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Impact of exchange rate swaps on the dollar coupon curve: an analysis according to principal components regression

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ABSTRACT

The objective of this article is to verify, based on balanced portfolio theory, the impact of the offer by the Brazilian Central Bank of exchange rate swaps and reverse swaps on the attributes of the term structure of the effective interest rate on dollar borrowings (the dollar coupon curve). For this purpose, we use linear regression of principal components. As a complementary analysis, we also study the volatility of the dollar coupon curve and the spot exchange rate. The results indicate that the reverse foreign exchange swaps do not generate an impact on the general level of the coupon curve, while the regular swaps generate significant changes.

Keywords: Dollar coupon curve; principal components analysis; linear regression of principal components; exchange rate determination theory.

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1 INTRODUCTION

"The Central Bank of Brazil and the *Federal Reserve* announce the establishment of a *swap* line of American dollars for reais in the amount of US$ 30 billion, valid until April 30, 2009. This line does not imply conditionalities of economic policy and will be used to augment the funds available for the liquidity provision operations in dollars by the BC."

This news, released on October 29, 2008, through the Central Bank of Brazil (Bacen) site, reflects the concern with the currency exchange after the worsening of the financial crisis unleashed in the United States in mid-September of 2008.

The determination of the exchange rate interested economists and financiers more strongly since the end of the gold standard. From that time on, the exchange rate is conditioned by several factors. Among them those of a financial origin stand out, like the arbitrage of the investors among the countries' interest rates, the interventions of the monetary authorities and the credit risk associated to each country, the so-called country risk.

Starting with the adoption of the Inflation Targeting Regime and the fluctuating exchange regime, in early 1999, the work of the Bacen in the spot exchange market and in the currency coupon market provoked considerable questioning about its effects. Such actions by the monetary authority, during the last years, were changing the value of the dollar or even its volatility? Would they be actual interventions in the exchange market?

The purpose of this work is to verify, based on the portfolio balance theory, what is the impact of the offers by the Bacen of the currency *swaps* and the reverse currency *swaps* on the currency coupon curve.[i]

This investigation took place in two stages. The first consisted in the regression using only the offers of currency *swaps* and reverse currency *swaps* in the Central Bank operations. During the second stage, three independent variables are considered in the analysis performed: the currency *swap* and reverse currency *swap* interventions promoted by the Bacen, the percentage of investment in the currency coupon by foreign investors with relation to the application total of the currency coupon market in the BMF and Embi Br. This second stage was carried out, for the coupon market in Brazil is made up of national economic agents and foreign investors that arbitrate the difference between the internal and the external rate, and by the fact that the country risk influences and is influenced by the investment of foreign

resources in the country. Since it is a term structure, with the rates at each vertex highly correlated, and, also, in face of the possibility of an interpretative approach, a method of analysis with multivaried data was used called principal components analysis (PCA), as it also makes use of the regression of the principal components analysis (RPCA). As a complementary analysis, there was a measurement of the impact of the offered currency *swap* variables and reverse currency swaps, Embi Br and foreign investors, volatility of the term structure of the currency coupon (TSCC) and the impact of the curve general level, of the Embi Br and the foreign investors in the volatility of the spot dollar or PTAX.[ii]

The results reveal that for the analyzed period, the currency *swaps* present an impact in the curve of the currency coupon, as well as about its volatility and the volatility of the spot dollar in the expected direction. The reverse currency *swaps* do not show themselves to be statistically significant to explain the variation in the level of the curve. As to the variation in its inclination and curvature, when regressed in the first stage, the reverse *swaps* show themselves to be significant, but, in contrary directions, which, in general, negates part of its effects on the short part of the curve (up to six months) and between the periods of 540 to 840 days. Upon analyzing the reverse *swaps* with the other variables, no significance is found. In both stages, the reverse *swaps* do not show themselves to be significant in the volatility of the TSCC.

Some academic papers investigated the behavior of market prices and the volatility on the occasion as a result of the Central Bank's performance through the *swaps*. Araújo and Goldfajn (2004) analyzed the impact of the interventions on the volatility of the exchange rate during the period of January 2000 to December 2003. The authors demonstrated that the Central Bank of Brazil's interventions reduce the volatility of the nominal exchange rate. According to the authors, the result of the work can lead to the assertion that the Central Bank has softened movements in the exchange rate, ratifying the importance of the foreign exchange intervention instruments for the stability of the relations of the exporting and importing agents and of the companies in commercial and financing transactions. Oliveira and Novaes (2005) also ratify these results, for the period of January 1999 to April 2003, except for two periods of high volatility in the nominal exchange rate: in the change of the exchange regime during the first semester of 1999 and in the pre-electoral period of the second semester of 2002. Ho and McCauley (2003), of the Economic Department of the BIS, promote a study on the role of the exchange rate in the economy of emerging countries. In analyzing the interventions in the Brazilian foreign exchange market, the authors corroborate the thesis that

these instruments aided the actions of the monetary policy, by diminishing the need for a more incisive increase in the interest rate and by contributing to the achievement of the inflation targets. In fact, the text of the 74th minutes of the Copom meeting in August 2002 highlights the interests of the Central Bank in dealing with the instruments of currency intervention: "In this sense, the interventions in the foreign exchange market have been necessary to manage the excessive volatility of the exchange rate in an environment of low liquidity and avoid the formation of a perverse dynamics in the exchange market."

This work contributes to the finance literature in at least three points. The first, by dealing with a period that covers the currency *swaps* as well as an ample period of reverse *swap* negotiations. The second by the use of DDI instruments instead of FRA - since the DDI is a spot rate, consistent with the construction of a term structure of interest rates - and third, by approaching the Bacen interventions according to the principal components regression of the coupon curve. The use of *scores* as dependent variables and the empirical test of the relations between these scores and the independent variables provides subsidies for a greater economic understanding of the variables obtained by the linear transformations and of their actual use for applied studies in the Finances area.

The present work is organized in the following manner: Section 2 presents the data utilized; Section 3 deals with the principal components and empirical model; the results are presented in Section 4 and discussed in the light of the economic scenario; and the last Section concludes the work.

2 DATABASE AND SAMPLE

The use of the interest rate of the *spot* dollar can be made in two ways, either multiplying the rate of first maturity of the DDI[iii] by the forward rate, or taking up the rate directly from the DDI contracts recorded starting with[iv] negotiated FRC operations.

Observing the vertices of six and nine months of the DDI and FRC, it can be seen, according to Figures 1 and 2, respectively, that the DDI presents greater variations than the second. However, the long term tendency is very similar.

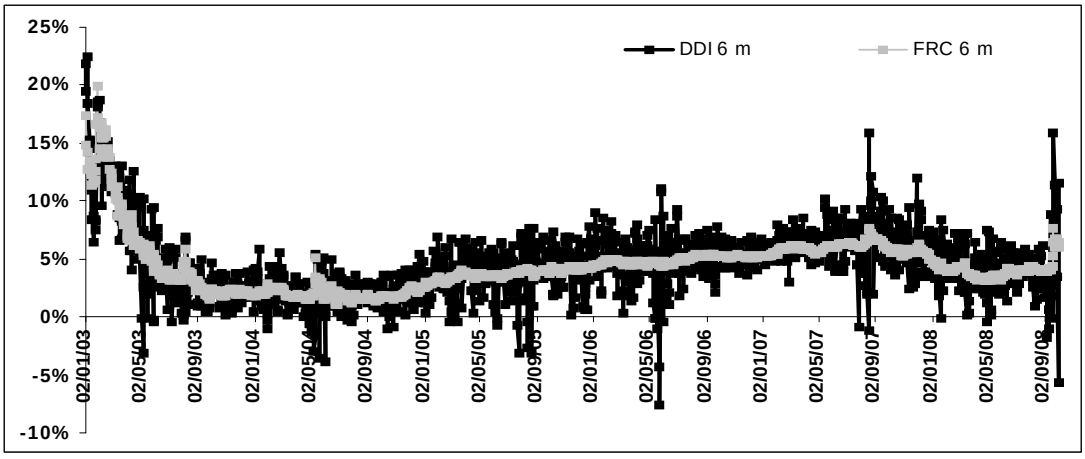


Figure 1. Daily oscillation of 6-month FRC and DDI vertex.

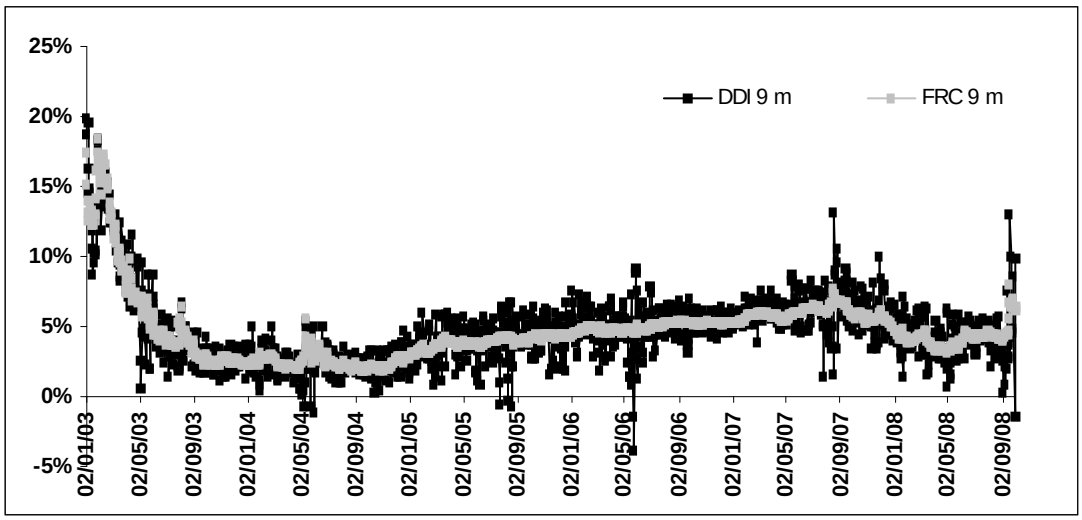


Figure 2. Daily oscillation of 9-month FRC and DDI vertex.

One chooses to use the constant rates in the DDI contracts, for the construction of the term curve of the currency coupon rate (TSCC). The brute data are the adjustment values of the DDI contracts – open currency coupon from BM&F for the period of 02/01/2003 to 30/09/2008. A total of 1426 observations – business days. For the construction of the curve and the linear regressions, the vertices of 60 to 1080 days are chosen, with intervals of 30 calendar days, totaling three years, in 35 vertices. With this, the first vertex that will be analyzed will refer to the 60 days maturity. 1426 interpolated curves were calculated by the cubic spline method for the 35 vertices.

As the currency coupon negotiated in the DDI contract is called a "dirty coupon", for in the contract specification, the base rate for the calculation of the exchange variation is the PTAX rate of the previous day ($PTAX_{d-1}$). So, an adjustment must be made so that the exchange rate reflects the variation in date d until maturity. Once one has the yearly rate of

the so-called dirty currency coupon (C_s), the clean currency coupon (C_l) is obtained by the following relation[v]:

$$C_l = 1 - \left[\left(\frac{Ptax_d}{Ptax_{d-1}} \right) * (1 + C_s) \right] \quad (1)$$

Figure 3 presents the TSCC. It is noted that the currency coupon level during the analyzed period presented a drop. It is also observed that the curvature changed during the period, oscillating, also, in the form of a short term curve, presenting itself as concave one moment, convex the next.

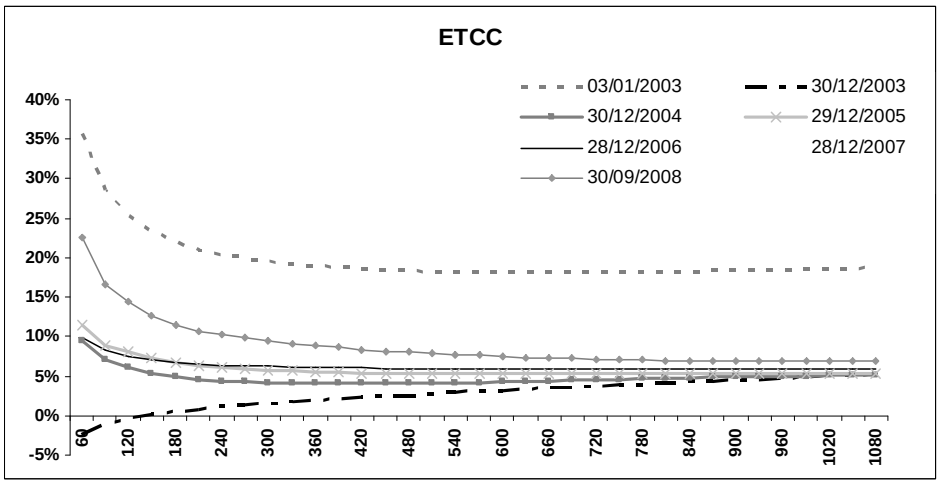


Figure 3: Term structure of the clean currency coupon, starting from the DDI contracts, transformed into a clean coupon.

The data used for the calculation of the principal components were on level, starting from the unit root test for all vertices of the curve, with the *Augmented Dickey-Fuller technique.* The tests were applied for three expected situations, the existence of the unit root by H0, versus a stationary series AR (1), versus the existence of a constant, or *drift*, in the temporal series added to the *random walk* and versus the existence of the intercept.

Table 1 shows the percentage of vertices in each of the levels of significance of rejection of the null hypothesis for the lags from 1 to 3, as well as the percentage of vertices in which it cannot be rejected. As can be seen, the results of the coupon rates obtained from the adjustment values of DDI present stationarity, in the period under review, for the significance level of 1% for all vertices, in lags 1 and 2.[vi]

Table 1 - Summary of the results for the unit root tests with up to 3 lags.

No. of	No intercept				With intercept				With intercept and tendency			
				Accepts				Accepts				Accepts
Lags	1%	5%	10%	Ho	1%	5%	10%	Ho	1%	5%	10%	Ho
1	100%	0%	0%	0%	100%	0%	0%	0%	100%	0%	0%	0%
2	100%	0%	0%	0%	100%	0%	0%	0%	100%	0%	0%	0%
3	74%	26%	0%	0%	100%	0%	0%	0%	77%	23%	0%	0%

The data from currency *swaps* and reverse currency *swaps* was obtained from the Bacen site and refers to the interventions it performed, in the period between 02/01/2003 and 30/09/2008. It is worth highlighting that the dates used in the regressions are auction dates and not liquidation or settlement dates, as the market is now pricing a new curve from the date of the auction and not its liquidation.[vii]

Figure 4 contains the daily frequencies of the *swap* auctions by Bacen. The positive values refer to the currency *swap* auctions, in which the Bacen buys the currency coupon contracts, the negative values refer to the so-called reverse currency *swaps*, in which the Bacen is the seller of the contracts, being bought in the currency variation.

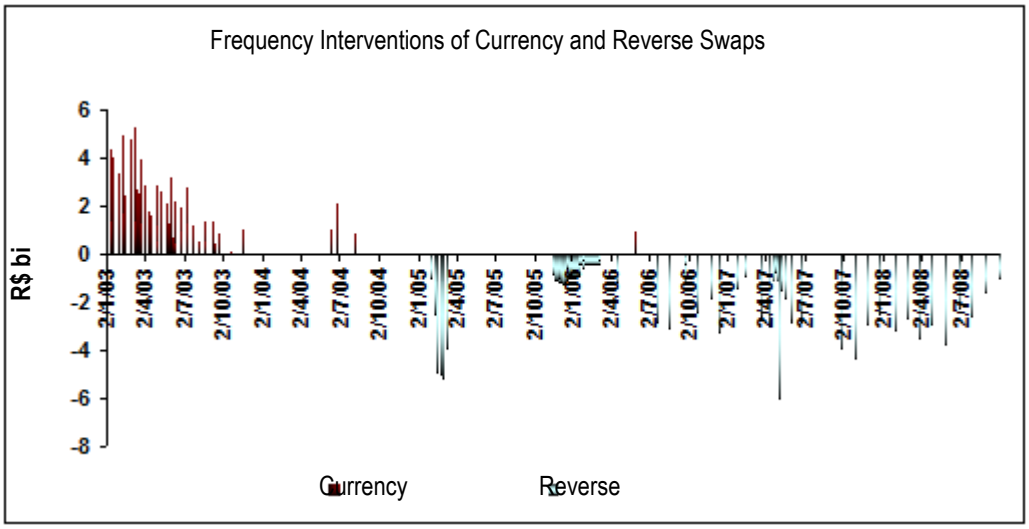


Figure 4 – Currency *Swap* Auctions (positive) and reverse currency *swaps* (negative values).
Source: Central Bank of Brazil

As can be observed, the currency *swap* interventions concentrate on the first semester of 2003, while the so-called reverse *swaps* occurred starting in February 2005. Also, the auctions are not carried out daily, there being extensive periods without the intervention of the Bacen, being this one of the reasons by which it was decided to carry out a regression on a weekly basis.

During this period, the Bacen offered R$ 95.09 bi in currency swaps and R$ 164.36 bi in a reverse currency *swap*. The daily average for the total period, including the days when there was no auction in the calculation, for the currency *swap* is in the amount of R$ 66.68 million, and, for the reverse *swap*, in the amount of R$ 115.26 million. It is worth mentioning that, if we consider only the period between January 2003 and January 2005, when there were, effectively, currency *swap* auctions, this average grows to the level of R$ 179.70 million. Now for the reverse *swaps*, considering the period between February 2005 and September 2008, the daily average is close to the average of the currency *swaps*, with the amount of R$ 181.01 million.

The data of the position of the foreigners was obtained in a survey at the BM&F site, without a differentiation in period. The data inserted in the empirical model refers to the liquid percentage participation in the market of the position of the foreign investors in the DDI contracts, from now on called foreigner DDI position[viii].

Figure 5 presents the DDI currency coupon rates. So a positive value refers to the net long position in rate. For the purposes of the regressions, however, the short position rate was used, only inverting the sign.

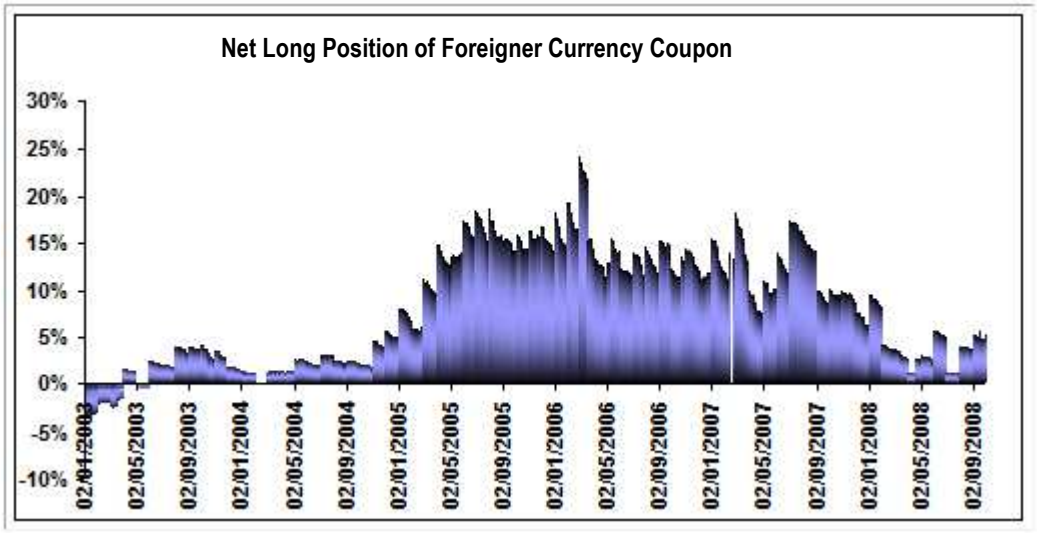


Figure 5 – The graph points to the long position in the currency coupon rate. Since the DDI contract is expressed in PU, this is the net short position in DDI contracts.

Since according to the portfolio balance theory, the investors are not neutral to risk-country, the empirical model cannot give up on this variable, represented in this work by Embi BR.[ix] The data on Embi BR were collected on the Bloomberg database. For the dates when there was no quote from Embi br, but there was trading on the BM&F, the values from the previous days were repeated. Four inclusions were made in the daily base (1426 observations), and only one inclusion in the weekly base (301 observations).

3 METHODOLOGY

3.1 - Principal Components

Starting with specified periods, one takes the first, second and third principal components, respectively, level, slope and curvature, as a dependent variable, and the work focuses on the interpretative nature of these variables, found in Litterman & Scheinkman (1991), and in Brazil, Bessada & Silveira (2003), Almeida *et al* (2007) among others.

The principal components method used was robust, with the use of the correlation matrix.[x] Starting from 1426 interpolated curves, the principal components were obtained. As will be shown in the results, the three principal components of the DDI curve are in accordance with the literature and represent the total, in this work, of 99.83% of the curve variability. The three components were necessary for the data analysis of the currency *swap* auctions of Bacen and the ortogonalized data of the Embi br and the foreign investors.

3.2 - Empirical Model

The exchange rate of the economy has been an object of study in several schools over the years, especially after the end of Bretton Woods, when volatility in the foreign exchange market became a concern for the various economic policy makers and investors in general.

Valente (2007) presents some of the principal models for estimating the exchange rate, among which stand out: i) Purchasing Power Parity; ii) Parity discovery / covered interest rate; iii) Portfolio Balance Theory; and iv) Microstructure Model for Exchange.

The portfolio balance theory assumes that domestic and foreign assets are not perfectly exchangeable. Thus, the exchange rate is not only determined by the balance of the money market, as by the supply and demand of assets throughout the entire economy. In this case, there is an exchange risk premium, defined as insurance against the risk of the economy as a whole and is highly correlated to country risk.

Thus, the *forward premium* rate can be expressed as follows, where p_t is the risk premium, s is the value of the spot dollar rate:

$$f_t = E_t\,(s_{t+k}) - s_t + p_t \tag{2}$$

Thus, considering that the equivalence between uncovered parity and covered interest occurs when the future expected rate and the spot rate in the future are equal:

$$i_t = i_t^* + \left[E_t(s_{t+k}) - s_t + p_t\right] \tag{3}$$

Where the i_t domestic interest rate in instant t and i_t^* is the international interest rate at time t.

In Brazil, most studies focused on the formulation of the equations considering the existence of an exchange risk premium. Empirical tests were conducted under this hypothesis, being that the Leme and Takami tests (2003) failed to validate the covered interest parity for the period studied, even adjusting to the country risk premium Now Garcia (2000) calculates the risk premium for the period of the Real Plan, with the *crawling peg* regime. Diógenes (2007) uses the premise of the exchange risk premium to study the sterilized Central Bank interventions in the foreign exchange market.

According to the portfolio theory, investors cannot be indifferent to the risk. As a result, there is not only the currency risk premium, as the country risk, which could be seen as a credit risk related to their solvency, or a condition of its judicial structure Thus, one can add a last equation to determine the exchange rate, which is the country risk (r_p).

$$i_t = i_t^* + \left[E_t(s_{t+k}) - s_t + p_t\right] + r_p \tag{4}$$

From the definition of currency coupon (the domestic interest rate purged of the exchange variation) and using as a basis the non-neutrality of agents when selecting the country to invest, the equation (4) can be mathematically described as follows:

$$Cupom\_Cambial = i_t^* + r_p \tag{5}$$

One can verify, therefore, that the interest rate that foreign investors actually arbitrate is the currency coupon rate, considering country risk represented by r_p in equation (5).

Studying which are the effects of the actions of the Bacen on the curve may be of great help for understanding dollar futures market, which presents liquidity only until the second month of maturity, and, after this period, is negotiated via the synthetic FRC operation. By acting on the currency coupon market, the Bacen modifies the offer of interest rates and dollars indirectly, as this coupon is integrated by both macro-financial variables. So when the Bacen purchases coupons, is it purchasing interest rates and selling dollars. When selling coupons, it is selling interest rates and buying dollars. In this manner, it changes the market condition in the arbitrage equation.

The curve analysis of the currency coupon is based on a linear regression using the PCA, taking the Bacen's interventions as independent variables to be regressed in components 1, 2 and 3 calculated. Another independent variable will be component 1, obtained by PCA applied to Embi br and foreigner DDI position, since the two variables have a high linear correlation (63%), which could cause problems of multicollinearity in the tested regressions. For the study of the PTAX volatility, the regression by principal components was used directly.

The values were calculated on a weekly basis, since, on a daily basis, there were several days without action from the Bacen, as can be seen in Figure 4. Operationally, the regression was carried out in the following manner. First, the daily principal components are calculated. First one takes components 1, 2 and 3 of the TSCC of the last business day in the week and regresses it against the sum of the currency *swaps* and the reverse currency *swaps* existing during the week and against the value of the last day in the week of component 1, obtained by PCA over Embi br and foreigner DDI position.

The equations for the first stage of this first analysis are described below:

$$Comp1_t = \alpha + \beta_1 cambial_s + \beta_2 reverso_s + \varepsilon_t \quad (6)$$

$$Comp2_t = \alpha + \beta_1 cambial_s + \beta_2 reverso_s + \varepsilon_t \quad (7)$$

$$Comp3_t = \alpha + \beta_1 cambial_s + \beta_2 reverso_s + \varepsilon_t \quad (8)$$

For the second stage, they are:

$$Comp1_t = \alpha + \beta_1 cambial_s + \beta_2 reverso_s + \beta_3 cp1embiestr_t + \varepsilon \quad (9)$$

$$Comp2_t = \alpha + \beta_1 cambial_s + \beta_2 reverso_s + \beta_3 cp1embiestr_t + \varepsilon \quad (10)$$

$$Comp3_t = \alpha + \beta_1 cambial_s + \beta_2 reverso_s + \beta_3 cp1embiestr_t + \varepsilon \quad (11)$$

In which $Comp1_t$ is the *score* of component 1 on the last day of the week (level), $Comp2_t$ is the *score* of component 2 on the last day of the week (slope), $Comp3_t$ is the *score* of component 3 on the last day of the week (curvature), $currency_s$ is the sum of the currency *swaps* (dollar sale) during the week ending in t, expressed in R$ billions, $reverse_s$ is the sum of the reverse currency *swaps* (buys dollar futures of dollar) during the week ending in t expressed in R$ billion, and $Cp1embiestr_t$ is the *score* of the last business day of the week of component 1 obtained by the application of PCA of the Embi br variables and foreigner DDI position.

The volatility of the curve was calculated using the principal component 1 of the last day of the week, according to Buhler et al (1999), applying the Egarch methodology (1.1) on that component.[xi] The weekly volatility of the curve was regressed against the variables already used in the previous modeling, whether they were currency swaps, reverse currency swaps and foreigner DDI position in the market of currency coupons. The form of regression for the first stage of the work that tested only the variables of the Bacen is transcribed below.

$$Volcurva_t = \alpha + \beta_1 cambial_s + \beta_2 reverso_s + \varepsilon_t \quad (12)$$

The equation that describes the test for the variable of the interventions of the Central Bank and the risk aversion continues exposed:

$$Volcurva_t = \alpha + \beta_1 cambial_s + \beta_2 reverso_s + \beta_3 cp1embiestr_t + \varepsilon_t \quad (13)$$

In which $Volcurva_t$ is the weekly volatility curve of the currency coupon calculated by egarch (1.1) based on component 1.

The pricing of the currency titles is made from the rates of the currency coupon. The foreign exchange market, then, influences and is influenced by the term structure of the currency coupon. In the face of this, one can analyze what is the impact of the curve in the volatility of the spot dollar.

$$Volptax_t = \alpha + \beta_1 Comp_1 + \varepsilon_t \quad (14)$$

The volatility of the weekly PTAX was calculated by Egarch (1.1) based on the PTAX of the last business day of each week. Another analysis refers to the relationship between the weekly volatility of the curve and the weekly volatility of PTAX - dollar / real spot rate. The purpose is to check if the volatility of the the curve affects the volatility of PTAX. One has, then, the linear regression that expresses this relationship:

$$Volptax_t = \alpha + \beta_1 Volcurva_t + \varepsilon_t \quad (15)$$

Testing the volatility with respect to Embi Br and investors, specifically, is interesting because the actions of the Bacen generate impact in two different directions. The first modifying the terms of arbitration, with greater or lesser supply of foreign currency assets; and the second changing the solvency conditions of Brazil, for they modify the profile of the public debt and, in the case of performances in the exchange market spot rate, increasing the volume of international reserves. Figures 6 and 7 show the extent to which these changes could impact the country risk indicator.

The equation that tests the relationship between the weekly volatility of PTAX and risk aversion is:

$$Volptax_t = \alpha + \beta_1 Cp1embie_1 + \varepsilon_t \quad (16)$$

The high positive correlation between the monthly series of Embi Br and the percentage of debt linked to the dollar compared to the total amount of public debt suggests that further analysis of the effect of Embi br on the volatility of PTAX, the behavior of the curve in its studied attributes, whether they are level - component1 - slope - component2 - curvature - component3 - and also about the volatility curve. This information will be used further ahead during the analysis of the results.

The negative correlation between the balance of international reserves and Embi br also indicates that the Bacen's purchases in the spot market generate an impact on country risk in the period under review.

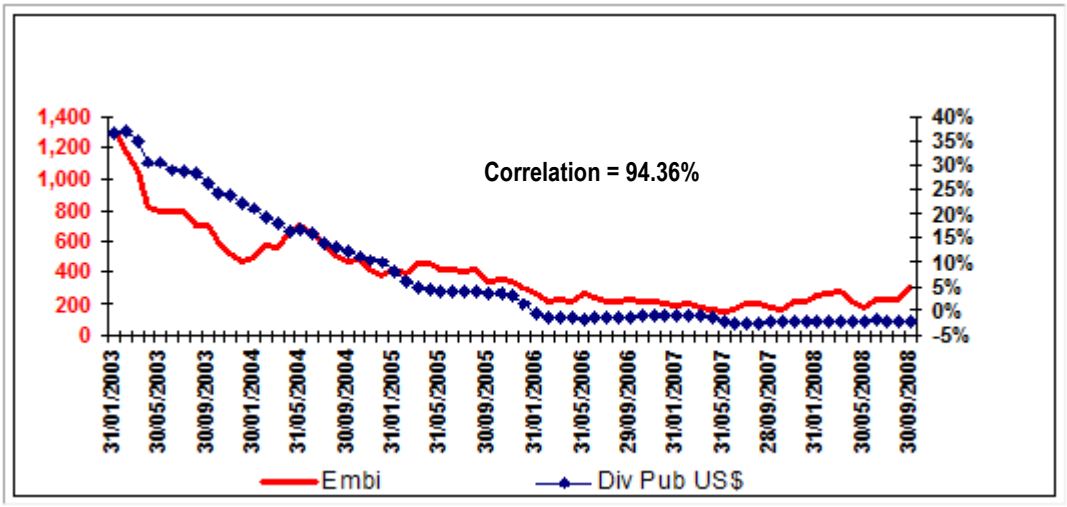


Figure 6 - Evolution of Embi Br and participation of the parcel of public debt linked to currency variation. Monthly Basis. Source: Bloomberg and Central Bank respectively.

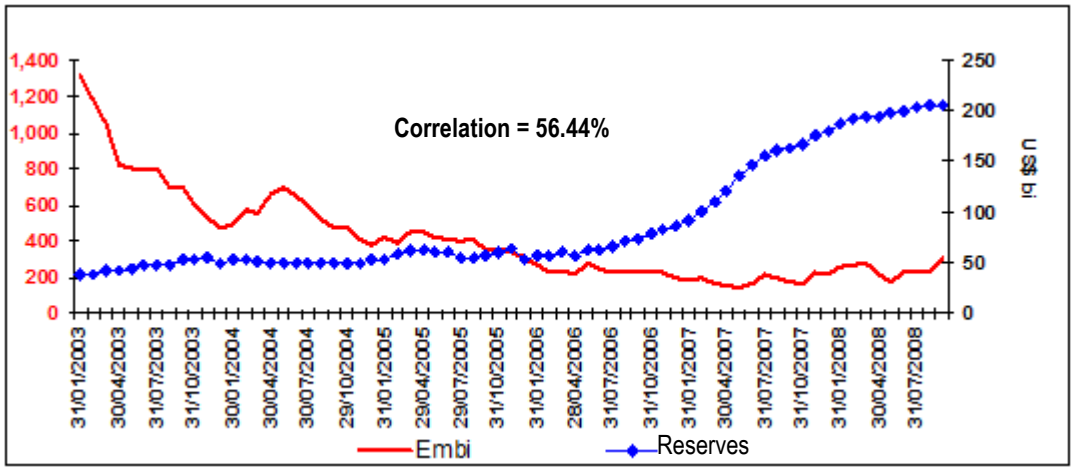


Figure 7 - Evolution of Embi Br and the balance in US$ of the International Reserves. Source: Bloomberg and Central Bank respectively.

4 RESULTS

4.1 Result of Principal Components

4.1.1 PCA applied over TSCC

According to Table 2, the first three principal components represent, cumulatively, 99.83% of the total variation of the curve. The graphs of the weights of each component illustrate the current interpretation of the literature (Litterman & Scheinkman, 1991; Bessada & Silveira, 2004; and Canedo, 2006). From this interpretation, it appears that component 1, which accounts for the greater variability of the data, is related to the level of the curve, since the coefficients for each vertex of the original curve (value for each position of the eigenvector) are quite close, as shown in Figure 8. The second component is the slope of the curve, with its point of rotation located at the center of a maturity of three years of TSCC's (Figure 9). The third component is related to the curvature of TSCC, as can be seen in Figure 10.

Table 2 – Accumulated proportion of the variance of the first three principal components.

	Component 1	Component 2	Component 3
Variance Proportion	92.09%	6.04%	1.7%
Accumulated proportion	92.09%	98.13%	99.83%

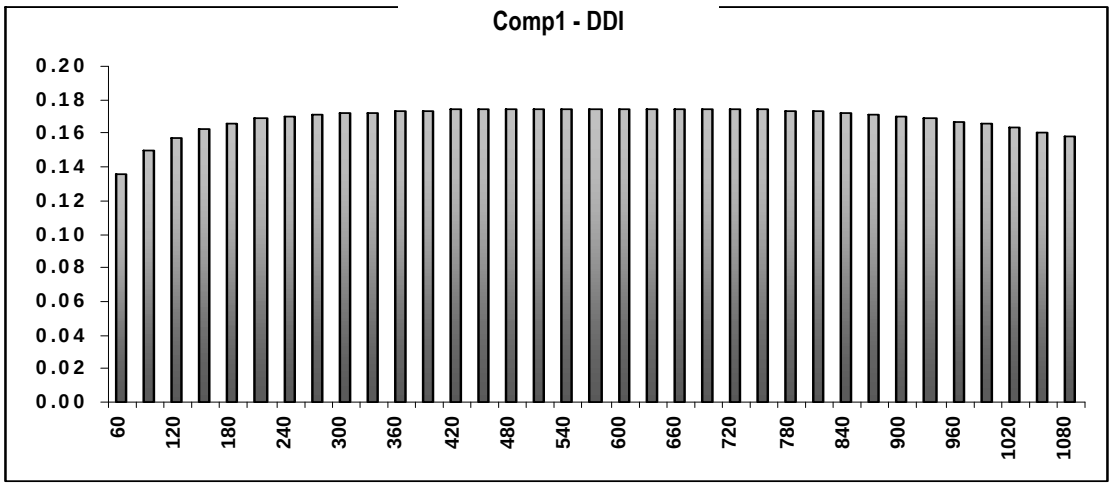
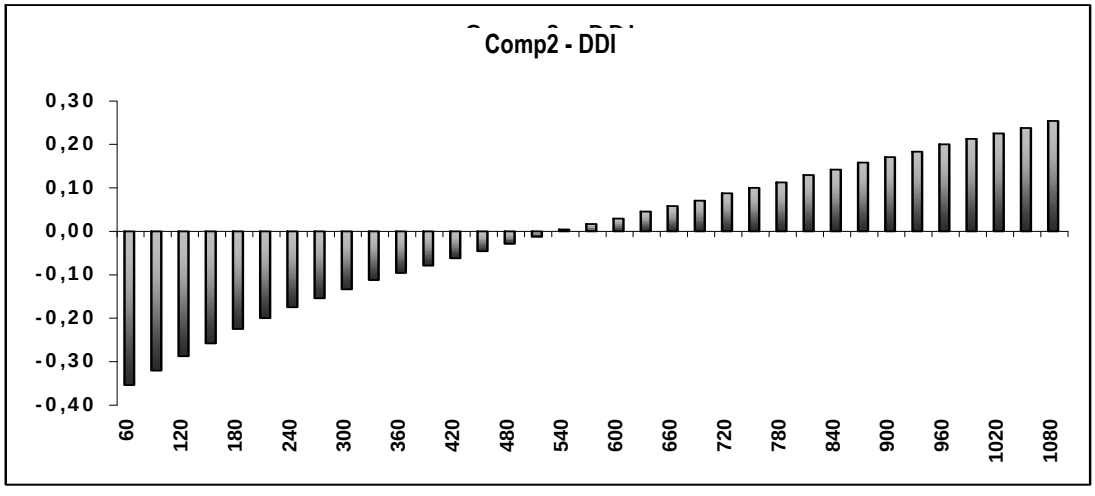


Figure 8 - The weights of each vertex are very close, configuring a general value, curve average, interpreted



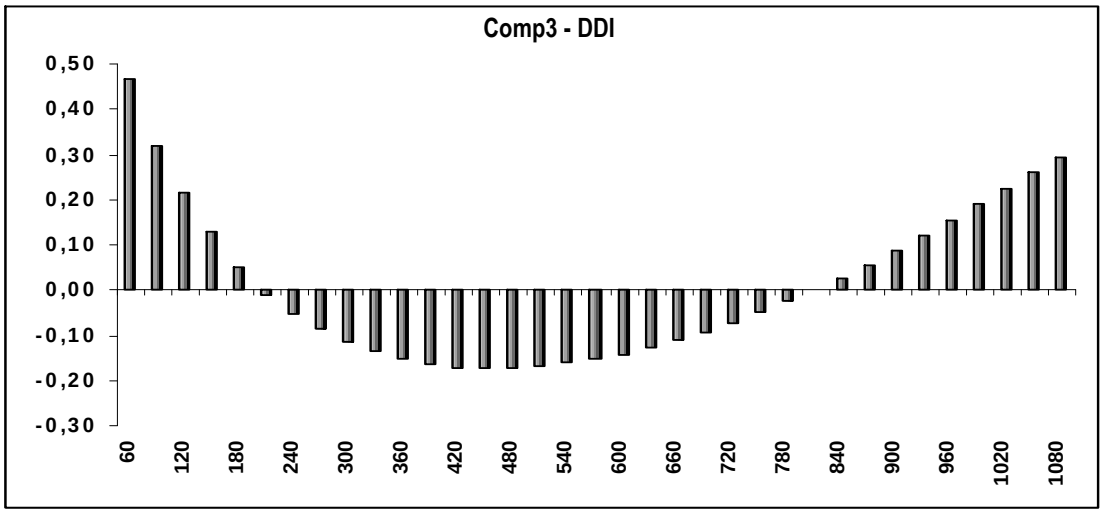
by Litterman & Sheinckman as curve level.
Figure 9 - Component two, which can be interpreted as the curve's inclination.

Figure 10 - Component three: curvature.

4.1.2 PCA applied on Embi br and Net Position of Foreigners in DDI contracts at BM&F

As previously stated, the Embi br variables and net short position in charge of foreign investors have high correlation (around 63%). Thus, the first component is extracted, which is practically 82% of the variability of the original data, for the composition of the variable representing regression. Table 3 presents the results.

Table 3 – Accumulated proportion of the variance of the first three principal components.



	Component 1	Component 2
Variance Proportion	81.53%	18.47%
Accumulated proportion	81.53%	100.00%

The implementation of PCA in the original variables Embi br and foreigner DDI position resulted in a component that has an interesting interpretation. This variable can be understood as "appetite return," because the greater the desire for the return, the greater the Embi and the greater the rate sold. Multiplying this variable by -1, we have its opposite, which would be risk aversion, and that is the value used in the regression. The higher the risk aversion, the higher the Embi br and the greater the short position in currency coupon rate - that is, foreign investors do not apply in foreign country, reducing its position in rate.

The second principal component would be associated with the appetite for return. That is, the higher the Embi br, the higher the return and the smaller the short position, i.e. the

greater the long position, the larger the investment However, as this variable did not add significant results to the regression and its use would greatly complicate the interpretation, this component was excluded from the regressions.

4.2 Analysis of the interventions of the Central Bank and the aversion to risk in the curve of the currency coupon

The results obtained from the tests carried out on Equations (6), (7) and (8) are presented in Table 4.

Table 4 – Results of Regression with weekly periodicity – only interventions by Bacen

	Regression Results Comp. 1 – "Level"		***Regression Results Comp. 2 – "Slope"***		***Regression Results Comp. 3 – "Curvature"***	
	Value	***P-value***	***Value***	***P-value***	***Value***	***P-value***
α	*Non-sig.*		*1.7401*	*0.0000*	*0.7377*	*0.0000*
β_1 *– Currency*	*0.0088*	*0.0000*	*0.0045*	*0.0000*	*0.0011*	*0.0000*
β_2 *– Reverse*	*Non-sig.*		*0.0006*	*0.0155*	*0.0003*	*0.0001*
R^2 *– Adjusted*	*0.3470*		*0.4683*		*0.3886*	

The results obtained from the tests carried out on Equations (9), (10) and (11) are demonstrated on Table 5.

Table 5 – Results of Regression with weekly periodicity

	Regression Results Comp. 1 – "Level"		***Regression Results Comp. 2 – "Slope"***		***Regression Results Comp. 3 – "Curvature"***	
	Value	***P-value***	***Value***	***P-value***	***Value***	***P-value***
α	*1.4699*	*0.0941*	*1.9818*	*0.0000*	*0.8263*	*0.0000*
β_1 *– Currency*	*0.0073*	*0.0000*	*0.0027*	*0.0000*	*0.0004*	*0.0000*
β_2 *– Reverse*	*Non-sig.*		*Non-sig.*		*Non-sig.*	
β_3 *– Risk aversion*	*2.4591*	*0.0010*	*3.095*	*0.0000*	*1.1350*	*0.0000*
R^2 *– Adjusted*	*0.3682*		*0.6484*		*0.6810*	

The results show that one cannot say that the actions of the Central Bank made at the lead purchased tip of the exchange variation, i.e., offers of reverse currency *swaps* have generated impact in the TSCC on your overall level. On the other hand, the currency *swaps* produced an impact on the three attributes analyzed of the currency coupon curve.

The increase in the general level of the currency coupon curve is consistent with the modification of the arbitration, since offering dollars and demanding rates, the authority contributes to the increase in the currency coupon.

The positive impact on the slope of the curve reveals that, in acting through currency *swaps*, the Central Bank reduces the short/medium coupon rates (60 to 540 days) period and raises the long term rates, more precisely between the periods of 540 days and 1080 days.

Component 3 – the curvature – is also influenced positively by the currency *swaps*, revealing that the currency *swaps* influence the increase of the medium term rates and the reduction of the short and long term rates.

One must point out that the coefficients obtained in the regression of equations (7) and (8) of the variable reverse *swaps* reveal that between the periods of 60 to 180 days, the effects of the mentioned variable in the slope and curvature practically cancel each other out. This situation is also seen between the periods of 540 days and 840 days. Which may not explain the significance of the variable to the attribute level of the curve. It is worth noting that when this variable is analyzed with respect to risk aversion, it shows itself not significant in all tested attributes.

As for the so-called risk aversion, its influence on the TSCC is positive in all attributes of the curve. Since the risk increases, the overall level of the curve rises, as expected. As the slope also rises, that is, as it is a more risky application, the difference between the applications of short and long term rates tends to be greater. For the curvature, this attribute, when it increases, strengthens the difference between the periods, reducing more the short-term rates and increasing those in the medium term, reducing those with a longer term again.

4.3 Analysis of the impact of the Bacen's actions, and risk aversion (Embi br and foreign investors) in the volatility of the TSCC and the volatility of the spot dollar rate

The complementary analysis refers to the impact of the independent variables on the volatility curve. In this case, the effects are also separated into a test only with the variables referring to currency *swaps* and reverse currency *swaps* offered by the Central Bank - equation (12) - and a second test, adding to such variables the risk aversion variable in equation (13).

The results of equation (12) are shown in Table 6.

Table 6 – Weekly Curve Volatility by the selected independent variables

Coefficients	*Value*	*P-value*
α	*8.6948*	*0.0000*
β_1 *– Currency*	*0.0064*	*0.0000*
β_2 *– Reverse*	*Non-sig.*	
R^2 *– Adjusted*	*0.4789*	

Table 7 contains the results found in the test made, based on equation (13).

Table 7 – Weekly Curve Volatility by the selected independent variables, including risk aversion

Coefficients	*Value*	*P-value*
α	*11.635*	*0.0000*
β_1 *– Currency*	*0.0045*	*0.0000*
β_2 *– Reverse*	*Non-sig.*	
β_3 *– Risk Aversion*	*3.144*	*0.0000*
R^2 *– Adjusted*	*0.5747*	

It can be observed by the result that the reverse *swap* does not cause an impact, in this case, in the TSCC volatility. The currency *swaps* as well as the foreigner DDI position and Embi br add volatility to the curve. It is worth pointing out the adjusted expressive R^2, indicating the explanatory power of the variables used for the volatility of the curve.

Next, there is the ratio of the volatility of PTAX with the level of the curve, for lag one (one week), according to Equation (14) and the relation of PTAX volatility with TSCC volatility, according to equation (15)[xii] The results are presented in Table 8.

Table 8 – Results of the Regression of Weekly Volatility of PTAX compared to Component 1 (Eq. 14) against the Volatility of the TSCC (Eq.15)

Coefficients	*Regression of Component 1*	*P-value*	*Regression of Volatility*	*P-value*
α	*0.04*	*0.0000*	*0.033*	*0.0000*
β_1	*0.0004*	*0.0000*	*0.0009*	*0.0000*
R^2 *– Adjusted*	*0.330*		*0.491*	

It is interesting to note that component 1 explains 33% of the volatility of PTAX, on a level of significance of 1%. The coefficient of regression points to an influence of 0.004% of addition in case the level of the curve increases in one unit. As the volatility here is weekly, this value is significant in annual terms. As regards the regression of volatility, for each additional percentage point of the volatility of the curve, 0.009% is added to the volatility of PTAX. The volatility of the curve explains the volatility of the spot asset, denoting the vaunted liquidity in the dollar futures market.

Another relation to be tested refers to the volatility of PTAX with aversion to risk, according to equation (16). The regression with two components - level of curve and aversion to risk - was not performed, for they proved to be in a linear correlation. The result of Table 9

is in accordance with the expected, that is, the aversion to risk is significant, and the greater the aversion to risk, the greater the volatility of the PTAX.

Table 9 – Results of the Regression of Weekly Volatility of PTAX and Aversion to Risk

Coefficients	*Value*	*P-value*
α	*0.0064*	*0.0000*
β_1 – *Aversion1*	*0.0421*	*0.0000*
R^2 – *Adjusted*	*0.3674*	

As can be seen in Figure 11, until mid-2003, the three- and fourth-month currency coupon presented a positive correlation with Embi br and the DI rate. Starting in February 2005, the currency coupon starts to present an increase, while Embi br and the DI continue their tendency to fall.

The rise in the coupon is a direct consequence of the Bacen's interventions, according to Figure 4. As in the reverse *swap*, the bank pays the currency variation plus a pre- tax, there is a tendency that the dollar will not go up, for the tendency to rise would tend to cancel out the remuneration by the Selic rate (the Selic rate is the Bacen's overnight rate). On the contrary, the movement towards the fall of the dollar favors a gain in the negative currency variation. Since the currency coupon is formed by internal interest rate minus the currency variation, this negative currency variation means a high in the currency coupon.

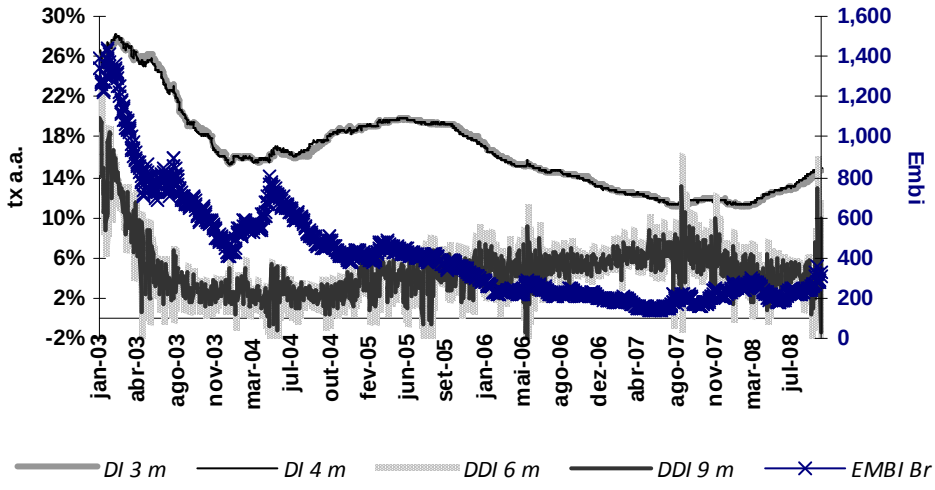


Figure 11 - Evolution of the Futures Markets of DI, Futures Market of Currency Coupon and Embi+ Brazil

Therefore, the explanation for this mismatch is due to the high in the currency coupon caused by the Bacen's interventions, and the fall of Embi br is due to the positive impacts resulting from the accumulation of foreign currency in the public debt and international reserves. The reduction of the amount of public debt tied to the dollar, since 2005, contributed greatly to the fall of the variable risk aversion and, thus, to the reduction of the studied components of the TSCC, as well as reduce its volatility and the volatility of the spot dollar Also, the position of foreign DDI (short position in coupon rate), directly and positively proportional to aversion, also decreased The combined effect of a high provoked by the negotiation of the instrument with effect of a low due to reduced aversion explains the non-verification of impact of reverse *swaps* on the attribute level of the curve. It is worth pointing out that these effects on the public debt and the international reserves are contrary to the effects expected by the portfolio theory. Such effects are caused by an improvement in the public debt profile, the decrease in interest rates resulting from the drop in inflation, the strong international liquidity present in much of the period under review, along with the improvement of terms of trade due to growth of world trade, in the improvement in the conditions of the country's solvency and, therefore, greater investor confidence in Brazil.

5 CONCLUSION

The purpose of this work is to verify, based on the theory of portfolio balance theory, what is the impact of the offers by the Central Bank of Brazil of the currency *swaps* and reverse currency *swaps* in the attributes referring to the term structure of the currency coupon. As demonstrated throughout this work, the currency coupon rate is the actual arbitration rate that influences and is influenced by the dollar, by the difference between domestic interest rates and the international and by the country risk.

Through the agency of two of the participants, the Bacen and foreign investors, the study sought to advance the studies on the interpretation of principal components in the futures market of the currency coupon

The results prove the portfolio theory when considering the variables of risk aversion (obtained by PCA on EMBI br and by the participation of foreign net position in the futures market DDI) and currency *swaps*. Since risk aversion is related to country risk and arbitration of foreigners, the portfolio balance theory predicts exactly the relationship of international interest rates, together with the country risk. Together with this, the currency *swaps* proved to be significant. In contrast, the reverse currency *swaps* proved to be significant for the slope attribute and curvature attribute in the regressions without the presence of country risk and

foreign investors. However, because the resulting coefficients had the same sign and the same order, the effects in certain parts of the term structure cancel each other out, not modifying, therefore, the overall level of the curve. When the risk aversion variable is inserted in the equation, the coefficients of the reverse *swaps* do not prove to be significant.

Some existing facts in this period can explain this situation. First, we took a fairly long period, which had strongly favorable changes in the international arena, like the abundant international liquidity and the vigorous growth of world trade, and on the domestic scene, as inflation targets were achieved, greater fiscal discipline, with successive primary surpluses and improved debt profile.

During this period, the performances of the Bacen in foreign exchange led to a rebuilding of international reserves to high levels that contributed to the improvement in the solvency condition. Add to this the fact that the reverse currency *swaps* interfered in the reduction of the participation of the portion of the public debt anchored to the dollar over the entire debt. As demonstrated, the evolution of both variables resulted in the fall of the country risk and, therefore, risk aversion to invest in the country. With this, the volatility of the coupon curve and volatility of the spot dollar was decreased.

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[i] Currency swap: swap operation registered at the BM&F, in the form of a "currency swap contract with a periodic adjustment – SCC", in which the BACEN buys the contract (currency coupon point) and the contemplated institutions take up the sales position in DI. Reverse currency swap: operation on a similar mold as the previous one, but in which the BACEN takes on the selling lead of the currency coupon (sells contract) and the contemplated institutions take on the position of buyers of DI.

[ii] The reference currency rate is known in the financial market as PTAX and is the mean rate weighted by the business volume carried out in the interbank foreign exchange market with liquidation in two business days, calculated and released daily by the BACEN according to Communiqué no. 6.815/99.

[iii] The DDI Product is a currency coupon futures contract negotiated at BM&F-Bovespa. Its introduction predated the FRA of the currency coupon. In its specification the DDI uses the PTAX of D-1 and for this the coupon calculated by the DDI is called a dirty coupon.

[iv] The FRA or FRC of the currency coupon is a synthetic operation that uses two DDI contracts to remove the exchange variation from the previous day and, according to the language used in the market, this operation cleans a dirty DDI coupon. The resulting rate is a *forward* rate, free of the daily volatility of the foreign exchange rate.

[v] See Araújo, Barbedo and Bessada for greater details

[vi] In lag 3, the data, for the most part, presents itself as stationary for levels 1%, and 26% of the data can be considered stationary for the 5% level, for the test without intercept. Therefore, the null hypotheses were all rejected.

[vii] Swap maturities were not considered as variables as they are an event expected by the market, being that its impact is dissipated during the maturation of the operation. The renovations were considered new operations for they are operations with different periods, new rates in also a new scenario – rate level, expectations of the economic agents among other points that constitute the economic scenario of the new auction.

[viii] From the BM&F, we obtained the long position of the foreigners in relation to the total long positions and the short position of the foreigners in relation to the total short position. This information is expressed in percentages. One position was subtracted from another day by day and the liquid position of the foreigners in the DDI market was obtained in this manner. The net purchased position in DDI is equivalent to the net sold position in currency coupon, since
the DDI contract is expressed in PU, and not in rate.

[ix] During the last few years, the Credit Default Swap (CDS) has been gaining strength as a measure of the country risk. However, as this work involves a period of over five years, it was decided to use the Embi br.

[x] Jolliffe (1986) reports some disadvantages for the use of the covariance matrix in detriment of the correlation matrix. Among the disadvantages what stands out is that the principal component structure can be completely modified if there are different units of measurement.

[xi] The egarch was used for two reasons. In Valente (2007), a more precise method was shown. The second factor results from the fact that the tgarch did not present the needed convergence.

[xii] The other components were not considered in the regression since they presented a reverse causality with the volatility of the PTAX.