Luísa do Amaral Camargo

Foreign exchange interventions through currency swaps in Brazil: an empirical study of the effects on the spot exchange rate

Brasília, DF, Brasil

Julho de 2019

Luísa do Amaral Camargo

Foreign exchange interventions through currency swaps in Brazil: an empirical study of the effects on the spot exchange rate

Dissertação apresentada como requisito parcial para a obtenção do título de Mestre em Economia pela Universidade de Brasília sob a orientação do Prof. Dr. Roberto de Goes Ellery Júnior.

Universidade de Brasília

Campus Darcy Ribeiro

Departamento de Economia

Brasília, DF, Brasil

Julho de 2019

Abstract

In different episodes in 2018, the Central Bank of Brazil (BCB) announced official interventions in foreign exchange market. The BCB used as core intervention strategy the traditional foreign exchange swap contracts, which consist of currency forwards that settle in BRL and provide hedging to agents without reducing directly foreign exchange reserves. Even though these operations are akin to sterilized interventions, whose mechanism of impact on exchange rates is not as clear as in non-sterilized cases, the existing literature for Brazilian case provides evidence to the fact that currency swaps offerings announcements can impact the USD/BRL exchange rate returns. However, the results found vary and studies present different conclusions regarding the existence of impacts and their magnitude. In the present work, hourly data for the period between 11/30/2017 and 10/18/2018 is used in order to estimate impacts of new and rolling traditional currency swap contracts offerings announced by the BCB on the USD/BRL returns. For the estimation, a GARCH(1,1) is adopted as benchmark model. Results suggest that new swap contracts announcements have an immediate appreciation impact on the BRL, reducing the USD/BRL exchange rate in 15 basis points (-0.15%) for each US$ 1 billion in contracts. Rolling swap contracts announcements do not present significant effects. The results are validated after the performance of a series of robustness tests and the estimation of a reaction function of the Central Bank which accounts for any endogeneity issue that could invalidate estimates obtained.

Keywords: Brazil; Derivatives; Sterilized Foreign Exchange Interventions; Currency Swaps; GARCH.

Resumo

Em diversos episódios no ano de 2018, o Banco Central do Brasil (BCB) anunciou intervenções oficiais no mercado de câmbio. Nesse contexto, o uso de *swaps* cambiais do tipo tradicional constituiu um mecanismo fundamental de intervenção do BCB, uma vez que esses contratos são liquidados em moeda doméstica (BRL) e proveem cobertura cambial aos agentes sem a redução direta das reservas internacionais. Apesar de essas operações serem como formas esterilizadas de intervenção cambial, cujo mecanismo de impacto na taxa de câmbio não é tão claro quanto no caso de intervenções não esterilizadas, trabalhos existentes na literatura para o caso brasileiro apontam evidências de que anúncios de ofertas de *swaps* cambiais do BCB podem impactar os retornos da taxa de câmbio USD/BRL. Entretanto, os resultados encontrados em diversas abordagens variam em relação à existência de efeitos de fato e à sua magnitude. No presente trabalho, dados em frequência horária para o período de 30/11/2017 a 18/10/2018 são utilizados para a estimação dos impactos dos anúncios de ofertas de contratos de *swaps* cambiais novos e de rolagem, do tipo tradicional, nos retornos da taxa de câmbio USD/BRL. Um modelo GARCH(1,1) é adotado para a estimação. Os resultados obtidos sugerem que os anúncios de novos contratos têm um efeito imediato de apreciação na moeda brasileira, causando uma redução de 15 pontos base (-0.15%) na taxa de câmbio USD/BRL para cada US$ 1 bilhão em contratos. Os anúncios de contratos de rolagem, porém, não apresentam impactos significantes. Esses resultados são validados por meio da realização de testes de robustez e da estimação de uma função reação do Banco Central como forma de incorporar qualquer efeito de endogeneidade que pudesse invalidar as estimativas encontradas.
Palavras-chave: Brasil; Derivativos; Intervenções Cambiais Esterilizadas; Swaps Cambiais; GARCH.

Contents

List of Figures

List of Tables

1 Introduction

Foreign exchange market interventions by central banks are commonly observed in emerging countries, and reasons for such operations include attempts to moderate exchange rate volatility, accumulate reserves, supply foreign exchange liquidity and contribute to the proper functioning of the market. Discussing the impacts these interventions may cause in economies, specially in exchange rates, is quite relevant, since countries that adopt independence of monetary policy and absence of capital controls cannot have also a determined exchange rate, in accordance to the impossible trinity in international economics. Indeed, considering the Brazilian case, there are no restrictions to capital mobility and the Central Bank of Brazil (BCB) determines the Selic interest rate with the main purpose of reaching the target inflation rate, therefore the exchange rate cannot be established. Meanwhile, it has been historically observed that the BCB intervenes in foreign exchange market; an essential point, though, is that these operations are sterilized, otherwise variations in monetary base would undermine the working of monetary policy. Not only in Brazil, central banks usually sterilize interventions in FX markets, preventing them from affecting the independence of monetary policy.

In this framework, therefore, impacts of sterilized foreign exchange interventions are not so evident: are they in fact capable of affecting exchange rate returns? If they are, the form how central banks intervene in FX markets, as well as the timing and size of the operations, configure important decisions to the monetary authority. After all, exchange rates play a key role in the performance of the economy, impacting, for example, inflation rates and balance of trade results.

The awareness of the potential effects that sterilized FX interventions can have in the path of exchange rates has made the empirical assessment of these episodes an important part of the literature on the area. In Brazil, several studies dedicated to addressing interventions made by the BCB during the last years have already been conducted. Even though they provide a great basis for understanding the Brazilian case, further analyses are still worth it and certainly will be as long as the BCB keeps on intervening on FX markets. Indeed, it is quite clear from a literature review on the interventions by the BCB that there is not a consensus regarding the existence of significant effects on the exchange rate and their magnitude. Results have differed according to interventions characteristics and types (e.g. spot or future markets, sales or purchases of USD) and to the periods considered in the analyses, in which motivations and purposes for interventions have varied significantly.

All in all, the literature covering Brazilian case has been constantly updating em-

pirical assessments on the subject and no final conclusions have been reached on the existence and magnitude of impacts of sterilized FX interventions on exchange rate returns. Recognising this point, a new assessment that covers more recent episodes of FX interventions in Brazil is made in this dissertation. Traditional currency swaps were an important instrument used by the BCB with the purpose of providing liquidity and contributing to the proper functioning of FX markets during episodes of market instabilities in 2018. In the period, for instance, presidential elections expectations and uncertainties in Brazil and USA-China trade war episodes were very relevant issues at hand, besides the general macroeconomic scenario in Brazil which was also a point of attention, since the economy presented a weak growth, still in an attempt of recovery from the recession period of 2015-2016.

In order to test empirically the impacts of FX interventions through currency swaps by the BCB on the USD/BRL exchange rate returns, this dissertation proposes a GARCH(1,1) model as benchmark specification. The choice is based on previous works in literature which presented GARCH processes as an efficient methodology for time series event studies involving exchange rate data, since they account for heteroscedasticity issues often observed in financial series. Hourly-frequency data is used in this work for the USD/BRL exchange rate and for other variables included as regressors in the mean equation of the GARCH model, computing relevant intraday impacts.

This dissertation is organized as follows. Chapter 2 presents the most important theoretical issues that underlie sterilized foreign exchange interventions, giving emphasis on the channels of influence through which these operations may impact exchange rates. Chapter 3 provides a review of the literature dedicated to FX interventions empirical assessment, including cases of developed countries in the early literature on the field and cases of emerging markets more frequently assessed years later. An emphasis on the Brazilian case is given in section 3.1, where details of episodes of interventions in Brazil and specific features of the BCB's methods for intervening are provided. In chapter 4, the process of data collection for the empirical assessment in this study is detailed. In chapter 5, the methodology of ARCH and GARCH models is presented, and the benchmark model with all variables considered for the estimation is described. Results are displayed in sequence, and robustness checks are made to validate them. Finally, a section is included in chapter 5 for the assessment of endogeneity issues that could possibly invalidate the results of the benchmark GARCH specification. This is made through the estimation of a reaction function for the Central Bank. Then, the GARCH model is re-estimated incorporating unexpected interventions, procedure that in turn validates results previously found with the benchmark GARCH specification.

2 Sterilized foreign exchange interventions: theoretical issues

A vast knowledge about the manner and the extent to which a central bank intervenes in FX markets requires taking into account key factors that characterize such interventions and may vary according to different countries, periods and other circumstances. Adler and Tovar (2011) list and explain briefly some of these points, as follows:

- Reasons: officially declared reasons for intervening in the FX market. Important motives include: (i) affecting the level of the exchange rate, (ii) affecting the speed of currency appreciation (or depreciation); (iii) containing the volatility of the exchange rate; (iv) increasing reserve buffers for precautionary motives. Additionally to reasons pointed by Adler and Tovar, FX liquidity provision to domestic markets is an important reason to mention.

- Framework: refers to whether interventions made by central banks are predetermined by rules or conducted in a discretionary manner. When of the former type, a characterization of such rules is an important point to be considered, such as "exchange rate-based" if the intervention is motivated by some exchange rate-related measure (e.g., change or volatility) or "quantity-based" if the rule does not specify any trigger for intervening, but an amount to be used in intervention operations during a period;

- Instruments: frequently observed mechanisms for interventions include FX purchases or sales in spot market and derivative financial instruments (forward, futures, options and swaps);

- Transparency: the timing of disclosure of information regarding FX operations, i.e., if intervention amounts are published before the operation takes place, within a week, at a later stage or never.

In addition to the points above, another characteristic regarding FX interventions refers to whether they are sterilized or non-sterilized operations, and this issue is particularly relevant for the purposes of the present work and of the majority of studies dedicated to evaluating the effectiveness of FX interventions. Indeed, it is noticeable that the core of analyses available in literature takes account of sterilized operations carried out by central banks, having non-sterilized interventions been rarely the focus of discussions and disagreements. Also, when considering the case of the BCB's currency swaps offerings and estimating their impacts on the USD/BRL exchange rate, the goal of this work only

makes sense if it is well-known that operations with these derivatives are akin to sterilized forms of intervening in foreign exchange markets. Further considerations on singularities of FX swaps used by the BCB will be made in section 3.1.

When distinguishing sterilized from non-sterilized mechanisms for intervening, Sarno and Taylor (2001) state that one intervention is defined sterilized when the authorities, simultaneously or in a short lag, act in order to offset the effects of a change in official foreign asset holdings on the domestic monetary base. Conversely, one intervention is said to be non-sterilized when there is not any offsetting procedure taken by the authorities after buying or selling foreign exchange against the local currency. In other words, Dominguez (2009) says that sterilization is the process by which monetary authorities ensure that foreign exchange interventions do not affect the domestic monetary base, which is one component of the overall money supply. Classical forms of sterilization widely used by central banks are open market operations in which the monetary authority buys (sells) financial assets, such as local currency denominated bonds, aiming to offset foreign exchange interventions that, in principle, would reduce (increase) the monetary base in the local economy.

The emphasis given by empirical studies on the sterilized methodology for intervening is understandable since there is not a consensus yet regarding its effectiveness, in contrast to the almost consensual effects of non-sterilized interventions. Indeed, the mechanism for non-sterilization case is clearly explained by economic theory: the exchange rate is impacted in a quite comparable way to when monetary policy takes place, that is to say, rates alter in proportion to the variation in the relative supplies of domestic and foreign money. In the sterilization case, in turn, there is not a consensus about the ways through which interventions could impact exchange rates, but there already exists a standard taxonomy commonly applied in the analysis. It defines channels of influence of sterilized operations: the portfolio balance and the expectations (signalling) channels. These were previously addressed by Mussa (1981) and, years later, formalized and discussed in more details by Sarno and Taylor (2001), who also suggested that a third channel of influence may operate as well: the coordination channel. In the next section, the main points that underlie the theory behind the functioning of these channels will be addressed, and a few works in the literature which tested their existence will be briefly presented.

2.1 The channels of influence: portfolio balance, signalling and coordination effects

A comprehensive approach to the working of portfolio balance channel and how it provides conditions for interventions on FX markets to impact exchange rates requires the introduction of fundamental concepts of International Economics and Finance that

underlie the framework of the channel operation. As Sarno and Taylor (2001) state, the effects of official intervention through the portfolio balance channel are based on the assumptions that set a Portfolio Balance Model (PBM) of exchange rate determination. The PBM is characterized by a scenario where agents decide between investment alternatives in an attempt to reach the utility-maximizing portfolio composition, considering assets of various countries on the basis of their relative expected risks and returns.

As a starting point to the analysis, following Diógenes (2007), it is convenient to introduce the concept of interest rate parity, since it plays an essential role in foreign exchange markets connecting interest rates, spot exchange rates and future exchange rates. Assuming high international capital mobility, the interest rate parity is a no-arbitrage condition in which the expected return on domestic assets equalizes the exchange rate-adjusted expected return on foreign currency assets. Under these circumstances, investors cannot profit by borrowing with a lower interest rate in a country, exchanging for foreign currency, and investing with a higher interest rate in another country, because the exchange rate is expected to adjust such that returns on domestic and foreign currency assets are exactly the same.

Interest rate parity takes on two distinctive forms in the literature: the uncovered interest rate parity and the covered interest rate parity.

The uncovered interest parity condition holds when the no-arbitrage condition is reached without forward contracts being used as a means of hedging against exchange rate risk. Risk-neutral investors are indifferent between the interest rates of assets in two different currencies because the exchange rate is expected to adjust in a way that returns on assets are equal, eliminating the potential for arbitrage profits. Then, when the uncovered interest rate parity holds, unless there is any shift on interest rates or on future exchange rate expectation, there is no possibility for a change in the spot exchange rate.

The mechanism described above is represented in the following equation,

$$(i_t + 1) = (i_t^* + 1)\frac{E_t(S_{t+k})}{S_t} \tag{2.1}$$

where i_t is the interest rate of domestic assets at time t, i_t^* is the interest rate of foreign assets at time t, $E_t(S_{t+k})$ is the expected exchange rate for time $t+k$ and S_t is the spot exchange rate. Importantly, the holding of the uncovered interest rate parity requires two assumptions, which make domestic and foreign assets perfect substitutes: perfect capital mobility and risk indifference by the investors.

Since the foreign exchange interventions in Brazil are sterilized, coherently with the fact that the BCB follows an inflation targeting regime in which the target interest rate is defined and pursued, the finding of any transmission channel through which FX interventions could impact the exchange rate under uncovered interest rate parity is

unlikely, as Diógenes (2007) shows. Supposing the Central Bank of Brazil intervened in FX market through sales of USD and the BRL appreciated; as a logical consequence, its expected appreciation (depreciation) would decrease (increase) and, assuming perfect capital mobility, capital outflows would cause the reversion of the appreciation trend so that the BRL would move back to the original level. Regardless, it is almost consensual among economists that the uncovered interest rate parity is rarely observed in practical applications.

The condition usually assumed in practice is the covered interest rate parity. This approach refers to a scenario in which a forward contract is used to hedge against exchange rate risk, allowing for the compliance of the no-arbitrage condition. Investors are indifferent among assets denominated in two different currencies because the forward exchange rate provides an equilibrium that equalizes returns on foreign currency assets and returns on domestic currency assets, not allowing covered interest arbitrage profits to exist. For instance, consider a domestic investor who takes a loan abroad paying foreign interest rate, i^*, invests in domestic market earning i and buys USD in future market in order to pay the foreign creditor. Even though he obtains hedging against risks of domestic currency depreciation, he pays the difference between the forward and the spot exchange rates, denominated forward premium. Therefore, costs and gains from the transaction are equalized and the no-arbitrage condition is satisfied.

In order to explain the mechanism above, the covered interest rate parity condition is represented as follows

$$(i_t + 1) = (i_t^* + 1)\frac{F_t}{S_t} \tag{2.2}$$

where F_t is the forward exchange rate at time t.

Following Garcia and Olivares (2001), the covered interest rate parity condition is rewritten as

$$i_t = i_{t^*} + f_t - s_t \tag{2.3}$$

where $f_t = log(F_t)$ and $s_t = log(S_t)$.

The forward exchange rate is determined by a parity relationship among the spot exchange rate and differences in interest rates between two countries, where the resultant equilibrium eliminates any arbitrage profits. In order for this equilibrium to hold under different interest rates, the forward exchange rate must generally differ from the spot exchange rate. Therefore, the forward rate is said to contain a forward premium or discount, adjusting for the interest rate differential.

The relation described above is expressed as

$$f_t = s_t + p_t \tag{2.4}$$

where p_t is the forward premium or discount at time t, if positive or negative respectively. It represents the difference, in percentage points, between the forward exchange rate and the spot exchange rate

Were agents assumed risk-neutral, the forward rate would be an unbiased predictor of the future spot exchange rate such that $f_t = E_t(s_{t+k})$. However, the framework underlying the portfolio balance channel assumes that agents consider risk differences between assets when making decisions regarding portfolio composition. Hence, there is a currency risk premium that creates a difference between the expected future spot exchange rate and the forward rate. The following equation represents it as

$$f_t = E_t(s_{t+k}) + c_t \tag{2.5}$$

where c_t is the currency risk premium at time t.

Combining (2.4) and (2.5), the resulting equation is

$$s_t + p_t = E_t(s_{t+k}) + c_t \tag{2.6}$$

$$p_t = E_t(s_{t+k}) - s_t + c_t \tag{2.7}$$

where the forward premium, i.e., the difference between forward rate and spot rate, is split into two components: the expected exchange rate depreciation and the currency risk premium.

When covered interest rate parity condition holds, as exposed in the previous paragraphs, investors will be indifferent to assets denominated in the two different currencies, and arbitrage is not possible since one has to pay a price for getting protection against currency depreciation risks, namely the forward premium. Consequently, as Diógenes (2007) shows, it follows that

$$i_t = i_{t^*} + p_t \tag{2.8}$$

The introduction of the forward premium from (2.7) into (2.8) leads to

$$i_t = i_{t^*} + E_t(s_{t+k}) - s_t + c_t \tag{2.9}$$

Based on (2.9), it is now convenient to present the mechanism through which the portfolio balance channel allows a possible impact of sterilized foreign exchange interventions on exchange rates. The key idea includes the essential role played by the currency risk premium, as the next paragraphs will demonstrate.

According to the discussion proposed by Sarno and Taylor (2001) about the portfolio balance channel, the effectiveness of sterilized intervention operations depends on the relaxation of the assumption that domestic and foreign assets are perfect substitutes.

In case they were equivalent to investors, the currency denomination of the bonds would not matter and agents would be indifferent as to the relative amounts of domestic and foreign assets they hold, i.e., the importance would remain only on the total quantity of assets. Alternatively, the relaxation of the premise above leads to a scenario of asset differentiation, where bonds denominated in distinct currencies are not perfect substitutes and changes in their relative supply can influence the exchange rate through the portfolio balance channel, since risk averse agents will take account of both risk and return when diversifying their asset portfolio to obtain the best combination. Based on this, by changing assets relative supply, sterilized intervention operations change risk characteristics of foreign and domestic bonds in the market portfolio, altering the equilibrium exchange rate, as Dominguez (2009) explains.

From the ideas above, it is clear that risk is an important factor usually considered by agents when choosing their portfolio composition. In a scenario of covered interest rate parity holding, the currency risk premium term, c_t, is associated to agents' risk aversion inherent to the fact that assets in different currencies present higher or lower risk characteristics. Accordingly, when buying future USD contracts, investors are willing to pay an extra cost for getting currency hedging, while agents who sell these contracts charge more than the expected exchange rate depreciation for having to entail higher risks. The equation (2.7) clarifies that the currency risk premium is what differentiates the forward premium from the expected variation in spot exchange rate from period t to $t + k$.

The ideas presented by Garcia and Olivares (2001) are helpful in summarizing fundamentals of the asset pricing theory and providing a better understanding of the key role played by currency risk premium in portfolio balance channel. The Capital Asset Pricing Model (CAPM) is used to determine a theoretically appropriate required rate of return of an asset in a framework of a well-diversified market portfolio, and an important result of the asset pricing theory is that systematic (non-diversifiable in market portfolio) risks indeed affect asset returns in the economy. As the authors show, this is represented by the coefficient β, which expresses the sensitivity of the expected excess asset returns to the expected excess market returns. On the other hand, when assets present risks that can be mitigated through diversification, their returns are prevented from being impacted.

Reuniting concepts exposed above, an important point is that currency risk premium exists when risks inherent to one currency can reflect systematically in the economy of a country. In contexts of greater systematic riskiness, currency risk premium becomes higher and prices of future USD contracts increase since they provide hedging against those risks, i.e., they work as an insurance against uncertainties, as Garcia and Olivares (2001) point. Currency crises, as exemplified by the same authors and by Diógenes (2007), are examples of situations in which exchange rate depreciation events are followed by col-

lapses in financial markets and, usually, by economic recessions in a country. Under these circumstances, risk diversification among domestic assets would be unlikely, therefore the currency risk premium included in the forward exchange rate is high.

As Diógenes (2007) explains, while demand for currency insurance depends on how uncertain the scenario of a country is, the supply for that is associated to access domestic residents have to foreign assets. The availability of foreign currency insures domestic residents against risks and uncertainties in a country, therefore, sterilized foreign exchange interventions, when altering USD supply in domestic market, change the currency risk premium and the forward exchange rate. Even though the sterilization process keeps monetary base unaltered, an increase in USD supply, for example, is not perfectly compensated by a decrease of domestic bonds in portfolios, since only assets denominated in USD insure agents against currency risks. Then, consequences in case of an operation of USD sale by a central bank would be a decrease in currency risk premium and in the expected return on domestic bonds, leading to an appreciation of domestic currency, as follows

$$i_t = i_{t^*} + E_t(s_{t+k}) - \downarrow s_t + \downarrow c_t \tag{2.10}$$

However, Diógenes (2007) raises an important issue: besides impacting USD availability, sterilized FX interventions may also affect demand for foreign currency because while an intervention of USD sale reduces currency risk premium, the operation also leads to a decrease in the amount of international reserves held by monetary authority. This issue is assessed by García and Soto (2004), who point that international reserves often play an important role in preventing financial or currency crises. They find that the probability of a crisis is strongly related to the ratio of reserves to short-term debt. Therefore, an intervention based on USD sale would, somehow, increase the probability of a currency crisis, having the effects of rising uncertainty related to economic background, increasing demand for hedging against risks, and, consequently, leading to higher currency risk premium. In short, the effects of increasing foreign assets supply and increasing demand for currency insurance operate in opposite directions when affecting the price of currency risk premium. Diógenes concludes, then, that the effectiveness of sterilized FX interventions in impacting exchange rates through the portfolio balance channel is not completely established in theory, and empirical analyses may find different results under distinct circumstances.

A second channel through which sterilized interventions can affect exchange rates is the expectations, information or signalling channel. This approach, addressed by Sarno and Taylor (2001), states that agents view an exchange rate intervention as a signal given by monetary authorities about their future decisions and actions concerning variables over which they have ultimate control. It is assumed that authorities have more precise information than private market participants, and current sterilized interventions on foreign

exchange markets are interpreted as a channel for implicitly revealing relevant information on future policy that the markets had not incorporated until then. As the exchange rate is a forward-looking variable, the impact of sterilized interventions on current exchange rate level, through the signalling channel, may be seen as a result of changes in market expectations regarding variables that may affect the exchange rate in the future, such as target interest rates and relative money supply.

Dominguez (2009) suggests that when it conveys future policy intentions from the central bank, sterilized intervention should not be considered an additional independent policy tool, even though it changes magnitude and timing impacts of monetary policy on exchange rates. Also, for the signalling channel to be an ongoing transmission mechanism, central banks should be seen to follow interventions with appropriate changes in monetary policy, so the efficacy of interventions is still strongly associated to the operation of traditional policy.

The discussion proposed by Vervloet (2010) details and exemplifies the working of signalling channel. Supposing a central bank is aware of possible future inflationary pressures in the economy, and plans to control it by means of monetary tightening some period ahead. In present time, one alternative the monetary authority has to avoid depreciation of exchange rate is to intervene in foreign exchange market through sterilized operations, increasing the amount of USD in domestic market without altering monetary base and interest rates. This foreign exchange policy procedure might be effective (through portfolio balance channel, for instance) and enhance inflation control, highly pursued by monetary authority. However, if the central bank systematically applies it as a manner of countering inflationary pressures, agents will begin to associate present USD sales to higher interest rates (lower money supply) some period ahead. It is known that when markets revise expectations on money supply, they also revise exchange rate forecasts. Therefore, agents anticipate an appreciation trend and demand more domestic currency in the present, resulting in an immediate appreciation of the exchange rate. The same mechanism works for the inverse situation, i.e., USD purchases by the central bank. As a result, an impact of sterilized FX interventions in exchange rates through the signalling channel can be observed.

As an additional contribution to the theory, Sarno and Taylor (2001) cite some limitations of the two traditional channels and claim that an analysis of a third possible channel, little explored by then, would be worthwhile: the coordination channel. Its working would be associated to remedying a coordination failure in foreign exchange market, subject to irrational speculative bubbles caused mostly by non-economic factors that make exchange rates move away from the level consistent with underlying economic fundamentals. When such a situation happens, individual market agents find it difficult to act effectively in altering the exchange rate because they failure to coordinate their

actions, even though they believe the rate is not in its fundamental equilibrium. Therefore, publicly announced intervention operations would act as a coordinating tool, organizing agents to enter in market at the same time and act simultaneously so as to sell (buy) the currency which is overvalued (undervalued) according to economic fundamentals.

An empirical analysis of FX interventions effects with a channel of influence distinction will not be addressed in the present work, but previous studies have deeply covered this issue. Some focus on testing the significance of effects for these channels using econometric methodologies, and in some cases empirical evidence is found in favour of one or another channel. Alternatively, other studies argue in favour or against the validity of channels based on institutional characteristics of the monetary authority from the country where given interventions occur. Hereinafter, some contributions for the literature dedicated to testing channels validity and potential effects will be presented.

Dominguez and Frankel (1990) attempt to isolate portfolio and signalling channels effects for the USD/DM exchange rate estimating a system consisting of two equations, one describing investors' portfolio behaviour and the other representing their formation of expectations, where the two endogenous variables are the current spot rate and investors' expectation of the future spot rate. They find evidence of both portfolio and expectations effect. The latter is specially large when interventions are publicly known, what conforms to the working of signalling mechanism.

Dominguez (1990) tests the effects of signalling channel using data from United States, Germany and Japan in an attempt to evaluate impacts of coordinated interventions from G-3 central banks on USD/DM and USD/Yen exchange rates. The efficacy of sterilized interventions is tested with basis on the hypothesis that markets believe central banks have inside information about future monetary policy and have incentives to reveal it truthfully through intervention signals, configuring the hypothesis of expectations channel. The empirical results found by Dominguez indicate that both unilateral and coordinated interventions by the G-3 central banks have influenced market expectations, revealing the existence of signalling channel effects.

Another empirical contribution regarding validity of expectation channel was provided by Kaminsky and Lewis (1996), who empirically examine the hypothesis using data of market observations on US interventions together with monetary policy variables and exchange rates during the late 1980s. They strongly reject the hypothesis that interventions convey no signal of future monetary policy. However, the results found show that, in some cases, interventions signalled changes in monetary policy in the opposite direction of the conventional signalling hypothesis, raising doubts on whether intervention policy was indeed effective.

In Brazilian background, the signalling effects do not seem to be a plausible channel for interventions to affect exchange rates, if considered fundamentals of inflation targeting

regime and principles that guide the BCB's decisions, some of them already commented by Diógenes (2007) and Vervloet (2010). In fact, official releases by the BCB emphasize that, under inflation targeting regime, the monetary authority commits to ensure that the effective inflation is in line with a pre-established goal announced publicly, by means of controlling one instrument: the short-term interest rate. Therefore, additional targets, such as the foreign exchange rate or the economic growth, cannot be attributed to the monetary policy, even though these are considered when the prospective scenario for inflation is defined. Besides that, an element that essentially characterizes the inflation targeting regime in Brazil is the transparency in ways of communication used by the monetary authority to inform society about the conduction of targeting regime, plans, goals and reasons for decisions made. Since the use of foreign exchange interventions as a means of signalling future monetary policy intentions was never mentioned by the BCB, the existence of this mechanism would not be in line with commitments and transparency principles prized and enforced by monetary authority in Brazil.

In addition, Diógenes (2007) finds evidence of portfolio balance channel when estimating the impacts of spot market and future market interventions on the USD/BRL spot rate. He finds that both have depreciative effects on BRL, but, at the same time, the consequences of the same interventions are neutral when considering variations in the forward premium, included in forward exchange rate calculation. Therefore, assuming expected future exchange rate constant, the effects of both types of interventions indicate an increase in currency risk premium associated to the spot exchange rate depreciation, perfectly consistent with portfolio balance approach.

An interesting empirical study on coordination channel effectiveness is from Reitz and Taylor (2008), who estimate a micro-structural model of daily exchange rate behaviour in order to evaluate Fed's interventions in USD/DM foreign exchange market, and in particular to examine the relevance of the coordination channel on intervention effectiveness. Parameter estimates reveal that the further the exchange rate moved from its fundamental value, the weaker became trading activity, situation that provided basis for the coordinating role of the Fed. Results show that the intervention policy tended to reduce misalignments in USD/DM exchange rate in a manner consistent with the coordination channel.

In this chapter, the goal was to provide knowledge on the mechanisms often assumed in the literature to be reasonable explanations on how sterilized FX interventions might be effective in impacting exchange rates. Whether effectiveness is indeed empirically observed or not is an issue which has been investigated in several studies, but remains a point of attention since the results found are diverse. Regarding this, the next chapter will address some relevant empirical analyses available in the related literature.

3 Sterilized foreign exchange interventions: empirical evidence

The debate over sterilized foreign exchange interventions effectiveness would not make sense before the 1970s. Until then, the establishment of Bretton Woods agreement internationally made fixed currencies the norm. This is to say, gave to central banks of participating countries the task of maintaining fixed exchange rates between their currencies and the USD, the reserve currency through which interventions were carried out to adjust rates. With the collapse of Bretton Woods system, in the early 1970s, currencies were allowed to float freely and, gradually, floating exchange rate regimes spread out in the world. The flexible regime is split into two types: the free float, in which a currency fluctuates in response to market mechanisms and authorities do not intervene at all; and the managed float, also called dirty float, in which the rate is still determined by markets through supply and demand, but intervention by the authorities may be observed in different forms and degrees, in an attempt to make the exchange rate change in some direction especially during extreme appreciation or depreciation movements.

It was only in the beginning of the 1990s, however, that literature on foreign exchange interventions was able to study the mechanism effectiveness with more robustness and consistency, as remarked by Sarno and Taylor (2001). By then, the lack of information due to non-disclosure of official interventions reports by central banks was a strong limitation to any empirical analysis. As an attempt to deal with data restrictions, some works in the literature used quarterly data on movements of international reserves held by monetary authorities as a proxy for interventions, what clearly represented an inaccurate variable since other factors would also cause international reserves variations. Apart from this issue, quarterly and monthly data would not reveal crucial daily information.

To exemplify, when disentangling the influence of two potential channels (portfolio balance and expectation) in central bank intervention operations between 1982 and 1987 for USD/DM rate, the work by Dominguez and Frankel (1990) exposes procedures taken in order to deal with data limitation for the empirical assessment. For intervention data from German authorities, an exceptional agreement with the German Bundesbank allowed the authors to use confidential daily intervention data over the period of l982-l987, what provided data accuracy not commonly observed in studies till then. In the case of United States data, however, the Fed did not provide official access to daily intervention data over the period needed, what led the authors to construct a daily intervention series for the US from descriptions of foreign exchange desk operations published in the Federal Reserve Bank of New York Quarterly Review and other Federal Reserve publications.

An improvement in information availability, in the early 1990s, was quite related to the decision from United States authorities to start releasing official daily data for interventions, fact that enabled a broader assessment of interventions impacts by the subsequent literature. Dominguez and Frankel (1993a) mention how that change in US releasing policy allowed for a more accurate analysis and more reliable results in their work, together with the exceptional fact of having authorization for consulting German Bundesbank data. Dominguez and Frankel (1993b) find important results that would not have been possible without previously unavailable daily data for interventions by the US Federal Reserve and the German Bundesbank. All in all, after the United States, other countries followed similar procedures in the subsequent years and started releasing official FX interventions data. This new framework definitely consisted of a more enabling environment for the development of a wide literature dedicated to addressing the effects of official foreign exchange interventions. The seminal series of studies by Dominguez and Frankel in the early 1990s marked the beginning of a literature capable of producing more accurate studies based on released official daily data.

As the intervention literature expanded and a variety of data sources, methodologies and results were observed, some authors engaged in developing surveys to compile them and compare important findings. One remarkable survey was provided by Neely (2005), who mentions the use of at least three types of methodologies in the literature investigating impacts of interventions on returns and volatility of exchange rates: time series event studies, the most common approach that typically uses a single equation in which intervention and a limited set of regressors explain returns in the exchange rate; other event studies, defined as analyses that typically use data only from around periods of intervention, ignoring the behaviour of exchange rates when no interventions happen; and structural analyses, which explicitly model structural economic relations to identify the effect of intervention on exchange rate behaviour.

Dominguez and Frankel (1993b) produced one of the pioneer works to address interventions through a time series analysis, in which the estimation of a reduced form exchange rate equation using official daily data led the authors to find strong evidence that interventions implemented by the Fed, the German Bundesbank and the Bank of Japan in the 1980s indeed influenced the USD/DM and USD/Yen exchange rates. Dominguez (1993) provides another remarkable work to FX intervention literature, in which a GARCH(1,1) model is used to assess the effects of interventions by the central banks on USD/DM and USD/Yen exchange rates level and volatility over the 1985-1991 period, on daily and weekly bases. Even though the analysis focuses on volatility issues, the coefficients on mean equation are estimated and reported. Results with daily data estimation show that effects from overall reported interventions from the three central banks on both currencies are positive signed and, in general, statistically significant when the entire sample is considered. In a weekly frequency data estimation, similar results

are found in terms of the signs of the coefficients, but for USD/Yen equations few of the parameter estimates were proved statistically significant.

Over the years, data availability also allowed the assessment of intraday impacts from interventions. Once again, Dominguez stands as an important reference in the literature. Dominguez (2003a) checks if evidence found in favour of interventions effectiveness in previous works regarding 1980s episodes - from Dominguez and Frankel and other authors - were still valid in the 1990s, i.e. if intervention policy continued to work or had become less effective. She analyses short-term (four hours) effects of G-3 intervention operations on exchange rate returns, as well as longer-term correlations between episodes of intervention and subsequent currency movements, and concludes that intervention policy was still alive and successful by then. Dominguez (2003b) uses even higher frequency data (tick-by-tick indicative quotes) for USD/DM and USD/Yen obtained from Reuters to examine the relationship between the efficacy of intervention operations made by the central banks and the "state of the market" at the moment when the operation is made public to traders. Results indicate that some traders know that a central bank is intervening at least one hour prior to the public release of the information. Also, the evidence suggests that the timing of intervention operations matters and that interventions coordinated with another central bank are more likely to be effective than the unilateral operations. In general, significant effects from the interventions by the three central banks are found in exchange rates returns.

Another notorious survey in FX intervention literature was published by Menkhoff (2013). By that time, a vast majority of empirical studies on interventions refereed to advanced economies, but the author recognised that a deeper research on the issue for emerging countries was crucial. Firstly, because advanced economy countries were not the main owners of currency reserves any more; secondly, due to the fact that the major central banks, in the advanced economies, had reduced considerably their interventionist procedures, while monetary authorities in emerging markets had been increasing those measures. All in all, "emerging markets feel a need for exchange rate management, as they are heavily outwards oriented, are tentatively less diversified than more mature markets, have less developed financial institutions and are thus concerned about their exchange rate stability" (Menkhoff, 2013). Hence, the scenario in question was that empirical research was mostly covering institutional circumstances that no longer configured the most meaningful trends in the area; the goal of the survey, then, was to compile available knowledge and raise issues focusing on emerging economies.

Among a variety of studies presented in the Menkhoff's survey for emerging economies, the choice here is to highlight works that applied the GARCH methodology for assessing FX interventions impacts. Therefore, more than introducing empirical analyses on the topic, a wider contextualization on the benchmark econometric methodology applied in

the present work will be provided. Moreover, as the main interest in the present study is to evaluate impacts of interventions on exchange rate returns (namely, on the mean equation), priority will be given to presenting findings on this point, even though some studies address the effects on volatility as well.

One of the pioneer works regarding emerging economies was published by Guimarães and Karacadag (2004). They examine the potential interventions have for impacting level and volatility of the exchange rates in Mexico and Turkey through a modified GARCH approach which includes one extra equation in the model for taking account of volatility at different time horizons. This specification allows for a time-varying long-term volatility, in contrast to the constant long-term volatility assumed in the standard GARCH models. Making use of daily data for the estimation, the study finds contrasting evidence on the effectiveness of the operations in both countries. In Mexico, foreign exchange sales have a non-negligible effect, with a US$100 mi sale of foreign exchange by the Central Bank estimated to appreciate the peso by 40 bps. However, foreign exchange purchases, which constituted the major part of interventions in the country during the period covered, do not appear to have had a statistically significant impact on the value of peso. When it comes to Turkey, neither sales nor purchases interventions seemed to affect exchange rate returns.

Another analysis on the cases of Mexico and Turkey is from Domaç and Mendoza (2004), who realise that central banks in emerging markets often make use of sterilized exchange rate interventions in response to large exchange rate shocks, trying to contain the impact of pass-through effects on inflation and to reduce excessive exchange rate volatility. The methodology applied is an Exponential GARCH using daily data, and the assessment made distinguishing sales and purchases presents results suggesting that a sale of US$ 100 mi appreciated the Mexican peso by 90 bps; meanwhile, in Turkey, an equivalent intervention appreciated the lira by 20 bps. On the other hand, purchases of USD revealed no statistical significance.

Kamil (2008) mentions the studies above, for Mexico and Turkey, as meaningful pioneer efforts for assessing the issue in emerging markets. Due to differences in motivations for intervening and mechanisms to it, he claims that results found cannot be easily generalized to other emerging markets, suggesting that additional investigations for different countries can always enrich the literature. Therefore, Kamil revisits the theme through Colombia's experience between 2004 and 2007, when the Colombian Central Bank engaged in large-scale discretionary purchases of foreign exchange to resist appreciation of the domestic currency. Colombia was seen as an interesting case because two sub-periods of discretionary intervention through FX purchases were observed in the covered sample, and these were associated with distinct stances of monetary policy: one with constant or falling interest rates and a loosening of monetary policy, and the other characterized by a

tightening of monetary policy to reduce inflationary pressures in an overheating economy. The methodology applied aimed to overcome two-way causality between exchange rates returns and interventions through a two-stage instrumental variable model based on estimates of the Central Bank's reaction function. In the reduced-form equation of exchange rate returns, a GARCH methodology was applied in order to account for time-varying conditional variance. The estimation results based on daily data show that, during the first intervention period, there was a considerable impact on exchange rate, and in the direction intended by the authorities: each US$100 mi purchased depreciated domestic currency by 78 bps. Conversely, in the second period, no statistically significant effects were observed. Hence, the results support the premise that interventions cannot systematically influence the level of the exchange rate when they oppose other goals of monetary policy somehow.

Regarding Colombian scenario as well, Rincón and Toro (2011) evaluate not only interventions, but also capital controls effectiveness in depreciating the exchange rate, reducing its volatility, and diminishing the exchange rate vulnerability to external shocks. For this purpose, the approach used high-frequency data for Colombia from 1993 to 2010 and an IGARCH(1,1) model for the exchange rate returns, incorporating statistical findings that volatility could become explosive and the standard GARCH model non-stationary, being inappropriate for analysing the data. The results suggest that FX interventions turned out to be non-significant in the mean return equation, not preventing the peso from appreciating. Also, capital controls, when used solely, did not succeed in depreciating the same currency. During the period 2008-2010, however, when both capital controls and FX interventions policies were used simultaneously, they were effective in producing a daily average depreciation of the peso.

Empirical evidence for Brazilian scenario will be addressed in the next section. Among a variety of methodologies, it will be demonstrated that GARCH models have been successfully used in important literature sources for evaluating impacts of interventions handled by the BCB in foreign exchange markets. Some remarkable features of the Brazilian case, including episodes, purposes, methods and results will be hereinafter discussed.

3.1 The case of Brazil

Important guidelines regarding the possibility of the BCB intervening in foreign exchange markets were given in 1999, when Brazil adopted a floating exchange rate regime. Besides reinforcing the priority commitment to fiscal consolidation and the important role of monetary and fiscal policies in assuring price stability achieved under the Real Plan, official releases affirmed that significant movements of the exchange rate could also

configure a short-term concern of monetary authority. In this framework, interventions by the BCB in FX market would be "occasional, limited, and designed to counter disorderly market conditions" (IMF Survey, 1999). Importantly, it should be mentioned that these key points officially raised in 1999 represent objectives and principles that, up to the present, guide somehow policy and intervention strategies by the BCB.

When intervening in foreign exchange market, the BCB usually informs its objectives through official releases. In fact, major intervention events in the period addressed in this work were accompanied by releases in the website of the BCB that reinforced important issues. For instance, in 05/02/18, a press release stated that, with the objective of smoothing FX markets movements, the Central Bank would supply currency swaps contracts in an amount beyond the necessary to roll the contracts maturing. In 05/18/18, the BCB announced an increase in the number of currency swaps contracts auctioned and, in the same release, reinforced the autonomy of monetary policy and its separation from the interventions made by the Central Bank in FX markets. In 06/22/18, a new press release informed the maintenance of currency swaps auctions and announced also a repo USD sale operation, emphasizing that the measures taken aimed to provide liquidity and contribute to proper functioning of FX markets.

Still regarding motivations and purposes of the BCB when intervening, it is essential to point out that they were not always the same over the years and changed in accordance to macroeconomic framework. For instance, from 2004 to the mid-2008 most interventions were purchases of USD, and the BCB declared through official reports that its acting in FX markets was part of a program of official international reserves reconstitution. Importantly, the monetary authority emphasized that the operations were based on liquidity conditions for the moment, having absolute neutrality over any impacts on exchange rate returns and volatility. The motivation for interventions clearly changed in the second semester of 2008, within the scenario of global economic crisis. The BCB resumed USD sales on spot market and traditional swaps offerings, aiming to provide liquidity in a moment of instability when domestic markets faced USD shortage, scenario that lasted until the beginning of 2009[1].

In a different framework years later, after the Fed's taper announcement in 2013, the BCB announced a major program of intervention[2] through FX swaps, with the aim of satisfying the excess demand for hedging and providing liquidity to the market. The program had some defined rules: daily offerings of US$ 500 mi in traditional currency swaps and the sale of US$1 bi on the spot market through repo USD lines (short term credit lines, with repurchase agreement) on Fridays. After some extensions were announced, the program lasted until March of 2015, and in general it differed from previous episodes

[1] A full analysis over motivations and types of interventions during the period of 2004-2010 is found in the work by Vervloet (2010).

[2] This program of FX interventions is widely discussed by Chamon, Garcia, and Souza (2017).

of intervention by the BCB not only because of the rules-based characteristic the program assumed, but also because the instruments used were exclusively currency swap auctions and repo USD lines. Meanwhile, more traditional methods for intervening on spot markets, such as simple USD sales and purchases, were never observed during the period.

In an overview, the BCB has four types of instruments for carrying out foreign exchange markets interventions: USD transactions in spot market, USD transactions in future market, repo USD transactions (sales in spot market with future repurchase agreement) and traditional/reverse currency swaps offerings.

The analysis of interventions of the BCB, broken down by types, since 2009[3], is possible with information summarized in figures 1 and 2. In Figure 1, it is displayed that, from May of 2009 until September of 2011, operations of USD purchases in spot market were quite important and the most frequently observed intervention modality, in accordance to measures taken for restoration of international reserves. Meanwhile, future market USD purchases were used in few episodes, of which the last and greatest one happened in March of 2012. In May of 2012, the last episodes of plain spot USD purchases operations were observed and, from this moment on, spot interventions in Brazil happened only through repo USD sales, as Figure 1 displays. In the chart, negative values for spot market repo USD transactions represent liquidity provision through USD sales, and positive values consist of the repurchase transactions some periods later.

Over the years, currency swaps became a crucial instrument for intervention operations made by the BCB, with high amounts of contracts increasingly being offered. The confirmation of these derivatives as core instruments for intervening became unquestionable when, in 2013, the BCB announced the program of intervention through currency swaps, which led to an important increase in the liability position of the BCB in foreign exchange regarding swap operations. The maximum value of US$115 bi was reached in March of 2015, as seen in Figure 2.

[3] Time series data for USD transactions in spot and future markets, as well as for repo USD transactions, is available in BCB's website only as of May of 2009.

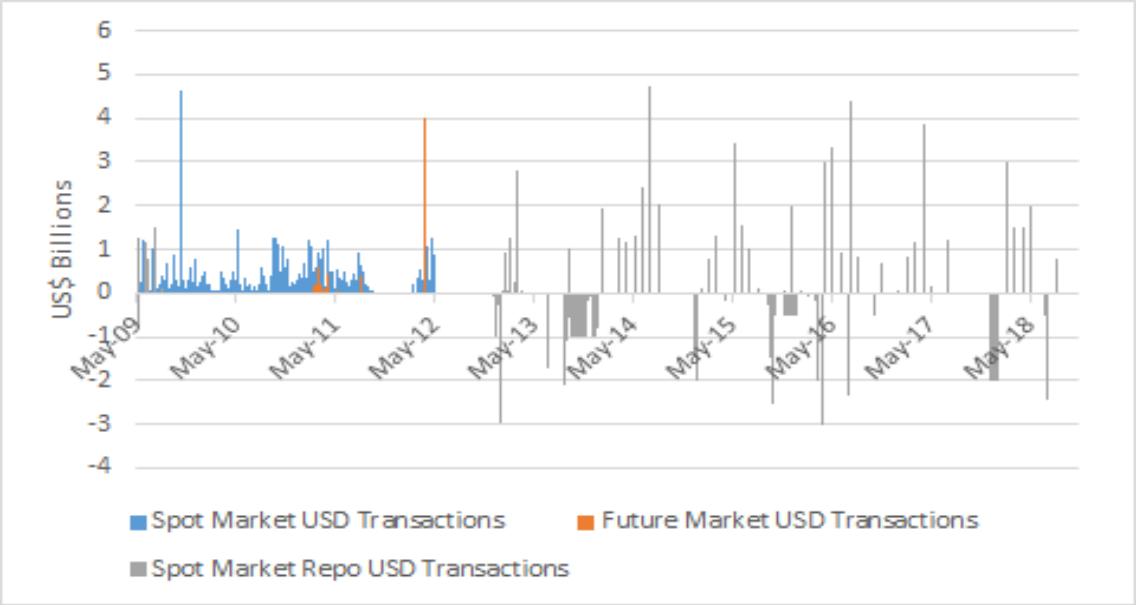

Figure 1 – Interventions of the Central Bank of Brazil through USD Transactions. Source: BCB.

Figure 2 also illustrates that, with the end of the major program of intervention, in March of 2015, the liability position of the BCB in foreign exchange relative to swaps decreased in the subsequent months. It kept relatively stable during 2017, in a level between US$17 bi and US$28 bi, until April of 2018, when it presented a sharp rise again. This was the highest increase in the BCB's liability position in foreign exchange for swap operations since the one observed during the program of intervention of 2013-2015. In 2018, the position reached the amount of US$ 68,9 bi as a result of new and rolling traditional currency swaps contracts auctioned, configuring them as the core mechanism for intervention again, even though repo USD sales were observed in occasional moments, specially in the end of the year [4] and when even more liquidity provision was necessary beyond the amounts provided by swap operations. These eventual repo USD sales in 2018 can be noticed in Figure 1.

[4] Significant spot USD sales with repurchase agreement operations were made in December of years 2012-2015 as well. According to Garcia and Volpon (2014), such transactions were frequently used to meet short-term, often seasonal, demand for USD. In year end period, many banking institutions would curtail international lending lines, causing temporarily illiquidity that could be partially solved with those operations

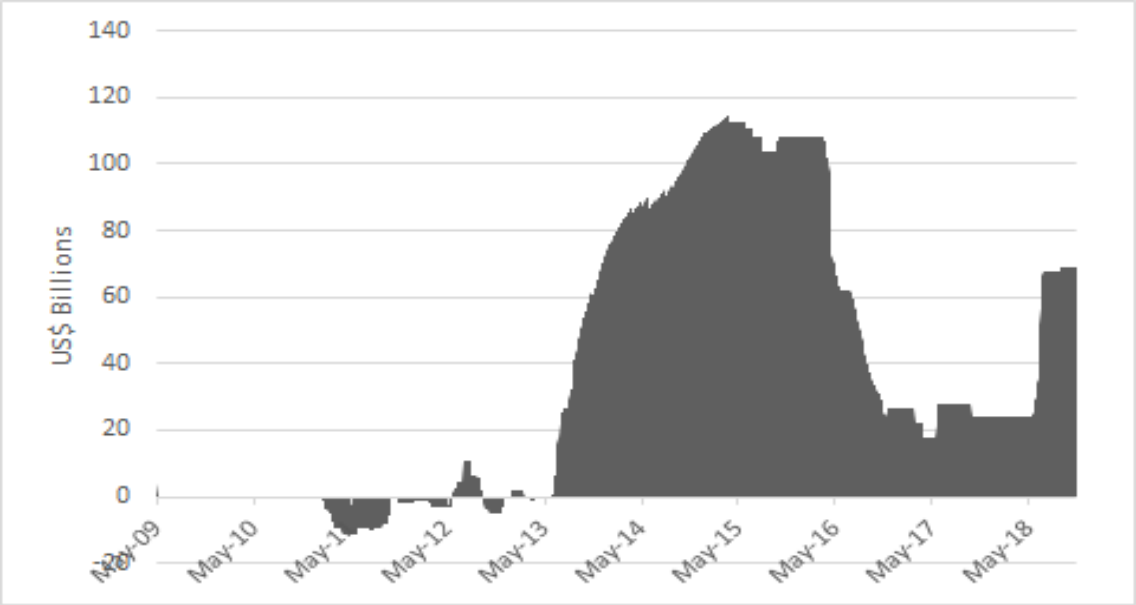

Figure 2 – Foreign Exchange Swap Contracts Balance of the Central Bank of Brazil. Source: BCB.

Since the goal of this dissertation is to find out impacts of currency swaps on the USD/BRL exchange rate returns, priority will be given to describing features of this modality of FX intervention specifically. Swaps are financial derivatives instruments that provide a simultaneous exchange of rates or returns of financial assets between economic agents. In Brazil, the currency swap operations exercised by the BCB consist of sales or purchases of derivative contracts negotiated in B3 S.A. – Brasil, Bolsa, Balcão. According to official information obtained from the BCB's website, by means of offering swap contracts to markets, the BCB attempts to avoid dysfunctional movements in foreign exchange markets, provide currency hedging against excessive changes in the USD/BRL exchange rate and, also, supply liquidity to domestic FX market.

Swap contracts offered by the BCB can be of two types: traditional or reverse. In the case of traditional swaps contracts, the BCB assumes the position of contract buyer and commits to pay, to the swap owner, the amount relative to USD/BRL variation added of a local onshore USD interest rate (the "cupom cambial"), and receives in exchange the amount given by cumulative variation of domestic interest rate (Selic) during the same period. In this situation, it is essential to highlight that the contract vendor gets protected in case of BRL depreciation against USD, and the contract offering operation works similarly to an USD injection in future market. When contracts are of reverse type, the positions taken by agents and the BCB invert.

Swap operations are registered in B3 S.A. according to the specifications of "Currency vs. Interest Rate Swap Contract with Periodical Adjustment - SCS". When they consist of traditional swap contracts, they are named "SWAPC"; when they are

reverse swap contracts, they are registered "SWAPV". For informational purposes, until 05/31/2013, swap operations were registered in B3 S.A. as "Currency vs. Interest Rate Swap Contract with Periodical Adjustment - SCC" and the interest rate exposure assumed as a counterpart of foreign exchange rate exposure was the DI rate instead of Selic.

Still according to official information from the BCB, it does not exist any predefined calendar informing days and times of the BCB's actuation in FX market. Swap contracts offerings are always preceded by announcements in "BC Correio", which are often released in the day before the event, at around 6:30 pm, although depending on market conditions auctions can be announced at any time of the day and shortly carried out. Results are released in the BCB's website immediately after the conclusion of the auction.

A brief review of currency swaps use by monetary authority in Brazil must include the instrument (re)introduction in Brazilian scenario during the floating exchange rate period, explained by Bevilaqua and Azevedo (2005). When analysing Brazilian experience with the use of foreign-exchange-linked debt instruments denominated in domestic currency, the authors state that the FX derivatives, which had not been used since the pre-floating period, were reintroduced by the Central Bank in 2002 and played an important role in replacing Treasury US$-linked notes (NTN-D). The new FX swap contracts presented lower credit risk than NTN-Ds because they were traded and settled at the BM&F and offered daily margin adjustments. As Garcia and Volpon (2014) notice, the development of a technology of offering USD substitutes as intervention instruments by the BCB was only possible because Brazil presented a highly developed financial structure characterized by an active FX derivative market.

Garcia and Volpon (2014) assert that the BCB's strategy of intervening in FX markets through currency swaps has some singular features. Even though other countries have used derivative instruments that settle in their local currencies for other purposes, the BCB's main objective of providing FX hedging is a quite unique strategy. The authors name the intervention instrument from the BCB as DNDFs (Domestic-Non-Deliverable Forwards), which are currency forwards that settle in domestic currency and differ from the NDFs (Non-Deliverable Forwards) in the sense that the Brazilian DNDFs are USD forwards that settle in local currency, while the NDFs of BRL settle in USD outside the Brazilian banking system.

According to the authors, the DNDFs are instruments that enable FX hedging in a different manner, providing investors a hedging similar to what they would obtain by buying spot USD and holding them until the maturity of the swap. By doing so, the BCB hopes to preserve foreign reserves despite high amounts of exchange rate interventions. However, even if one can mistakenly argue that, as long as those instruments are settled in domestic currency the BCB can offer an unlimited amount of DNDFs, a limit to the

strategy of using DNDFs indeed exists. They will only be marketable instruments if they are perceived to be effectively "collateralized" by reserves and if economic agents believe they can go easily from DNDFs to spot USD, i.e., if convertibility risk is negligible. The authors exemplify the existence of convertibility risk with the events of 1983 in Brazil, when facing a shortage of international reserves and a considerable depreciation of the BRL, the BCB intervened in FX market by fixing the exchange rate and imposing quota restrictions on foreign exchange transactions.

All in all, a crucial idea behind the BCB's manner of intervening through DNDFs is to separate cases that need foreign currency instruments for hedging or speculative reasons - but do not actually need to settle transactions in foreign currency - from those that do need actual USD. If convertibility risk is negligible, meaning that DNDFs are a good substitute for USD, agents who look for hedging or speculation can benefit quite well from DNDFs.

For a comprehension on how interventions with DNDFs work, it is essential to point out how it changes the level of onshore USD rate, the "cupom cambial", and provides incentives for investors and commercial banks to bring spot USD onshore. Garcia and Volpon (2014) describe this mechanism, noticing that onshore USD yields will vary negatively with the price of the forward exchange rate. According to covered interest parity:

$$(r_t + 1) = (q_t + 1)\frac{F_t}{S_t} \tag{3.1}$$

where S is the spot rate, F is the forward rate, r is the local interest rate, and q is the onshore USD rate.

By selling DNDFs, the BCB makes F decrease, and even though some impact on S is observed in the short run, q increases in the process. Then, a sale of forward FX by the BCB reduces forward against spot exchange rate, providing a lower cost for hedging a short USD spot position and having the effect of raising USD rates onshore. So, higher onshore USD rates encourage banks that have access to multiple markets to bring USD onshore, what is key for financing eventual current account deficits. In this scenario, the BCB is clearly willing to pay the banking system a premium to bring USD to Brazil in substitution to FX spot intervention, as shown by Garcia and Volpon (2014).

Besides the already mentioned limitation that convertibility risk must be negligible for the interventions through DNDFs to work, the authors also emphasize that even though the BCB's instrument has the advantage of preserving foreign reserves, it is necessary to keep in mind that these instruments are BRL denominated/USD indexed liabilities of the BCB. Then, in the case of a sharp decrease of BRL, great losses would have to be financed by the government.

The Brazilian case of sterilized foreign exchange interventions, including impacts

on USD/BRL, has already been pretty well addressed in the literature, with quite interesting evidence being provided. One of the pioneer works is from Diógenes (2007), who makes use of daily data and a reduced-form equation to exchange rate estimated by Ordinary Least Squares and Two-Stage Least Squares methods to find out impacts of sterilized interventions during the period of 2003-2006. Results with both methods suggest that sterilized interventions indeed have effects on USD/BRL exchange rate, varying according to the type of operation. The estimates for USD purchase interventions (in spot and future markets) indicate a depreciation of BRL that varies between 17 bps (OLS) and 70 bps (2SLS) for each US$1 bi purchased. Estimates for USD sales show an appreciation of BRL between 29 bps (OLS) and 34 bps (2SLS) for each US$1 bi sold. When splitting interventions into spot market and currency swaps derivatives and making use of 2SLS method in order to account for endogeneity issues, the estimate found for spot USD purchases suggests a depreciation of 60 bps, and the estimate for reverse currency swaps indicates a depreciation of 20 bps. For traditional swaps, an appreciation of 39 bps is estimated. All in all, coefficients estimated present the expected signals.

Stone, Walker, and Yasui (2009) analyse the Brazilian case with daily data of the years of 2007-2009, covering a moment of market instability arising from local USD liquidity shortage in the scenario of the global financial crisis. The main purpose of their work is to investigate the effectiveness of the foreign exchange liquidity provisioning measures of the BCB during the period, and the conclusion they have on this point is that those actions seemed to have alleviated market instabilities, meeting the demand for foreign exchange liquidity and relieving pressure in USD lending market. The authors also estimate a reduced-form equation for the exchange rate returns in order to assess impacts of FX interventions by the BCB on the level of USD/BRL exchange rate. They break down the estimation of interventions effects into announcements and the operations themselves and find that, in the former case, both spot and future markets types present significant negative coefficient estimates, indicating appreciation of the BRL exchange rate. With regard to the interventions themselves, the coefficient for spot market interventions is statistically significant and of the expected negative sign, suggesting that a sale of US$1 bi appreciated the spot exchange rate by 30-40 bps. The coefficient estimated for future market intervention is not significant.

Another remarkable study is from Vervloet (2010), who estimates, for the period between 2004-2010, with daily data, two models: a reduced-form equation for exchange rate return (estimated by OLS and 2SLS) and a Vector Error Correction Model (VEC). The latter model aims to correct better for simultaneity bias issues resultant from interventions responses to exchange rate variation. Taking into consideration results obtained in the different approaches, it is possible to affirm that there is strong evidence that spot USD/BRL exchange rate is affected by the BCB's sterilized FX interventions, but effects are small and of short duration. Numerical results vary from 7 bps to 140 bps for each US$

1 bi sold or purchased in spot or future markets. In the model that splits interventions into spot/future markets and presents estimates for currency swaps impacts specifically, it is relevant to state that the estimated coefficient for traditional currency swaps is not statistically significant, even though it presents the expected negative signal. On the other hand, reverse swaps present a significant coefficient that indicates a depreciative impact on BRL of 20 bps for each US$ 1 bi in contracts.

Kohlscheen and Andrade (2014) use 15-min frequency data for a 27-month period between 2011-2013 to compute systematic impact of currency swaps auctions taken by the BCB on the spot USD/BRL exchange rate. In order to account for volatility clustering related to heteroscedasticity issue, they estimate a GARCH(1,1) as baseline specification. Results are reported with a distinction of traditional and reverse swaps, since in the period covered both types of interventions were observed. Interestingly, the effects estimated for traditional swaps were of greater magnitude than for reverse type: -70 bps versus 20 bps, summing up coefficients for the six time lags immediately after the announcement of an average size auction. Among a variety of robustness tests to confirm results found, it is estimated a VAR model that allows for the possibility that currency swaps react to exchange rate movements, what could consist of a endogeneity issue in the benchmark GARCH(1,1) model. The VAR estimation results resemble closely the results obtained in GARCH(1,1), confirming the evidence found.

Finally, Chamon et al. (2017) use a synthetic control approach to estimate the impact of the major program of sterilized foreign exchange intervention through currency swaps announced by the BCB following the Fed's tapering release on May of 2013, with the purpose of providing hedging and liquidity to the FX market. The counterfactual results, based on the experience of other emerging markets, indicate that the entire program led to an appreciation of the BRL in the range of 10-19 percentage points. The authors state that, if this result is compared to evidence from other works, taking into account the total volume of intervention mobilized during the program, it would be broadly in line with estimates for the impacts of FX intervention in Brazil previously found.

It is quite clear from the literature review that there is not a consensus regarding effectiveness of sterilized FX interventions and the magnitude of their impacts on exchange rates. Apparently, results vary not only according to intervention characteristics and types, but also depend on the country where the operations are exercised and on other circumstances, such as global and domestic macroeconomic scenarios, institutional development, political framework and others. Recognising this point, it is important that the literature on the field constantly updates and provides new evidence for the matter in question, idea that motivates this dissertation in proceeding with empirical studies of FX intervention episodes in Brazil and assessing their impacts on the USD/BRL exchange rate, making use of a sampling period which has not been used in literature yet.

During the period chosen for the analysis in this work, important amounts of traditional swap contracts were auctioned by the BCB. As mentioned in the beginning of this section, based in Figure 2, a rise in the liability position of the BCB in FX relative to currency swaps was clearly noticed as of May of 2018, after a period of relative stability under lower levels. The subsequent months consisted of a period in which FX interventions through derivatives were quite meaningful, operating in a context when instabilities in domestic and international markets were triggering events of sharp depreciation of the BRL and high volatility in the exchange rate. In Figure 3, the amounts of traditional swap contracts, in USD, as well as the USD/BRL exchange rate are displayed for the period between 11/30/2017 and 10/18/2018, covered in the present work.

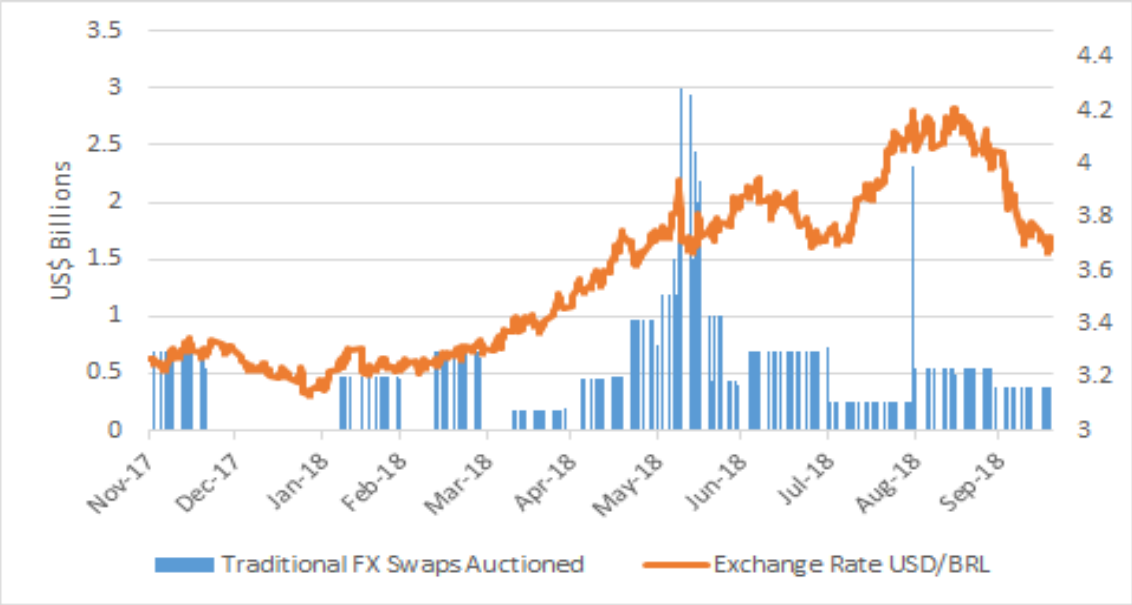

Figure 3 – Traditional Foreign Exchange Swap Interventions and USD/BRL Exchange Rate. Source: BCB and Bloomberg.

Additionally, one key aspect in this work relies on splitting the analysis into rolling and new traditional FX swap contracts, an approach enabled through the collection of more detailed information regarding the contracts and that provides a deeper and more accurate analysis. Figure 4 highlights the distinction of new and rolling contracts auctioned and shows that new contracts were concentrated in the months of May, June and, to a lesser extent, August of 2018, while rolling contracts had more frequent occurrences during period analysed. The possibility of separately estimating impacts of both types of traditional swap contracts on the exchange rate returns might lead to the identification of any relevant distinction that shall be commented.

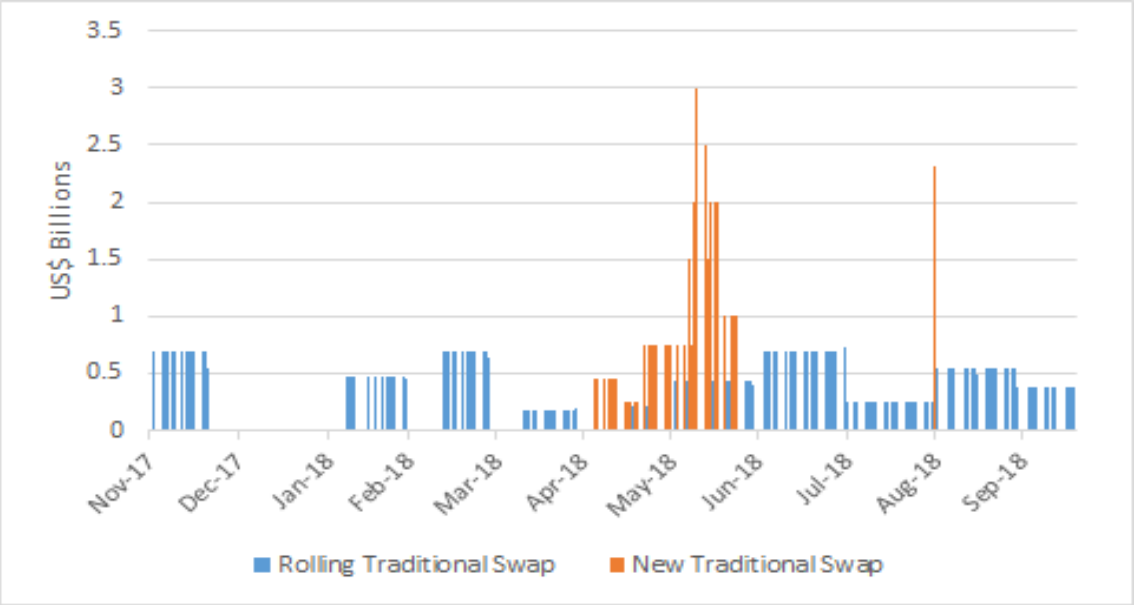

Figure 4 – New and Rolling Traditional FX Swap Contracts Auctioned. Source: BCB.

Importantly, the availability of all information regarding currency swaps auctioned by the BCB, USD/BRL exchange rates and all other variables used in the empirical study of this dissertation was possible due to careful data collection procedures. In next chapter, data used for the econometric exercise and the process for its acquisition will be presented, with a detailed listing of all sources accessed. In addition, the importance of each element from the database for setting variables in the econometric model will be explained.

4 Data

In order to investigate possible impacts of currency swaps operations announcements by the BCB on the spot USD/BRL exchange rate returns, the empirical analysis in this dissertation uses hourly data for the period between 11/30/2017 and 10/18/2018. The hourly frequency is chosen for providing an analysis accounting for intraday effects, and the choice of the sampling period allows the estimation of FX interventions effects with data that covers noticeable episodes in Brazil not addressed in the literature yet.

Data concerning the main variable of interest, the USD/BRL exchange rate, was obtained from Bloomberg. The terminal enabled the collection of exchange rate hourly quotes from 10 am to 6 pm, Brasilia time (BRT), excluding weekends and national holidays. As the hour closing quotes were used, trading period covered was from 9 am to 6 pm. For obtaining the percentage returns for the exchange rate, the procedure was to take the quotations' natural logarithm and their first difference, resulting in a total of 1980 observations in the sample.

Now accounting for information regarding swap contracts offerings announcements, if the analysis were made with daily frequency data, the tables released monthly and available in the website of the Central Bank of Brazil, in "Open Market Press Releases", would suffice. In the tab "Public Offerings of Foreign Exchange Swap Contracts", information on each swap contracts offering in the refereed month is found, including the number of the release from the Department of Open Market Operations (Demab) that contemplates the offering in question, the days when releases and respective events happened, the amounts of contracts offered, the type of operation in each offering, among others. Concerning the type of operation, it is essential to highlight that, in the sampling period, only traditional currency swap offerings happened, i.e., the BCB always assumed the buyer position and the commitment to pay the amount relative to USD variation added of the "cupom cambial" to dealers, receiving in exchange the amount relative to variation of Selic rate until the maturity of the contract. This operation is registered as "SWAPC" in the BCB database. Reverse currency swap offerings, registered as "SWAPV", were not observed during the period considered. Furthermore, all operations showed in tables available in the website of the BCB are also registered in B3 S.A. – Brasil, Bolsa, Balcão as "Contrato de Swap Cambial com Ajuste Periódico - SCS".

However, the tables of "Public Offerings of Foreign Exchange Swap Contracts" do not contain any information on Demab releases hours for swap offering operations. As this analysis works with hourly data, this issue is of major importance because it is necessary to place correctly each announcement on the time of the day when it happened. In order to

obtain the proper information, the system for documents search in the website of the BCB was accessed and enabled the search for Demab releases whose numbers were included in the tables mentioned above. Accessing each release separately, detailed information on the time of the announcement, as well as on the time of the auction itself was obtained. In addition, through these releases, it was possible to collect information regarding the types of contracts offered in each operation, i.e., new traditional swap contracts provisioned by the BCB or rolling traditional swap contracts that were due to mature. Still regarding swap contracts variables in the model, it is important to say that they are included in terms of US$ billions and the notional amount of each contract is the equivalent of US$ 50.000.

The inclusion of proper control variables in the model is essential for a more accurate estimation of impacts of currency swap auctions on USD/BRL returns. The model proposed by Kohlscheen and Andrade (2014) and the regressors used on it motivate the choice of the majority of variables for the empirical analysis in this dissertation.

First of all, data for the CBOE Volatility Index (VIX), a measure of equity market volatility computed by the Chicago Board Options Exchange, was obtained in hourly frequency from Bloomberg. The hour closing quotes were used and the percentage returns of the index were obtained by taking the natural logarithm and the first difference. The reason for including the VIX index is based on results found in the work of Kohlscheen (2014a), where the author shows that, for Brazil, Mexico and Chile, changes in country specific risk premium are proxied by returns in the VIX index, as the strong correlation of the VIX with changes in countries' sovereign credit default swap (CDS) spreads had already been documented earlier in literature. The CDS spreads, in turn, are correlated to capital inflows in emerging countries, affecting exchange rates. However, using changes in the CDS spread of Brazil directly would possibly cause the problem of reverse causality, since the USD/BRL returns could have effects on the CDS spread within the same day. The option, then, is to use the VIX, since it is unlikely that any exchange rate could impact the VIX spread, a global index.

The decision to include a commodities index as control variable in the model follows conclusions reached by Kohlscheen (2014b). The author shows that long-run behaviour of the USD/BRL exchange rate can largely be explained by the price variation of a basket of five commodities that, by then, accounted for a great part of Brazilian export revenues. Hence, in order to control effects of commodities prices variations on USD/BRL exchange rate, the model in the present work includes the Bloomberg Commodity Index (BCOM), whose hour closing quotations were obtained from Bloomberg as well. The BCOM is calculated through the weighting of future contracts prices of a variety of commodities in markets, attempting to minimize the focus on any product or sector; currently the index is composed by 22 future contracts prices of commodities in 7 sectors. Similarly

to procedures taken for VIX, the natural logarithm and the first difference were taken, resulting in percentage returns for the BCOM.

Information regarding other forms of FX market interventions exercised during the period analysed were obtained from Time Series Management System in the website of the BCB. The series searched were "17843 - Banco Central spot net interventions", "24425 - Banco Central net interventions - forward" and "24448 - Banco Central net interventions - repo lines of credit". All of the three series displayed settled contracts, in US$ millions. When checking data for the period analysed, it is clearly verified that, aside from swap contracts operations, the BCB intervened in FX market also through repo USD lines, so it is essential to control for the possible effects these operations may have had on USD/BRL returns. For details of days and hours when official announcements of repo USD transactions by the BCB happened, the system for documents search in the website of BCB was accessed and releases from Departamento das Reservas Internacionais (Depin) for each of these operations were consulted.

The assessment of possible effects that releases of results for important economic indicators in Brazil and United States may have on USD/BRL returns is a recommended procedure, as Kohlscheen and Andrade (2014) point out. The comparison between actual results with previous market projections of domestic product and inflation indicators configures a manner of evaluating effects of macroeconomic "surprises". The definition of a surprise variable is provided by Andersen, Bollerslev, Diebold, and Vega (2003) and Kohlscheen and Andrade (2014) as the difference between the announced figure and the last available survey expectations divided by the sample standard deviation of the variable in question. In the present work, actual results and market projections for the following economic indicators were collected:

- Gross Domestic Product of Brazil (PIB): main economic indicator quantifying the performance of economic activity in Brazil, calculated and released by the Brazilian Institute of Geography and Statistics (IBGE). The quarterly results, in percentage points relative to last/second-to-last quarters variation, were obtained from Agência Estado Broadcast (AE Broadcast) database. Announcement dates were obtained from the same database and confirmed through the IBGE official calendar, available in the website of the institution. The choice for collecting data from AE Broadcast was due to the fact that it shows, besides the final official result for the indicator, the PIB result informed in the moment of the official announcement. As a consequence of revisions made afterwards[5], sometimes the final result (currently available in the website of the IBGE) differs from the one announced at first, i.e., the one that in fact caused the "surprise effect" in markets. Regarding hours of releases of PIB

[5] According to an official explanatory note on the IBGE website, series may change in consequence of the incorporation of new information and eventual methodological improvements.

results, the IBGE was consulted and informed that results are always sent to the press and displayed on the IBGE website at 9 am, which is a standard time for all indicators announcements from the IBGE[6]. Now taking account of information regarding market expectations for PIB results, the source was also AE Broadcast database, which provided values that consisted of an average of projections made by several economic consulting companies, brokerage firms, banks and academic institutions, all collected and compiled by AE Broadcast.

- Consumer Price Index of Brazil (IPCA): measures the variation of market prices to consumers and consists of the official inflation index in Brazil, calculated and released by the IBGE. The monthly results, in percentage points relative to last/second-to-last months variation, were obtained from the AE Broadcast database. The procedures for getting information on dates and hours of IPCA results announcements followed the ones taken for PIB information collection. The most part of average market projections was obtained from AE Broadcast; the only exception was for the IPCA projection made in April of 2018 (referring to March result) which was not available in the AE Broadcast database. Therefore, the projection provided by Valor Data (Valor Econômico) was used.

- Central Bank Economic Activity Index (IBC-Br): created as an attempt to anticipate PIB results, the indicator configures a prior parameter for the progress of economic activity in Brazil. It is calculated and released by the Central Bank of Brazil. Monthly results and announcements dates were obtained from AE Broadcast and confirmed through the press releases available in the BCB website, where it was also found that the announcements always occurred around 8:30 am. Average market projections for the indicator were collected from AE Broadcast database as well.

- United States Gross Domestic Product (GDP): main indicator quantifying the performance of economic activity in the United States. It is calculated and released by the Bureau of Economic Analysis (BEA), from whose website quarterly results and days/hours of announcements were collected. Average market projections for the GDP were obtained from Bloomberg releases.

- United States Core Consumer Price Index (CPI Core): measures the variation of market prices to consumers in the United States. It is calculated and released by the Bureau of Labor Statistics (BLS). The Core index, used in this work, does not include goods that usually present highly volatile prices, such as energy and food products. Monthly results, dates and hours of the announcements were obtained

[6] Information established in "Art.1º da Portaria do Gabinete do Ministro de Estado do Planejamento, Orçamento e Gestão número 355", in 11/05/2007.

from the website of BLS, and average market projections were collected from Reuters releases.

Lastly, taking into account the context relative to the sampling period in this work, a last variable was included in the model as an attempt to capture, somehow, the effects of market expectations for 2018 presidential elections in Brazil on USD/BRL exchange rate returns. In the scenario of a run-up to the elections in any country, it is not surprising that markets present reactions according to polls results eventually released, since several economic policy measures are at stake in government plans, which naturally vary from one candidate to another. The results found by Mauser and Fitzsimmons (1991) suggest that published polls had a powerful impact on the value of the Canadian dollar during the 1988 Canadian federal election, fact that appears to have been due to the importance of economic issues in the federal campaign and the distinctive positions taken by the major political parties.

In Brazil, during 2018, empirical evidence pointed to the fact that new information regarding the performances of candidates to presidential elections in polls seemed to play an important role in the path of USD/BRL rate. These indications were often reported by Brazilian and international press releases and commented by economic analysts, leading to the decision, in the present work, of incorporating a variable capable of capturing the mentioned effects in the model. For this purpose, the choice is to identify announcements of polls results from two important Brazilian research institutions, Ibope and Datafolha, whose polls in months prior to the elections usually guide considerably population and markets expectations. Then, procedures for data collection involved accessing the PesqEle system in the website of Tribunal Superior Eleitoral (TSE), where a list of all registered polls realized by Ibope and Datafolha is provided. Also, the electoral law determines a minimum period of five days between the record of a poll in the system of PesqEle and the release of its results. However, as Ibope and Datafolha are not indeed responsible for the releasing process[7], the identification of days and times of polls results announcements was made through the search of news published by the main Brazilian press agencies, such as G1, Uol, Folha de S. Paulo and Estado de S. Paulo.

All the data collected enables the estimation intended in this work through a proper econometric approach. In the next chapter, relevant specifications concerning the econometric model used will be presented and explained.

[7] Ibope and Datafolha provide the results for media institutions that ordered them for journalistic purposes.

5 Methodology and Estimation Results

An important and frequent assumption in econometric models is homoscedasticity, namely a constant variance in time series processes. However, it has been broadly known since the publication of Mandelbrot (1963) that the variance of speculative prices usually changes over the time, what has become a notorious characteristic of financial series. Bearing this in mind, applied researchers in financial and monetary economics started modelling time variation in second-order moments, a subject broadly addressed by Bollerslev, Chou, and Kroner (1992). The authors recognise that one of the most prominent tools developed for incorporating changing variances in econometric approaches is the Autoregressive Conditional Heteroscedasticity (ARCH) model of Engle (1982) and its various extensions. Therefore, the introduction of ARCH and GARCH methodologies was crucial for the development of an extensive literature addressing financial time series, which often used the new modelling strategy, as exposed in the work of Bollerslev, Chou and Kroner through a survey of important contributions to the topic.

Exchange rate series are a typical example of financial series that present volatility clusters, i.e., large (small) price changes tend to be followed by other large (small) price changes. Hence, similarly to various cases of financial series characterized by speculative prices, some commonly observed issues in exchange rate series have not been adequately incorporated by traditional time series models. Among these features, Bollerslev et al. (1992) emphasize not only the interleaved periods of high volatility and stability, but also the leptokurtic unconditional distributions frequently verified in data from financial variables series. In such a framework, the ARCH class of models stands out as a more appropriate and efficient tool, usually capable of incorporating those issues better than other available econometric approaches.

Taking these facts into account, the methodology used in the present work for addressing the behaviour of exchange rate returns will be based on the above mentioned class of models, as it proved to be effective in modelling temporal variation in volatility processes. More specifically, a GARCH model will be used for the estimation, and the reasons for the choice of it instead of other models from ARCH class will be detailed along the next sections.

The chapter proceeds as follows: firstly, the main issues and assumptions underlying ARCH and GARCH methodologies are introduced; next, statistical properties of the exchange rate returns series used in this work are presented; then, the main features of the GARCH model used in the empirical exercise are addressed; the results obtained are presented and followed by robustness tests that validate them; lastly, it is provided

an analysis aiming to deal with any possible endogeneity issue that could lead to doubts regarding the results found.

5.1 ARCH(q) Models

Intending to generalize the hypothesis frequently assumed as valid in traditional econometric models - but not usually true empirically - that errors variance is constant, Engle (1982) introduces a new class of stochastic processes named Autoregressive Conditional Heteroscedasticity (ARCH). Some features of these processes include mean zero, the absence of serial correlation, but a changing conditional variance typical of heteroscedastic processes, even though the unconditional variance is constant. Therefore, ARCH processes have the goal of incorporating a conditional variance equation in the model specification, such that it can be explained by past errors.

When modelling a time series making use of ARCH, let ϵ_t be the error terms. ϵ_t is split into a stochastic term z_t, which is a white noise process, and a time-dependent standard deviation, σ_t,

$$\epsilon_t = z_t \sigma_t \tag{5.1}$$

$$z_t \; i.i.d., \qquad E(z_t) = 0, \qquad Var(z_t) = 1, \tag{5.2}$$

where ϵ_t is serially uncorrelated with mean zero, but its conditional variance, σ_t^2, depends on time t. Usually, ϵ_t corresponds to an innovation in the mean for a process such as

$$y_t = \beta x_t + \epsilon_t \tag{5.3}$$

$$\epsilon_t | \psi_{t-1} \sim \; D(0, \sigma_t^2), \tag{5.4}$$

where y_t is a random variable whose mean is assumed to be given by $x_t\beta$, which represents a linear combination of endogenous and exogenous variables included in the information set ψ_{t-1}; β is a vector of parameters to be estimated and D is some parametric distribution.

Engle (1982) suggests that an appropriate parametrization for the conditional variance is to express it as a linear function of past squared values of the innovation, as follows

$$\sigma_t^2 = \omega + \alpha_1 \epsilon_{t-1}^2 + ... + \alpha_q \epsilon_{t-p}^2, \tag{5.5}$$

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \epsilon_{t-i}^2 \tag{5.6}$$

$$\omega > 0, \qquad \alpha_i \geq 0, \; i = 1, ..., q \tag{5.7}$$

where σ_t^2 represents the conditional variance, q is the ARCH process order, and ω (the intercept) and each α_i compose a vector of unknown parameters to be estimated in the model.

Even though Engel's initial purpose when specifying ARCH processes was not the application in financial time series, the methodology has been widely used in econometric analyses of stocks, interest rates, exchange rates and other financial variables. Since the paths of these variables respond promptly to information shocks whose impacts vary according to circumnstances, it is common that these time series alternate periods of high and low volatility, resulting in volatility clusters. Hence, it is not reasonable to assume that error terms in these series present constant variance, a required point in most traditional econometric estimations. Indeed, it is commonly assumed that conditional variance of error terms in financial series changes over time, being determined by past information. In these cases, thus, the ARCH methodology consists of a proper tool, being capable of dealing with heteroscedaticity through a conditional variance model. As Engle (2001) highlights regarding ARCH processes applied to financial series, not only they correct failures that traditional Ordinary Least Squares estimators would present in these cases, but they can also realize forecasts for conditional variances of errors term, two features of major importance in econometrics for financial analysis.

5.2 GARCH(p, q) Models

Based on ARCH processes introduced by Engle (1982), Bollerslev (1986) proposes a generalized model that allows for a more parsimonious lag structure, which is also capable of accounting for the long memory process usually observed in empirical work. This model is named GARCH (Generalized Autoregressive Conditional Heteroscedasticity) and the generalization that characterizes it can be comprehended analogously to the one observed in the extension of the standard time series AR (Autoregressive) process to the general ARMA (Autoregressive Moving Average) in the seminal work by Box and Jenkins (1976). In general, GARCH, when compared to ARCH models, have a similar advantage to the one observed in ARMA processes in comparison to AR: they permit a more parsimonious description in situations that would require many temporal lags.

Bollerslev (1986) formally defines a GARCH(p, q) process as follows:

$$\epsilon_t|\psi_{t-1} \sim \ D(0, \sigma_t^2), \tag{5.8}$$

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \epsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2, \tag{5.9}$$

$$p \geq 0, \qquad q \geq 0, \qquad \omega > 0, \tag{5.10}$$

$$\alpha_i \geq 0,\ i = 1, ..., q, \qquad \beta_i \geq 0,\ i = 1, ..., p. \tag{5.11}$$

Similarly to the definition of an ARCH(q) process, in GARCH(p, q) models the ϵ_t terms correspond to innovations in the mean of a linear regression, as expressed below

$$\epsilon_t = y_t - \beta x_t \tag{5.12}$$

The equation (5.9) shows that the conditional variance at time t, in a GARCH process, depends basically on three components: the intercept ω, the lagged squared innovations from mean equation and the lagged conditional variance terms. An important feature observed in the equation for a general GARCH(p, q) process is that, in the case of $p = 0$, it reduces to the ARCH(q) process, and for $p = q = 0$, ϵ_t is simply white noise, with constant variance.

Summing up, the main difference between ARCH and GARCH processes is that, in the former, the conditional variance is specified as a linear function of past squared innovations in the mean only; on the other hand, in a GARCH(p, q), the process accounts for lagged conditional variances effects as well. For a better comprehension of the idea behind these models, an intuitive interpretation for the conditional variance equation is expressed as follows: a higher conditional variance for a given variable in present may be a consequence of unexpectedly high (or unexpectedly low) values of this variable in the previous periods, and, also, of high conditional variances observed for it in last periods. This is consistent with the volatility clustering events commonly observed in series for which ARCH and GARCH methodologies are often applied.

The verification of autocorrelation and partial autocorrelation functions for the squared process ϵ_t^2 is useful for identifying time series behaviour in the conditional variance equation of GARCH models, as mathematically demonstrated by Bollerslev (1986). The logical is the same as using these same functions to identify time series of the ARMA form in the conditional mean, an already well established procedure by Box and Jenkins (1976).

Bollerslev adopts the method of Maximum-Likelihood Estimation (MLE) for the GARCH process, referencing the results previously found by Engle (1982). The gain in efficiency from the utilization of MLE rather than Ordinary Least Squares (OLS) is emphasized by both authors and justifies the prevalence of the former estimation approach in the literature addressing both ARCH and GARCH econometric models.

For informational purposes, it is important to document that, besides the generalization from ARCH to GARCH, over the time a range of different models were derived from them, each one with different specificities and applicabilities. Similarly to the traditional ARCH and GARCH processes, these variations became widely applied to financial

series data in which heteroscedasticity often consists of an important issue. To exemplify, some of these variations are: the Exponential GARCH (EGARCH) and the Nonlinear Asymmetric GARCH (NAGARCH), which account for leverage effects; the GARCH-in-mean (GARCH-M), that adds an heteroscedasticity term into the mean equation; the Integrated GARCH (IGARCH), a restricted version of the GARCH model where the persistent parameters sum up to one; and several other variations. Details and specific features of these alternative models will not be a focus of further discussions in this work, since the benchmark methodology used will be a parsimonious GARCH(1,1), which consists of a more general specification that will be proved capable of fitting well the data available. The reasons supporting the choice of a GARCH(1,1) and important features of the model will be later presented in the section 5.4.

5.3 Descriptive Statistics of the USD/BRL Exchange Rate Returns

It is important to highlight some features of the data used in this work that support the choice of a GARCH methodology for the econometric exercise. Due to non-stationarity of the USD/BRL series, the explained variable in the approach, it is more appropriate to work with the exchange rate returns. The natural logarithm transformation is applied and the first difference is taken, in order to obtain the exchange rate returns in percentage points. The behaviour of this variable, for the period from 11/30/2017 to 10/18/2018, is shown in Figure 5, where S_t stands for the USD/BRL exchange rate at time t.

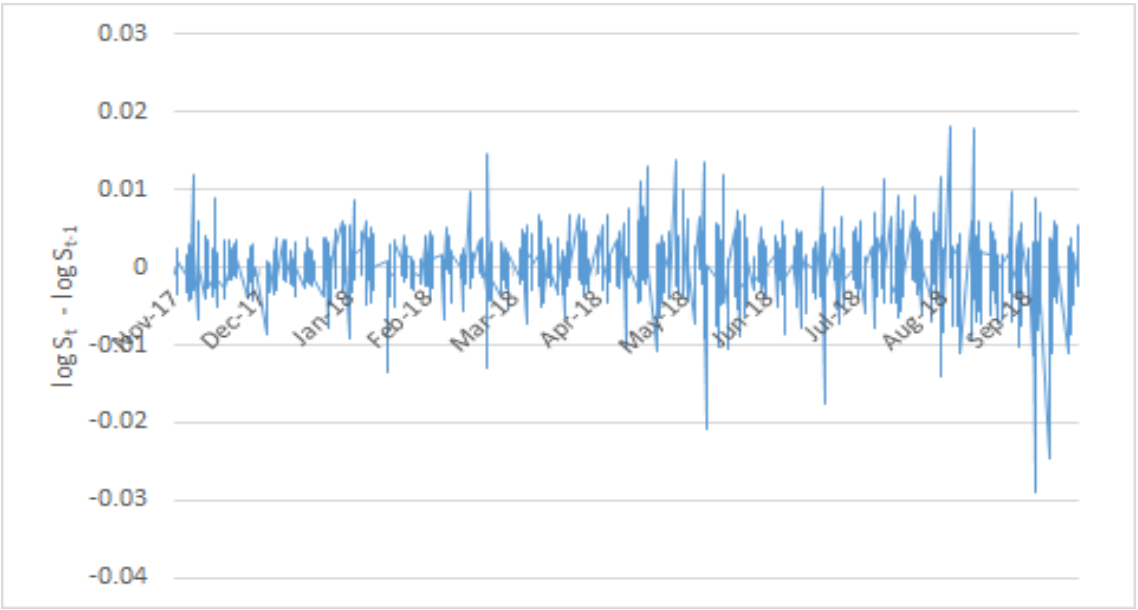

Figure 5 – USD/BRL Exchange Rate Percentage Returns. Source: Bloomberg.

In Table 1, the main descriptive statistics measures of exchange rate returns in the sample are summarized.

Table 1 – Exchange Rate Returns Descriptive Statistics

Variable: $\log S_t - \log S_{t-1}$	
Measure	Value
Mean	6.52e-05
Variance	1.005e-05
Skewness	-0.71
Kurtosis	9.31
Q(10) S	16.998
Q(10) S^2	92.256**

Note: ** denotes statistical significance at 1% confidence level.

Among the measures shown in Table 1, the measure of kurtosis is a relevant point to be commented. The theory of statistics determines that the kurtosis of any univariate normal distribution is 3, and a higher measure characterizes distributions that exhibit tail data exceeding the three standard deviations from the mean predicted by the normal bell-curved distribution. The kurtosis of the exchange rate returns in the sample considered in the present analysis is 9.31, suggesting that the distribution of the variable has fatter tails, being considered leptokurtic. Regarding this, the study of Westerfield (1977) has already found evidence of leptokurtosis in exchange rate returns. Additionally, Hsieh (1988) confirmed the evidence and found that the leptokurtosis is mostly associated to heteroscedasticity in exchange rate returns, and even though there is some serial correlation in the data, it does not account for the strong rejections of the i.i.d. hypothesis as much as heteroscedasticity does. Hence, there is suggestive evidence for the existence of temporal clustering in the conditional variance of the series considered, with large changes followed by large changes, and small changes followed by small changes as well. The histogram for the series is expressed in the Figure 6.

The Q-statistics displayed in Table 1 represent the results of Ljung-Box tests to the identification of high-order serial correlation, for both the percentage exchange rate returns and its squared value. The fact that Q-statistic for the squared variable is considerably higher is suggestive of the presence of conditional heteroscedasticity in the series, as Dominguez (1993) firstly indicated and Araújo (2004) also mentioned.

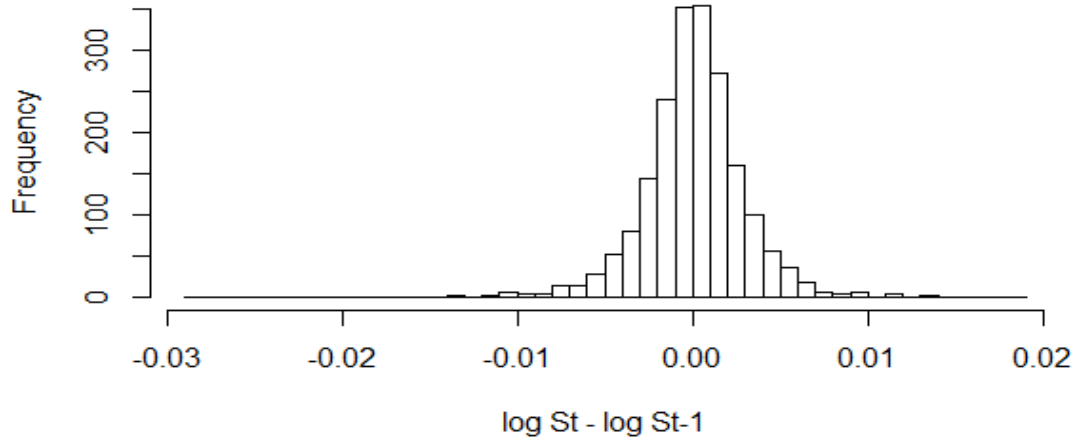

Figure 6 – Histogram of USD/BRL Exchange Rate Percentage Returns. Source: Bloomberg.

The evidence above, in addition to the existing literature that identifies and addresses the frequently observed heteroscedasticity in financial series data, motivates the search for an econometric approach capable of incorporating and addressing properly this feature in the present study.

5.4 A GARCH Model for the USD/BRL Exchange Rate

The adoption of a GARCH(1,1) model as the benchmark methodology in this work is explained not only by the theory regarding the applicability of the ARCH class of models on series with heteroscedasticity, but also by the availability of previous works in the literature that have already assessed impacts of FX interventions on exchange rate returns through similar methods, as demonstrated in chapter 3.

Among other specifications available in the ARCH class of processes, the choice is to work with a GARCH(1,1), and the first reason for this preference relates to the improvements it delivers in comparison to the original ARCH(q) processes. As shown in sections 5.1 and 5.2, the main advantage of a GARCH(1,1) over an ARCH(q) is the provision of a more parsimonious description in situations that would require many temporal lags if only ARCH components were available, point broadly discussed by Bollerslev (1986). In order to demonstrate empirically the improvements provided by GARCH models, the author applies an ARCH(8) and a GARCH(1,1) to an approach proposed earlier by Engle and Kraft (1983) and shows that the GARCH(1,1), besides providing a better fit than the ARCH(8) model, also exhibits a more appropriate and reasonable lag structure.

One could argue in favour of specifying a model capable of accounting for leverage effects in financial series data. As briefly mentioned in section 5.2, one of the models frequently used for it is the EGARCH(p, q) developed by Nelson (1991). As suggested by Black (1976), the leverage effect frequently noted in stock markets causes a reduction in the equity value to raise the debt-to-equity ratio, hence increasing the riskiness of the asset and, consequently, its future volatility. In other words, due to the leverage effect, future volatility is negatively related to the current return on the stock, and the linear GARCH might not be able to capture this pattern because it models conditional variance as a function of past conditional variances and squared innovations, i.e., the sign of innovations plays no role in affecting the volatility. Then, in cases when leverage is present, it is possible to point a limitation of the standard GARCH formulation, and it serves as one of the primary motivations for the use of EGARCH models, which characterize volatility as depending not only on the magnitude of the past surprises in returns but also on their corresponding signs.

Although leverage effect is indeed a frequent issue when modelling the conditional variance of stock returns series, resulting in some degree of asymmetry, it does not seem to represent a relevant concern in cases of exchange rates. Bollerslev et al. (1992) clearly affirm that the two-sided nature of the foreign exchange market tends to avoid leverage effects and makes such asymmetries less likely. Consequently, the plain GARCH(p, q) appears to be a proper model for handling with the USD/BRL returns data of this work.

Among several empirical studies about impacts of official foreign exchange interventions on exchange rates, the work of Kohlscheen and Andrade (2014) is elected as the main reference for the econometric specification of the present dissertation. Since their paper addresses Brazilian case in a relatively recent framework, some variables are still appropriate and relevant for the analysis with 2017-2018 data, therefore being used in the present approach. Moreover, the benchmark methodology used by them is a parsimonious GARCH(1,1), considered suitable for the present analysis due to reasons mentioned above.

The econometric specification that underlies the estimation of the benchmark model in the present study is the following GARCH(1,1)

$$\begin{aligned}\Delta S_t = \alpha + \sum_{i=1}^{I} \beta_i \Delta S_{t-i} + \sum_{j=0}^{J} \gamma_j New_{t-j} + \sum_{k=0}^{K} \delta_k Roll_{t-k} + \sum_{l=0}^{L} \eta_l Repo_{t-l} \\ + \theta \Delta v_t + \lambda \Delta c_t + \sum_{m=0}^{M} \xi_m M_{t-m} + \sum_{n=0}^{N} \psi_n P_{t-n} + \sum_{p=1}^{P} \phi_p \epsilon_{t-p} + \epsilon_t\end{aligned} \tag{5.13}$$

$$\sigma_t^2 = \omega + \rho \sigma_{t-1}^2 + \zeta \epsilon_{t-1}^2 \tag{5.14}$$

where (5.13) is the equation for the mean and (5.14) is the conditional variance equation.

In the mean equation,

- S represents the log of the spot USD/BRL exchange rate;
- α is a constant that may capture any eventual long-run trend;
- New is a variable that indicates the announcement of new traditional currency swap contracts auctions, in US$ billions. A similar variable is not included for new reverse swap contracts operations since none was observed during the considered period;
- *Roll* is a variable indicating the announcement of rolling traditional currency swap contracts auctions, in US$ billions. A similar variable is not included for rolling reverse swap contracts operations since none was observed during the considered period;
- *Repo* represents repo USD sales (spot sale transaction with a future repurchase agreement), in US$ billions;
- v is the log of CBOE Volatility Index (VIX);
- c stands for the log of Bloomberg Commodity Index (BCOM);
- M stands for a vector of standardized "surprise" results for macroeconomic indicators announcements from Brazil and United States: PIB, IPCA, IBC-Br, GDP and CPI Core;
- P is a dummy variable that takes the value of 1 when Ibope or Datafolha polls results for Brazilian presidential elections are released; otherwise, the variable assumes the value of 0;
- ϵ is the residual.

One important point is that the specification allows the announcements of currency swap auctions, repo USD sales operations, news regarding macroeconomic indicators in Brazil and United States and releases of Brazilian presidential elections polls to impact the exchange rate with time lags.

In the conditional variance equation,

- σ^2 stands for the conditional variance of ϵ;
- ω is the intercept;
- ϵ^2 represents the squared residuals (from the mean equation).

Emphasis must be given to the fact that the conditional variance is a time-dependent variable, and the one-lagged terms of conditional variance and squared residuals in the conditional variance equation characterize the benchmark specification as a GARCH(1,1).

5.5 GARCH(1,1) Estimation Results

The goal of this work is to assess the impact of traditional swap contracts auctions announcements by the BCB on the USD/BRL exchange rate return, and this will be made through the estimation of parameters γ and δ in the proposed model. An impact of traditional swap operations (of either new or rolling contracts) in the sense of reducing the USD/BRL requires that their respective parameters estimates have negative signs. The statistical significance of the estimated coefficients will be assessed through significance tests that will also be presented in this section.

The benchmark GARCH(1,1) model is estimated by Maximum Likelihood, following the procedures specified by Engle (1982) and Bollerslev (1986). A student-t distribution is assumed for the error terms, based on evidence from several works in the literature. Hsieh (1988) estimates an ARCH model for five different currencies and realises that standardized residuals for all of them were non-normal, even though they had less kurtosis than the raw data, what pointed to the fact that time-varying variance was not enough to account for all the leptokurtosis in exchange rate changes. In a subsequent research, Hsieh (1989) finds that other distributions fit standardized residuals from ARCH and GARCH models better than standard normal density. Following a similar idea, Baillie and Bollerslev (1989) find that, when accounting for ARCH effects in foreign exchange rates returns, the improper assumption of conditional normality can be successfully replaced by the assumption of t-distributed errors. Once again, it is emphasized by Dominguez (1993) that the GARCH(1,1) with a conditional student-t distribution is the most appropriate model for daily exchange rate data, instead of a normal distribution for error terms. The Adjusted Pearson Goodness-Of-Fit Test applied to model estimation results in the present work confirms the great performance provided by the student-t distribution assumption, as displayed in Table 2.

The decision for including a time series ARMA(1,1) process in the mean equation of the model was based on the identification of autocorrelation on standardized residuals of the mean equation estimated by Ordinary Least Squares, requiring procedures to eliminate it. The presence of autocorrelation was noticed through the Portmanteau tests (Box-Pierce and Ljung–Box), whose Q-statistics were 6.77 and 6.78 respectively, both significant at 5%. These indicated rejection of the null of independence standardized residuals of the regression, but the inclusion of AR(1) and MA(1) terms was enough for accounting for the mentioned autocorrelation. Also, the ARMA(1,1) presented the value of -17365.9 for Akaike Information Criterion (AIC), the lowest one among models whose ARMA orders differed: AR(1), AR(2), MA(1) and MA(2). When applying the same Box-Pierce and Ljung–Box tests for autocorrelation in the standardized residuals of the new mean equation containing ARMA(1,1) terms, both statistics indicated the non-rejection of the null hypothesis of independence.

Before estimating the GARCH(1,1), the presence of heteroscedasticity in the residuals of the model containing the ARMA(1,1) terms and the other regressors was confirmed. Both the Portmanteau (Box–Pierce and Ljung–Box) and the Lagrange Multiplier tests for the null hypothesis that the squared residuals of the model are not autocorrelated indicated rejection of the null and the presence of heteroscedasticity, with significance of 1%. Additionally, the kurtosis and skewness measures for the residuals were obtained, presenting values of 10.6 and -0.48 respectively.

Proceeding with the estimation of GARCH(1,1), whose results will be exposed below, the effectiveness of the benchmark model in dealing with autocorrelation in squared residuals was confirmed through the weighted Ljung-Box test on standardized squared residuals, whose Q-statistic calculated for the eighth lag was of 1.84 (not significant). For inferior lags it was never found to be significant as well, so the results lead to the acceptance of the null hypothesis of independence of squared residuals. Also, the weighted Li-Mak test attested the adequately fitted ARCH process with the non-rejection of the null hypothesis, showing the capability of the model of accomplishing its purpose of dealing with heteroscedasticity.

The measure calculated for kurtosis in standardized residuals of the GARCH(1,1) was of 7.81, proving that the model was able to capture some of the excess kurtosis that had been observed in residuals of ARMA(1,1) model estimation. The remaining excess is in line with the assumption of a student-t distribution for error terms, based on literature discussed above. The measure of -0.17 for skewness shows that the estimated model could account for most part of the skewness observed previously (which was already relatively low), regarding that the minor amount describes an approximately symmetric distribution.

The Table 2 presents a summary of important statistics calculated for the benchmark GARCH(1,1). It displays results for log likelihood obtained in the estimation, statistics that attest the non autocorrelation of standardized residuals and squared standardized residuals, and the Adjusted Pearson Goodness-of-Fit test for student-t, which proves the adequacy of the distribution assumption for the error terms. All the information presented is important for validating the effectiveness and appropriateness of the elected GARCH(1,1) specification.

Table 2 – Statistics for Benchmark GARCH(1,1) Model

	Statistic	p-value
Log Likelihood	$l(\theta, y) = 9003.756$	
Weighted Ljung-Box on Standardized Residuals	$Q(8) = 1.691$	0.9903
Weighted Ljung-Box on Squared Standardized Residuals	$Q(8) = 1.8446$	0.8821
Weighted Li-Mak on Autocorrelations	$Q(8) = 2.4163$	0.7263
Adjusted Pearson Goodness-of-Fit - Student-t with 50 bins	$\chi^2 = 52.68$	0.3338

In accordance to the specification of equation (5.13), it is determined that the benchmark GARCH(1,1) model includes as explanatory variables, besides the new and rolling traditional swaps auctions announcements, the terms for ARMA(1,1), returns on VIX and Commodity indexes, elections polls results releases, repo USD sales operations and surprise results for economic indicators of Brazil and United States announcements. Taking into account all these regressors and their lagged components, there is a total of 27 explanatory variables in the benchmark specification, besides the intercept. The Table 3 displays all the parameter estimates.

The choice of periods considered when evaluating impacts of swaps announcements, both for new and rolling contracts, is of two lags after the event and one lead intervention variable, besides the impact observed at the same time window of the event itself, t, resulting in a total of four hours of impact assessment. The choice for including one lead variable is made in light of a point raised by Kohlscheen and Andrade (2013), who affirm that even when working with intraday data - which normally tends to diminish the risk of simultaneity bias - a possibility exists that, in discretionary intervention regimes, currency swap auctions are a consequence rather than the cause of exchange rate movements. The authors state that a possible indication for this pattern could exist if coefficients leading closely the time of auctions announcements were actually positive signed, revealing an attempt from the BCB to revert an exchange rate depreciation movement.

Following with lag choices considerations, as repo USD sales by the BCB also represent a sort of foreign exchange market intervention, the variable is also allowed to impact the exchange rate in two lags besides t. In the case of VIX and Commodity indexes returns series, the impact on the explained variable is assessed at t only. For all other variables included in the model, the decision is to include only one lag besides t for possible effects on USD/BRL exchange rate returns.

Among important results that deserve attention in the analysis, it is noticed that some variables that had already shown to be significant by Kohlscheen and Andrade (2014) appear, again, as important explanatory variables of the USD/BRL returns at intraday frequency.

Firstly considering the ARMA(1,1) terms, the one-lagged USD/BRL returns variable is significant at 1% and negatively signed, indicating a mean-reverting pattern for exchange rate variation observed also in the work of Kohlscheen and Andrade. The parameter for lagged residuals, on the other hand, is positive signed, but also significant at 1% confidence level.

The VIX returns variable, in line with the results presented by Kohlscheen (2014a) and Kohlscheen and Andrade (2014), is significant at 1% confidence level and, importantly, the estimate for the parameter presents the expected positive sign, reflecting depreciating effects on Brazilian exchange rate caused by global risk increases.

Table 3 – Parameter Estimates of the Benchmark GARCH(1,1) Mean Equation

Dependent variable: $logS_t - logS_{t-1}$, where S is USD/BRL rate

Explanatory variable	t value	Estimate
$logS_{t-1} - logS_{t-2}$	-3.906996	-0.699954**
Residual t-1	3.375120	0.659581**
$logVIX_t - logVIX_{t-1}$	7.750673	0.011888**
$logBCOM_t - logBCOM_{t-1}$	-10.392400	-0.319786**
New Traditional Swap t+1	-0.148815	-0.000061
New Traditional Swap t	-3.204427	-0.001477**
New Traditional Swap t-1	1.705621	0.000630
New Traditional Swap t-2	1.540100	0.000624
Rolling Traditional Swap t+1	0.087334	0.000031
Rolling Traditional Swap t	-0.516229	-0.000255
Rolling Traditional Swap t-1	1.705137	0.000735
Rolling Traditional Swap t-2	-1.293131	-0.000526
Elections polls t	-3.002523	-0.002816**
Elections polls t-1	-0.042773	-0.000031
IPCA news t	1.046091	0.000912
IPCA news t-1	-0.726950	-0.000553
PIB news t	-1.504321	-0.001486
PIB news t-1	-0.000219	-0.204473
IBC-Br news t	-0.500080	-0.000470
IBC-Br news t-1	-2.199783	-0.001899*
GDP news t	-1.091346	-0.001716
GDP news t-1	0.611371	0.000632
CPI Core news t	4.007867	0.003746**
CPI Core news t-1	-0.362532	-0.000436
Repo USD Transaction t	-1.383648	-0.000439
Repo USD Transaction t-1	2.472817	0.000719*
Repo USD Transaction t-2	-3.099355	-0.000862**
Intercept	2.110010	0.000119*

Note: * and ** denote statistical significance at 5% and 1% confidence levels, respectively. The sample covers data from 11/30/2017 to 10/18/2018.

As expected from the significance observed for the Commodity Research Bureau index by Kohlscheen and Andrade (2014), the Bloomberg Commodity index coefficient included in the model of the present work is shown to be a meaningful regressor, statistically significant at 1% level and with the expected negative sign. The channel through which the index affects negatively returns on the USD/BRL is strongly explained by the impacts that commodities prices usually have on the balance of trade of Brazil, a framework in which higher prices lead to an appreciation of the BRL due to Brazil's role as an important commodities exporter.

It is essential to highlight that both VIX and Bloomberg Commodity indexes are

incorporated in the model in terms of their percentage returns, so that their parameter estimates reveal effects of a 1% variation in the indexes on the exchange rate return, also in percentage points. Therefore, an increase of 1% in VIX impacts the USD/BRL rate in about 0.012%, while an increase of 1% in the Commodity index causes a variation of -0.32% in the exchange rate. Another point to mention is that these two variables do not raise any reverse causality issue in the model, since they are global control variables for which effects caused by the USD/BRL returns would be unlikely.

Regarding the macroeconomic news surprise variables in United States, the only one for which significance is verified is CPI Core. The estimated significant impact (at 1% confidence level) of the inflation indicator on the USD/BRL exchange rate returns stands at time t. It is interesting to observe that the parameter estimate sign is positive, leading to the perception that when the announced figure is greater than market previous expectations, there is a depreciation of the BRL or an appreciation of the USD. In this case, it makes more sense that the US inflation index announcement causes an appreciation of the USD. Even though it seems controversial that a higher than expected inflation causes the appreciation of a country's currency, perhaps it may be justifiable in the context of the United States: the country had been facing a long period of low inflation, which kept below the FED's target of 2% for several months, what even turned to be a concern for authorities at certain point. Even though in 2017 and 2018 a slight increase in inflation levels in American economy was observed, perhaps markets were still well-responsive to slightly higher than expected inflation results.

An impact of surprises concerning the IBC-Br index announcements in Brazil, with one lag, is found significant at 5% confidence level. The negative sign for the parameter estimate follows the expectation: a higher value for the announced figure, in comparison to market previous expectation, impacts the USD/BRL rate negatively, revealing the appreciation of the BRL. This is in line to what is expected for the coefficient, since the IBC-Br is a key indicator for Brazilian economic activity performance, anticipating PIB results. Then, announcements of higher than expected figures usually surprise markets positively and lead to an appreciation of the currency.

A quite interesting result is noticed for the effects of elections polls news on the exchange rate. The 1% significance calculated for the parameter at t confirms the hypothesis that this can be a remarkable factor affecting exchange rates during presidential sweepstakes in a country, as was the context in Brazil during the period covered in the sample. Since candidates diverge in government plans and markets might react distinctly in face of one or other candidate's performance in polls, it makes sense that the exchange rate is impacted. The negative sign for the parameter estimate indicates that the release of Ibope and Datafolha polls results during the period had an appreciating overall impact of 28 bps (-0.28%) on the exchange rate.

Significant parameters were also estimated for repo USD sales operations taken by BCB, at lags $t-1$ and $t-2$. However, both estimated coefficients show effects of small magnitude, of the order of less than 10 bps for each US$ 1 bi sold in the operations. Also, the sign for coefficients differ between lags considered, what leads to the perception that this type of intervention on foreign exchange markets did not have a remarkable or conclusive overall impact on the exchange rate during the sampling period.

Directing now the analysis to the impacts caused by the main variables of interest in the present work: the announcements of new and rolling traditional currency swap contracts auctions by the BCB. Due to the fact that, in the sampling period considered in this work, the occurrence of reverse swap contracts offerings was not observed, a separate assessment of the possibly distinct effects for traditional and reverse contracts is not possible. Alternatively, the approach used in this work involves the split of traditional swap contracts into new and rolling types as a manner of checking whether impacts on the exchange rate differ, and also of providing a more detailed analysis of the traditional swap contract sort, the prevailing FX intervention instrument in Brazil during the last years.

Results displayed in Table 3 indicate that effects of new and rolling traditional swap contracts diverge considerably. While parameter estimates for the rolling type do not present statistical significance, neither at t nor at the two lags, the coefficient for new traditional contracts at time t is found significant at 1% confidence level and presents the magnitude of -0.001477. In other words, for each US$ 1 bi announced by the BCB in new traditional currency swap contracts, a decrease of approximately 15 bps (-0.15%) is observed on USD/BRL at time t - computed at the end of the same hourly length of time in which the announcement happened. It is important to highlight that, while analyses that use higher frequency data point also for significant lagged effects, such as the one by Kohlscheen and Andrade (2014) that uses data with a 15 minutes frequency, the fact that significant effects restrict to time t in the estimation of the present work is in line with expectations, since hourly frequency data is used. Additionally, it shall be mentioned that no significant estimates were found for possible lead effects (at $t+1$), neither for rolling nor for new contracts, what contributes to ruling out the chance of simultaneity bias. The possibility of existence of endogeneity issues will be further addressed in section 5.7.

The impact in fact estimated for new contracts announcements may be due to possible surprise effects they can cause in markets. As observed from information regarding all currency swaps auctions realized in the sampling period, the magnitude of the BCB liability position in FX relative to these operations kept unaltered from December of 2017 until April of 2018, and increased substantially over the following months. Observing the Brazilian scenario at that time, the increase was in line with the BCB acting in foreign exchange markets as a manner of providing liquidity and contributing to foreign exchange

markets proper functioning, in a context of instabilities due to oscillating expectations for the economic and political situation. In this framework, it seems logical that an increase in the BCB liability position would require that existing swap contracts were rolled, fact that may have been assimilated by markets and expected for contracts due to mature. However, even though agents probably expected that new contracts auctions were eventually announced, the timing for these events may have been a surprise factor, perhaps contributing for a concrete appreciation effect of new contracts on exchange rate returns. Related to this point, Nogueira (2014) also shows that more unexpected interventions indeed have more potential for impacting the exchange rate.

All in all, a significant effect of new traditional swap contracts offerings announcements is found on the USD/BRL returns. It is a short-term impact, computed significant only at time t, meaning that they do appreciate the BRL during the first hour following the announcement, but no additional effects are observed in the next periods. Moreover, the effect presents a considerably small magnitude, but in line with evidence already presented by the literature. Actually, previous analyses pointed to results that vary somewhat, as already exposed in chapter 3; for instance, Vervloet (2010) finds no significant effects for traditional swap contracts, while Kohlscheen and Andrade (2014) find an accumulated effect of -70 bps in around 90 minutes. Anyway, after an overall literature review, it is possible to affirm that the result found in the present work seems reasonable and credible.

The Table 4 shows the parameter estimates for conditional variance equation of the benchmark GARCH(1,1). In the estimation, the variance targeting specification is applied, as referred by Engle and Mezrich (1996) and addressed by Ghalanos (2014). This is an estimation technique that replaces the intercept ω in the conditional variance equation by 1 minus the persistence multiplied by the unconditional variance of ϵ, which is consistently estimated by its sample counterpart at every iteration of the solver following the mean equation filtration, as defines Ghalanos (2014). Applying variance targeting in the benchmark model, the ω is replaced by

$$\overline{\sigma^2}(1 - \alpha - \beta) \tag{5.15}$$

where $\overline{\sigma^2}$ is the unconditional variance of ϵ, and α and β are GARCH(1,1) conditional variance equation parameters. The persistence is given by $P = \alpha + \beta$.

All in all, variance targeting is the act of specifying the asymptotic variance, assumed as the unconditional variance, in order not to have to estimate ω. The usual result of variance targeting is that the optimization is quicker, and for some optimizers more likely to be near the global optimum. As ω is not estimated in this case, the use of variance targeting technique justifies the absence of the statistic t for the intercept in Table 4.

Table 4 – Parameter Estimates of GARCH(1,1) Conditional Variance Equation

Dependent variable: Conditional Variance at t		
Explanatory variable	t value	Estimate
Conditional variance $t-1$	34.571962	0.9**
Squared residuals $t-1$	7.606632	0.05**
Intercept	-	4.44e-07**

Note: ** denotes statistical significance at 1% confidence level.

The results presented in Table 4 attest that all the parameter estimates in the conditional variance equation are positive signed and found to be significant at 1% confidence level. Therefore, previous interval conditional variance affects the present conditional variance positively, and larger absolute residuals at $t-1$ increase the conditional variance at t as well.

5.6 Robustness Checks

A variety of checks should be conducted in order to assure that results found for the effects of currency swap contracts announcements on the USD/BRL returns with the benchmark GARCH(1,1) are indeed robust. Therefore, some changes are made in the model in the following aspects: imposing alternative error distributions, adopting less parsimonious GARCH specifications, removing Brazil and US economic indicators surprises variables from the model, including more lags to swap auctions announcements effects, removing lead variables for them and removing variance targeting specification. The Table 5 summarizes the new parameter estimates obtained for all these model variations and confirms that the results previously found, in terms of significance and magnitude, do not present any important change. Only significant coefficients are displayed, but, importantly, they are exactly the same significant parameters found in the benchmark model estimation.

Firstly, the model was re-estimated with different distributions for the error terms. When both normal and skew-student-t distribution were assumed, the pattern of the coefficient estimates resembled the one previously reported in Table 3. For swaps auctions announcements (new and rolling contracts), at all periods, the estimates remained of similar magnitude (with maximum difference of the order of 1 bp), and the coefficient for new swap contracts announcements variable at time t remained as the only significant among them. However, the overall fit of the model became worse, since the AIC increased from -9.0634 in benchmark model to -8.8652 when a normal distribution was imposed and to -9.0621 when a skew-student-t distribution was adopted for error terms, confirming the proper choice of a student-t distribution for the benchmark specification.

As a second part of robustness checks, the GARCH order was modified with the aim of considering less parsimonious models. For GARCH(2,1) and GARCH(1,2) specifications, it was verified that an increase in the order did not change the results in any significant way. Again, estimates for swaps auctions announcements, at all periods, remained similar to the ones in GARCH(1,1), differing not more than 1 bp. The order increases also did not change the fact that the parameter estimate for new contracts effects at time t is the only significant among swaps auctions announcements variables.

Another procedure applied as a robustness check was removing Brazil and US economic indicators surprise variables from the model for a further re-estimation. In this case, the coefficient for new contracts at t kept almost the same as in benchmark specification (from -0.001477 to -0.001478). The issue of significance of all parameters remained unaltered as well.

Additionally, the inclusion of two extra lags when accounting for swaps announcements effects (for both rolling and new contracts) was made. One more time, it was found that the pattern of coefficients properly resembled the one for the benchmark model. The difference in the estimate for new contracts parameter at t was only slightly higher than 1 bp, what still consists of a minimal amount.

Lead variables considered for new and rolling swap contracts announcements impacts on USD/BRL rate were excluded, as these variables were not significant in the benchmark model and in any of the models estimated for robustness checks. The specification estimation results, again, enhance the robustness of the estimates found in the benchmark model.

Finally, when imposing the absence of variance targeting in the Maximum Likelihood estimation, results again resembled the benchmark estimation quite well. In the coefficient for new swap contracts announcements at t, there was a difference of slightly more than 1 bp. The AIC fell very little, from to -9.0634 to -9.0723, but the benchmark model performed better in the Weighted Ljung-Box Test on Standardized Squared Residuals ($Q(8) = 1.8446$ with p-value of 0.8821 in benchmark model, against $Q(8) = 9.0765$ with p-value of 0.05572 with no variance targeting), reason for what it was decided to keep the specification of variance targeting in the benchmark model.

Table 5 – Robustness Checks - Parameter Estimates for Model Variations

Dependent variable: $logS_t - logS_{t-1}$, where S is USD/BRL rate

Variable	1	2	3	4	5	6	7	8	9
$d\ logS_{t-1}$	-0.699954**	-0.699954**	-0.699953**	-0.699953**	-0.699954**	-0.715690**	-0.654042	-0.699794**	-0.678003*
Residual t-1	0.659581**	0.659581*	0.659581**	0.659582**	0.659581**	0.679305**	0.636268	0.659181**	0.659681
$d\ logVIX_t$	0.011888**	0.012578**	0.011921**	0.011902**	0.011943**	0.012557**	0.011910**	0.012032**	0.011700**
$d\ logBCOM_t$	-0.319786**	-0.319848**	-0.319782**	-0.319758**	-0.319793**	-0.315358**	-0.309137**	-0.313385**	-0.315496**
New Trad Swap t	-0.001477**	-0.001425**	-0.001385**	-0.001522**	-0.001402**	-0.001478**	-0.001584**	-0.001346**	-0.001600**
Elections polls t	-0.002816**	-0.002200**	-0.002836**	-0.002836**	-0.002899**	-0.003744**	-0.003035**	-0.002853**	-0.003035**
IBC-Br news t-1	-0.001899*	-0.001685*	-0.001917*	-0.001913*	-0.001894*	-	-0.001840*	-0.001929*	-0.001863*
CPI Core news t	0.003746**	0.003658**	0.003732**	0.003732**	0.003848**	-	0.003985**	0.003719**	0.004100**
Repo USD t-1	0.000719*	0.000758*	0.000713*	0.000695*	0.000730*	0.000714*	0.000788*	0.000706*	0.000812*
Repo USD t-2	-0.000862**	-0.000761*	-0.000977**	-0.000896**	-0.000870**	-0.000852**	-0.000887**	-0.000957**	-0.000887**

Note: * and ** denote statistical significance at 5% and 1% confidence levels, respectively. Only significant coefficients are displayed. The models considered are the following: (1) Benchmark; (2) Normal distribution for error terms; (3) Skew-student-t distribution for error terms; (4) GARCH(2,1); (5) GARCH(1,2); (6) No indicator surprise variables; (7) Two additional lags for swaps; (8) No lead variables for swaps; and (9) No variance targeting

5.7 Endogeneity Issues

In the literature that assesses impacts of central banks' FX interventions on exchange rates, authors often make considerations regarding the possibility of endogeneity problems related to simultaneity bias, in which interventions could be both cause and consequence of exchange rate variations. In the previous sessions, impacts of interventions on the variation of the USD/BRL exchange rate were estimated, but it was not accounted the possibility that the interventions, regressors in the GARCH model, could also be determined by the exchange rate returns, configuring a scenario in which the BCB would be reacting to devaluation movements of exchange rate.

The first issue to consider would be the existence of a contemporaneous effect of exchange rate returns on the BCB decisions to intervene in FX markets. According to Neely (2005), daily event studies usually face this problem and many researchers deal with it by using an instrumental-variables procedure, estimating the model through two-stage least squares (2SLS). However, this strategy would require instruments that are reliably correlated with interventions but not with exchange rate returns, and such instruments are difficult to find.

Conveniently, the present study makes use of hourly data, which reduces considerably the risk of contemporaneous simultaneity. Neely recognises that an important advantage of intraday studies is that they facilitate avoiding contemporaneous simultaneity under two assumptions: the timing of intervention is measured precisely enough and the decision interval of the central bank is of lower frequency than the data frequency used for the estimation. When these assumptions are valid, it is unlikely the existence of contemporaneous impact of exchange rates on intervention. In the present work, information on the timing of the announcements of swaps auctions by the BCB was accurately collected in releases available in the website of the institution. Furthermore, it is quite unlikely that the BCB decides to intervene in FX market through currency swaps auctions within one hour frequency. A considerable part of the auctions in the sample was announced at 6:30 pm of the day before the event, in which case contemporaneous impacts on the exchange rate were computed in the first hour period of the following day, so the possibility that the exchange rate return has determined the announcement does not exist. Even though there are auctions announced at various times during the day, an announcement in reaction to the exchange rate behaviour at contemporaneous hour period would consist of a highly, and unlikely, short-run policy decision. Therefore, the present analysis appears to meet the requirements for reducing considerably the risk of contemporaneous simultaneity bias.

Nevertheless, intervention can be correlated with recent exchange rate movements, even at the intraday frequency. Hence, as a precautionary measure for validating the results, proper procedures are applied in order to deal with the possibility that, in dis-

cretionary intervention regimes as the one adopted by the BCB during the period in question, currency swap auctions are also a consequence of lagged intraday exchange rate movements. To allow for this possibility, the choice is to use an approach similar to the ones used by Fatum, Pedersen, and Sørensen (2013), Kohlscheen and Andrade (2013) and Dominguez, Fatum, and Vacek (2013). Firstly, a reaction function of the Central Bank is estimated, with FX interventions explained by lagged exchange rate changes within one-day period (8 lags). Next, the residuals of the reaction function are used to replace the actual intervention variable in the GARCH(1,1) model for exchange rate returns. Taking this measure, it is ensured that any component of intervention that is predictable, or captured by the reaction function estimation, is not leading to a bias of the estimated effects on the exchange rate variation. The results of this exercise for both new and rolling swap contracts auctions announcements are shown in Table 6 and Table 7.

Table 6 – Estimated Reaction Function of the Central Bank - New Traditional Swap Contracts Auctions

Dependent variable: New Traditional Swaps (US$ bi)		
Explanatory variable	t value	Estimate
$logS_{t-1} - logS_{t-2}$	-0.2469	-0.9409658
$logS_{t-2} - logS_{t-3}$	0.6278	0.8124446
$logS_{t-3} - logS_{t-4}$	-0.0866	-0.1682821
$logS_{t-4} - logS_{t-5}$	0.1112	0.2692253
$logS_{t-5} - logS_{t-6}$	2.1315	2.6725393*
$logS_{t-6} - logS_{t-7}$	-1.2826	-2.8623711
$logS_{t-7} - logS_{t-8}$	1.1546	2.6835016
$logS_{t-8} - logS_{t-9}$	0.9776	1.5658985
Intercept	5.3974	0.0251907**
Adjusted R-squared: 0.00338		
Wald test: F=1.187 Pr(>F)=0.3029		
Note: t-statistics based on HAC standard errors are reported. * and ** denote statistical significance at 5% and 1% confidence levels, respectively.		

In the case of new contracts announcements, in fact there is an indication, significant at 5% confidence level, that the Central Bank tends to carry out more contracts auctions after the USD/BRL increased, with an effect of US$2.67 bi in contracts for 1% variation in the exchange rate, occurring around five hours before the auction announcement (lag 5). It has to be noticed, however, that the low adjusted R2 (0.00338) and F (1.187) statistics indicate that the reaction function does not explain a significant portion of the BCB action.

For rolling contracts announcements, no significant parameter estimates for lagged exchange rate returns are found when the reaction function is estimated. Furthermore, the adjusted R2 statistics calculated shows a negative value of -0.0001361, what leads

to the conclusion that there are no effects to be accounted for regarding past exchange rate variations on the decisions of the Central Bank of intervening through rolling swap contracts.

Table 7 – Estimated Reaction Function of the Central Bank - Rolling Traditional Swap Contracts Auctions

Dependent variable: Rolling Traditional Swaps (US$ bi)		
Explanatory variable	t value	Estimate
$logS_{t-1} - logS_{t-2}$	1.6626	1.5974340
$logS_{t-2} - logS_{t-3}$	-1.0997	-1.8727184
$logS_{t-3} - logS_{t-4}$	0.4695	0.3800819
$logS_{t-4} - logS_{t-5}$	-0.0244	-0.0179605
$logS_{t-5} - logS_{t-6}$	-0.2187	-0.1774368
$logS_{t-6} - logS_{t-7}$	-0.7174	-0.5668873
$logS_{t-7} - logS_{t-8}$	-0.1599	-0.1196331
$logS_{t-8} - logS_{t-9}$	0.6975	0.6278035
Intercept	12.0983	0.0365286**
Adjusted R-squared: -0.0001361		
Wald test: F=0.6903 Pr(>F)=0.7005		
Note: t-statistics based on HAC standard errors are reported. ** denotes statistical significance at 1% confidence level.		

Taking into account the evidence from Table 6, suggesting the possibility of an endogeneity issue in the case of new contracts announcements - even though it appears to be quite small, according to statistics - the procedure taken now is to re-estimate the GARCH(1,1) model using the difference between the actual intervention amounts and the fitted intervention components estimated through a parsimonious reaction function. This includes the intercept and the fifth lag of the exchange rate variation, shown to be significant in Table 6.

In Table 8, the parameter estimates found to be significant in the GARCH(1,1) re-estimation exercise are displayed. It is clearly seen that results closely resemble the estimates of the benchmark GARCH(1,1) specification, in both significance and magnitude of parameters. The coefficients found significant here are exactly the same as the ones found significant in the benchmark specification, and values estimated differ very slightly. For the main variable of interest, the new traditional swap contracts auctions announcements at time t, a value of -0.001386 is found, which differs in less than 1 bp from the estimate of -0.001477 in the benchmark model, a negligible amount. This validates the results previously found and points to the fact that endogeneity does not represent a major concern in the proposed benchmark GARCH(1,1) model.

Table 8 – Parameter Estimates of the GARCH(1,1) Mean Equation (Accounting for a Reaction Function of the Central Bank)

Dependent variable: $logS_t - logS_{t-1}$, where S is USD/BRL rate

Explanatory variable	t value	Estimate
$logS_{t-1} - logS_{t-2}$	-3.936047	-0.700176**
Residual t-1	3.396697	0.659772**
$logVIX_t - logVIX_{t-1}$	7.781084	0.011921**
$logBCOM_t - logBCOM_{t-1}$	-10.389902	-0.319851**
New Traditional Swap t	-2.941319	-0.001386**
Elections polls t	-3.009759	-0.002823**
IBC-Br news t-1	-2.228921	-0.001918*
CPI Core news t	3.984299	0.003726**
Repo USD Transaction t-1	2.410232	0.000701*
Repo USD Transaction t-2	-3.460340	-0.000950**
Intercept	2.111991	0.000119*

Note: * and ** denote statistical significance at 5% and 1% confidence levels, respectively. Only significant coefficients are displayed.

6 Conclusion

The goal of this dissertation was to find out whether foreign exchange interventions through currency swaps, frequently used by the Central Bank of Brazil, have any impact on the USD/BRL exchange rate returns. In case they do, a second concern of this work was to reach results regarding the magnitude of the impact.

Firstly, this work discussed important features of sterilized foreign exchange interventions. Since FX swaps are instruments akin to sterilized interventions, as they do not directly alter the monetary base, the mechanism of impact on exchange rates is not as clear as in the cases of non-sterilized operations. However, it was shown that the literature has already identified three reasonable channels of influence for sterilized interventions: portfolio balance, signalling and coordination channels. Even though these channels are not directly tested in the present work, fundamentals of the BCB form of operating indicate an unlikelihood that interventions could function as means of signalling future monetary policy. On the other hand, evidence in the literature associated to currency risk premium variation in Brazil indicates that portfolio balance channel could be operating in future market interventions.

Several works in literature dedicated to study sterilized foreign exchange interventions were presented, with a special emphasis on their impacts on spot exchange rates. It was pointed that pioneer empirical studies assessed almost exclusively cases of developed economies; years later, the literature for emerging markets expanded considerably and, fortunately, studies for the Brazilian case have already provided great evidence as well. However, an overview of all these works indicates that there is not a consensus on the existence and magnitude of impacts of sterilized FX interventions on exchange rate returns, with results varying for different countries, periods, and through different methodologies of assessment.

The Central Bank of Brazil has historically used diverse manners for intervening, which have become more or less frequent over time, and currently the FX swaps consist of a key strategy used by the BCB. Even though other central banks also intervene through derivatives, the uniqueness of the instrument used in Brazil relies on the fact that the contracts are settled in domestic currency. Despite the disadvantage of sometimes involving some convertibility risk to agents (not in fact a concern in the current scenario of Brazil), these FX swaps are capable of providing the same hedging obtained by buying spot USD and keeping it until the maturity of the contract. At the same time, the BCB preserves foreign reserves even in moments of high amounts of exchange rate intervention.

The methodology used here was proven suitable in the literature for assessing

financial series data, which very often presents heteroscedasticity. Regarding FX interventions impacts on exchange rates studies specifically, GARCH models have proven to be an efficient econometric tool. The empirical assessment made here was based on a sampling period from 11/30/2017 to 10/18/2018, in hourly frequency. The choice of the period aimed to provide an analysis with data not used in the literature yet, covering important recent episodes of FX interventions through currency swaps by the BCB.

The results of impacts of FX swap contracts auctions announcements on the spot USD/BRL exchange rate were split into new and rolling traditional swap contracts, providing a more detailed and accurate analysis for the traditional type of contract. Reverse contracts of swaps were not included in the empirical analysis because occurrences of this form of intervention were not verified in the period. The impact found through the benchmark GARCH(1,1) model estimation was that, for each US$1 bi in new traditional swap contracts announced, a decrease of around 15 bps (-0.15%), significant at 1% level, occurred on the USD/BRL exchange rate at time t, i.e., in the same time window that the announcement was made. No significant effects were found for the subsequent lags. For the rolling swap contracts announcements, no significant effects were found at all. These results indicate an important difference regarding new and rolling contracts, as only the former showed capable of appreciating the BRL. Perhaps it happened due to a more surprising feature that new contracts had to agents, since rolling operations could be more expected when contracts were due to mature, specially in moments of instabilities in which the BCB was acting to provide liquidity and willing to increase the stock of FX swaps. The amounts and timing of new contracts announcements, on the other hand, probably were more unexpected to agents.

Regarding interventions through repo USD transactions, significant effects for two lags were found, but they had a magnitude of less than 9 bps (0.09%) and indicated effects in contrary directions. Therefore, very conclusive results cannot be established about their overall impact.

One quite interesting result in this work was found for the effects of presidential elections polls news on the exchange rate returns. The impact was of around -28 bps (-0.28%) at time t, significant at 1% level, indicating an appreciation effect on the BRL. An impact of magnitude even higher than the one estimated for new swaps announcements highlights how much expectations regarding Brazilian political scenario courses played an important role in the path of the exchange rate during the period analysed. Further studies assessing effects of elections expectations on exchange rate returns can be worthwhile.

The robustness of results for FX swaps impacts was verified through a series of tests that changed some specifications of the benchmark GARCH model: higher GARCH orders, lag variables addition, lead variables removal, error terms alternative distributions, removal of economic indicators surprises variables and removal of variance targeting spec-

ification. Results not only for new swap contracts announcements parameters estimates, but for coefficients of all regressors in the model resembled quite well the results obtained in the estimation of the benchmark GARCH(1,1) specification.

Moreover, it was addressed the possibility of endogeneity in the GARCH(1,1) model, in which exchange rate returns would not only be impacted by swaps announcements, but also have effects on the decision of the BCB of announcing intervention operations. Reaction functions for the interventions of the BCB with both new and rolling swaps contracts were estimated, including lagged exchange rate returns as regressors. For the rolling swaps announcements, no significant effects were found. For the new swaps, the exchange rate return at the fifth lag was found significant. Then, the difference between the actual amounts of new swaps and the values obtained through the estimation of the reaction function was calculated, and the GARCH(1,1) model was re-estimated in order to take account only of intervention operations that were not possibly determined by exchange rate previous returns. The results obtained were, one more time, very similar to the ones found in the benchmark model estimation. The possibility of a contemporaneous impact of exchange rate returns on swaps auctions announcements was considered unlikely, since the approach in this work uses hourly data, a frequency probably higher than the intervention decision frequency by the BCB.

The result of an appreciation impact of 15 bps, namely a variation of -0.15%, on the exchange rate for each US$1 bi offered in new swap contracts is in line with results previously obtained by the literature for Brazilian case. These results, not only for swaps, but also for other forms of FX interventions, vary among different analyses, ranging on most works from 10 bps to 50 bps of impact for each US$ 1 bi. Different data frequencies and specifications adopted in existing studies turn accurate comparisons more difficult, but, in general, evidence found does not indicate much higher impacts, and usually these impacts have a short duration. The absence of a consensus in the literature regarding FX interventions impacts makes it worth that updates are frequently provided, assessing new episodes and making different specifications according to data availability. The fact that the BCB adopts a unique form of intervening, the FX swaps that settle in domestic currency, makes the analysis of Brazilian case quite enriching for international literature on the area. Perhaps, if more central banks one day adopt a similar form of intervening, comparisons of impacts with the BCB's FX swaps interventions effects will certainly provide interesting unprecedented studies.

References

(n.d.).

Adler, G., & Tovar, C. E. (2011). Foreign exchange intervention: a shield against appreciation winds?

Andersen, T. G., Bollerslev, T., Diebold, F. X., & Vega, C. (2003). Micro effects of macro announcements: Real-time price discovery in foreign exchange. *American Economic Review*, *93*(1), 38–62.

Araújo, J. D. P. (2004). *Suavizando movimentos da taxa de câmbio ou adicionando volatilidade? um estudo empírico sobre intervenções do banco central no mercado de câmbio.* (Dissertação de Mestrado em Economia, Pontifícia Universidade Católica do Rio de Janeiro)

Baillie, R. T., & Bollerslev, T. (1989). The message in daily exchange rates: A conditional-variance tale. *Journal of Business & Economic Statistics*, *7*(3).

Bevilaqua, A., & Azevedo, R. (2005). Provision of fx hedge by the public sector: the brazilian experience. *BIS Papers*, *24*, 119–26.

Black, F. (1976). Studies in stock price volatility changes," proceedings of the american statistical association, business and economic statistics section, 177-181.(1986). *Noise," Journal of Finance*, *41*, 529–543.

Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. *Journal of econometrics*, *31*(3), 307–327.

Bollerslev, T., Chou, R. Y., & Kroner, K. F. (1992). Arch modeling in finance: a review of the theory and empirical evidence. *Journal of econometrics*, *52*(1-2), 5–59.

Box, G. E., & Jenkins, G. M. (1976). Time series analysis: Forecasting and control. In *Holden-day series in time series analysis.* Holden-Day.

Chamon, M., Garcia, M., & Souza, L. (2017). Fx interventions in brazil: a synthetic control approach. *Journal of International Economics*, *108*, 157–168.

Diógenes, F. C. (2007). *Efeitos sobre o câmbio das intervenções cambiais esterilizadas: o caso brasileiro de 2003 a 2006.* (Dissertação de Mestrado em Economia, Pontifícia Universidade Católica do Rio de Janeiro)

Domaç, I., & Mendoza, A. (2004). *Is there room for foreign exchange interventions under an inflation targeting framework? evidence from mexico and turkey.* The World Bank.

Dominguez, K. M. (1990). Market responses to coordinated central bank intervention. In *Carnegie-rochester conference series on public policy* (Vol. 32, pp. 121–163).

Dominguez, K. M. (1993). *Does central bank intervention increase the volatility of foreign exchange rates?* (Tech. Rep.). National Bureau of Economic Research.

Dominguez, K. M. (2003a). Foreign exchange intervention: did it work in the 1990s. *Dollar Overvaluation and the World Economy*, *16*, 217–245.

Dominguez, K. M. (2003b). The market microstructure of central bank intervention. *Journal of International economics*, *59*(1), 25–45.

Dominguez, K. M. (2009). Sterilization. In K. A. Reinert & R. S. Rajan (Eds.), *The Princeton Encyclopedia of the World Economy* (p. 1035-1038). Princeton: Princeton University Press.

Dominguez, K. M., Fatum, R., & Vacek, P. (2013). Do sales of foreign exchange reserves lead to currency appreciation? *Journal of Money, Credit and Banking*, *45*(5), 867–890.

Dominguez, K. M., & Frankel, J. (1990). *Does foreign exchange intervention matter? disentangling the portfolio and expectations effects for the mark* (Tech. Rep.). National

Bureau of Economic Research.
Dominguez, K. M., & Frankel, J. (1993a). Foreign exchange intervention: an empirical assessment. *On Exchange Rates*, 327–345.
Dominguez, K. M., & Frankel, J. (1993b). *Does foreign exchange intervention work?* (Vol. 83).
Engle, R. (1982). Autoregressive conditional heteroscedasticity with estimates of the variance of united kingdom inflation. *Econometrica: Journal of the Econometric Society*, 987–1007.
Engle, R. (2001). Garch 101: The use of arch/garch models in applied econometrics. *Journal of economic perspectives*, *15*(4), 157–168.
Engle, R., & Kraft, D. (1983). Multiperiod forecast error variances of inflation estimated from arch models. *Applied time series analysis of economic data*, 293–302.
Engle, R., & Mezrich, J. (1996). Garch for groups: A round-up of recent developments in garch techniques for estimating correlation. *Risk*, *9*, 36-40.
Fatum, R., Pedersen, J., & Sørensen, P. N. (2013). The intraday effects of central bank intervention on exchange rate spreads. *Journal of International Money and Finance*, *33*, 103–117.
Garcia, M., & Olivares, G. (2001). O prêmio de risco da taxa de câmbio no brasil durante o plano real. *Revista Brasileira de Economia*, *55*(2), 151–182.
Garcia, M., & Volpon, T. (2014). *Dndfs: a more efficient way to intervene in fx markets?* (Tech. Rep.). Texto para discussão.
García, P., & Soto, C. (2004). Large hoarding of international reserves: Are they worth it?
Ghalanos, A. (2014). rugarch: Univariate garch models. [Computer software manual]. (R package version 1.4-0.)
Guimarães, R. F., & Karacadag, C. (2004). The empirics of foreign exchange intervention in emerging market countries: The cases of mexico and turkey.
Hsieh, D. A. (1988). The statistical properties of daily foreign exchange rates: 1974–1983. *Journal of international economics*, *24*(1-2), 129–145.
Hsieh, D. A. (1989). Modeling heteroscedasticity in daily foreign-exchange rates. *Journal of Business & Economic Statistics*, *7*(3), 307–317.
Kamil, H. (2008). *Is central bank intervention effective under inflation targeting regimes? the case of colombia* (No. 8-88). International Monetary Fund.
Kaminsky, G. L., & Lewis, K. K. (1996). Does foreign exchange intervention signal future monetary policy? *Journal of Monetary Economics*, *37*(2), 285–312.
Kohlscheen, E. (2014a). The impact of monetary policy on the exchange rate: A high frequency exchange rate puzzle in emerging economies. *Journal of International Money and Finance*, *44*, 69–96.
Kohlscheen, E. (2014b). Long-run determinants of the brazilian real: A closer look at commodities. *International Journal of Finance & Economics*, *19*(4), 239–250.
Kohlscheen, E., & Andrade, S. C. (2013). *Official interventions through derivatives: affecting the demand for foreign exchange* (Tech. Rep.).
Kohlscheen, E., & Andrade, S. C. (2014). Official fx interventions through derivatives. *Journal of International Money and Finance*, *47*, 202–216.
Mandelbrot, B. (1963). The variation of certain speculative prices. *The Journal of Business*, *36*, 394–419.
Mauser, G. A., & Fitzsimmons, C. (1991). The short-term effect of election polls on foreign exchange rates: the 1988 canadian federal election. *Public Opinion Quarterly*, *55*(2), 232–240.

Menkhoff, L. (2013). Foreign exchange intervention in emerging markets: a survey of empirical studies. *The World Economy*, *36*(9), 1187–1208.

Mussa, M. (1981). *The role of official intervention*. Group of Thirty New York.

Neely, C. J. (2005). An analysis of recent studies of the effect of foreign exchange intervention.

Nelson, D. B. (1991). Conditional heteroskedasticity in asset returns: A new approach. *Econometrica: Journal of the Econometric Society*, 347–370.

Nogueira, L. R. (2014). *As intervenções do banco do central do brasil no mercado de câmbio e seus efeitos no nível intradiário da taxa de câmbio.*

Reitz, S., & Taylor, M. P. (2008). The coordination channel of foreign exchange intervention: A nonlinear microstructural analysis. *European Economic Review*, *52*(1), 55–76.

Rincón, H., & Toro, J. (2011). Are capital controls and central bank intervention effective?

Sarno, L., & Taylor, M. P. (2001). Official intervention in the foreign exchange market: is it effective and, if so, how does it work? *Journal of Economic Literature*, *39*(3), 839–868.

Stone, M. M. R., Walker, W. C., & Yasui, Y. (2009). *From lombard street to avenida paulista: foreign exchange liquidity easing in brazil in response to the global shock of 2008-09* (No. 9-259). International Monetary Fund.

Vervloet, W. T. d. F. (2010). *Efeitos de intervenções esterilizadas do banco central do brasil sobre a taxa de câmbio.* Rio de Janeiro. (Dissertação de Mestrado em Economia, Pontifícia Universidade Católica do Rio de Janeiro)

Westerfield, J. M. (1977). An examination of foreign exchange risk under fixed and floating rate regimes. *Journal of International Economics*, *7*(2), 181–200.