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Abstract

This paper investigates the impact of central bank interventions on the level and volatility of exchange rates. We explore the case of Brazil, the 7th largest economy in the world in 2012, which since 1999 has adopted a floating exchange rate. As Central Bank decisions to intervene in the exchange market are not independent of market conditions, we estimated a Central Bank reaction function using a logit model including market fundamentals and macroeconomic surprises as explanatory variables. We employed the nonparametric Propensity Score Matching (PSM) method to find counterfactual pairs of intervention and non-intervention days. This indicated that the effectiveness of foreign exchange interventions depends on the period analyzed. For instance, from 1999 to 2003, with scarce and smaller interventions, the buying operations of U.S. Dollars depreciated the Brazilian Real whereas from 2004 to 2012, a period with larger and frequent interventions, only selling interventions were significant, and tended to increase the currency's volatility.

JEL Classification: C14, G14, G15, F31

Keywords: Central Bank intervention; Exchange rate; Futures exchange rate; Derivatives intervention; Propensity Score Matching

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1 Introduction

At the beginning of 2013, the use of the expression "currency wars" could be found in many places around the globe (see Wolf, 2010; The Economist, 2010, 2012, 2013). Academics, market practitioners, politicians and the media were debating the spill-over effects of expansionary monetary policies, adopted since the Great Recession. Repeated Quantitative Easing (QE) policies by the Federal Reserve and the Bank of England had a strong side-effect in the rest of the world, especially regarding exchange rates. Accordingly to Portes (2012), the Federal Reserve Bank of St. Louis calculates that the Fed's $1.725 trillion asset purchases resulted in a 6.5% nominal depreciation of the dollar. Similarly, QE policies by the Bank of England resulted in a 4% nominal depreciation of the sterling. But how are emerging economies situated in this context? How can they defend themselves against currency appreciation? Relatively large emerging economies, like Brazil, face the "impossible trinity" (trilemma) where it states the impossibility of keeping capital markets open, monetary policy autonomy and exchange rate stability. Since the beginning of the World Financial Crisis in late 2009, Brazil has been responding by imposing a transaction tax and many other restrictions in capital inflows (see Portes, 2012; Garcia and Chamon, 2013). However, since the adoption of floating exchange rate regimes in 1999, Brazil has always made use of Central Bank foreign sterilized interventions to affect the exchange rate. That is why we focus on understanding the impact of those interventions, if there are any, on the exchange rate. Before that, let's first try to understand the international economic context since the start of the adoption of floating exchange rates by the main economies of the world.

The Bretton Woods system (BWS), established after the end of the World War II, was conceived with the intention of rebuilding the international monetary system. The main goals were to promote international growth, encourage international trade, boost investment and avoid disruptive policies, such as protectionism and the competitive depreciations that characterized the 30s. To by-pass the lack of capacity to issue currency and manage its use, as national economies do, the BWS was set up to maintain fixed exchange rate regimes among its members, using the U.S. Dollar as a reserve currency[1]. Members of the BWS had their currencies pegged to the U.S. Dollar, while the latter tried to keep ballasted to gold (Bordo, 1993). In the early 70s, the Nixon Shock - unilateral actions that broke down the dollar-gold convertibility – triggered the BWS fixed-parity system collapse (Garber, 1993).

Even though the split instigated the formation of currency blocks (as occurred in March 1973 with six European countries: Italy, Belgium, France, Germany, Luxemburg and the Netherlands), and a movement towards new international coordination (as seen in the Committee of the Twenty, even before the Bretton Woods fall), most of the period that followed, between 1973 and 1985, can be characterized in terms of the main developed economies adopting flexible exchange rate regimes (Bergsten et al., 1993; Bordo et al., 2010). According to the Bordo et al. (2010), the foreign exchange interventions that followed aimed to support actions to counter disorderly market conditions[2].

In the mid 80s, the developed economies started an exchange rate intervention period in a coordinated form. The change in U.S. monetary policy's during the Paul Volcker mandate as

[1] According to Robert Mckinnon (Bergsten et al., 1993), the fixed-parity system was not intended and emerged as a result of the Marshall Plan.

[2] This followed the G7 1975 Rambouillet metting that emphasized the need for exchange-rate stability but saw stability as a result of "orderly underlying economic and financial fundamentals."

chairman of the Federal Reserve appreciated the U.S. Dollar and fostered political pressures (coming from domestic tradable sectors and foreign economies) that culminated in the Plaza and Louvre agreements. The Plaza Accord, which occurred in 1985 with the G5[3], was intended to depreciate the U.S. currency, to deal with its current-account imbalances and to avoid protectionism threats. Two years later, at the presence of the G6[4], the Louvre Accord sought to stabilize the dollar-mark and dollar-yen exchange rates.

For the emerging economies, the dissemination of floating or managed floating exchange rate regimes is a recent trend which began in the late 90's, when many emerging economies formally adopted inflation targeting regimes (Galimberti and Moura, 2013). Not surprisingly, due to the scarcity of data up till a few years ago, the literature on exchange rate intervention in emerging economies is still incipient (Disyatat and Galati, 2007).

Emerging economies have seemingly always intervened in foreign exchange markets and, as noted by Calvo and Reinhart (2002), it seems that these countries have a fear of floating. Canales-Kriljenko (2003) claim that interventions conducted by emerging economies are more likely to affect exchange rates because the way policymakers conduct their foreign exchange operations increase their advantages in terms of information. They are supposed to have a better grasp of aggregate order flows than the market participants and may also choose a degree of transparency about the nature and size of their interventions relative to foreign exchange market turnover that make a higher level of effectiveness possible. Although the amount of this literature is still very limited, a growing body of recent studies has indicated that these interventions tend to be more effective than those of developed countries (Berganza and Broto, 2012; Adler and Tovar, 2011; Kamil, 2008; Égert, 2007; Tapia et al., 2004).

One of main contributions of this study is to add to this literature by using a unique database of exchange interventions by the Brazilian Central Bank. However, our data about emerging economies is unique in the following ways. First, it covers a relatively large span of almost thirteen years of daily data (July 1st, 1999 through January 31st, 2012) on Brazilian market exchange interventions. Second, it includes not only Central Bank interventions on the spot market but also commonly used interventions in the swaps market. Third, we investigate the impact of interventions, not only on the spot market but also on the future market, which is much more liquid and larger than the spot market[5].

Finally, we also contribute to the body of literature by addressing the problem that a monetary authority's decision to intervene in the market is subject to a "self-selection" effect without the existence of a "counterfactual" for the movement of the exchange rate without intervention, as Fatum and Hutchison (2010) pointed out. We carried out this task by adopting a non-parametrical matching method known as Propensity Score Matching (PSM).

The remainder of this paper is organized as follows: in the next section we discuss the main channels that might work when we analyze intervention in the foreign exchange markets. The third section reviews the main results of this literature concerning developed economies, emerging markets and focuses specifically on the Brazilian case. Section four discuss the PSM methodology and in the last section explores the results, conclusions and limitations of the study.

[3]The G5 consisted of U.S., France, Western Germany, Japan and United Kingdom.

[4]The G6 was composed of the G5 plus Canada.

[5]According to Ventura and Garcia (2012), the traded volume in the futures exchange (i.e., the first expiration of the futures market) is about five times greater than the volume traded in the interbank spot market (considering over-the-counter trading).

2 How exchange intervention is supposed to work

The fall of the Bretton Woods system triggered the publication of numerous studies in industrialized countries. With so many episodes of activity on the foreign exchange market, it is necessary to identify what the effectiveness of such interventions is likely to be. With regard to non-sterilized interventions, i.e. those affecting the domestic money supply, the answer is straightforward: the change in the money supply would affect the interest rate and that, in turn, would also affect the exchange rate. However, in practice, monetary authorities often sterilize interventions with open market operations in order to keep the domestic money supply constant. In this case, however, according to Sarno and Taylor (2001), the impact of interventions should be noticeable through one of the following channels: the portfolio balance channel and the signaling or expectations channel.

The basic assumption of the portfolio channel relies upon the imperfect substitutability of domestic for international bonds. When a monetary authority purchases/sells U.S. Dollars, it changes its relative supply of international to domestic assets. If there is a foreign exchange risk perception which cannot be diversified internally, it triggers a premium associated with this kind of risk, creating reallocation incentives for all asset holders. Thus, sterilized interventions ultimately affect the exchange rate risk within the context of covered interest parity, so that the interest rates and expected exchange rate will not change. One of the main criticisms of this channel is that the Central Bank may not be representative enough to affect the relative supply of assets in the economy. Moreover, with markets becoming increasingly integrated, the premise that domestic and foreign assets are imperfect substitutes can also be questioned.

As Mussa (1981) argues, the signaling channel is based on the assumption that the Central Bank has more information on key aspects of the economy than the market. The monetary authority sends its additional information to the market participants. To be credible, there must be incentives for signaling true value. Being concerned about inflation, for example, the central bank's use of foreign exchange interventions to defend the domestic currency in order to avoid devaluations due to stress could cause future inflation. This interpretation of the signaling channel is also subject to some criticism since it implies an incentive for the monetary authorities to clearly reveal their intentions regarding future monetary policy. Thus, it needs to be asked why central banks are often so secretive about their interventions.

A third channel through which interventions affect the foreign exchange is known as a noise trading channel. According to Hung (1997), some market participants in the foreign exchange market sustain foreign exchange positions according to their beliefs or by following patterns, which are often not related to fundamental analysis – according to Szakmary and Mathur (1997), Central Bank's intervention type could also affect such market behaviors[6]. If a representative number of agents follow those beliefs the exchange rate may remain away from it's fundamental value. Secretive interventions of the monetary authority can change traders' beliefs towards different market trends, which in turn can induce them to dismantle their positions and, consequently, to change the value of the exchange rate in the desired direction of the central bank.

[6]Central Bank *leaning-against-the-wind* interventions type – i.e. foreign exchange change directions would be confronted trying to be reverted – could explain profitability of trading returns for three currencies (German mark, Japanese yen and British Pound) from 1977 to 1991.

3 Measuring the effectiveness of interventions

One of the main tasks of the exchange intervention literature is to estimate the effectiveness of interventions. As Neely (2005) states, most of the literature has made use of three different econometric approaches: time series regressions, event studies and structural identification. We can start by briefly reviewing the literature on developed economies and then focus on the more recent literature for emerging economies in general and, as a final step, we can narrow our focus onto the Brazilian case.

3.1 *Developed Economies*

Even after all this time, there seems to be little consensus about these matters. Edison (1993) and Sarno and Taylor (2001) surveyed Central Bank interventions. The former covered the period from the 80s to the early 90s and the latter mainly the 90s. More recently, the availability of richer datasets allowed the development of more detailed studies. Menkhoff (2010), who surveys the literature focusing on studies that use high-frequency data, stresses that the evidence found corroborates the hypothesis that interventions move the exchange rate level in the desired direction, especially if they are coordinated with other central banks. Nevertheless, Central Bank interventions can also increase volatility, especially in the short run.

The majority of the exchange intervention studies make use of time series regressions employing instrumental variables to deal with the endogeneity problem. The endogeneity comes from the fact that the central bank's decision to intervene is not independent of the market conditions and the exchange rate change.

Most of the studies from the late 80s found that the coordinated interventions conducted after the Plaza and Louvre agreements, were, at that time, effective. Dominguez and Frankel (1993) analyze interventions using data from U.S. Dollar, German mark and Swiss franc between 1982 and 1988. Their study points to the presence of a significant portfolio channel in the U.S. Dollar and German mark markets. Lewis (1995) studies of interventions made by US, Germany and Japan focused on the Louvre Accord period (late 80s). Starting from a structure derived from an asset price model, where exchange rate depends on the probability of intervention, the author finds evidence that when exchange rates deviate from their targeted levels established by the agreement, central banks' interventions can reduce levels of exchange rate variability.

A considerable part of the recent literature is focused on Japan after the 90s when its housing bubble burst and the Bank of Japan (BoJ) was forced to lower its interests to its lower bound. Some studies suggests that the BoJ interventions during the 90's were mainly motivated by deviations of the spot exchange rate from implicit target ranges and were a response of a rise in market uncertainty (Galati et al., 2005; Beine et al., 2009a). According to Ito and Yabu (2007) and Kim and Sheen (2006), BoJ interventions became more proactive after 1995, and their frequency and size increased. The reason for this was that monetary policy interest rates had reached the zero bound. This could explain the ineffective result of the mean return suggested by Galati et al. (2005), since their study contemplates both periods (1993 to 2000).

A recent contribution made by Chen et al. (2012), which proposes a new method to deal with the well-known endogeneity problem, applies a Bayesian MCMC approach to aggregate the high frequency data and then turn this augmented data into daily frequency. The authors analyze the case of Japan exchange interventions from 1999 to 2002 and found that an intervention

more than double its effects (1.8 percent) compared to an OLS approach[7], what highlight the size of the endogeneity problem.

More recently, intraday studies have been possible as data becomes available (Dominguez, 2003, 2006). Fatum and Pedersen (2009), for example, focus on intraday data from the Danish central banks' interventions against the Euro currency from 2002 to 2004. Departing from a two-step weighted least square procedure, their results suggests that sterilized interventions are effective only when they are consistent with monetary policy (e.g., a period in which depreciations occurs simultaneously with a spike of inflation, which would cause an increase in interest rates).

Another approach lies in the noise trading channel. Beine et al. (2009b) study of the European Central Bank (ECB, Bundesbank before the Euro) and the Federal Reserve (Fed)'s interventions in the U.S. Dollar-Euro (German mark before 1999) market from 1985 to 2003uses a noise trading approach to try to separate the chartist-fundamental regimes using a Markov switching model and conclude that these interventions became effective when they led to an increase in the proportion of fundamentalist traders, thus creating an exchange rate closer to fundamental value. In a similar fashion, Reitz (2005) studied the German mark to U.S. Dollar from 1979 to 1992.

Other studies focused on a different methodology from time series regressions by using the event study method. This approach makes use of intervention clusters observed in the data, as a single intervention event, and compares the effects of the exchange rate between a pre-intervention and a post-intervention period. According to Fatum and Hutchison (2003), the event study has the desirable feature of not having to rely on a structural model given a lack of consensus over the appropriate structural exchange rate model.

Fatum and Hutchison (2003) were probably the first to apply this technique to the foreign exchange market interventions. They analyzed the U.S. and German interventions, from 1985 to 1995, and found that sterilized interventions affects exchange rate in the short run. Their results are robust with regard to definitions of different event windows and to controlling for changes in central banks' interest rates during events.

Using the same econometric approach, Fatum and Hutchison (2006) examine the case of the Japanese economy from 1991 to 2000. According to the authors, the BoJ's interventions, as well as the Fed's actions in the yen market over the U.S. Dollar strongly affected the yen/U.S. Dollar only in the short run. The interventions were more successful when the U.S. and Japanese central banks coordinated their efforts. This was also true when interventions were not associated with interest rate changes. These results are in accordance with Fratzscher (2008), who analyzed interventions made by U.S., Japanese and Euro area monetary authorities in foreign markets (data from 1990 to 2003), which showed that oral communications and actual interventions can affect exchange rates in the short run and can become more effectively when they are coordinated. The author also highlights that these interventions can have medium run effects.

Also employing event studies methods, Edison et al. (2006) found that the Reserve Bank of Australia's (RBA) interventions from 1984 to 2001 had only limited impact in reducing the depreciating tendency of the Australian/U.S. Dollar. Their study also finds evidence that RBA interventions increased exchange rate volatility and may have added to market uncertainty.

[7]This comparison exercise was made by departing from the same intervention amount: one trillion Japanese Yen.

Besides time series regressions and event studies, a relevant part of the exchange intervention literature employs alternative methods. Kearns and Rigobón (2005) study of Japan and Australia's interventions - used data, respectively, from 1991 to 2002 and from 1986 to 1993. They set-up a simple model of Central Bank intervention based on implicit moving targets for the policymaker. The authors make use of a structural break in the central bank's behavior as a way to identify more moments and estimate them through a GMM procedure. Their results concluded that while the Reserve Bank of Australia's (RBA) interventions had a significant impact on exchange rates (a purchase of US$ 100 million would affect the Australian dollar by 1.35 to 1.81 percent), operations of the same amount performed by the BoJ would only have a limited impact (0.2 percent over the Japanese yen).

Iwata and Wu (2012) studied the Japanese economy from 1991 to 2002 in the context of zero lower bound. Their findings, based upon a nonlinear structural VAR approach, suggest that interventions can still be effective even though their impacts become lower when interest rates are constrained to zero. Their Impulse Response Function (IRF) graphs, for both types of economies - with and without the zero interest rate boundary - display some initial yen depreciation after an intervention shock but with different starting point estimates (the liquidity trap economy indicates depreciation of around 0.08 and the unrestricted economy at 0.15).

Similarly to the present study, Fatum and Hutchison (2010) apply PSM to deal with the endogeneity issue and investigate interventions in the Japanese economy, from 1999 to 2004. Their results for the Japanese case indicate that, whatever event study the literature stresses, only infrequent and sporadic interventions affect the exchange rate.

In summary, although not consensual, the literature of exchange rate interventions for developed economies may lead us to some common results. First, as earlier studies suggest, coordinated interventions during the late 80's were effective in changing the exchange rates in the desired direction. Second, more recent studies, using a vast set of techniques, indicate that interventions had more limited impact in the 90's and 2000's and even can add volatility, as in the case of RBA interventions. Finally, we guess that those differences found among interventions in the 80's compared to more recent ones may be related to the predominance of uncoordinated interventions in the latter period.

3.2 *Emerging Markets*

The literature on developing economies, as Kamil (2008) and Vervloet (2010) point out, suffers from data scarcity. Kamil (2008) identifies a lack of transparency from the central banks with regard to the reserve accumulation's objectives.

Kumhof and van Nieuwerburgh (2007) drew attention to another characteristic of developing economies: a higher volatility of temporary government spending than in developed economies. According to the authors, the portfolio channel relies upon the fiscal policy's characterization. Economies that make more use of temporary spending instead of being financed by endogenous tax responses (i.e. economies that are subjected to exogenous spending shocks or a discretionary use of government spending), make room for a rise in risk perception, determining a degree of imperfect asset substitutability. Developing countries present higher volatility of spending not related to automatic stabilizers than industrialized countries. Thus, emerging economies tend to have a more active portfolio channel than those in the developed world. Although those conclusions may be a little out of date, after the great world recession of 2008/09 and the

debt crises in developed economies that followed, the point might be valid for most of our sample covering the 1999-2012 period. Besides, we prefer to leave interactions with government spending to further studies.

Adler and Tovar (2011) used a panel of 15 countries over 2004-2010 with a special focus on Latin America. Since high frequency data on the central bank's foreign exchange position is often unavailable, their weekly database also considers foreign exchange market transactions or changes in international reserves as proxies. Their quantitative estimation, assessed through a two-stage IV-panel, suggests that interventions can be successful in lowering the pace of appreciation (which seems to be a result of an easing of global financial conditions) but that the effects decrease with the degree of capital account openness. This also suggests that sterilized interventions are more effectively in the context of 'overvalued' exchange rates.

Although the literature on emerging economies constitutes a growing number of studies, their findings on the efficacy of interventions in the foreign exchange market are not definitive. Some studies have produced positive results. For example, Égert (2007) studied patterns of intervention in emerging European economies between 1996 and 2006, using the event study method and showed that the interventions were effective for a period of up to 10 days in Croatia, the Czech Republic, Slovakia, and Turkey. The study observed more pronounced results when the purpose of an intervention was to contain currency appreciation and more lasting results when an intervention was combined with changes in interest rates or with communications from the central bank. Égert (2007) also distinguished between the effects of sterilized and non-sterilized interventions and, interestingly, did not find that there was a significant difference between the two.

Disyatat and Galati (2007) found, through an instrumental variable approach, that interventions have a weak statistical impact on the exchange rate level and had no impact on its volatility when they investigated the case of the Czech Republic between 2001 and 2002. They used data on macroeconomic variables and policy decisions to differentiate between the effect of interventions and other effects relevant to the determination of the exchange rate.

Pontines and Rajan (2011) tested for the evidence of fear of floating – as in Calvo and Reinhart (2002) – for six Asian emerging economies (India, Korea, Philippines, Singapore, Thailand and Indonesia), using data from 2001 to 2009, through a Central Bank reaction function followed from a minimization problem (described by a loss function). For these countries there are asymmetric interventions responses regarding fears of depreciation against appreciation. In fact they find strong evidence of "fear of appreciation" in those economies, which makes sense, since a relative higher own currency value hurts the export led growth model of those economies.

There are indications that country-specific factors might also influence the reactions of the foreign exchange market to intervention. Guimaraes and Karacadag (2004) demonstrated in their study of Mexico and Turkey - using data from 1996 to 2003 and from 2001 to 2003, respectively, through an Asymmetric Component Threshold GARCH (ACT-GASRCH) - that interventions affected exchange rate volatility in opposite ways in each country. Whereas interventions increased volatility in Mexico, there were indicators of a reduction in volatility in Turkey.

Tapia et al. (2004), who analyzed the Chilean economy from 1998 to 2003, found evidence, through a two-stage instrumental variable estimation, that exchange rates react to public announcements instead of the usual spot market interventions. According to the authors, the success of the interventions is a result of the central bank's transparency.

Given the recent history of Inflation Target (IT) regimes (since the New Zealand Central Bank adopted the regime in 1990), it is important to disentangle the IT context from the non-IT. A few studies have analyzed the effectiveness of foreign exchange interventions in such a situation. Kamil (2008) discusses the case of Colombia from 2004 to 2007 and analyzes it using a two-stage instrumental variable. The first stage being an instrument generated through a central bank's reaction function which then, in the second stage, was fed into a GARCH model. Their results suggests that the Colombian central bank's interventions have been successful between the 2004-2006 appreciation of its currency, but not during 2007.

In a broader approach, Berganza and Broto (2012) discuss the role that IT regimes may have in emerging economies given their greater financial and real vulnerabilities, in respect do developed economies, and the fear of floating (Calvo and Reinhart, 2002). He highlights that these economies face a dilemma between sticking to "strict IT" or to "flexible IT". The former implies a fully flexible exchange rate and the latter entails a de facto managed-floating exchange rate with foreign exchange interventions to moderate exchange rate volatility. Through a pooled OLS panel data model for 37 countries, the authors found that foreign exchange interventions in some IT countries have been more effective for lower volatility than in non-IT countries.

In summary, even though the emerging economy literature is still incipient, the results indicate that the monetary authority's interventions seem to be closer to being more effectiveness compared to those carried out in developed economies. In some sense, this seems to be a result of central bank's informational advantage, lower liquidity and a more limited size of the exchange markets in emerging economies, as well as a "fear of floatin" or a preference for a more depreciated currency.

3.3 *The Brazilian case*

In the specific case of Brazil, the exchange rate has been an important tool of policy since it became a republic in 1889. Since World War II the Brazilian exchange rate history has included five different exchange rate regimes (Table 1).

Before the end of the Bretton Woods system (1973), the Brazilian economy experienced two exchange regimes. The first one, from 1953 to 1964, is marked by discontinuity due to the political environment and the abrupt change in economic conditions. During this period the Brazilian economy had a multiple exchange rate regime which aimed to boost exports and discourage non-essential imports. In 1964 a dictatorial military government took over and implemented a structural reform concerned with, among others things, inflation and external imbalances. In the years that followed, from 1964 to 1968, the economy passed through a period of adjustment in succeeding years in terms of economic growth. The exchange rate regime that prevailed at that time was a pegged exchange rate with constant adjustments due to the disparity in Brazilian and U.S. inflation.

After 1968, there were basically three exchange rate regimes. Just before the end of the Bretton Woods' system, the regime changed to a pegged exchange rate with managed devaluations. At first, it followed the strategy of performing constant and sporadic mini-devaluations on the pretext of dealing with speculation. In between, there were two maxi-devaluations: the first one, in December 1979 (with 32.7 percent of month devaluation)[8], caused by the second oil shock and the second, in February 1983 (with 38.6 percent a month devaluation) , a result of

[8]Data obtained from the Brazilian Central Bank's website (http://www.bcb.gov.br/).

the debt and balance of payments crisis that affected most emerging economies. Before 1994, Brazil saw the end of the dictatorship regime in 1985, and simultaneously struggled to solve the hyperinflation problem - manifested in numerous heterodox economic plans. In the early 90s, the country faced a trade liberalization that preceded the plan (called "Real", currently the name of the Brazilian currency) and that succeeded in establishing price stability.

[INSERT TABLE 1 ABOUT HERE]

As a result of the Russian and Asian crisis, in January 1999 Brazil suffered a massive speculative attack with huge losses of international reserves and decided to abandon the crawling peg regime with horizontal bands, one of the building blocks of the inflation stabilization Real plan, and let the exchange rate be defined by the market forces[9]. In July of the same year, the Central Bank adopted the Inflation Target Regime. In order to preserve the price stability objective, the monetary authority is obligated to sterilize all foreign exchange market interventions (rebalancing the monetary base to its starting point before intervention). In the absence of any channel other than the traditional and facing the impossible trinity (i.e., the impossibility of having a fixed exchange rate, free capital mobility and an independent monetary policy at the same time), all interventions should have no effects on the exchange rate.

One of the side effects produced by the economic plan that reined in higher inflation rates in Brazil was the increased exposure of the Brazilian debt to the exchange rate. Since the early 2000s, as noted by Azevedo and Bevilaqua at a BIS gathering (Bank for International Settlements, 2005), the Central Bank has been intervening not to control volatility or to choose a level, but to recompose international reserves and reduce the government's exposure to the U.S. Dollar variations with the objective of avoiding sudden stop risks.

Literature focused exclusively on Brazilian Central Bank interventions is still scarce but it has being growing given the recent availability of data. Meurer et al. (2010), analyzes the Brazilian spot foreign exchange market interventions from 1999 to 2008 using an event study method applied to different periods segmented by a Markov Switching-VAR. The authors find that continuous interventions have more chance of success (in affecting the exchange rate returns) than through discrete ones. Moreover, the evidence suggests that interventions can have short-term effect (one to two days following an intervention).

Oliveira and Plaga (2011), on the other hand, investigated how foreign exchange market interventions affect the exchange rate volatility. Analyzing the period of 1999 to 2006 - with particular interest over periods of currency crises of 1999 and 2002 - using a model of conditional volatility, E-GARCH, the authors found that the Central Bank was able to reduce volatility during normal times (when there were no crises) and the 2002 crisis but that the 1999 crisis was responsible for adding volatility.

With regard to the actions taken by the monetary authorities during crises, Stone et al. (2009) examined how the Brazilian Central Bank responded during the global shock of 2008-09. After documenting and analyzing foreign exchange liquidity providing measures, the authors concluded that the actions of the Central Bank appeared to have reduced the relative onshore cost of dollar liquidity on impact and seemed to have stabilized market expectations of exchange rate volatility, suggesting that these kinds of liquidity easing operations could become standard Central Bank tools.

[9] 6565th Communiqué of the Central Bank of Brazil, issued January 18, 1999, in which the then-Minister of Finance, Mr. Pedro Malan, told the International Monetary Fund and the market that the country would adopt a floating exchange rate regime.

With the massive reserve accumulation observed in the Brazilian economy from $54 billion at the end of 2005 to $350 billion at the end of 2011[10], Vervloet (2010) put the portfolio's channel to the test over the period between 2004 and mid-2010. The author first used a time series approach and tested the covered interest parity structure with an OLS and 2SLS. Then the VAR/VEC structural identification approach was tested. The results, which were also divided among different types of markets (spot and future) and different types of directions (purchases versus sales), supported the principle of effective intervention in suggesting that each sterilized US$ 1 billion purchase/sale increases/decreases the returns in between 0.07% and 1.4%. It also showed that its effects have a short-term life of 4 to 10 days.

Contrary to what the above studies seem to indicate, Garcia (2011) believes that the recent period of abundant liquidity in financial markets, together with the good perspectives of the Brazilian economy - as well as many emerging economies -, might be associated with an capital inflow that enters not to primarily take advantage of the high interest rates, but to seek returns on longer term assets. In this context, and since sterilized operations occur through restoring the interest rate level to levels prior to the purchases/sales of U.S. currency, sterilized interventions may not be sufficient to avoid nominal and real appreciation effects over the exchange rate.

4 Methodology and data

4.1 *Propensity Score Matching: Self-selection, Counterfactuals and Average Treatment on the Treated*

Our main goal is to understand the impact of Central Bank interventions in the exchange rate market. In order to measure this impact, however, the researcher has to consider that interventions are probably not random, instead are due to some specific circumstances on the economic environment. In other words, the Central Bank decision to intervene was subject to a *self-selection* procedure, indicating that we introduce a *selection bias* when we compare days that the Central Bank intervenes in the market with days where there was no intervention. However, the estimation problem comes from the fact that we have no *counterfactual*, in other words, we cannot observe on the same day the market behavior that occurs either as a result of intervention or when it is absent. Ideally, we should find a method that can postulate how this *counterfactual* exchange rate changes in the absence of interventions.

The construction of this necessary counterfactual can be accomplished by adopting a matching method known as Propensity Score Matching (PSM). This technique has been largely applied to measuring causal treatment effects in diverse fields of study (Caliendo and Kopeinig, 2008). The main idea of the PSM developed by Rosenbaum and Rubin (1983) was to select a non-treatment group as a control in order to make them resemble the treatment group in everything but the treatment (foreign exchange interventions made by central banks). Usually this would be done by condition treatment effects in all relevant pre-treatment characteristics (denoted by X). As the set of variables to be used in the matching process grows, the chances of finding an exact match decreases (problem known as *curse of dimensionality*). Thus, instead of including a large set of characteristics that both groups have, the PSM approach uses a propensity score - an estimated probability of being part of the treatment group - so reducing the multi-dimension problem to being one-dimensional.

[10]Source: central bank of Brazil.

In our case, the propensity score is the probability of the Central Bank intervening given observed characteristic X. In order to properly apply the PSM, all characteristics need to be independent of the intervention decisions and both groups (treated and non-treated) should share the same support in X. This way X affects the intervention decision, but the groups are not affected by the decision itself.

Denoted by D_t our binary treatment variable, where $D_t = 1$ if the Central Bank intervened at date t and $D_t = 0$ if it did not. Considering that Y_t is our variable of interest, it may indicate the return or volatility of the exchange rate at time t, for instance. We can assume that this variable will be affected by the treatment variable $Y_t(D_t)$. Therefore, assuming that an intervention occurred at time t, we would compute the effect of the intervention as:

$$\tau_t = Y_t\left(1\right) - Y_t\left(0\right) \tag{1}$$

The problem in computing (1) is that we cannot observe the counterfactual outcome $Y_t(0)$ because, by assumption, the Central Bank intervened at time t. So, we do not know what would have happened if the Central Bank did not intervene at time t, thus there is no *counterfactual*. Therefore, the goal of PSM is to find a proper empirical *proxy* for this true *counterfactual*.

Our interest is in estimating the "average treatment effect on the treated" (ATT), which is the effect estimated only for those dates which had undergone treatment (in our case, exchange rate intervention). The ATT is expressed in the following formula:

$$\tau_{ATT} = E\left[\tau|D=1\right] = E\left[Y(1)|D=1\right] - E\left[Y(0)|D=0\right] \tag{2}$$

If we opt to use $E[Y(0)|D=0]$ instead of $E[Y(0)|D=1]$ in equation (2), we would probably incur a self-selection bias, given that:

$$E\left[Y(1)|D=1\right] - E\left[Y(0)|D=0\right] = \tau_{ATT} + E\left[Y(0)|D=1\right] - E\left[Y(0)|D=0\right] \tag{3}$$

If the Central Bank's decision to intervene was random, then the selection bias, E[Y(0)|D=1] − E[Y(0)|D=0], would be zero. However, it is very likely that the decision to intervene would be influenced by the market conditions (or macroeconomic conditions) on that specific day and those specific condition would also affect our variable of interest Y_t.

A possible solution was proposed by Rosenbaum and Rubin (1983) who suggested the use of balancing scores. One candidate for a balancing score is the probability of intervention given a set of factors X, $P(D=1|X) = P(X)$.

Given our literature review, our underlying assumption is that this set of factors X is represented by the recent behavior of the exchange rate, the current macroeconomic fundamentals and unanticipated news about economic indicators, domestic and external (represented by the U.S. economy).

We also need an additional assumption that potential outcomes are independent on treatment conditioned on the probability of intervention. Thus, we can impose a conditional independence assumption (CIA) based on the propensity score (PS):

$$Y(0), Y(1) \text{ II } D|P(X) \tag{4}$$

Finally, we need to impose a further necessary overlap condition:

$$0 < P(D = 1|X) < 0 \tag{5}$$

Assuming that equations (4) and equations (5) hold, the ATT effect, τ_{ATT}^{PSM}, is:

$$\tau_{ATT}^{PSM} = E_{P(X)|D=1}\left\{E[Y(1)|D = 1, P(X)] - E[Y(0)|D = 0, P(X)]\right\} \tag{6}$$

As Caliendo and Kopeinig (2008) state, the PSM estimator for the ATT is "the mean difference in outcomes over the common support, appropriately weighted by the propensity score distributions of participants".

In simplified form, our methodology had two parts. First, we estimated the reaction function of the Central Bank through a probability model[11] for the entire sample and derived an intervention probability score (*propensity score*) associated with each day. Thus, regardless of whether an intervention occurred, each observation has an associated probability of intervention and an observed exchange rate variation.

For each day in our sample, the Central Bank either decides to intervene ($Y = 1$) or does not ($Y = 0$) based on a set o economic factors X, so a Central Bank reaction function for intervention is defined by:

$$\begin{aligned} Pr(Y = 1|X) &= F(X, \beta) \\ Pr(Y = 0|X) &= 1 - F(X, \beta) \end{aligned} \tag{7}$$

Where β is the vector of parameters that reflects the impact of changes in X on probability. We employ the logistic distribution for the function $F(\cdot)$, so we specify the following logit model:

$$Pr(Y = 1|X) = \frac{exp(\beta' X)}{1 + exp(\beta' X)} \tag{8}$$

Then we separated the sample between the treatment group (with intervention) and the control group (no intervention) and matched its units according to probabilities. To select the pairs of observation among the groups with the most similar *propensity scores*, we used different matching algorithms and then tested for the mean differences in the variations of the exchange rate in order to establish whether the interventions did, in fact, change how the exchange rate should be interpreted.

Within the PMS estimators, there are four different types of algorithm being used (Caliendo and Kopeinig, 2008): (a) nearest neighbor matching, (b) calliper and radius matching, (c) stratification matching, and (d) kernel and local matching. The first chooses a pair based on their proximity in terms of probability score. The second tries to deal with cases when the nearest neighbor might be far away. In this case, a maximum distance to which is applied the selection according to the nearest neighbor (calliper) is established - the radius algorithm uses all possibilities contemplated within this range. The stratification matching identifies the

[11] Probit or Logit nonlinear models, which ensure probabilities between 0 and 1. We use a Logit model, following the suggestion of Fatum and Hutchison (2010).

difference between the control and treatment groups within each stratum of probability - for example, it analyzes the groups between 0-10 percent, 11-20 percent and so on - and calculates a weighted average according to their size on the sample (it considers only those stratum that have controls, otherwise it is set a zero weight to it). The last algorithms, the kernel and local matching, are non-parametric estimators that use all individuals in the control group assigning then weights according to their distances from the participant observation for which the counterfactual is estimated.

The results of our study are based on the algorithms (a), (b) and (d). When using the nearest neighbor algorithm with 1 neighbor, we considered a no replacement strategy (which consists in the absence of re-usage of data). Whenever required, we assume a maximum distance of controls of 0.25 percent of the standard deviation of PScore, as Rosenbaum and Rubin (1983) recommend. In this way, we ensured that we only considered the control features that were sufficiently close. At the same time, we checked the counterfactual validity through a propensity score test that analyzed the distribution similarity of the control and treatment groups among a large number of covariates.

4.2 *Data description*

Despite the Brazilian Central Bank (BCB) disclosing only monthly interventions, we used a daily proxy provided by the BCB[12] that, once aggregated over the month, presents a correlation of 95.99 percent with the monthly data - which contemplates interventions in different kinds of markets: spot, future, foreign currency loans and repurchased foreign currency loans. We will refer to this intervention proxy as the general intervention variable, since it includes all kind of Central Bank interventions in the exchange rate market. We also make use of interventions made through only the swaps market, available from BM&FBovespa (the Brazilian main stock market for equities, futures and derivatives). Those swap transactions are registered on the BM&FBovespa in the form of "a currency swap contract with Periodical Adjustment - SCC" with the BCB as the counterpart to the private sector. The registered values in U.S. Dollars of these contracts were discounted to present value by the contractual rate until the date of the auction in order to properly measure their impact on the foreign exchange market. The use of negative values implies that the BCB assumes the position of the buyer of that contract. BCB will receive the specified amount of Brazilian Real plus interest in exchange for paying the U.S. Dollar change in the period. Likewise, positive values express the BCB by assuming the position of the contract vendor and, therefore, the BCB will be buying U.S. Dollars. The number of contracts accepted by the market in each auction was multiplied by the default value of each contract (USD 50,000) and discounted to its present value as of the date of the auction rate agreed. The data was kindly provided by the BM&FBovespa.

Our choice of the variables X and their respective description are in Table 2. The *Central Bank variables* reflect the fact that interventions were generally clustered on consecutive days. Thus, motivated in part by recent trends, we included lagged interventions of up to three lags and the moving average distance for 3 and 6 months and one year. The *macroeconomic fundamentals* variables included proxies for the economic scenario from the financial side (EMBI+, VIX,

[12]This intervention proxy is named: *Fatores condicionantes da base monetária - Operações com o setor externo* (Conditional factors of the monetary base - external sector operations). This variable has to be adjusted from a delay of two days, since the central bank's action (registered at D day) are liquidated two days after the operation takes place (D+2).

CRB index, DXY index, SP500, Ibovespa) and market GDP growth expectations. The third and fourth groups of variables included *macroeconomic announcement shocks* for the domestic market and external markets, represented by the U.S. macroeconomic indicators, since we deal with the Brazilian Real / U.S. Dollar exchange rate (hereafter denoted by R$/US$). The surprise in each announcement is defined as the difference between the disclosed data expected value:

$$S_{k,t} = \frac{I^a_{k,t} - I^e_{k,t}}{\sigma_k} \tag{9}$$

Where $S_{k,t}$ is the surprise component of indicator k announced at time t, $I^a_{k,t}$ and $I^e_{k,t}$ are, respectively, the disclosed and expected values for the macroeconomic indicator k and σ_k is the standard deviation of the same indicator k. More specifically, the expected value of a given macroeconomic indicator is the median value of expectations collected from the Bloomberg survey with a sample of market analysts.

[INSERT TABLE 2 ABOUT HERE]

The database used in this study includes 3,184 observations that corresponded to individual business days in the period between June 1, 1999 and January 31, 2012. Figure 1 shows the exchange interventions values and the spot R$/US$ exchange rate. It can easily be seen in the figure that the whole period has two very distinct intervention periods: from 1999 to 2003 and from the 2004 to 2012. The former period is characterized by sporadic and relatively lower interventions with a devaluating trend for the exchange rate, R$/US$. The latter period is quite the opposite, with more frequent and relatively larger interventions with a valuating trend for Brazilian Real. Comparing buying and selling activities, the histogram presented in Figure 2 illustrates that buying interventions were on average larger and more frequent than selling interventions. Table 3 shows descriptive statistics for the whole period and the previously mentioned sample periods of 1999-03 and 2004-12. Bearing in mind the striking differences between these two periods, we conducted our empirical exercise for the whole sample and also for the two sub-samples.

[INSERT FIGURE 1 ABOUT HERE]

[INSERT FIGURE 2 ABOUT HERE]

[INSERT TABLE 3 ABOUT HERE]

It should be noted that we estimated separate models for the intervention episodes of buying and selling, both compared to counterfactuals using non-intervention days, because the observations were sorted in binary form, $Y = 0$ or $Y = 1$. Furthermore, we aimed to differentiate between the impact of buying and selling, which may have different dynamics. As we mentioned above, we believe that the characteristics of the Brazilian market reinforce the need for researchers to examine the impact of interventions in the spot and future markets separately since the latter is a much bigger and liquid market. Furthermore, the derivatives market showed a lower spread than those observed in the spot market, which indicated greater liquidity in this market segment. However, it is reasonable to assume that the same volume of intervention in the currency causes different impacts in the spot and future market. Therefore, we will investigate the impact of intervention for the spot and futures market.

5 Results and robustness testing

5.1 *Central bank's reaction function*

Table 4 and 5 presents the results for the BCB's reaction function; that is, the Logit function that indicates the likelihood of an intervention by the monetary authority given a particular economic environment.

Interventions on previous days seemed to increase the likelihood of further action on a given day, regardless of the instrument of intervention and the objective of the BCB's activity. We also found strong evidence of a significant effect for selling activity. These features - a cluster of interventions - are quite common in the Central Bank's behavior. This finding makes sense for several reasons. First, the expected outcome of an action, regardless of its nature, could hardly be achieved in a single day of work given the size of the Brazilian foreign exchange market. Second, monetary authority is required to reinforce the particular course of action required to influence market expectations and achieve the set objective.

[INSERT TABLE 4 ABOUT HERE]

[INSERT TABLE 5 ABOUT HERE]

We expected that the difference between the level of exchange rate and its recent moving average would have a significant and negative coefficient for purchasing activity and a significant and positive coefficient for sale activity. For instance, if the exchange rate follows a strong appreciation trend and, therefore, a negative difference with the rate's moving average, the BCB may feel compelled to buy currency to reverse that trend in order to improve local net exports. Likewise, we applied the reverse logic to sale interventions. Although we found significance and the expected signs in many combinations across samples, buying or selling activity and general or swap interventions, there were also some cases of significant coefficients with opposite signs to those expected.

In terms of the macroeconomic fundamental variables, we would expect to find the country risk and risk aversion (variations on EMBI+ and VIX) signs to be negative for purchases and positive for sales interventions. The reason for this is that a high-stress environment, where a currency tends to be devalued, is associated with a lower (higher) likelihood of a central bankt's buying (selling) activity. Our Logit results in Tables 4 and 5 indicate that, although the signs are mixed, most of the significant coefficients, mainly in purchases made through swap contracts, are moving in the right direction.

On the other hand, we would expect that the variations coming from the interest rate differential and the commodity index, CRB, would attract capital inflows leading to currency appreciation. In this context, we would expect a positive sign for purchases and a negative sign for sale interventions. Our results, however, indicate that in almost all cases these variable coefficients are not significant.

With regard to the international value of the U.S. Dollar, measured by the DXY[13] index, its increase would depreciate the R$/US$ exchange rate, reducing (increasing) the central bank's

[13]The DXY is an index (or measure) of the value of the United States dollar relative to a basket of currencies. It is calculated by using a weighted geometric mean of the dollar's value compared with the Euro, Japanese Yen, Pound sterling, Canadian dollar, Swedish krona and the Swiss franc.

likelihood to purchase (sell). Despite all the coefficients being insignificant, purchase interventions showed signs in the right direction, while sales signs were mixed[14].

With respect to both stock exchange markets indexes, Ibovespa and SP500, is hard to advocate a unique reasoning. One may argue that an increase in market stock indexes (domestic and abroad) would reflect better economic conditions that would be consistent with more capital inflows towards the Brazilian economy (in the case of Ibovespa) leading to currency appreciation pressure. However, we could also argue that changes in the stock market indexes may be related to portfolio reallocation among domestic investors with no direct impact on capital inflows and the exchange rate. If our empirical evidence can light this issue, we can say that an increase in stock markets tends to decrease the probability of selling interventions, at least when we consider our full sample (1999-2012). Regarding buy interventions, stock market coefficients are significant only for swap interventions but often give out mixed signals.

The estimates of the last variables of the macroeconomic fundamentals group, GDP growth expectation variables (for current and next year), can also be difficult to interpret. An increase in growth expectations can be viewed as an investment opportunity (an investor's portfolio reallocation) that would imply capital inflows, thus appreciating the domestic currency. On the other hand, an increase in growth could lead to higher imports, worsening the trade balance and creating pressures for currency depreciation. Tables 4 and 5 show that most of its coefficients suggest that the first story would be more appropriate, i.e., higher growth expectations increase the probability of buying interventions and decrease selling actions by the monetary authority. The same reasoning used above regarding economic activity (expected GDP growth) may be used for our third group of controls, the macroeconomic announcement shocks. For the Brazilian economy, we expect that all variables associated with the real economy growth (job creation, GDP growth, wholesale sales and industrial production) would have the same signs (except for the unemployment rate, which would have an opposite sign). When we consider general interventions, Table 4 only surprise is in the General Price Index, which seems to infer that higher domestic inflation decreases the probability of buying interventions. However, domestic macroeconomic announcement shocks appear to have a more significant role when we consider only interventions operated through swaps, as shown in Table 5. An increase in the monetary policy interest rate (Selic) as well as an increase in the CPI (which is the official inflation rate pursued by the BCB) decreases selling activity. We may also note that an increase in the CPI increases the probability of purchase interventions. This result makes sense, since Brazil adopts an inflation targeting regime, and because higher than expected interest rates or inflation would increase expect real interest rates and attract capital inflows.

Concerning the U.S. macroeconomic surprise variables, we would expect that indications of higher economic activity abroad would attract capital towards the U.S. economy. This would create pressure for a devaluation of the Brazilian currency against the U.S. Dollar. In fact, this reasoning is confirmed by our logit estimation. Higher than expected new home sales, wholesale sales and job creation tend to decrease (increase) the probability of purchases (sales) of the U.S. Dollar by the BCB. This effect is much more evident and significant for the swap interventions (Table 5) than when we analyze all kind of interventions (Table 4).

We also estimated all models using all macroeconomic fundamental variables with a lag of one day. In general, the logit results worsened with many of coefficients turning out to be insignificant, so we preferred to rely on our original estimation exercise.

[14]The same models were estimated dropping the DXY, but showed no significant quantitative (and qualitative) changes.

5.2 *Propensity Score Matching Test*

Previous to the *propensity score matching* (PSM) results, we ran some tests to assess its validity. The idea behind the PSM, as already noted on the methodology section, is to create a counterfactual that may be used to evaluate the treatment results. So this test tries to assess how good the fit of the covariate's distribution as a whole is, and this is done through a bias measure generated from the probabilistic model and the data. The literature does not seem to offer a consensual way to test or measure the size of the bias that should be achieved. So, our understanding is that any reduction in the bias that is made using the counterfactual data would be a sign of improvement. Tables 6 and 7 expose these biased results, of raw and matched (counterfactual) data, using the statistical mean and median.

[INSERT TABLE 6 ABOUT HERE]

[INSERT TABLE 7 ABOUT HERE]

In general, most results indicate a bias reduction, giving more credibility to our PSM exercise. It is worth noting that most worsening occurs in the second sample period, 2004-2012, which could be explained by the recent 2008-2009 crisis that is still present in many of the world economies. Besides that, the purchase activity using swap instruments registers the higher concentration of worse results. Since swap contracts were mostly used during the second sample period and are usually applied to the sales activity, this could explain part of the first sample period's worse results.

5.3 *Impact on the exchange rate's level and volatility in the spot exchange market*

Table 8 and 9 presents the results of the *propensity score* matching method in our analysis of the impact of interventions on the exchange rate in the spot market; that is, the power of the BCB to influence currency value.

Our main results indicate that foreign exchange interventions in the spot market depend on the period analyzed. The first subsample, 1999-2003, indicates that U.S. Dollar purchase interventions by the BCB succeeded in devaluating the domestic currency. This result holds only for our general intervention variable, as intervention using only swap instruments indicated non-significant results. Sale interventions did not present any significant results, mostly indicating the expected signs (appreciation for sales and depreciation for purchases). In respect to the second subsample, 2004-2012, all interventions - purchases and sales - showed themselves to be insignificant, but with the expected signs. The difficult in measuring the impact of interventions in the second sub-period may in part be justified by the World financial crisis of 2008-2009. With regard to the spot market, we see some interesting results regarding the influence of BCB interventions on the second moment of the exchange rate. With respect to the first subsample, 1999-2003, the volatility impact through purchase activities was successful in reducing exchange rate volatility for our general intervention variable, but it is not significant when we consider interventions only with swap instruments. However sales interventions within this subsample were mostly insignificant, although indicating a positive sign, in that the Central Bank's sales interventions tend to increase volatility.

[INSERT TABLE 8 ABOUT HERE]

[INSERT TABLE 9 ABOUT HERE]

In general, the results observed in the PSM provided a typical example of the monetary authority's *leaning-against-the-wind*. That is to say, the BCB tended to intervene in the foreign exchange market to curb the trends in the exchange rate. Therefore, when it sold dollars, the Central Bank tried to minimize or contain the devaluation of the Real, and the opposite occurred in the case of purchasing activity. Our empirical evidence of those *leaning-against-the-wind* interventions showed the limited efficacy of the BCB actions. Although we found the expected sign in many cases, interventions were only statistically significant in the desired direction for buy intervention in the sub period 1999-20003. During this period the buy interventions depreciated the currency and reduced exchange rate volatility. Selling interventions in the 2004-2012 sub-period, however, seemed to increase volatility. We can suggest some reasons for those results. First, we can attribute them to a series of effects that occur more frequently in the market than the daily frequency that we studied. Beine et al. (2002) noted that hours after an episode of successful intervention, the market can attack the currency to test how determined the Central Bank is in defending it. Such an attack would cause the Real, for example, to appreciate immediately after the BCB's sale of dollars but, by the day's close, would leave it more depreciated than at the start unless the monetary authority continued to defend its decision. This hypothesis can only be tested with an investigation of intra-day data[15], data that we unfortunately do not have for this present study.

The above discussion can be enriched if we include the role of traders (*noise traders*) and if we regard the interventions as being secret or open. Our explanation only makes sense if we admit the existence of this group of players, noise traders, who can move the price of the exchange rate far from its fundamental value. As Hung (1997) reports, speculators' demand for currency is influenced by beliefs and feelings that are not always fully consistent with economic principles. Their actions may be motivated, for example, by graph analysis (*feedback* rules that recommend purchase when the price is rising and selling when the price is dropping) or even by the goal of testing the strength of the Central Bank in the market.

Many researchers have argued that interventions should be kept secret to minimize the position of noise traders in market activity. In the case of Brazil, especially in periods when the BCB sold dollars (typically 2002 and 2008), this argument is plausible. Moments of crisis were somewhat aggravated by the presence of speculators who bet against the Real and against the determination of the Central Bank to defend the currency. Despite a certain level of secrecy about the BCB's kind of activity in the interventions (i.e., volumes or moments of activity, at least for the spot and *swap* auctions), the monetary authority's consistent presence in these periods increased the certainty of new interventions. Thus, our explanation in relation to *noise traders* seems to make sense.

Furthermore, we hypothesized that the BCB was a major provider of market liquidity during the periods when it was a seller of dollars. As noted above, in 2002 and 2008, the positions purchased in dollars increased exponentially, and often there were no other buyers in the market besides the BCB. The Central Bank thus played an important role in bringing liquidity to the market. We should note that there is a potential explanation for the increased uncertainty in the market when the Central Bank sells dollars. According to Guimaraes and Karacadag (2004), sales of foreign currency by the Central Bank are not entirely credible given the monetary authority's interest in defending the currency. The depreciation of local currency and increased volatility

[15]See Dominguez (2003, 2006) and Fatum and Pedersen (2009) for studies of intervention with high frequency data.

are highly correlated, and therefore their effect on the exchange rate variance is direct. This result also confirms our results for the impact of selling activity on the exchange rate level.

5.4 *Impact on the level and volatility of the exchange rate on future exchange rates*

Table 10 and 11 present the results of the *propensity score matching* method in our analysis of the impact of interventions on the exchange rate in the future exchange rate market. It is well-known that current and future dollar value is related to preventing market arbitration. However, we do not know which price is first formed in the market and which is adjusted to maintaining the non-arbitrage relationship.

Garcia and Urban (2004) hypothesized that for Brazil the price formation occurs in the futures market because it is more liquid and transparent and that, once the futures rate is formed, we can obtain the current exchange rate for interest arbitration. The authors also proved the temporal antecedence of prices in the Brazilian derivatives market through a Granger's causality test.

Based on Garcia and Urban (2004) findings, it is reasonable to ask whether the central bank's foreign exchange interventions would have a different effect if we analyzed the dynamics of the futures market, especially the level and volatility of the first future value of BM&FBovespa. We propose such an analysis in this section without, however, fully delving into this issue due to its theoretical density, as evidenced by the numerous works devoted to the topic of pricing and transmission between the spot and futures markets.

Therefore, we repeated the application of the *propensity score matching* method with the same specifications as those discussed above. We replaced the level and volatility of the spot exchange rate with the level and volatility of the first future BM&FBovespa value.

[INSERT TABLE 10 ABOUT HERE]

[INSERT TABLE 11 ABOUT HERE]

The results presented in Tables 10 and 11 show some evidence that BCB's interventions in buying U.S. Dollars help to appreciate the currency for future markets and lowered the volatility of the exchange rate. However, the appreciation is statistically significant only in a few cases.

More robust evidence was found for selling interventions for the 1999-2003 period, but with an opposite sign than expected by a *leaning-against-the-wind* policy. In fact, selling interventions on the spot market during this sub period depreciated the future exchange rate. We emphasized a possible *signaling effect* from the spot to the futures market, emphasizing that selling interventions can indicate the future depreciations that the BCB is trying to avoid or limit.

For swap interventions, we can highlight the increase in future exchange rate volatility implied by selling interventions on the spot market, especially for the 2004-2012 period. Interestingly, the effects that we observed for selling interventions in the volatility of exchange rates in swap instruments were, as a rule, of greater magnitude than those observed in the general interventions case. Analogously, the effects in the level of exchange rates in swap instruments were

lower in magnitude than those observed in the proxy instrument. We observed this effect in both kind of activities, purchase and sales.

6 Conclusions

This study aims to analyze the real impact of Central Bank interventions in the trajectory of exchange rates in the Brazilian economy. Our motivation was to contribute to the research on exchange rate policy and to highlight the fundamental importance of this issue in times were "currency wars" were commonplace in headlines around the world. To this end, we used the propensity *score matching* method, which, to the best of our knowledge, has not yet been applied to a case study about the Brazilian or any other emerging economy. Our results for the level and volatility of exchange rates were conclusive and robust in terms of changing for both the spot and futures exchange rates.

Assuming that the Central Bank intervenes in the market to *lean-against-the-wind* and reduce volatility, our main results indicate that the efficacy of foreign exchange interventions in the spot market depends on the period being analyzed. From 1999 to 2003, with scarce and smaller interventions, the buying operations of U.S. Dollars depreciated the Brazilian Real. From 2004 to 2012, a period with larger and frequent interventions, only sell interventions were significant, tending to increase volatility of the Brazilian Real.

With respect to the volatility impact effects, our results indicate that purchase activities in the first 1999-2003 subsample were successful in reducing these effects with regard to the general interventions variable. However, sales interventions using swap instruments, mainly concentrated on the second subsample, indicate a quite different form of behavior. Whenever the Central Bank intervened, the volatility increased. Once most of the sales through swap contracts occurred during the 2008-2009 crisis, this might be seem to be the result of the rational behavior of market participants in a context where they understood the central bank's intervention as a signal that economic conditions were worsening more than initially expected.

The impact of the BCB's spot market foreign exchange interventions in future market rates also depends on the period analyzed. Taking a broad view, BCB's purchase intervention results seem to be less robust. Only a few results of our exercises, mainly through general interventions, indicate that the future exchange rate level would be depreciated after a U.S. Dollar purchase. Since the future market is more liquid and reflects not only current, but future economic conditions, this is not a surprising result. On the other hand, sale activities, in the future market tend to have the opposite expected effect, depreciating future exchange rates. These results, which appear only for general interventions, are concentrated on the first subsample period.

With regard to future exchange rates, the effects on volatility are similar to the effects found for the spot market: the volatility tends to increase in the second subperiod sample for swap interventions.

These results demonstrate the importance of assessing the impact of interventions in emerging economies. Such economies, on average, have less liquid markets and are more vulnerable to international crises and abrupt movements in capital flows, as observed in the Brazilian confidence crisis in 2002 and the World financial crisis of 2008/2009. Our results indicate that the efficacy of the intervention is at best limited and does not always work as desired. In many

cases, the Central Bank will fail to determine the tendency of the exchange rate and will only operate as a liquidity provider to the market.

Of course, our study has many limitations. One of them, which needs to be addressed in future studies, is to use high-frequency intra-day data. Another possibility is to disentangle announced and secret interventions. In general, the use of more informative and complete data bases will make it possible to further understand the dynamics of interventions in emerging economies. The main challenge is to have this kind of data available, especially for emerging economies. Our contribution to this study relies on taking a small step in this direction, using a daily and comprehensive sample of exchange interventions for Brazil.

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Figure 1: Central Bank exchange rate interventions and the exchange rate value

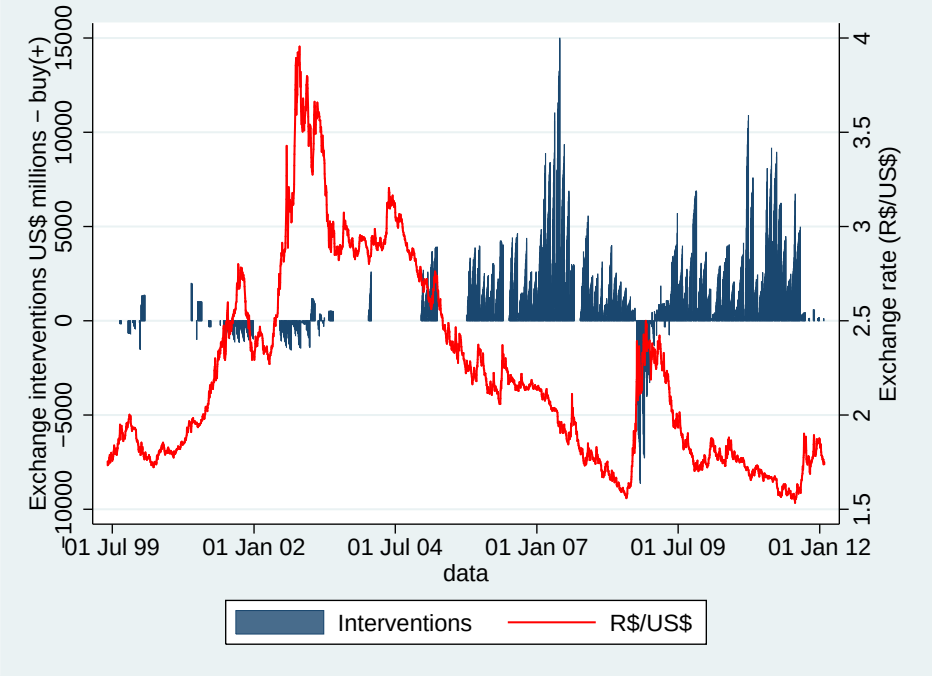

Figure 2: Central Bank exchange rate interventions and the exchange rate value

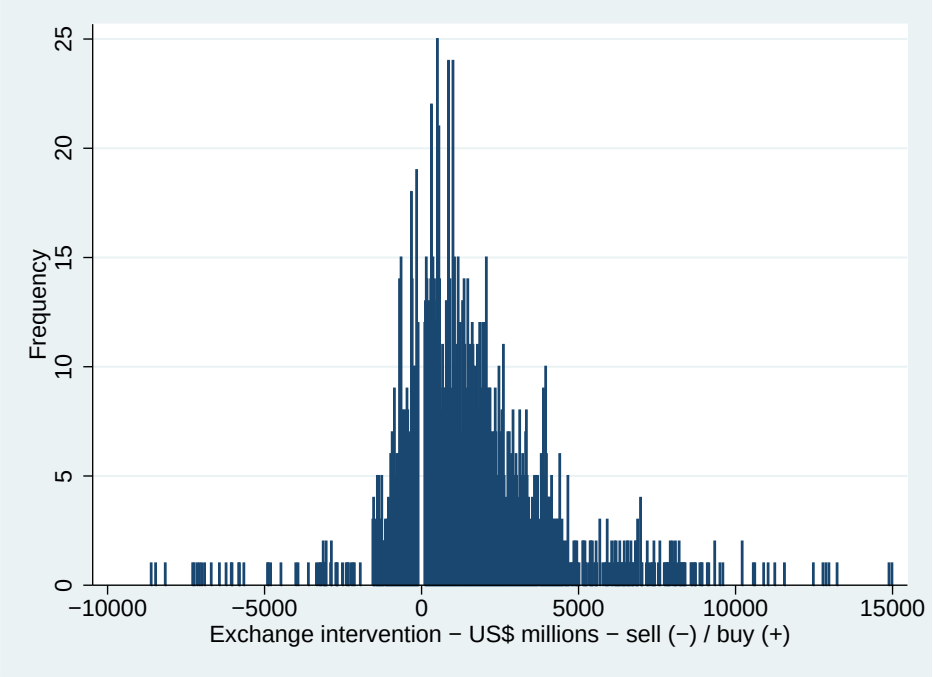

Table 1: Brazilian exchange rate regimes and economic fundamentals - yearly averages

	Multiple Exchange Rates	Pegged Exchange Rates	Pegged exchange rate with managed devaluation	Crawling Peg with horizontal bands	Free Floating
Period	1953-1964	1964-1968	1968-1994	1994-1999	1999-2011
GDP Growth	6.76	5.30	5.33	2.59	3.36
Inflation*	37.98	43.20	602.15	12.70	9.52
Unemployment**	na	na	9.57	10.33	10.09

(*) Inflation is measured using the IGP-DI from Getúlio Vargas Foundation. Since unemployment and inflation were calculated with monthly data, we focused on the Crawling Peg regime from Aug/1994 to Jan/1999.

(**) Unemployment is measured using data from PME-IBGE, which started in Feb/1980 and changed the survey methodology in 2002. Thus, all data were constructed using the time series from the new one and were concatenated with the old data.

Table 2: Variables description

Variable	Definition	Source
	Dependent Variables (Logit and PSM)	
Exchange Rate - spot	Brazilian Real per unit of U.S. Dollar - daily official rate (Ptax) from the Central Bank of Brazil	BCB[a]
Exchange rate return - spot	Log return of the exchange rate	BCB[a]
Exchange Rate volatility - spot	Log return of the exchange rate squared	BCB[a]
Exchange Rate - future	Brazilian Real per unit of U.S. Dollar - First future from the BM&FBovespa stock exchange	BCB[a]
Exchange rate return - future	Log return of the exchange rate - First future	BCB[a]
Exchange Rate volatility - future	Log return of the first future exchange rate squared	BCB[a]
Buy Intervention (Billions of $)	Intervention values by the BCB obtained from the daily balances of the series: "Factors conditioning the monetary base - External sector operations" - Daily values above US$100 million	BCB[a]
Sell intervention (Billions of $)	Intervention values by the BCB obtained from the daily balances of the series: "Factors conditioning the monetary base - External sector operations" - Daily values bellow US$100 million	BCB[a]
	Explanatory Variables (Logit)	
Fundamentals		
EMBI+	Emerging Markets Bond Index Plus (EMBI+) - average spread of Brazilian against U.S. sovereign bonds	DataStream
VIX	Chicago Board Options Exchange Market Volatility Index	DataStream
CRB	Commodity index calculated by Thomson Reuters/Jefferies	Bloomberg
DXY	An index of the value of the U.S. Dollar relative to a basket of foreign currencies	Bloomberg
Interest rate differential	Difference between two interest rates: Selic and Federal Funds	BCB[a] / Fed[b]
SP500 return	Log return of the market-value weighted index of the 500 largest stocks in the US markets	DataStream
Ibovespa return	Log return of the index of about 50 stocks that are traded on the Brazilian Stock Exchange	DataStream
Exp. GDP growth (current year)	Median expectations of the Focus Survey conducted by the Central Bank with market participants - Expected growth rate for the GDP for the current year	BCB[a]
Exp. GDP growth (next year)	Median expectations of the Focus Survey conducted by the Central Bank with market participants - Expected growth rate for the GDP for the next year	BCB[a]
Macroeconomic Surprises (Brazil)		
Mon. Policy interest rate (Selic)	Difference between the announced macroeconomic indicator value and the market expected value surveyed by Bloomberg, divided by the standard deviation of the announced values. Variable takes a zero value for non announcement dates.	Bloomberg
CPI		Bloomberg
General Price Index		Bloomberg
GDP growth		Bloomberg
Unemployment rate		Bloomberg
Job creation		Bloomberg
Wholesale sales		Bloomberg
Industrial Production		Bloomberg
Trade balance		Bloomberg
Macroeconomic Surprises (US)		
Fed Funds rate	Difference between the announced macroeconomic indicator value and the market expected value surveyed by Bloomberg, divided by the standard deviation of the announced values. Variable takes a zero value for non announcement dates.	Bloomberg
CPI		Bloomberg
ISM index		Bloomberg
New home sales		Bloomberg
Wholesale sales		Bloomberg
Job creation		Bloomberg

[a]Brazilian Central Bank; [b]Federal Reserve Bank of St. Louis.

Table 3: Descriptive statistics

	Full Sample					*1999-2003*					*2004-2012*				
	Obs	Mean	Std.Dev.	Mininum	Maximum	Obs	Mean	Std.Dev.	Mininum	Maximum	Obs	Mean	Std.Dev.	Mininum	Maximum
Exchange Rate - spot	3184	2.22	0.52	1.53	3.95	1155	2.46	0.6	1.72	3.95	2029	2.09	0.42	1.53	3.2
Exchange rate return - spot[a]	3074	1.76	15.84	-2359	2248	1116	11.65	16.4	-2359	1199	1958	-3.88	15.51	-2323	2248
Exchange Rate volatility - spot[a]	3074	0.16	0.58	0	13.91	1116	0.17	0.56	0	13.91	1958	0.15	0.59	0	13.48
Exchange Rate - future	3131	2.23	0.52	1.54	3.96	1142	2.47	0.6	1.72	3.96	1989	2.1	0.42	1.54	3.22
Exchange rate return - future[a]	2985	0.08	17.58	-3745	1552	1097	7.75	19.06	-3745	1552	1888	-4.38	16.66	-1557	1483
Exchange Rate volatility - future[a]	2985	0.19	0.83	0	35.07	1097	0.23	1.21	0	35.07	1888	0.17	0.49	0	6.06
Buy Intervention (Billions of $)	1516	2325	2128	102	14992	93	905	436	147	1986	1423	2418	2161	102	14992
Sell intervention (Billions of $)	378	1121	1503	101	8623	300	625	383	105	1545	78	3027	2419	101	8623
Fundamentals															
EMBI+	3306	483.34	230.61	153.32	938.95	1197	230.38	54.16	153.32	388.26	2109	626.9	157.36	329.01	938.95
d(EMBI+)	3304	13.76	13.49	-2358	1599	1195	19.42	18.73	-2358	1599	2109	10.55	9.28	-2353	1273
VIX	3189	22.35	9.24	9.89	80.86	1154	24.39	5.33	15.58	45.08	2035	21.2	10.67	9.89	80.86
d(VIX)	3074	-39.26	98.57	-8834.83	12499	1112	-48.51	81.84	-4269.49	4245	1962	-34.02	106.92	-8834.83	12499
CRB	3185	261.48	72.86	130.73	473.52	1152	180.99	24.29	130.73	245.42	2033	307.09	47.21	200.34	473.52
d(CRB)	3073	5.78	18.33	-1733.23	1448	1109	12.73	14.91	-1361.56	715	1964	1.85	20	-1733.23	1448
DXY	3287	91.07	13.56	71.33	120.9	1188	106.91	8.25	86.92	120.9	2099	82.11	5.21	71.33	92.33
d(DXY)	3268	-1.43	8.5	-684.66	636	1179	-2.83	8.01	-411.51	455	2089	-0.64	8.77	-684.66	636
Interest rate differential (IRD)	3184	11.82	3.71	5.41	22.2	1155	14.33	3.99	8.19	22.2	2029	10.39	2.64	5.41	15.22
d(IRD)	3075	-27.75	254.85	-51750	60521	1116	3.02	342.84	-51750	60521	1959	-45.27	187.17	-33526	23123
SP500 return[a]	3074	0.45	21.68	-2386	2761	1112	-2.69	21.09	-1513	1404	1962	2.22	22.01	-2386	2761
Ibovespa return[a]	3043	12.12	30.34	-3048	3447	1091	17.72	30.36	-2426	1849	1952	8.98	30.33	-3048	3447
Exp. GDP growth (current year)	3151	3.19	1.83	-1.27	7.64	1125	2.11	1.34	-1.27	4.27	2026	3.79	1.79	-0.73	7.64
Exp. GDP growth (next year)	3131	3.7	0.59	0	5.15	1105	3.38	0.68	0	4.42	2026	3.88	0.44	2.25	5.15
Macroeconomic Surprises (Brazil)[b]															
Mon. Policy interest rate (Selic)	122	-0.51	6.28	-33	27	49	-1	9.18	-33	27	73	-0.18	3.15	-12	13
CPI	142	2.55	29.47	-145	134	46	0.91	40.18	-145	73	96	3.33	22.85	-35	134
General Price Index	93	-1.26	18.51	-65	62	0	0	0	0	0	93	-1.26	18.51	-65	62
GDP growth	42	-18.98	64.26	-219	94	12	-41.08	92.88	-219	74	30	-10.13	47.78	-127	94
Unemployment rate	106	-1.62	16.74	-46	41	11	7	15.54	-19	24	95	-2.62	16.66	-46	41
Wholesale sales	105	12.05	40.86	-122	128	0	0	0	0	0	105	12.05	40.86	-122	128
Industrial Production	136	-11.07	62.2	-316	290	38	-1.39	76.38	-132	290	98	-14.82	55.75	-316	61
Trade balance	104	8.88	38.23	-103	168	12	2.25	8.93	-16	21	92	9.75	40.47	-103	168
Macroeconomic Surprises (US)[b]															
Fed Funds rate	97	-0.42	2.83	-14	6	32	-0.63	3.77	-14	6	65	-0.32	2.26	-11	4
ISM index	137	-9.72	31.36	-93	77	47	-16.55	26.54	-77	43	90	-6.16	33.19	-93	77
CPI	131	2.14	40.44	-140	140	45	-1.87	31.81	-84	84	86	4.23	44.33	-140	140
New home sales	141	1.99	19.48	-48	73	47	4.81	16.04	-38	35	94	0.57	20.93	-48	73
Wholesale sales	118	-0.35	65.63	-224	184	30	-1.33	65.57	-131	105	88	-0.01	66.03	-224	184
Job creation	139	-12.42	39.82	-150	90	47	-21.85	45.94	-150	86	92	-7.6	35.61	-99	90

Note: The sample includes 3,184 daily observations from June 1, 1999 to January 31, 2012. We consider only non-zero values for Buy and Sell interventions and macroeconomic surprises. [a]Annualized values in percentage points. [b]Values in percentage points.

Table 4: Central Bank reaction function to intervene in Exchange Rate (Ptax) using general interventions

	Buy Intervention			*Sell Intervention*		
	Full Sample	1999-2003	2004-2012	Full Sample	1999-2003	2004-2012
Centra Bank variables						
Intervention (t-1)	5.87 ***	24.92 ***	5.56 ***	4.36 ***	4.53 ***	4.39 **
	(0.41)	(1.24)	(0.44)	(0.47)	(0.54)	(1.83)
Intervention (t-2)	0.13	-19.47	0.11	-0.041	-0.43	4.27 **
	(0.5)	(omitted)	(0.54)	(0.54)	(0.62)	(1.82)
Intervention (t-3)	1.33 ***	1.19	1.22 ***	1.05 **	1.01 **	3.36 *
	(0.39)	(1.24)	(0.43)	(0.44)	(0.48)	(2.03)
Moving average distance - 1 year	5.95	17.48	11.67 **	12.11 ***	7.59	53.39 ***
	(3.67)	(11.32)	(4.87)	(4.32)	(5.76)	(17.16)
Moving average distance - 6 months	-13.28	-35.87	-28.61 **	-5.48	0.76	-95.01 **
	(9.31)	(26.35)	(12.5)	(9.55)	(11.56)	(37.84)
Moving average distance - 3 months	-7.32	-10.93	8.03	5.51	1.11	77.04 **
	(8.64)	(20.26)	(11.12)	(8.9)	(10.34)	(35.08)
Macroeconomic Fundamentals						
d(EMBI+)	-6.64	-29.97	3.86	10.99	2.51	123.68 **
	(24.73)	(52.02)	(31.33)	(13.38)	(14.7)	(56.33)
d(VIX)	-1.38	6.72	-2.36	-4.47	-1.28	0.61
	(3.14)	(11.31)	(3.5)	(4.45)	(5.47)	(13.87)
d(Selic - FedFunds)	0.31	-2.13	0.79	0.86	1.70 *	-0.09
	(0.89)	(2.85)	(1.04)	(0.9)	(1.02)	(2.66)
d(CRB)	-4.72	40.53	-8.29	6.35	16.85	-18.38
	(11.73)	(39.96)	(13.2)	(14.27)	(18.73)	(33.91)
d(DXY)	-10.40	-45.89	-14.60	-20.93	7.76	-146.47
	(25.3)	(67.17)	(29.14)	(28.36)	(35.74)	(91.52)
SP500 return	-9.24	-8.14	-4.62	-0.46	3.35	36.19
	(17.1)	(43.7)	(21.89)	(15.74)	(20.4)	(46.46)
Ibovespa return	0.66	37.53	-9.34	-19.94 *	-12.81	-66.07
	(10.02)	(29.41)	(11.63)	(10.35)	(12.15)	(44.38)
Exp. GDP growth (current year)	0.07	1.62	-0.08	-0.1 *	-0.10	
	(0.09)	(1.64)	(0.1)	(0.11)	(0.16)	
Exp. GDP growth (next year)	0.93 ***	-1.00	1.17 ***	-0.64 **	-0.74 *	
	(0.34)	(2.16)	(0.43)	(0.29)	(0.4)	
Macroeconomic Surprises (Brazil)						
Mon. Policy interest rate (Selic)	3.78	9.02	-4.23	6.01	7.38	
	(10.67)	(41.2)	(17.91)	(11.01)	(11.26)	
General Price Index	-6.46 **		-6.59 **	-0.59		
	(2.62)		(2.68)	(10.17)		
CPI	1.05	2.52	1.60	-0.10	-0.15	
	(2.39)	(3.82)	(4.64)	(2.76)	(2.68)	
Job creation	-4.28		-5.36	1.48		
	(3.57)		(3.65)	(23.06)		
GDP growth	-0.66	8.09	-3.26	-0.70	-0.75	
	(1.41)	(5.2)	(2)	(2.01)	(1.77)	
Unemployment rate	-3.67	7.66	-3.01	7.31	8.64	
	(3.27)	(25.09)	(3.32)	(6.79)	(7.29)	
Wholesale sales	1.99		1.74	0.24		
	(1.33)		(1.31)	(4.21)		
Industrial Production	0.23	-0.35	0.79	-1.39	-0.26	
	(0.8)	(3.36)	(0.91)	(1.23)	(1.31)	
Trade balance	-2.12	64.76	-1.96	0.24	49.57	
	(1.36)	(157.03)	(1.36)	(4.57)	(42.53)	
Macroeconomic Surprises (US)						
Fed Funds rate	-8.82	64.39	-20.60	15.15	27.56	
	(18.04)	(200.35)	(21.95)	(20.65)	(35.15)	
CPI	-0.28	-0.15	-0.27	-0.63	0.82	
	(1.16)	(4.25)	(1.3)	(2.66)	(3.63)	
ISM index	2.27	4.28	2.76 *	0.86	1.80	
	(1.53)	(12.6)	(1.63)	(2.65)	(3.06)	
New home sales	-1.71	-3.54	-1.56	2.81	2.70	
	(2.28)	(10.06)	(2.37)	(3.5)	(3.76)	
Wholesale sales	-1.33 **	-2.66	-1.03	0.08	-0.11	
	(0.64)	(4.09)	(0.69)	(1.17)	(1.77)	

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Job creation	-1.59	-0.94	-2.40 *	-0.21	-0.49	
	(1.1)	(2.18)	(1.38)	(2.03)	(2.25)	
Constant	-7.45 ***	-6.42	-7.22 ***	-1.69 *	-1.19	-7.48 ***
	(1.21)	(4.04)	(1.53)	(0.98)	(1.27)	(1.44)
Pseudo R^2	0.83	0.81	0.77	0.78	0.74	0.92
Prob > χ^2	0.00	0.00	0.00	0.00	0.00	0.00
Obs	2472	729	1743	1472	927	546

Note: Values in parenthesis indicate standard errors and the asterisks *,**,*** imply significance at 10%, 5% and 1%, respectively.

Table 5: Central Bank reaction function to intervene in Exchange Rate through Swap interventions

	Buy Intervention			*Sell Intervention*		
	Full Sample	1999-2003	2004-2012	Full Sample	1999-2003	2004-2012
Centra Bank variables						
Intervention (t-1)	2.43 ***	4.72 **	2.21 ***	2.65 ***	2.16 ***	2.34 ***
	(0.31)	(1.96)	(0.33)	(0.26)	(0.3)	(0.71)
Intervention (t-2)	1.35 ***		1.41 ***	0.65 **	0.47	1.06
	(0.36)		(0.36)	(0.31)	(0.34)	(0.83)
Intervention (t-3)	2.02 ***		1.99 ***	0.45	0.00	0.11
	(0.33)		(0.33)	(0.31)	(0.36)	(0.83)
Moving average distance - 1 year	-13.67 ***	-35.29 *	-12.18 *	-4.20 *	-5.77 *	-3.53
	(5.23)	(18.27)	(6.42)	(2.5)	(3.1)	(5.34)
Moving average distance - 6 months	19.29 *	62.27	15.61	9.14	7.22	35.65 **
	(11.11)	(42.28)	(13.45)	(5.75)	(7)	(15.75)
Moving average distance - 3 months	-6.28	14.76	-7.45	2.09	2.07	-2.29
	(9.27)	(32.09)	(11)	(5.38)	(6.39)	(13.72)
Macroeconomic Fundamentals						
d(EMBI+)	-46.43 ***	-52.04	-58.09 *	-7.49	-8.03	40.22
	(14.59)	(33.49)	(30.93)	(8.71)	(10.28)	(27.2)
d(VIX)	-4.27	20.85	-5.61 *	-3.85	2.07	-16.78 **
	(3.15)	(20.08)	(3.3)	(2.72)	(3.92)	(6.64)
d(Selic - FedFunds)	-0.45	-2.01	0.42	-0.13	0.17	-0.19
	(0.74)	(1.49)	(1.07)	(0.44)	(0.47)	(1.23)
d(CRB)	10.97	-34.77	13.26	-3.15	20.24	-19.12
	(12.34)	(54.9)	(12.96)	(8.71)	(13.38)	(16.16)
d(DXY)	-18.04	-42.45	-9.85	-16.13	-13.23	28.23
	(24.9)	(117.79)	(28.03)	(18.83)	(25.53)	(36.2)
SP500 return	-31.41 *	114.87 *	-46.11 **	-18.95 *	-8.27	-35.56
	(17.6)	(68.65)	(20.48)	(10.31)	(14.7)	(23.17)
Ibovespa return	15.06	-26.94	20.57 *	-2.26	-4.07	-6.87
	(9.77)	(39.2)	(10.93)	(6.69)	(8.64)	(16.43)
Exp. GDP growth (current year)	0.14	0.36	0.05	-0.08	0.19	-1.11 ***
	(0.1)	(1.16)	(0.1)	(0.08)	(0.17)	(0.28)
Exp. GDP growth (next year)	-0.12	-1.36	-0.38	-1.30 ***	-1.34 ***	-1.53 *
	(0.33)	(1.9)	(0.38)	(0.23)	(0.29)	(0.78)
Macroeconomic Surprises (Brazil)						
Mon. Policy interest rate (Selic)	5.23	4.47	3.97	-13.87 ****	-14.22 ***	-24.70
	(10.81)	(23.46)	(18.91)	(4.99)	(5.5)	(33.01)
General Price Index	3.84		3.45	0.60		2.75
	(2.91)		(2.85)	(4.13)		(5.07)
CPI	2.48 **	-2.71	2.84 ***	-2.55 **	-1.61	-0.81
	(1.06)	(5.09)	(1.1)	(1)	(1.02)	(12.03)
Job creation	-1.11		-1.64	-3.08		-4.74
	(4.61)		(4.44)	(4.73)		(8.12)
GDP growth	-0.66	7.50	-0.98	1.39	0.72	0.17
	(1.3)	(19.78)	(1.77)	(2.23)	(2.29)	(4.25)
Unemployment rate	4.75	10.55	4.24	5.36 *	17.00 ***	-9.20 **
	(3.54)	(417.41)	(3.39)	(2.95)	(5.92)	(3.76)
Wholesale sales	-1.38		-1.27	-0.63		-0.63
	(1.44)		(1.29)	(1.9)		(3.91)

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Industrial Production	0.25	1.03	0.32	-0.47	-1.54	7.10 *
	(1.08)	(10.18)	(1.3)	(0.71)	(0.94)	(4.2)
Trade balance	1.45	-26.43	1.34	-0.08	-5.82	-1.39
	(1.53)	(86.53)	(1.48)	(2.22)	(25.66)	(2.11)
Macroeconomic Surprises (US)						
Fed Funds rate	-10.56	10.07	-10.52	18.88	35.80	-16.96
	(14.69)	(391.73)	(16.76)	(23.83)	(31.31)	(37.16)
CPI	-2.55 **	-1.53	-2.99 **	0.51	1.37	1.06
	(1.12)	(16.96)	(1.23)	(1.33)	(1.92)	(2.54)
ISM index	-1.32	8.64	-1.40	2.39	1.71	5.25
	(1.58)	(18.04)	(1.57)	(1.83)	(2.63)	(3.47)
New home sales	1.70	-19.67 *	1.65	3.20 *	3.96	-3.35
	(2.11)	(10.8)	(2.07)	(1.92)	(2.81)	(4.09)
Wholesale sales	0.00	-2.25	-0.11	0.75	0.01	1.83 *
	(1.04)	(10.63)	(1.06)	(0.76)	(1.05)	(0.94)
Job creation	-1.67	-5.03 **	-2.08	0.89	2.13	0.74
	(1.14)	(2.45)	(1.48)	(1.17)	(1.55)	(3.24)
Constant	-4.18 ***	-4.57	-2.66 **	1.06	1.16	3.12
	(1.1)	(4.63)	(1.36)	(0.72)	(0.8)	(2.96)
Pseudo R^2	0.38	0.59	0.38	0.39	0.24	0.73
Prob $> \chi^2$	0.00	0.00	0.00	0.00	0.00	0.00
Obs	2636	878	1748	2672	980	1692

Note: Values in parenthesis indicate standard errors and the asterisks *,**,*** imply significance at 10%, 5% and 1%, respectively.

Table 6: Propensity Score Matching Tests - General interventions - Exchange Rate (Ptax)

Buy Intervention	*Full Sample*				*1999-2003*				*2004-2012*			
	Mean Bias		Median Bias		Mean Bias		Median Bias		Mean Bias		Median Bias	
	Raw	Matched	Raw	Matched	Raw	Matched	Raw	Matched	Raw	Matched	Raw	Matched
One-to-one matching	80.67	34.63	40.95	21.47	83.8	42.73	16.36	15.67	61.28	29.83	9.172	23.38
K-nearest neighbours (K=2)	80.67	11.8	40.95	10.51	83.8	14.1	16.36	12.1	61.28	15.47	9.172	11.92
Radius matching	80.67	12.33	40.95	8.503	83.8	11.71	16.36	11.43	61.28	13.83	9.172	7.585
Kernel matching	80.67	11.98	40.95	9.839	83.8	14.71	16.36	15.2	61.28	12.4	9.172	6.933
Local Linear matching	80.67	11.54	40.95	14.24	83.8	53.19	16.36	61.56	61.28	11.45	9.172	12.44

Sell Intervention	*Full Sample*				*1999-2003*				*2004-2012*			
	Mean Bias		Median Bias		Mean Bias		Median Bias		Mean Bias		Median Bias	
	Raw	Matched	Raw	Matched	Raw	Matched	Raw	Matched	Raw	Matched	Raw	Matched
One-to-one matching	95.05	24.54	34.19	13.79	85.23	22.14	37.13	14.87	131.2	31.97	26.23	30.55
K-nearest neighbours (K=2)	95.05	13.39	34.19	9.612	85.23	10.91	37.13	11.76	131.2	57.44	26.23	58.3
Radius matching	95.05	13.92	34.19	12.83	85.23	7.269	37.13	4.915	131.2	57.44	26.23	58.3
Kernel matching	95.05	11.69	34.19	7.816	85.23	8.735	37.13	7.316	131.2	57.22	26.23	58.34
Local Linear matching	95.05	14.68	34.19	8.521	85.23	13.05	37.13	6.836	131.2	118.7	26.23	69.29

Table 7: Propensity Score Matching Tests - Swap Interventions - Exchange Rate (Ptax)

Buy Intervention	*Full Sample*				*1999-2003*				*2004-2012*			
	Mean Bias		Median Bias		Mean Bias		Median Bias		Mean Bias		Median Bias	
	Raw	Matched	Raw	Matched	Raw	Matched	Raw	Matched	Raw	Matched	Raw	Matched
One-to-one matching	7.15	23.67	6.59	14.46	na	na	na	na	6.72	11.07	6.35	9.38
K-nearest neighbours (K=2)	7.15	6.66	6.59	6.10	32.15	69.09	16.53	57.48	6.72	7.79	6.35	9.08
Radius matching	7.15	5.20	6.59	4.89	32.15	46.62	16.53	29.49	6.72	3.699	6.35	2.52
Kernel matching	7.15	5.60	6.59	3.87	32.15	22.82	16.53	19.65	6.72	4.247	6.35	3.66
Local Linear matching	7.15	17.18	6.585	21.81	na	na	na	na	6.724	7.184	6.347	6.35

Sell Intervention	*Full Sample*				*1999-2003*				*2004-2012*			
	Mean Bias		Median Bias		Mean Bias		Median Bias		Mean Bias		Median Bias	
	Raw	Matched	Raw	Matched	Raw	Matched	Raw	Matched	Raw	Matched	Raw	Matched
One-to-one matching	51.05	21.6	25.29	14.32	26.32	19.95	15.13	20.86	95.7	50.51	34.9	37.34
K-nearest neighbours (K=2)	51.05	11.24	25.29	5.28	26.32	10.48	15.13	10.37	95.7	18.66	34.9	14.72
Radius matching	51.05	10.19	25.29	5.90	26.32	6.545	15.13	5.762	95.7	18.69	34.9	13.55
Kernel matching	51.05	9.932	25.29	5.97	26.32	6.661	15.13	5.923	95.7	20.71	34.9	17.81
Local Linear matching	51.05	10.9	25.29	6.185	26.32	7.167	15.13	6.726	95.7	1180.5	34.9	1225.5

Table 8: Propensity Score Matching Results - General interventions - Exchange Rate (Ptax)

Model	*Full Sample*			*1999-2003*			*2004-2012*		
	Difference	Std. Err.	T-stat	Difference	Std. Err.	T-stat	Difference	Std. Err.	T-stat
Exchange rate return - Buy Intervention									
One-to-one matching	0.173	0.162	1.066	0.468	0.263	1.779 *	0.157	0.181	0.865
K-nearest neighbours (K=2)	0.173	0.226	0.763	1.13	0.364	3.091 ***	0.0226	0.269	0.084
Radius matching	0.355	0.127	2.798 ***	1.02	0.322	3.182 ***	0.113	0.147	0.767
Kernel matching	0.25	0.132	1.895 *	1.08	0.333	3.228 ***	0.0983	0.152	0.647
Local Linear matching	0.303	0.142	2.131 **	1.75	0.397	4.401 ***	0.0694	0.175	0.397
Exchange rate return - Sell Intervention									
One-to-one matching	-0.00938	0.365	-0.0257	0.0281	0.293	0.096	-2.33	1.45	-1.605
K-nearest neighbours (K=2)	0.00431	0.331	0.013	0.193	0.279	0.689	-0.779	2.27	-0.343
Radius matching	0.182	0.243	0.75	0.16	0.222	0.719	-0.779	2.27	-0.343
Kernel matching	0.0854	0.249	0.344	0.127	0.225	0.564	-0.752	2.27	-0.332
Local Linear matching	0.0979	0.255	0.384	0.168	0.261	0.645	1.05	3.85	0.272
Exchange rate volatility - Buy Intervention									
One-to-one matching	-0.00662	0.00468	-1.415	-0.0101	0.00461	-2.2 **	-0.00589	0.00547	-1.077
K-nearest neighbours (K=2)	-0.00239	0.00728	-0.329	-0.00923	0.00603	-1.531	-0.00193	0.00886	-0.218
Radius matching	-0.00499	0.00234	-2.135 **	-0.0082	0.00401	-2.042 **	-0.00315	0.00332	-0.949
Kernel matching	-0.00498	0.00242	-2.053 **	-0.00877	0.00418	-2.098 **	-0.00369	0.00344	-1.074
Local Linear matching	-0.00505	0.00217	-2.324 **	-0.0259	0.00465	-5.58 ***	-0.00203	0.00373	-0.545
Exchange rate volatility - Sell Intervention									
One-to-one matching	0.0236	0.0183	1.288	0.00923	0.00771	1.197	-0.0125	0.0374	-0.333
K-nearest neighbours (K=2)	0.0126	0.00942	1.334	0.0092	0.00727	1.265	0.0889	0.119	0.747
Radius matching	0.0142	0.00813	1.749 *	0.00472	0.0055	0.858	0.0889	0.119	0.747
Kernel matching	0.013	0.00828	1.565	0.00351	0.00555	0.632	0.0898	0.119	0.754
Local Linear matching	0.0121	0.00851	1.417	0.00299	0.00604	0.494	0.148	0.184	0.807

Note: The asterisks *,**,*** imply significance at 10%, 5% and 1%, respectively.

Table 9: Propensity Score Matching Results - Swap Interventions - Exchange Rate (Ptax)

Model	*Full Sample*			*1999-2003*			*2004-2012*		
	Difference	Std. Err.	T-stat	Difference	Std. Err.	T-stat	Difference	Std. Err.	T-stat
Exchange rate return - Buy Intervention									
One-to-one matching	-0.0915	0.175	-0.522	-5.15	na	na	0.177	0.119	1.486
K-nearest neighbours (K=2)	-0.185	0.194	-0.957	-4.68	5.26	-0.891	0.0924	0.164	0.562
Radius matching	-0.0513	0.168	-0.306	-4.84	5.25	-0.923	0.0932	0.164	0.568
Kernel matching	-0.0877	0.164	-0.535	-3.07	2.71	-1.132	0.0969	0.163	0.596
Local Linear matching	-0.114	0.166	-0.688	-5.41	5.25	-1.031	0.142	0.16	0.888
Exchange rate return - Sell Intervention									
One-to-one matching	-0.206	0.161	-1.278	-0.0637	0.155	-0.412	-0.75	0.649	-1.156
K-nearest neighbours (K=2)	-0.0669	0.198	-0.337	0.0341	0.16	0.213	-0.58	0.615	-0.944
Radius matching	-0.011	0.164	-0.0671	-0.119	0.145	-0.823	-0.669	0.557	-1.2
Kernel matching	-0.00355	0.163	-0.0218	-0.0835	0.144	-0.582	-0.761	0.527	-1.444
Local Linear matching	0.00509	0.164	0.031	-0.0281	0.145	-0.194	5.13	9.18	0.559
Exchange rate volatility - Buy Intervention									
One-to-one matching	0.0105	0.0117	0.896	0.434	na	na	0.00389	0.0041	0.949
K-nearest neighbours (K=2)	0.00679	0.0101	0.676	0.435	0.432	1.008	0.00457	0.0035	1.305
Radius matching	0.00887	0.00949	0.935	0.418	0.432	0.967	0.00441	0.00398	1.107
Kernel matching	0.00837	0.00915	0.915	0.174	0.215	0.809	0.00432	0.00394	1.096
Local Linear matching	0.00536	0.00932	0.575	0.403	0.432	0.934	0.00424	0.00393	1.079
Exchange rate volatility - Sell Intervention									
One-to-one matching	0.00678	0.00515	1.316	0.00518	0.00294	1.758 *	0.0497	0.0281	1.772 *
K-nearest neighbours (K=2)	0.0146	0.00767	1.902 *	0.00347	0.00289	1.2	0.0535	0.0232	2.308 **
Radius matching	0.0179	0.00697	2.57 **	0.0019	0.00293	0.649	0.0532	0.0229	2.319 **
Kernel matching	0.0183	0.00695	2.63 ***	0.00222	0.00289	0.768	0.0506	0.021	2.41 **
Local Linear matching	0.017	0.00697	2.446 **	0.00203	0.00294	0.692	0.233	0.2	1.165

Note: The asterisks *,**,*** imply significance at 10%, 5% and 1%, respectively.

Table 10: Propensity Score Matching Results - General interventions - Future Exchange Rate (First)

Model	*Full Sample*			*1999-2003*			*2004-2012*		
	Difference	Std. Err.	T-stat	Difference	Std. Err.	T-stat	Difference	Std. Err.	T-stat
Exchange rate return - Buy Intervention									
One-to-one matching	0.224	0.188	1.187	0.46	0.291	1.581	0.172	0.218	0.792
K-nearest neighbours (K=2)	0.119	0.272	0.436	0.467	0.376	1.244	0.146	0.319	0.458
Radius matching	0.264	0.143	1.855 *	0.432	0.353	1.222	0.0705	0.171	0.413
Kernel matching	0.157	0.148	1.065	0.41	0.366	1.121	0.064	0.177	0.362
Local Linear matching	0.288	0.16	1.803 *	1.61	0.463	3.487 ***	0.131	0.2	0.659
Exchange rate return - Sell Intervention									
One-to-one matching	0.109	0.408	0.266	0.342	0.374	0.913	-2.16	1.78	-1.214
K-nearest neighbours (K=2)	0.508	0.358	1.419	0.672	0.309	2.177 **	-0.837	2.38	-0.352
Radius matching	0.475	0.259	1.835 *	0.539	0.228	2.365 **	-0.837	2.38	-0.352
Kernel matching	0.433	0.265	1.634	0.543	0.231	2.348 **	-0.798	2.38	-0.336
Local Linear matching	0.452	0.272	1.663 *	0.568	0.267	2.128 **	1.78	4.56	0.39
Exchange rate volatility - Buy Intervention									
One-to-one matching	-0.00823	0.00705	-1.167	-0.00777	0.00457	-1.699 *	-0.00847	0.00828	-1.024
K-nearest neighbours (K=2)	-0.00334	0.0112	-0.297	-0.000521	0.00628	-0.0829	-0.00384	0.0131	-0.294
Radius matching	-0.0039	0.00334	-1.168	-0.00105	0.00567	-0.185	-0.0033	0.0048	-0.688
Kernel matching	-0.00436	0.00346	-1.259	-0.000931	0.00586	-0.159	-0.00365	0.00497	-0.733
Local Linear matching	-0.00529	0.0033	-1.606	-0.0178	0.00753	-2.359 **	-0.00446	0.00469	-0.951
Exchange rate volatility - Sell Intervention									
One-to-one matching	0.0362	0.0182	1.99 **	0.0288	0.019	1.514	0.00765	0.0282	0.271
K-nearest neighbours (K=2)	0.00879	0.0118	0.742	0.00297	0.00696	0.427	0.0591	0.0871	0.679
Radius matching	0.0119	0.0106	1.124	0.00166	0.00577	0.287	0.0591	0.0871	0.679
Kernel matching	0.0114	0.0107	1.06	-0.000117	0.00583	-0.0201	0.0598	0.0871	0.687
Local Linear matching	0.00872	0.011	0.791	-0.00221	0.0064	-0.346	0.114	0.197	0.577

Note: The asterisks *,**,*** imply significance at 10%, 5% and 1%, respectively.

Table 11: Propensity Score Matching Results - Swap Interventions - Future Exchange Rate (First)

Model	*Full Sample*			*1999-2003*			*2004-2012*		
	Difference	Std. Err.	T-stat	Difference	Std. Err.	T-stat	Difference	Std. Err.	T-stat
Exchange rate return - Buy Intervention									
One-to-one matching	0.00918	0.169	0.0541	0.118	na	na	0.234	0.122	1.92 *
K-nearest neighbours (K=2)	-0.0897	0.196	-0.457	0.215	1.78	0.121	0.059	0.179	0.329
Radius matching	0.0105	0.16	0.0657	0.00867	1.77	0.00491	0.0293	0.179	0.163
Kernel matching	-0.0445	0.157	-0.283	0.257	1.07	0.24	0.0281	0.177	0.158
Local Linear matching	-0.0738	0.159	-0.464	0.245	1.85	0.132	0.0678	0.174	0.389
Exchange rate return - Sell Intervention									
One-to-one matching	-0.166	0.184	-0.903	0.00623	0.167	0.0374	-0.642	0.65	-0.988
K-nearest neighbours (K=2)	-0.152	0.223	-0.682	0.0383	0.177	0.216	-0.579	0.62	-0.934
Radius matching	-0.131	0.173	-0.76	-0.112	0.167	-0.67	-0.621	0.562	-1.104
Kernel matching	-0.146	0.171	-0.855	-0.0952	0.165	-0.576	-0.573	0.533	-1.076
Local Linear matching	-0.142	0.172	-0.822	-0.0678	0.167	-0.405	-12.2	10.4	-1.175
Exchange rate volatility - Buy Intervention									
One-to-one matching	-0.000513	0.00777	-0.066	0.0281	na	na	0.00183	0.00502	0.365
K-nearest neighbours (K=2)	-0.00218	0.00709	-0.307	0.0279	0.0297	0.938	0.00429	0.00523	0.821
Radius matching	-0.000403	0.00536	-0.0752	0.00846	0.0337	0.251	0.0042	0.00489	0.859
Kernel matching	-0.000891	0.00522	-0.171	-0.00134	0.0309	-0.0434	0.00407	0.00484	0.842
Local Linear matching	-0.00749	0.00531	-1.411	-0.0327	0.0404	-0.811	0.00399	0.00481	0.83
Exchange rate volatility - Sell Intervention									
One-to-one matching	0.00442	0.00655	0.674	0.00893	0.00365	2.446 **	0.0468	0.0293	1.596
K-nearest neighbours (K=2)	0.0101	0.00911	1.108	0.00918	0.00367	2.501 **	0.0529	0.0208	2.547 **
Radius matching	0.0152	0.00696	2.186 **	0.00433	0.00701	0.617	0.0521	0.0203	2.563 **
Kernel matching	0.0154	0.00683	2.251 **	0.00456	0.0068	0.671	0.0467	0.0186	2.508 **
Local Linear matching	0.0147	0.00695	2.115 **	0.00488	0.00706	0.692	-0.56	0.245	-2.282 **

Note: The asterisks *,**,*** imply significance at 10%, 5% and 1%, respectively.