanatory variables to the system estimation.

Table 19
SUR pooled panel estimation

	VARIABLE	$d.C_{b,t}$	$d.B^{r}_{b,t}$	$d.B^{rf}_{b,t}$	$d.F^{ff}_{b,t}$	$d.F^{h}_{b,t}$	$d.NPL_{b,t}$
Returns/ Rates	$d.r^{h,spr}_{b,t-1}$	$-1.02***$	0.203	0.211	-0.23	$-1.60**$	-0.39
		(0.00)	(0.73)	(0.61)	(0.23)	(0.04)	(0.19)
	$d.r^{loans}_{b,t}$	0.062	0.068	0.075	-0.02	$-0.37**$	-0.06
		(0.48)	(0.62)	(0.43)	(0.57)	(0.03)	(0.34)
	$d.r^{FED}_{t}$	$-2.43***$	$-2.76**$	-0.30	-0.39	$-5.87***$	-0.80
		(0.00)	(0.03)	(0.73)	(0.36)	(0.00)	(0.22)
	$d.Selic_t$	-0.29	-0.00	0.308	0.073	0.191	-0.13
		(0.16)	(0.99)	(0.18)	(0.51)	(0.65)	(0.43)
Risk	$d.CDS_t$	0.008	-0.01	-0.01	-0.00	-0.04	0.005
		(0.61)	(0.51)	(0.33)	(0.32)	(0.22)	(0.67)
	$d.VIX_t$	0.034	0.031	0.031	0.024	$0.119*$	0.011
		(0.26)	(0.51)	(0.33)	(0.12)	(0.05)	(0.63)
	$d.l.Liq_t$	-2.44	-2.94	-1.48	-0.79	-7.84	-1.97
		(0.32)	(0.44)	(0.57)	(0.53)	(0.11)	(0.31)
General controls	$d.GDP_t$	0.090	-0.13	-0.02	-0.00	-0.10	-0.05
		(0.22)	(0.22)	(0.79)	(0.83)	(0.47)	(0.35)
	$d.pr_{b,t}$	$-0.23***$	-0.04	$0.146*$	$-0.13***$	$-0.45***$	0.040
		(0.00)	(0.73)	(0.08)	(0.00)	(0.00)	(0.51)
	$crise_t$	-1.10	-1.42	0.790	-0.32	-0.44	-0.29
		(0.25)	(0.34)	(0.44)	(0.51)	(0.81)	(0.69)
	$cons$	$1.960*$	-0.99	$6.475***$	$1.412***$	$17.53***$	0.433
		(0.05)	(0.53)	(0)	(0.00)	(0)	(0.58)

P-valueinparentheses
***p<0.01,**p<0.05,*p<0.01

NOTE: This tables present the pooled estimations of the system of equations (7) and (11) using SUR (especification (g)). We omit the fixed effects and seasonality controls. In the comlumns are the system's equations with the dependent variable identified in the columns' labels. In the rows are the variables used as explanatory variables to the system estimation.