Empirical evidence of the compensation principle in the Brazilian economy: 1994 to 2011

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Abstract

The compensation principle extends the concepts of endogenous money and exogenous interest rate to the open economy analysis. Yet, even within post-Keynesians, it is rarely acknowledged as an essential feature for debating short-term interest rate setting. As a result, the search for empirical validity of the principle is still not extensive and only limited to a few economies. The debate about monetary policy of developing countries is especially implicated with the compensation principle considering that these countries accumulated substantially more foreign reserves than developed economies during the past decade. In order to subsidize this debate, we tested the validity of the compensation principle in the case of Brazil. Autoregressive distributed lags (ARDL) models were estimated and results suggest that the compensation principle was valid in Brazil, from 1994 to 1998 and from 2004 to 2011. Therefore, the results support the validity of the principle in different institutional arrangements and during an exchange crisis build up (1990s) and a "bonanza" period (2000s).

Keywords: compensation principle, endogenous money, open economy, exogenous interest rate, developing economies.

1 Introduction

The compensation principle[1] extends the concepts of endogenous money and exogenous interest rate to the open economy analysis, as it demonstrates that, regardless of exchange rate regime, foreign currency flows do not impose operational constraints on monetary authority's ability

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[1] Also known as the "compensation view" (Angrick, 2017), "compensation thesis" (Bozhinovska, 2015, Lavoie, 2001, 2014, Lavoie and Wang, 2012), or "Banque de France view" (Lavoie, 2014, p. 469). These terms are used interchangeably throughout the paper.

to set the short-term interest rate nor change the quantity of money in the economy.[2] While endogenous money (more than exogenous interest rate) has been a common feature to all different strands of post-Keynesianism,[3] relatively recently it has also been recognized by mainstream authors such as Woodford (2000, 2002) and Furfine (2000). Yet, even post-Keynesians, when debating monetary policy autonomy in the context of an open economy, rarely bring up the existence and/or acknowledge the consequences of the compensation principle for interest rate[4] setting. As a result, the search for empirical validity of the principle is still not extensive and only limited to a few economies.

This debate is especially relevant for developing economies, which have accumulated substantially more foreign reserves than developed economies during the past decade (Rodrik, 2006), making compensation a key principle to correctly understand monetary policy in these countries. Since external constraints are viewed as an important limitation for developing countries, a common argument known as "impossible duality" is that, in the context of financial globalization, these economies lack autonomy to conduct monetary policy, regardless of exchange rate regime, due to the external position of their currencies (de Paula et al., 2017, Prates, 2015, Palludeto and Abouchedid, 2016, Conti et al., 2014). By acknowledging the compensation principle, it is possible to offer an alternative perspective about monetary policy in developing economies and contribute to a more thorough debate grounded on essential features of post-Keynesianism.

In order to subsidize this debate, we built two empirical models to test the validity of the compensation principle in the case of Brazil, which is particularly interesting for examination. Firstly, most of the empirical literature investigating the validity of the compensation principle is directed to Asian emerging markets (Angrick, 2017, Lavoie and Wang, 2012), with exception of Bozhinovska (2015) who focuses on the Macedonian case. Hence, Brazil as the largest economy among Latin American commodity exporters, would add complementarily towards the argument of general validity of the compensation principle. Secondly, Brazil experimented distinct conditions regarding accumulation/loss of foreign reserves and also changes in institutional arrangements within the Central Bank (CB) during a relatively short (and recent) period of time. This allows us to build two models that test the validity of the principle in different institutional arrangements and during an exchange crisis build up (1990s) and a “bonanza” period (2000s).

The estimation strategy consists in identifying cointegration relationships among the variables through the estimation of autoregressive distributed lag models (ARDL) and the use of the bounds testing procedure (Pesaran and Shin, 1999, Pesaran et al., 2001). The existence of cointegration among the variables suggests that they share a long-run relationship, bespeaking a market mechanism in operation, rather than discretionary decisions by the CB.

[2] More precisely, the quantity of money is relative to high-powered money, or, bank reserve balances (hereafter, reserve balances) plus cash held by the public.
[3] We adopt a broad definition of post-Keynesianism, following Lavoie (2011).
[4] Hereafter, “interest rate” means the short-term interest rate targeted by the Central Bank.

The remaining of this paper is organized as follows. The next section contains a brief explanation of the compensation principle mechanism. The third section presents the Brazilian economy historical context and Central Bank of Brazil (CBB) institutional arrangements. The fourth section comprises the methodology and analysis of results. The fifth section attempts a first approximation to discuss the compensation principle as an alternative to the trilemma and impossible duality views.

2 The compensation principle

In the conventional view of open economies, based on the Mundell-Fleming framework, under assumption of perfect capital mobility and asset substitutability, a fixed exchange rate regime is considered to constrain the monetary authority's ability to set the interest rate. This constraint would stem from accumulation (loss) of foreign reserves by the CB to sterilize inflows (outflows) of foreign currency due to surpluses (deficits) in the balance of payments (Serrano and Summa, 2015). Sterilization would be mandatory for a CB willing to control the exchange rate, otherwise there would be an appreciation (depreciation) of the domestic currency.

To carry out sterilization, the CB has to purchase (sell) foreign currency in the exchange market through crediting (debiting) reserve balances in banks' accounts.[5] Therefore, when there is an inflow (outflow) of foreign currency, the reserve balances credited (debited) to banks' accounts would increase (decrease) the monetary base and, consequently, bid down (up) the interest rate. To put it simply, it would mean that the monetary base responds endogenously[6] to changes in the foreign reserves held by the CB (Lavoie, 2001).

The additional reserve balances, available for banks due to foreign currency inflows, would be employed through credit concession and multiplied in bank deposits creation.[7] Interest rate and the quantity of money in the economy, both would be changed by balance of payments disequilibria. If the CB not only wishes to sterilize the impact of foreign reserves accumulation on the exchange rate but also keep control over the money supply, it would engage in open market operations, *at its own initiative*, to sell government bonds and reduce the monetary base. It should be stressed that this is considered a discretionary decision by the CB to establish a quantitative target of monetary aggregates (Lavoie, 2001, 2014, Angrick, 2017).

That would not be the case of the economy operating a floating exchange rate regime. The CB is not forced to intervene[8] in the exchange market because it does not have a fixed parity to defend. As a result, balance of payments surpluses (deficits) would cause exchange

[5] Commonly, CBs prefer to hold interest yielding assets rather than foreign currency (which do not yield interest). Foreign currency purchased by the CB is mostly used to acquire interest yielding assets (most likely US Treasury securities).

[6] This is a supply-led endogeneity, different from the post-Keynesian demand-led endogeneity. For a more detailed discussion, see (Lavoie, 2006, 2014).

[7] This process assumes a stable "money multiplier" (Lavoie, 2001).

[8] Of course, most countries operate a managed floating regime, which means the CB occasionally buys or sells foreign currency to avoid undesired exchange rate fluctuations.

rate appreciation (depreciation) which would lead it back to equilibrium. In other words, the exchange rate flexibility would grant a self-adjusting characteristic for the balance of payments. Thus, if the CB does not intervene in exchange markets, foreign currency flows are not followed by credited or debited reserve balances in the banking system. Base money and interest rate are thus unaltered by balance of payments disequilibria.

Alternatively, the compensation principle implies that, even under a fixed exchange rate regime, the CB retains control over the interest rate and the money supply is endogenously demand-led determined. Indeed, defending a fixed parity requires that the CB accumulates foreign reserves when there is a balance of payments surplus, which in turn leads to crediting reserve balances at the banking system. However, at this point the compensation principle part ways with the Mundell-Fleming framework. The additional reserve balances do not cause banks to increase credit concession because "[i]n real world, banks extend credit, creating deposits in the process, and look for reserves later" (Wray, 2015, p. 88).

Effectively, banks accommodate creditworthy clients' demand for loans and the CB accommodates banks' demand for reserve balances, because it has an interest rate target and it has to ensure the soundness of the payment system. Hence, additional reserve balances created by exchange market interventions do not initiate a money multiplier process. Banks that end up with reserve balances created by the sterilization, will have already granted as many loans as creditworthy clients have solicited. Therefore, they will either use excessive reserve balances to buy back their interest-bearing liabilities owed to the CB [9] or buy interest yielding assets from the CB, depending on the institutional arrangement in place between private banks and the CB.[10]

It is at the private sector's initiative that the compensation principle unfolds. There is no reason *ceteris paribus* for banks to hold noninterest yielding assets (reserve balances) instead of reducing their interest-bearing debt or acquiring interest yielding assets (Fullwiler, 2006). As long as in the endogenous money approach the money multiplier is "simply an *ex post* ratio of reserves to deposits" (Wray, 2015, p. 104), if banks which had their accounts credited are too slow to buy government securities[11] or to repay their debt, the most likely consequence would be a falling leverage ratio for the banking sector, not a change in quantity of money in the economy (Serrano and Summa, 2015).

Inasmuch the CB sets an interest rate target and adopts a defensive position – being a residual buyer and seller of government securities and/or lending reserve balances as requested – there will be changes in its own balance sheet composition that compensates for the increased foreign reserves without concomitant increase of the monetary base. Such changes will occur through a market mechanism, regardless of CB taking the initiative to sell government securities,

[9] Albeit individual banks may decide to buy interest yielding assets held by private agents or repay their debt owed to private agents, this is not a possibility for the whole of the banking sector. For instance, buying a privately held bond will only exchange ownership of the bond and excessive reserve balances remain in the banking system, only in another bank's account.

[10] See (Lavoie, 2001, 2014) for more details about the classification between asset-based and overdraft economies.

[11] Government securities can be issued by the Treasury or the CB itself, depending on institutional arrangements in each case.

because the private sector will not hold noninterest yielding assets. If private agents repay their outstanding debt or buy Treasury securities from the CB, an increase in foreign reserves is compensated by a decrease in other CB's assets. Likewise, if the CB issues its own securities or provide repurchase agreements (hereafter, repos), an increase in foreign reserves is compensated by an increase in CB's liabilities other than the monetary base.

Similarly, a balance of payments deficit is compensated at the initiative of banks, that borrow from the CB, sell government securities or engage in reverse repos when reserve balances are drained by exchange market interventions. However, a distinction between surplus and deficit positions is necessary, especially in fixed exchange rate regimes. While surpluses do not find restrictions because they simply entail foreign reserve accumulation, persistent deficits, over time, deplete foreign reserves, thus, reducing CB's capacity to defend the fixed parity, at first, and eventually forcing the peg to be abandoned (Lavoie, 2001, Wray, 2006). In that case, compensation will only continue up to the point that CB still has foreign reserves.

3 Historical context and institutional arrangement

In Brazil, the 1990s and 2000s had opposite realities regarding the external sector and, especially, foreign currency flows. Additionally, the institutional arrangement within the CBB also went through important changes in the early 2000s. While the 1990s came to end with an exchange crisis, the 2000s were a "bonanza" period, with sizable accumulation of foreign reserves. Hence, a brief overview of foreign currency flows, foreign reserve accumulation/loss and changes in CBB's institutional arrangement throughout this period is in order to justify choices of variables and periods for the estimated models.

3.1 Historical context of the Brazilian economy and evolution of the foreign reserves

The Brazilian economy, during the 1980s, was characterized by high inflation and a severe external debt crisis. To cope with high inflation, numerous economic plans were attempted and successively failed to stabilize prices. The Mexican debt crisis, in 1982, represented for Brazil – and other emerging markets – the onset of deteriorating conditions to finance the external debt. Gradually, foreign currency inflows ceased and, eventually, turned to outflows. As a response, extra importance was placed on the result of the trade balance, which translated in pursuit of depreciated domestic currency and restrictions to import.[12]

The return of capital flows, in early 1990s, represented a key factor for the success of the price stabilization plan of 1994, known as the 'Real plan'. In July 1994, the final phase of implementation of the plan meant adopting an exchange rate pegged to the US dollar.

[12]Literature about the 1980s external debt crisis of developing economies is extensive. For more information, see Cruz et al. (1995), Serrano (1998) and French-Davis et al. (1994).

Evidently, this could only be done due to the return of foreign currency inflows which enabled foreign reserves to more than double between 1991 and 1992 (Serrano, 1998). Alongside price stabilization and appreciated domestic currency (relatively to the US dollar), there was growth recovery with a considerable increase of imports.

Under the pegged exchange rate, a substantial increase in current account deficits was observed. These deficits gradually depleted foreign reserves that were accumulated in the three previous years. To slowdown foreign reserve loss, the CBB used high interest rate to attract capital inflows and (most importantly) to elevate the cost of capital outflows (Lavoie, 2001). Complementarily, the government started a privatization plan that, among other motivations, had the explicit objective of attracting foreign direct investment (Barbosa-Filho, 2008). Even though the exchange rate was pegged, the CBB was still able to set the interest rate. Hence, it seems that monetary policy autonomy was more associated with the dynamic of the foreign reserves accumulation than with the exchange rate regime.[13] Throughout this period, the CBB sterilized practically all foreign currency flows to defend the exchange rate peg.

As of 1995 several crises occurred in different emerging markets, such as Mexico (1995), East and Southeast Asia (1997) and Russia (1998). The Asian and Russian crises increased the fragility of the Brazilian external position through a contagion effect which hampered CBB's capacity to sustain the peg. By the end of 1998, Brazil's current account deficit had reached 4.5% of gross domestic product (GDP) and the stock of foreign reserves was lower than the required to carry on defensive action by the CBB to sustain the peg. Inevitably, in the last semester of 1998, Brazil's own exchange crisis triggered an speculative attack against the domestic currency (Barbosa-Filho, 2008).[14]

In the aftermath of the exchange crisis, the CBB was forced to break the peg, adopting a managed floating regime, and implementing an inflation targeting regime as an expectations anchor to stabilize prices. Nonetheless, the CBB still sterilized a considerable amount of the foreign currency flows. Thus, it is feasible that the compensation principle had a role, which would not be the case of a free floating regime. Even after a floating exchange regime was in place, the CBB carried out exchange market interventions that would have affected considerably the liquidity of the domestic banking system had the compensation principle not been valid.

After the burst of the dot-com bubble, in 2001, the world economy experienced a period of elevated growth, mainly driven by China, followed by the "commodity boom" - a combination of high prices and strong imports of these goods (Ocampo, 2007). Major commodity exporters, such as Brazil, greatly benefited from this growth dynamic. This could be observed by recurrent surpluses in the balance of goods and services (hereafter, BS), from 2002 to 2006, exceeding 4% of GDP and current account surpluses exceeding 2% of GDP. In addition, expansionary monetary

[13] Angrick (2016, p. 8) emphasizes that if the compensation thesis is taken into account "an economy's degree of autonomy ultimately depends on its ability to accumulate foreign exchange rather than its choice of exchange rate regime".

[14] The magnitude of the speculative attack against Brazilian domestic currency can be expressed by the loss of 57% of its value against the dollar, between December 1998 and February 1999 (Barbosa-Filho, 2008).

policy in the US, as a response to the 2001 crisis, amplified international liquidity and allowed the CBB to acquire a growing stock of foreign reserves.

From June 2009 to September 2012, foreign currency inflow had qualitatively changed. After the Global Financial Crisis (GFC) of 2007/2008, CBs around the world adopted counter cyclical measures. Federal Reserve's monetary policy (quantitative easing) flooded financial markets with liquidity that searched for higher yields in emerging markets, whereas interest rate in most developed countries were close to (or even below) zero (Biancarelli et al., 2017). Albeit previous current account surpluses became deficits, external capital inflows were still sufficient to cover the deficit and to maintain the accumulation of foreign reserves.

As of 2012 there were indications of a reversal of the quantitative easing conducted after the GFC,[15] leading to a halt in Brazil's foreign reserve accumulation. This could be interpreted as the end of the "double bonanza" period, expressed by high commodities prices and substantial capital flows directed to emergent markets (Reinhart et al., 2016). Since then, Brazil has been able to attract capital inflows in the approximate amount necessary to finance its current account deficit, yet, not enough to accumulate foreign reserves. Besides small short-term fluctuations, foreign reserves have remained practically unaltered from April 2012 (US$ 374 billions) until April 2019 (US$ 383 billions). Due to the lack of variation of foreign reserves, the period between 2012 and 2019 is uninteresting in terms of the compensation thesis.

3.2 Institutional arrangement of the CBB

Alongside the aforementioned external sector and exchange rate regime changes, the CBB also went through alterations in its institutional arrangement, especially during the first years of the 2000s, which reflected in modifications of its balance sheet. Consequential to modifications in the CBB's balance sheet is the way compensation takes place.

An important change for compensation was in May 2000, when the Law of Fiscal Responsibility[16] forbade the CBB to issue new bonds after May 2002.[17] This was a relevant prohibition as the CBB issued bonds represented 40,02% of total CBB's liabilities denominated in domestic currency, at the time. As Lavoie and Wang (2012) explain, it is common that in developing countries the CB issues bonds, as those are perceived by financial markets as less risky than Treasury securities. Indeed, the dataset presented by Angrick (2017) and Bozhinovska (2015) seem to confirm that CB bonds are a relevant component of CB's liabilities in developing economies. Another important modification was the item of claims on banks, which was considerable during the 1990s (40,5% of assets employed in monetary policy operation, in July 1996) but negligible during the 2000s. A simplified representation of CBB's balance sheet between 1994 and 1998 is depicted in table 1, which shows Treasury securities and claims on banks as the most relevant

[15] See Eichengreen and Gupta (2015) for more details about the "tapering talks".
[16] In Portuguese, *Lei de Responsabilidade Fiscal*.
[17] Complementary law Nº 101, article 34, May 2000.

items in the asset side, and CBB bonds, compulsory reserve requirements, and Treasury account as the most relevant items in the liability side.

Table 1: CBB Balance sheet: 1994 to 1998

Assets	Liabilities
Foreign reserves	Monetary base
Treasury securities	Treasury account
Claims on banks	Compulsory reserves
	CBB bonds

That was also the case of Brazil until 2002, however, the prohibition to issue new bonds forced a gradual decrease in CBB bonds available to monetary policy operation.[18] Not coincidentally, repos – which amounted to 0,5% of GDP in 2000 – quickly grew to reach 10,88% of GDP in 2012.[19] In absence of CBB bonds to operate the monetary policy, repos became the most important item to compensate for autonomous sources of reserve balances (Santos et al., 2017).[20] This includes but is not limited to foreign reserve accumulation, whereas the payment of high interest rate on existing stock of repos, redemption of Treasury bonds, primary result of central government, and changes in compulsory reserve requirement are some of the factors that were also compensated by the growing stock of repos (Santos et al., 2017, CBB, 2018).[21] Table 2 depicts a simplified version of current CBB's balance sheet, in which Treasury securities is the most important item in the asset side, and repos, Treasury account, and compulsory reserve requirements are the most relevant in the liability side.

Table 2: CBB Balance sheet: 2004 to 2011

Assets	Liabilities
Foreign reserves	Monetary base
Treasury securities	Treasury account
	Compulsory reserves
	Repos

In summary, during the 1990s, the main items in CBB's balance sheet expected to have compensated for foreign reserve accumulation/loss were government securities (both CB and Treasury issued), purchased (sold) by the private sector when there were excessive (scarce) reserve balances, and claims on banks, decreased (increased) when banks paid (borrowed)

[18] By November 2006, there were no more CBB bonds held by the private sector.
[19] Data is available in CBB (2018).
[20] Shortly after the issuance of CBB bonds was terminated, reverse repos were allowed to be engaged with financial institutions that are not "dealers", facilitating access to reverse balances. More details are found in circular nº3132/2002 and circular nº3108/1999.
[21] The CBB accumulates a substantial stock of repos while reverse repos are not frequent, indicating a structurally liquid banking system.

reserve balances to (from) the CBB. The CBB (2018) and literature dedicated to study CBB's operation (Santos et al., 2017) seem to agree that, currently, repos became the most important compensating item. Banks and other financial institutions engage in repos that yield interest rate rather than hold noninterest bearing assets. Private banks no longer have significant debt held by the CBB, making claims on banks irrelevant for the current way compensation is expected to materialise.

Therefore, we identified two periods with distinct characteristics, including different exchange rate regime, conditions for accumulation/loss of foreign reserves, and institutional arrangement within the CBB. Hence, two models are in order to test the validity of the compensation principle in these two periods.

4 Empirical models

4.1 Estimation strategy

The econometric strategy can be summarized in a few procedures. Firstly, we perform unit root tests to all variables. Secondly, the possibility of a long-run relation between the variables is tested by estimating an autoregressive-distributed lag (ARDL) model and applying the bounds tests proposed by Pesaran et al. (2001).

ARDL models have been reintroduced by Pesaran and Shin (1999) as a valuable method to test for the presence of a cointegration relation between time-series variables. For a number of reasons, as the fact that it is better suited to small samples and that it allows for both I(1) and I(0) variables, it is an interesting approach to our model. The model is a standard least squares regression that includes lags of the variable in the right hand side of the equation (the AR part) as well as lags and current values of the explanatory variables, as shown in equation 1 for an ARDL(i,j,k) model with two explanatory variables, i lags of the dependent variable Y, j lags of the explanatory variable X_1, and k lags of the explanatory variable X_2.

$$Y_t = \beta_0 + \sum \beta_i Y_{t-i} + \sum \gamma_j X_{1,t-j} + \sum \delta_k X_{2,t-k} + e_t \tag{1}$$

Long term coefficients and the error-correction (ECM) form can be derived from the estimated equation by applying a linear transformation. For the simple ARDL(1,1,1) model in equation 2, the ECM form is given by equation 3:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \gamma_0 X_{1,t} + \gamma_1 X_{1,t-1} + \delta_0 X_{2,t} + \delta_1 X_{2,t-1} + u_t \tag{2}$$

$$\Delta Y_t = \gamma_0 \Delta X_{1,t} + \delta_0 \Delta X_{2,t} + \beta' [Y_{t-1} - (\beta_0' + \theta_1 X_{1,t-1} + \theta_2 X_{2,t-1})] + u_t \tag{3}$$

where $\beta' = \beta_1 - 1$ is the adjustment coefficient, $\beta_0' = \beta_0/(1-\beta_1)$ is the restricted constant, $\theta_1 = -(\gamma_0+\gamma_1)/(\beta_1-1)$ is the long term coefficient associated with X_1, $\theta_2 = -(\delta_0+\delta_1)/(\beta_1-1)$ is the long term coefficient associated with X_2, and u_t is a white noise.

The model allows for either I(1) or I(0) variables, as long as there is no variable of a higher integrating order.[22] This is an especially interesting feature as the power of unit root tests is known to be quite low (Campbell and Perron, 1991) and different tests can lead to different conclusions, leaving room for ambiguity.

The presence of a cointegration relation among the variables is identified by the so-called bounds tests (Pesaran et al., 2001). This first test consists of simply performing a *F*-test to test the null hypothesis of no level relation between the dependent and the explanatory variables by excluding the lagged level variables Y_{t-1}, $X_{1,t-1}$, and $X_{2,t-1}$ in equation 3. Thus, it tests the joint null hypothesis that β', θ_1, and θ_2 are equal to zero against the alternative that at least one of them is different from zero. There are two sets of critical values, which provide a band that covers all possible classifications (purely I(0), purely I(1), or mutually cointegrated). If the *F* statistic falls outside the critical value bounds, inference can be made without assessing the order of the variables or determining the cointegration rank of the variables (Pesaran et al., 2001, p. 299). In case this first test leads to the rejection of the null hypothesis, Pesaran et al. (2001) suggest testing for the exclusion of the Y_{t-1} variable by applying a *t*-test. Once again, there are two sets of critical values, with inference being possible if the *t* statistic falls outside the critical value bounds.

The lag order of the equations followed the Bayesian information criterion (SIC), which renders a more parsimonious model. When needed, the lag order was adjusted and other information criteria were used until there was evidence of homoscedasticity and absence of residual autocorrelation. The equations estimate the changes of the variables that may be compensating changes in the other balance sheet items, which are included as exogenous variables. In other words, because the compensating entries may react to changes in other variables besides the foreign reserves, these variables are also included as exogenous variables. Also, a trend and constant terms were included in the estimated equations.

For both models, the data was collected from the Central Bank of Brazil. All series are monthly, denominated in domestic currency (including the foreign exchange reserves, as explained below) and taken in logarithm. When needed, the X12 ARIMA adjustment method was applied to attenuate cyclical fluctuations.

[22] Thus, it is advisable to test whether the variables are I(2) by performing unit root tests on their differences. These tests are reported in the appendix section.

4.2 Pegged exchange rate (1994 to 1998)

4.2.1 Dataset

Table 3 reports data included in the model for the 1990s. The monetary base presented strong cyclical behavior and was seasonally adjusted.

Table 3: Dataset (1994 to 1998)

Variable	Description
FOREX	Foreign reserves
TSECURITIES	Treasury securities at the Central Bank
MB	Monetary base
TACCOUNT	Treasury account at the Central Bank
CRESERVES	Compulsory reserves at the Central Bank
CBSECURITIES	Bonds issued by the CBB
CLAIMS	Central Bank claims on domestic banks

Two of these variables had minor modifications to properly test the compensation principle. First, the concept of monetary base adopted by the CBB includes compulsory reserve requirements on demand deposits. To obtain a monetary base concept compatible with cash plus reserve balances only held voluntarily, we subtracted compulsory reserve requirements.

Second, although the exchange rate was pegged, there were still variations that could cause considerable capital gain/loss on the stock of foreign reserves (denominated in domestic currency), which is undesirable for testing the compensation principle. Hence, following Lavoie and Wang (2012) we removed capital gain/loss resultant from exchange rate fluctuations.[23] Furthermore, due to increasing current account deficits, the CBB responded by borrowing abroad (increasing foreign liabilities) to replenish foreign reserves required to sustain the pegged exchange rate. In order to eliminate foreign reserve accumulation obtained through increasing foreign liabilities, which does not entail creation of reserve balances in the domestic banking system, we followed Angrick (2017, p. 9) suggestion to subtract foreign liabilities from the stock of foreign reserves.

The estimation period goes from July 1994 to December 1998, rendering 54 observations. It is a period of deteriorating external conditions for the Brazilian economy and was the build up for an exchange crisis. It is not clear in the existing literature which were the most likely items to have compensated for foreign currency flows. In absence of indications, we tested the variables that seemed to be the most relevant in CBB's balance sheet, at the time, identified in the previous section.

[23] The stock of foreign reserves was calculated by $FOREX = \sum \Delta FR_{t+n} EX_{t+n} + FR_{t-1} EX_{t-1}$, where FR is the stock of foreign reserves denominated in US dollars, EX is the nominal exchange rate (between domestic currency and US dollar), t is the first observation of data sample, and n is the number of periods after t.

4.2.2 Results

In order to test whether the compensation thesis was verified in this period, the main accounts in the CBB balance sheet are tested. Due to the behavior of the foreign exchange reserves variable, an interaction dummy which takes the value of the trend from April 1998 to December 1998 was added in all specifications.

Table 4 reports the bounds tests for the estimated models. The results for the monetary base model[24] suggest the existence of a cointegration relation between the monetary base and the exogenous variables, which is further scrutinized below. The other specifications refer to the CBB claims on private banks,[25] Treasury securities,[26] and the CB securities.[27] For these equations, the *t* bounds tests do not offer support for the hypothesis of cointegration between the variables at the 5% significance value.

Table 4: Bounds tests (1994 to 1998)

		F-test	
Dependent variable	*F*-statistic	Critical value (lower)	Critical value (upper)
MB	7.09	2.63	3.62
CLAIMS	3.17	2.81	3.76
TSECURITIES	4.32	2.81	3.76
CBSECURITIES	5.53	2.81	3.76
		t-test	
Dependent variable	*t*-statistic	Critical value (lower)	Critical value (upper)
MB	-6.88	-3.41	-4.69
CLAIMS	-3.76	-3.41	-4.52
TSECURITIES	0.45	-3.41	-4.52
CBSECURITIES	-3.06	-3.41	-4.52

Note: Critical values correspond to the 5% significance level.

While the results in table 4 suggest that neither of the three main accounts (except the monetary base) were compensating the changes in the net foreign exchange reserves, the results reported in table 5 suggest that this role was not exerted by the monetary base either, as there is no support for a long-run relationship between the the monetary base and the foreign exchange reserves.

[24] ARDL(1, 0, 1, 4, 4, 0, 0), order: CRESERVES, FOREX, TACCOUNT, CBSECURITIES, TSECURITIES, CLAIMS.
[25] ARDL(1, 1, 0, 0, 0, 2), order: CRESERVES, FOREX, TACCOUNT, CBSECURITIES, TSECURITIES.
[26] ARDL(4, 3, 1, 4, 4, 4), order: CLAIMS, CRESERVES, FOREX, TACCOUNT, CBSECURITIES.
[27] ARDL(2, 0, 0, 2, 4, 2), order: TSECURITIES, CLAIMS, CRESERVES, FOREX, TACCOUNT,

Table 5: Cointegration equation for monetary base (1994 to 1998)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CRESERVES	-0.26	0.1	-2.64	0.01
FOREX	0.03	0.05	0.53	0.60
TACCOUNT	0.16	0.08	2.07	0.05
CBSECURITITES	0.1	0.12	1.00	0.32
TSECURITIES	0.14	0.05	2.79	0.01
CLAIMS	0.02	0.02	0.91	0.37

Consequently, the results for this period support the compensation thesis inasmuch as they show that the monetary base was not permanently affected by changes in the net foreign reserves. Yet, the results do not indicate which account compensated the movements in the latter variable. Given the particularities of the period, it is possible that this role was exerted by different variables in different subperiods, thus preventing the direct identification of the compensating variables.

4.3 Managed floating regime (2004 to 2011)

4.3.1 Dataset

Table 6 reports the data included in the model for the 2000s. The monetary base, treasury account and repos[28] presented strong cyclical behavior and were seasonally adjusted.

Table 6: Dataset (2004 to 2011)

Variable	Description
FOREX	Foreign reserves
TSECURITIES	Treasury securities at the Central Bank
MB	Monetary base
TACCOUNT	Treasury account at the Central Bank
CRESERVES	Compulsory reserves at the Central Bank
REPOS	Repurchase agreements

Likewise the previous model, compulsory reserve requirements on demand deposits were subtracted from CBB's monetary base. Foreign reserves also received the same adjustment as in the previous model in order to eliminate capital gain/loss resultant from exchange rate fluctuations. As there was not an increase in foreign liabilities from 2004 to 2011, they were not subtracted from the stock of foreign reserves.

The estimation period goes from January 2004 to December 2011, rendering 96 observations. Therefore, it consists of the period in which Brazil accumulated foreign reserves more

[28]The series for repos is given by the net difference between the stock of repos and reverse repos.

intensively (especially after 2006). Consequently, the main research question is whether the accumulation of foreign reserves was compensated by increases in the monetary base and/or in the repos. The compensation thesis and the analysis provided by the CBB (2018) suggest that monetary base should not have had a long-run relation with foreign reserves, while we expect to find evidence that repos presented a long-run relation with the latter.

4.3.2 Results

In order to test the validity of the compensation thesis for the Brazilian economy between 2004 and 2011, two equations are estimated. The equation for the monetary base includes the foreign exchange reserves, the Treasury securities, the Treasury account at the Central Bank, the compulsory reserves and the repos as explanatory variables. The equation for the repos includes the foreign exchange, the Treasury securities, the Treasury account at the Central Bank and the compulsory reserves as explanatory variables.

Following the method described in section 4.1, the model for the monetary base is an ARDL(2,0,0,1,0,0)[29] and the model for the repos is an ARDL(1,1,0,0,0).[30] The F and t bounds tests on these models are reported in table 7. The F-test is inconclusive for the monetary base equation (test statistic between the critical values), but the t-test suggests that the series does not adjust to the cointegration equation (suggesting the absence of cointegration). On the other hand, both the F-test and t-test provide evidence that the repos are cointegrated with the explanatory variables.

Table 7: Bounds tests (2004 to 2011)

	F-test		
Dependent variable	F-statistic	Critical value (lower)	Critical value (upper)
MB	2.93	2.81	3.76
REPOS	7.31	3.05	3.97
	t-test		
Dependent variable	t-statistic	Critical value (lower)	Critical value (upper)
MB	-2.88	-3.41	-4.52
REPOS	-5.52	-3.41	-4.04

Note: Critical values correspond to the 5% significance level.

Ergo, the result for the monetary base equation are in agreement with the compensation thesis and its claim that the monetary base does not compensate the changes in the foreign exchange reserves. Similarly, the results for the repos equation also provide evidence for the compensation thesis, as there is support for cointegration between the variables. This conclusion

[29] Order: MB FOREX CRESERVES REPOS TACCOUNT TSECURITIES.

[30] Order: REPOS FOREX CRESERVES TACCOUNT TSECURITIES. An interaction dummy, which takes the value of the trend from 2004 to 2005, was also added due to the dynamics of the series in the beginning of the estimation period.

is further reinforced by the analysis of the cointegration equation for this model, reported in table 8, which shows that the repos presents a long-run response to changes in the level of all variables (all variables are significant at the 5% significance level). In particular, it suggests that, on average, a 1% change in foreign exchange reserves led to a 1.21% change in the amount of repos between 2004 and 2011.[31]

Table 8: Cointegration equation for repurchase agreements (2004 to 2011)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
FOREX	1.21	0.18	6.88	0.00
CRESERVES	-1.19	0.16	-7.49	0.00
TACCOUNT	-0.43	0.20	-2.19	0.03
TSECURITIES	0.56	0.24	2.29	0.02
TREND	0.01	0.01	2.09	0.04

5 Neither trilemma nor impossible duality: a first approximation

There are two opposing approaches concerning monetary policy autonomy in open economies. On one side, the famous trilemma, based on the Mundell-Fleming framework, states that given a scenario of free capital mobility, there is an unavoidable conflict between fixed exchange rate regime and monetary policy autonomy.[32] Thus, an open economy's CB can only choose two out of three: free capital mobility, fixed exchange rate regime, and monetary policy autonomy. Opting for a fixed exchange rate regime necessarily imply losing the ability to set interest rate.

On the other side, more recently, the "impossible duality" has emerged as a contestant view, which argues that under free capital mobility, regardless of exchange rate regime, monetary policy autonomy is forfeited. Hence, instead of a trilemma there is an "impossible duality" or "irreconcilable duo",[33] meaning that monetary authorities have to choose between free capital mobility and monetary policy autonomy, indifferently of the adopted exchange rate regime (Flassbeck, 2001, Rey, 2015). This argument, initially general, has been narrowed and applied to discuss the (supposed) lack of autonomy constraining developing countries' monetary policy. In the context of financial globalization, commonly associated with high capital mobility, monetary policy autonomy, especially in those countries, is considered to be inevitably compromised.

The compensation principle differs, simultaneously, from the trilemma and impossible duality views. While the exchange rate regime choice does not have a direct impact on monetary

[31] Taking the average values for this sample, this elasticity means that for every increase in foreign exchange reserves by R$ 1, the repos account would, *ceteris paribus*, increase by R$ 0.78 on average.

[32] The explanation for this conflict was outlined in section 2.

[33] The term "impossible duality" was first introduced by Flassbeck (2001, p. 39). Rey (2015, p. 3) uses the terms "dilemma" or "irreconcilable duo" for similar meaning.

policy autonomy, similarly to the impossible duality view and contrary to the trilemma, conclusions that follow from the compensation view are also different from the former. Albeit a fixed exchange rate regime demands accumulated foreign reserves to avoid default risk, both floating and fixed exchange rate are not *a priori* a constraint on CB's ability to reach its targeted interest rate. Therefore, it is not likely that any CB would not be able to control its own monetary policy (Lavoie, 2001).

Thus, the compensation principle lays out an alternative perspective to discuss monetary policy in open economies, including developing countries. This paper presented empirical evidences for the Brazilian economy that seems to be in line with the still limited existing literature supporting such principle. As expected, the evidences in favor of the compensation principle are more compelling in the model estimated comprising the period of intensive foreign reserve accumulation (2004-2011). On the other hand, the model estimated for the period including the exchange crisis (1994-1998) provides less clear results, as while a long-run effect of changes in foreign reserves on the monetary base were not identified, the compensating accounts could not be identified either. Ergo, the results for this period are in line with the affirmation that "[w]hen a currency is under attack, the domestic central bank may in fact take measures that run counter to the endogenous compensation principle" (Lavoie, 2001, p. 235). Therefore, the 1990s period still requires further investigation.

As discussed herein, the empirical validation of the compensation principle may have significant implications for the debate about monetary policy autonomy in developing countries. Hence, further evidences can greatly contribute to improving this debate and to clarifying the restrictions upon developing countries. While this paper contains an attempt for a first approximation to discuss the compensation principle as an alternative to the trilemma and to the impossible duality views, further research is required both for more empirical evidences and for better development of the argument.

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Appendix A: Unit root tests

ARDL models require that the variables are either I(0) or I(1). Therefore, to make sure that our variables are not I(2), we perform unit root tests on their first differences. Tables 9 and 11 report the results from the Phillips-Perron unit root test for the variables included in the 1990s and 2000s respectively. All tests reject the null hypothesis that the series is integrated of order one, except for the first difference of the foreign exchange reserves in the 1990s. However, the unit root with break test, reported in table 10, rejects the null hypothesis of non-stationarity, suggesting that there is a break in the series.

Table 9: Phillip-Perron unit root test (1994 to 1998)

	constant and trend	constant	none
D(CLAIMS)	-8.71***	-8.36***	-8.25***
D(FOREX)	-0.90	-0.03	-0.01
D(MB)	-9.67***	-9.59***	-8.64***
D(CRESERVES)	-6.18***	-5.99***	-5.83***
D(CBSECURITIES)	-8.44***	-7.87***	-7.29***
D(TACCOUNT)	-8.77***	-8.95***	-6.96***
D(TSECURITIES)	-5.65***	-5.45***	-5.17***

Significance levels: * 10%, ** 5% and *** 1%.

Table 10: Unit root with intercept break test (1994 to 1998)

	constant and trend	constant
D(FOREX)	-5.83***	-6.01***

Significance levels: * 10%, ** 5% and *** 1%.

Table 11: Phillip-Perron unit root test (2004 to 2011)

	constant and trend	constant	none
D(CRESERVES)	-7.80***	-7.70***	-7.42***
D(FOREX)	-8.87***	-8.88***	-8.00***
D(MB)	-15.58***	-14.59***	-8.50***
D(REPOS)	-11.42***	-11.47***	-11.19***
D(TACCOUNT)	-11.82***	-11.90***	-11.38***
D(TSECURITIES)	-14.57***	-14.05***	-12.30***

Significance levels: * 10%, ** 5% and *** 1%.