Expectations and exchange rate in a Keynes-Harvey model: an analysis of the Brazilian case over 2002-2017 using ARDL

Leandro Vieira Araújo Lima[1]
Fábio Henrique Bittes Terra[2]

Abstract

This paper investigates the statistical relationship between future expectations of the exchange rate and GDP growth and the current nominal exchange rate in Brazil, over 2002-2017. The theoretical framework in which the paper is based is a decision-making model grounded on Keynes (1921, 1964) and Harvey (2006, 2009a), from which the empirical model of the paper emerges. This model is empirically tested with Autoregressive Distributed Lags models, to identify short- and long-term statistical relationships in time series. The empirical estimations suggest that expectations of future changes in both the exchange rate and GDP growth have statistically significant relationship with the current nominal exchange rate in Brazil, just as Keynes-Harvey model advocates.

Keywords: Expectations; Exchange rate; Harvey; Keynes.

JEL words: E 12; F 31; F 37.

Introduction

One of the key features of the Post Keynesian perspective is the importance of expectations to explain economic dynamics. Although Keynes stressed the role of expectations in his 1936 *The General Theory of Employment, Interest and Money*, it is possible to recall a model of decision-making under uncertainty from his 1921 *Treatise on Probability*. When combined, both books furnish an investment decision-making model in which uncertainty and its counterpart, expectations, are key elements.

In turn, Harvey (2006, 2009a) focused on the roles of uncertainty and expectations on the exchange rate determination, adapting Keynes' ideas to an open-economy. Harvey has developed his mental models to understand the mutual relationship between expectations and exchange rate. He designs a system that shows how expectations of future exchange rate are formed, based on the so-called base factors and processes. Nevertheless, Harvey's model also details principles and mental stages that form expectations.

[1] PhD Candidate, Federal University of Rio Grande do Sul, Brazil.
[2] Professor of Federal University of ABC and PPGE-UFU. CNPq Researcher, Brazil.

This paper analyzes the role expectations played on the exchange rate determination in Brazil, from January 2002 to December 2017. It first develops a Keynes-Harvey investment decision-making model, which theoretically sets the function of expectations in the decision-making process under uncertainty (the Keynes side of the model) and how this process encompasses the external sector and affects the exchange rate determination (the Harvey side). This Keynes-Harvey model theoretically grounds the formal model by which statistical estimations are undertaken. They aim to check the statistical significance of expected future change of both the exchange rate and GDP growth as explanatory variables of current exchange rate in Brazil. This empirical strategy makes use of Autoregressive Distributed Lags (ARDL) models to estimate short- and long-term statistical relationships between expectations and the Brazilian current exchange rate.

The relationship between expectations and exchange rates is researched in different perspectives in the Post Keynesian literature. Deprez (1997) developed a model of aggregate supply and demand regarding an open-economy, where both expectations and exchange rate influence the demand price that entrepreneurs await. Another perspective focuses on how expectations affect exchange rate determination. (Kaltenbrunner, 2015; Priewe, 2014). A further view on the expectations-exchange rate relationship is the debate of hierarchy of currencies and the asymmetries of the international monetary and financial system (Prates and Andrade, 2013; De Paula et al., 2017). In this case, the latter literature foregrounds not only the expectations-exchange rate connection, but also the various degrees of liquidity that each national currency has.

This paper fits itself into the second of the mentioned perspectives, the one focusing on how expectations affect the exchange rate determination. There are two research topics in this perspective. One deals with expectations, capital flows, financial speculation and exchange rate determination (Minsky, 1975; Kindleberger, 2000; Harvey, 2006, 2009a, 2009b; Kaltenbrunner, 2011, 2015). The other argues that external capital flows are defined by the sensibility of expectations in relation to the expected future value of the foreign currency rather than by speculation and arbitrage gains in the international forex markets (Davidson, 2011). However, in spite of their differences, both views take expectations as crucial to explain exchange rates and capital movements among countries.

Two are the contributions of this paper. At the theoretical side, it links Harvey's (2006, 2009a) exchange rate determination model with Keynes' (1921, 1964) decision-making under uncertainty model. This Keynes-Harvey model shows the macroeconomic

effects, in terms of exchange rate determination, of individual decision under uncertainty. The other contribution is the empirical analysis of the relationship between expectations and exchange rate in Brazil, from January 2002 to December 2017. Although expectations and exchange rate are a common theme on the Post Keynesian perspective, empirical estimations of their relationship are very much scarce, being Kaltenbrunner (2011) the only one. She also analyzes the Brazilian case from 2003 to 2009, a period shorter than the one estimated in this paper, and with a different method, Vector Autoregressive models. Moreover, Kaltenbrunner (2011) considers stock exchange prices, external capital flows and the Brazilian market future interest rate as proxies to expectations. Differently, this paper uses data of expectations themselves – the expected future change of the exchange rate and GDP growth. These data are furnished by a weekly research undertaken by the Brazilian Central Bank, which is set via interviews with many financial institutions operating in Brazil.

The paper has three more sections besides this Introduction and final remarks. Section 1 presents Keynes' decision-making under uncertainty model and Harvey's exchange rate determination model so as to build what we call the Keynes-Harvey model of exchange rate determination under uncertainty, that is the theoretical framework for the formal model of Section 3, which displays the empirical method of analysis, divided in two subsections. The first describes the Autoregressive Distributed Lags model; the second reports the dataset used in the paper and undertakes the tests required to the specification of the empirical model. The third Section reports the outcomes and analyzes them.

1. Keynes-Harvey model of exchange rate determination

Keynes (1921) developed a model of human epistemology that deals with how an individual acquires knowledge and the method of knowledge. The way Keynes (1921) perceived the absorption of knowledge is quite similar to what in Keynes (1964) is the decision-making process of entrepreneurs. When combined, Keynes (1921) and (1964) allow for designing a decision-making under uncertainty model, which we will use to formalize the exchange rate determination under uncertainty.

Keynes (1921) defined a three step process regarding human process of retrieving knowledge. The first is direct acquaintance. By means of immanent skills individuals apprehend direct knowledges that, in turn, are evidences that constitute knowledge. The second step is gathering direct knowledge, to extend the range of evidences detained by

an individual. From the set of direct knowledge emerges the third step, the quest for something that is not clarified in the agent's mind, namely the indirect knowledge. This is arguments or conclusions to which he or she arrives departing from the set of direct knowledge previously held. The indirect knowledge is the attempt to enlarge what is known by an individual.

Indirect knowledge results from direct knowledge, however, the former is always bigger than the latter. So, every reached conclusion necessarily surpasses the set of evidences that has formed itself. Thus, indirect knowledge, in fact, does not exist otherwise than as an expectation, whose corroboration or refutation comes with future. Because of that, indirect knowledge is uncertain, as it necessarily goes further than the group of evidences from which it emerged[3].

Keynes' (1921) probability theory rests in the relationship between direct and indirect knowledges and has a qualitative nature. His model states that agents have not a numerical probability of an event, but some qualitative degree of rational belief in the conclusion *A* they reached departing from evidences (direct knowledge) *H.* The degree of rational belief of agents remains somewhere in between total ignorance and full certainty and depends on the weight of the argument, a concept Keynes (1921) created.

Vercelli (2010) shows that there are three definitions of weight of the argument. First, it refers to the size of the set of evidences that bases a particular conclusion. Second, it is also the comparison between agents' sets of knowledge and ignorance. Finally, the last notion of weight of argument relates to what is really known of what is known, as illustrated by Keynes "the existing facts which we can assume to be known *more or less for certain*" (1964, p. 147, italics added)[4].

Relating this epistemological model with Keynes' (1964) behavior of entrepreneurs allows for attaining a model of decision-making under uncertainty. According to Keynes (1964), businesspeople must decide their asset portfolio by choosing assets of two natures, namely financial – amongst it, debts nominated in foreign money, or even foreign money itself – and capital goods. To do so, businesspeople form a conclusion, an expectation of a future scenario partly built upon existing facts known more or less for certain and "partly future events which can only be forecasted with more

[3] The effort of going further than the joint of evidences that has based a conclusion is a manner of obtaining knowledge "inductively, and shares the uncertainty to which all inductions are liable" (Keynes, 1921, p. 95).

[4] Broadly speaking, these three notions of the weight of the argument, as Runde (1990) and Vercelli (2010) state, complement each other.

or less confidence" (Keynes, 1964, p. 147). Based on Keynes (1921), elements acknowledged with more or less certainty are direct knowledge businesspeople detain whereas indirect knowledge are conclusions to which they arrive to, coming from the former[5]. So, conclusions are expectations in which entrepreneurs have more or less confidence – or, following Keynes (1921) great or small degree of rational belief. Thus, a decision in favor of an investment in particular, local or external, financial or productive, heavily depends on the confidence entrepreneurs hold on the conclusions of their thought, that is, their expectation.

In turn, Harvey's (2006, 2009a) models of the expectation-exchange rate relationship furnishes content to the decision-making model evolved from Keynes (1921, 1964) as the former establishes which direct knowledge foreign investors seek to ground their expectations (indirect knowledge) about future exchange rates. Moreover, as investors' portfolio decisions are influenced by what they prospect about the future value of the exchange rate, their expectations affect, in aggregate, external capital flows and, finally, exchange rate itself.

Harvey (1993, 1998, 2006, 2008, 2009a) developed his heuristic models to report the processes that guide agents' decision of composing portfolio with external assets. In his models, key Post Keynesian elements like expectations, uncertainty and conventional behaviour enter into play to constitute the motivations of individuals in their decision-making process. Inherently facing these elements, how does the mental process of the decision maker happen?

Harvey (2006, 2009b) segregates this process into individuals' heuristic principles and mental stages. The heuristic principles are the mechanisms that furnish the scores of knowledge that support a particular decision. There are five principles: (i) Availability, which concerns the frequency of receiving evidences and is responsible for supplying the information to agents'. (ii) Representativeness, that regards individual capacity of formulating expectations in accordance with assessed evidence. (iii) Anchoring, that initially links a particular action to an expected outcome. (iv) Conventional wisdom, which considers that an individual looks friendlier at evidences aligned to socially shared creeds – conventions – than at thoughts he or she conveys alone. (v) Lastly, the principle

[5] Amongst these known elements, conventions are a special one. Resende and Terra (2017) explain that conventions are agents' socially shared creeds that help shaping expectations. As in several situations, agents prefer to follow the trend of the majority instead of acting alone, this emulated behavior spreads conventions across individuals and imply on them similar doings, creating events like *Boom* periods or bandwagon effects.

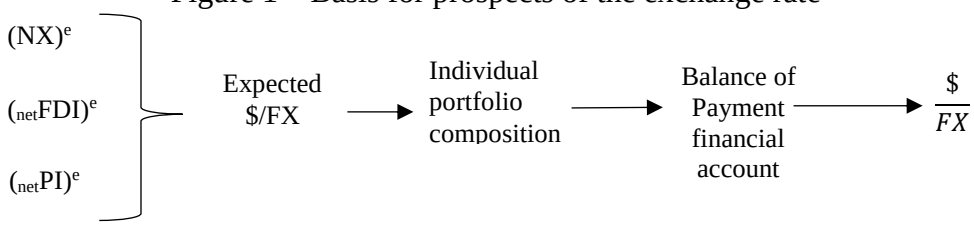
of framing articulates the other principles to constitute a general opinion. These principles apprehend how an individual collects, selects and uses the evidences required to think an expectation.

Furthermore, Harvey (2009b) states five stages between mentally creating a decision and its materialization. The first two deals with the analysis of possibilities and the match between available choices and their consequences. For each possible choice, future expected eventualities are elaborated, and their waited consequences are compared. The third stage is weighting the decision, in that the decision maker organizes the preferred options by examining the decisions of the first two stages. Fourth and fifth stages are, respectively, the choice itself and the post-event exam, where agents execute a decision and afterwards assess its results to observe errors and corrections.

These stages can be seen as the transmission channel of expectations in the mind of the decision maker, in a way closely related to Keynes' (1921) model of obtaining knowledge. In the initial stages of Harvey (2009b), expectations incipiently emerge. After that, they are preliminarily assessed, their possible outcomes are designed, their consequences compared, and lastly the preferred possibilities are revealed. In the latter stages, expectations are a particular conclusion that drives the action of the investor, that is, they become expectations imminently convertible into decisions.

The next step of Keynes-Harvey model is to elucidate the direct link between expectations and the exchange rate. Harvey (2009a) specifies three reasons for buying foreign money, namely international trade (NX), foreign direct investment (FDI) and external portfolio investment (PI). Expectations directly affect the latter two reasons; however, they eventually influence international trade either, unfolding movements in international transactions so that the exchange rate switches as well. Hence, agents' outlooks on the exchange rate depend directly on the analysis they make of the processes that generate international flows of goods, services and capital, as Figure 1 synthesizes. At the same time, what agents expect of the exchange rate grips their demand of assets nominated in that particular exchange rate.

Figure 1 – Basis for prospects of the exchange rate

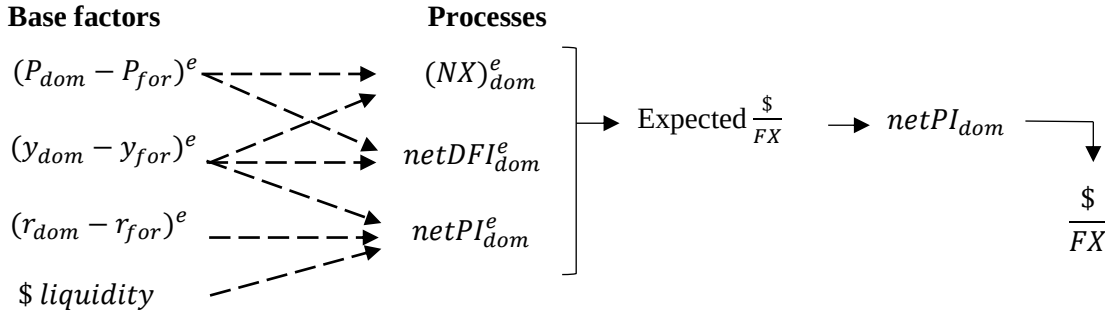


Source: Author's own elaboration based on Harvey (2009a)
Note: the superscript e holds for external.

What do agents consider when regarding external flows? Harvey (2009a) argues that many variables are considered to form what he defines as base factors. The synthesis of these various indicators[6] is found in four concrete elements, namely liquidity of currencies[7], national and international differentials of price levels, interest rates and GDP growth. These factors – direct knowledge known more or less for certain in terms of Keynes (1964) – allow agents to form expectations of the three basic external processes, net FDI, NX and PI.

Expectations of base factors and the outlooks they inspire in agents about the relevant processes of the external sector are the core of Harvey's (2009a) mental model, summarized in Figure 2. Moreover, the Figure shows the unescapable feedback effect: expectations of future exchange rate depend on agents' prospects about the relevant processes; however, these expectations affect the exchange rate itself, because it alters the amount of external assets that investors carries in their portfolio and so affects the volume of portfolio investments a country receives.

Figure 2 – The mental model summarized



Source: Authors' own elaboration based on Harvey (2006, 2008, 2009a).
Note: the bound dashed arrows mean medium/long-term expectations. The superscript *e* holds for external.

Harvey's (2009a) model stresses another key point of Keynes (1964) that is in all decision-making processes: the state of confidence of investors, that is, Keynes' (1921)

[6] Within the elements that serve to form individuals' opinions about the base factors are announces of economic authorities (like the fiscal, monetary and exchange rate ones), political news, economic events in general, and everything else affecting the creed of individuals. The institutional operation of forex markets, as Oberlechner, Sluneck and Kronberger (2004) argue, is also regarded.

[7] Liquidity premium is a key feature regarding exchange rate determination. Liquidity represents the security and convenience of an asset, including money, in national and international levels. Under uncertainty, liquidity preference displays the subjective creed of individuals. In international terms, according to Kaltenbrunner (2015) and Conti and Prates (2018), the quality of a currency is crucial for its global attractiveness, and it is defined mostly by the international liquidity attached to that currency. Assets' liquidity premium affects portfolio decisions, depending on investors´ state of confidence.

degree of rational belief. It is the state of confidence that makes an individual effectively move in some direction, whether hoarding money or investing it. The state of confidence is crucial in the first four stages of the decision-making process, which are the track up to the final decision. In the fifth stage, after a decision has been made, agents' prior confidence is tested in reality, and it can change along with outcomes, their assessment and some new information that may arise.

Lastly, the easier it is to make prospections based on available information, the greater are the chances of having better states of confidence. Contrarily, misleading information may disturb expectations, bringing together mistrusted confidence, making it likely to observe problems like flight to quality, bandwagon effect, sudden stops and overshooting in a country's forex market. In addition, projections and confirmations of what would be the conventional behaviour also contribute to both formulating and reformulating expectations, and so decisions – as bandwagon effects illustrate (Harvey, 2009a). Hence, the interaction between an individual and the whole (base factors and processes) is at all the time in force in the exchange rate determination. This makes the creation of expectations even more complex and leaves them more sensible to changes.

The Keynes-Harvey model developed in this Section offers the theoretical content that grounds the empirical model formalized in the next Section. This empirical model accounts for the role expectations play on the exchange rate determination. Next Section also undertakes empirical estimations using ARDL models for examining the exchange rate determination in Brazil, from 2002 to 2017.

2. An ARDL econometric analysis of the relationship between expectations and the exchange rate determination

2.1 The ARDL model

Our empirical strategy consists of using the Autoregressive Distributed Lags (ARDL) model to exam the statistical relationship between the current nominal exchange rate (dependable variable) and the variables of interest, namely expectations of future change of the exchange rate and the awaited Brazilian GDP growth. These two expectations are proxies to how expectations affect the current exchange rate in the view of the Keynes-Harvey theoretical model, which grounds the empirical research of the paper.

ARDL estimations are ordinary least squares regressions that use lags of both the independent and dependent variables as regressors. As in Pesaran and Shin (1999) and

Pesaran et al. (2001) our model outcomes will be investigated by two different methods, the Bounds Testing Approach (BTA) and the Error Corrector Model (ECM)[8].

After looking at the preliminary statistics[9], ARDL/BTA regression is estimated and permits inferences about the long-term relationship of the variables depending on their cointegration order. The null hypothesis indicates no cointegration, that is, $\delta_1 = \delta_2 = 0$, and so the variables do not hold long-term relationship. This hypothesis is rejected if the F statistics of the estimation is bigger than the critical values reported by Pesaran et al. (2001)[10].When the F statistic is either lower than the superior limit or greater than the inferior limit of the critical values calculated by Pesaran et al. (2001) the testes are inconclusive.

BTA estimation enables using time series without the strict previous control of the variables' integration order. It allows the simultaneous use of stationary and non-stationary variables and also attenuates a potential bias when there is endogeneity, as it permits estimating statistically significant coefficients even when some regressors are endogenous (Pesaran, 1997). The usual ARDL/BTA model is:

$$\Delta(Y)_t = \alpha_0 + \delta_1 Y_{t-1} + \cdots + \delta_s Y_{t-s} + \beta_1 X_{t-1} + \cdots + \beta_s X_{t-s} + \cdots \varepsilon_t \qquad (1)$$

where α_0 is the intercept, X_t is the matrix of I(1) variables, δ are long-run coefficients, ρ are short-term coefficients and ε_t are disturbances.

ECM is the second analytical approach of ARDL models. It identifies short-term relationships amongst the variables. The ECM also investigates the adjustment of the dependent variable over time to a punctual disturb it suffers from first difference effects of a given independent variable. Habitually, an ARDL/ECM model is expressed as:

$$\Delta(Y)_t = \alpha_0 + \delta_1 Y_{t-1} + \delta_2 X_{t-1} + \sum_{i=0}^{n} \rho_1 \Delta Y_{t-i} + \sum_{i=0}^{n} \rho_2 \Delta X_{t-i} + \varepsilon_t \qquad (2)$$

[8] There is further information regarding BTA and ECM in Subsection 2.3.

[9] ARDL/BTA models require preliminary tests to diagnose the conditions of the variables. Four tests are undertaken and their results are reported in the next Subsection. First, unit root tests, to identify whether the series is stationary or not and to check the variables' integration order. Second, autocorrelation is investigated by the Lagrange Multiplier Test (LM). Third, the normality of the residues is analyzed via Jarque-Bera test (histogram analysis). Fourth, long-term stability of the series is checked through the cumulative sum (CUSUM) and cumulative sum square (CUSUMSQ) tests. It is worth saying that non-stationarity of data – indicated by the unit root tests – is not a restriction of the ARDL model. In fact, the combination of series with and without unit root justifies the use of ARDL models (Pesaran and Shin, 1999; Pesaran et al., 2001).

[10] The test presents a range of critical lines of 5% and there is stability when the parameter is out of these critical values, in accordance with Pesaran et al. (2001). Also, this test is key to ARDL regressions, because they allow diagnosing the influence of structural breaks in the estimations.

where ρ are short-term coefficients.

2.2 Initial presentations, the unit root diagnosis and other tests

Table 1 reports the details of the data used in the empirical model. It displays all variables, their acronyms, unit of measurement and source. To better fit the Keynes-Harvey theoretical framework into the empirical model, there are three different equations (called systems). Keynes-Harvey model base factors – namely Brazil and USA inflation differential (DIFP), Brazil and USA nominal base interest rate differential (DIFI), Brazil and USA quarterly GDP growth differential (DIFG) and liquidity (LIQ) – and processes – net exports (NX), foreign direct investment (FDI) and portlio investment (PI), all data of Brazil – are analyzed both jointly (systems 1 and 2) and separately (system 3). Expectations of the awaited future change of the Brazilian exchange rate (VEXPER) and GDP growth (EXPG) entry all the three systems, because they are the variables of interest. Three different models are supposed to furnish better outcomes and so give higher consistence to the empirical exam. Table 1 also indicates in which system each variable appears.

Table 1 – Description of the variables

Variable	Description	Unit	System	Source
NER	Brazilian current nominal exchange rate	BRL/USD	1 - 2 - 3	IMF
DIFP	Brazil and USA inflation differential (based on the countries' consumer price index)	%	1 - 3	IMF
DIFI	Brazil and USA nominal base interest rate differential	%	1 - 3	IMF
DIFG	Brazil and USA quarterly GDP growth differential	%	1 - 3	OECD
LIQ	Liquidity, total credit to non-bank borrowers[11]	Millions of USD	1 - 2 - 3	BIS
NX	Brazilian net exports (international trade)	Millions of USD	2 - 3	IMF
FDI	Brazilian net foreign direct investments	Millions of USD	2 - 3	IMF
PI	Brazilian net portfolio investments	Millions of USD	2 - 3	IMF
VEXPER	Expected future change of the Brazilian nominal exchange rate (BRL/USD)	Quarterly % variation	1 - 2 - 3	BCB
EXPG	Expected Brazilian GDP growth	Annual % variation	1 - 2 - 3	BCB

Fonte: Authors' own elaboration.
Note: IMF is the International Monetary Fund, OECD is the Organization for the Economic Co-operation and Development, BIS is the Bank for International Settlements and BCB is the Brazilian Central Bank.

[11] We assume total credit to non-bank borrowers as a proxy for international liquidity to the private sector because it is the methodology adopted by the Bank for International Settlements.

Starting with the empirical tests, Table 2 presents the outcomes of the unit root tests. They are prior to the regressions as they signal the pertinence of using ARDL models as the empirical strategy[12]. Table 2 reports that there is a mixed set of both stationary and non-stationary variables at a significance level of 5%. In these circumstances, in which the series are either of order 1 (non-stationary) or 0 (stationary), ARDL models are useful and can be applied to exam the statistical relationship between expectations and the exchange rate.

Table 2 – Unit root tests and trend evidences

Variable	Stationarity Evidence at 5%	Trend Evidence at 5%	Integration
NER	KPSS	Negative	I(1)
DIFG	ADF, PP, DF GLS, e KPSS	ADF, PP, e KPSS	I(0)
DIFI	Negative	KPSS	I(1)
DIFP	ADF, PP, DF GLS, e KPSS	Negative	I(0)
LIQ	KPSS	KPSS	I(1)
NX	PP e KPSS	ADF e KPSS	I(1)
FDI	ADF, PP, DF GLS e KPSS	Negative	I(0)
PI	ADF, PP, DF GLS e KPSS	Negative	I(0)
EXPG	DF GLS	KPSS	I(1)
VEXPER	ADF, PP, DF GLS e KPSS	Negative	I(0)

Source: Authors' own elaboration based on the output of the software Eviews 10.
Note: More detail of the results and other outputs of the various tests performed are in the Annex.

Once it is clear that the variables suit ARDL models, the systems can be described. The three systems are formalizations of the Keynes-Harvey model developed in the previous Section. System 1 accounts for the relationship between the current nominal exchange rate (BRL/USD), expectations and base factors (DIFP, DIFI, DIFG and LIQ). System 2 takes into the current nominal exchange rate, expectations and processes (NX, FDI and PI) – so, system 2 excludes base factors. Lastly, system 3 is the whole Keynes-Harvey model; to explain the current nominal exchange rate it regards expectations, processes and base factors. The three equations are presented below,

$$\text{System 1: } NER_t = \beta_0 + \beta_1 DIFP_t + \beta_2 DIFI_t + \beta_3 DIFG_t + \beta_4 LIQ_t + \beta_5 EXPG_t + \beta_6 VEXPER_t + \varepsilon_t$$

$$\text{System 2: } NER_t = \beta_0 + \beta_1 NX_t + \beta_2 FDI_t + \beta_3 PI_t + \beta_4 LIQ_t + \beta_5 EXPG_t + \beta_6 VEXPER_t + \varepsilon_t$$

[12] The unit root tests are Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), Dickey-Fuller GLS (DF GLS), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS). The presence of an unit root is identified comparing the statistics of each test, at 1%, 5% and 10% significance level, to the value of the tests. The null hypothesis of the ADF, PP and DF GLS tests says that there is unit root (non-stationary series) whereas KPSS null hypothesis establishes that there is no unit root (stationary series).

$$\text{System 3: } NER_t = \beta_0 + \beta_1 DIFP_t + \beta_2 DIFI_t + \beta_3 DIFG_t + \beta_4 LIQ_t + \\ + \beta_5 NX_t + \beta_6 FDI_t + \beta_7 PI_t + \beta_8 EXPG_t + \beta_9 VEXPER_t + \varepsilon_t$$

where the variables follow the abbreviations shown in Table 1, the subscript *t* means current time observation and ε_t is the error term.

The last tests consist of using the Akaike Bayesian Criteria to find the best lag for each system as well as presenting LM, Jarque-Bera, CUSUM and CUSUMQ tests. Table 3 reports this information. The outcomes show that Systems 1 and 2 have six lags while System 3 has four. Also, there is no autocorrelation[13] in any system and the residuals are normally distributed[14]. Furthermore, the CUSUM and CUSUMSQ tests report results in between the established 5% range confirming that all systems are stable.

Table 3 –ARDL models: specification and tests[15]

System	ARDL models	LM test	Histogram	Stability tests
1	(6, 6, 3, 3, 5, 6, 6)	3.080 (0.143)	0.408 (0.815)	Stable (CUSUM and CUSUM SQ)
2	(6, 6, 0, 6, 5, 6, 5)	2.432 (0.167)	0.533 (0.765)	Stable (CUSUM and CUSUM SQ)
3	(4, 4, 4, 3, 2, 1, 0, 3, 0, 2)	1.533 (0.292)	1.073 (0.584)	Stable (CUSUM and CUSUM SQ)

Source: Authors' own elaboration based on the output of the software Eviews 10.
Note: It was not observed statistical significance when a trend was included in the tests; only the constants were significant in all systems.

3. Results and analysis

Table 4 reports the outcomes of the ARDL/BTA regression, also taking into consideration the critical values of Pesaran et ali. (2001). The null hypothesis is that the vectors are not cointegrated in the long-term. The results reject this hypothesis to all estimations at a significance of 5% and 10%; so, there are long-term associations in all equations. However, system 2 at a significance level of 5% has its F statistics within the limits of the range, making the cointegration inconclusive at this degree of significance.

Table 4 – Cointegration tests ARDL/BTA model[16]

[13] The coefficients of the regressors are available in the Annex. Moreover, all the estimations and tests can be furnished.
[14] Under the null hypothesis of normality in the series, the Jarque-Bera statistics is distributed in the form of x^2 with two degrees of freedom. The reported probability is that the statistics exceeds, in absolute values, the null hypothesis observed value.
[15] The ARDL models set of numbers in the Table represents the most significant variable lags for each system. Notice that ARDL models estimate a large number of equations and variables lags in order to find the one which best fits in terms of statistical significance. Thus, the number itself correspond to the lag of each variable, whose order follows the same one used to specify each equation (1) to (3).
[16] The output of this test presents F and t statistics associated to two critical values I(0) (bottom) and I(1) (top), determining the ranges through which the null hypothesis defines the levels between the dependent variable and the regressors of the equation: over the superior limit there is long-term relationship between the variables, below the inferior limit there is not, and within the limits, the outcome is inconclusive.

		Critical Values				
		I(0) Bound		I(1) Bound		
System	**F statistics**	**5%**	**10%**	**5%**	**10%**	**Long-term cointegration**
1	3.942421	2.27	1.99	3.28	2.94	Yes (at 5% and 10%)
2	2.991315	2.27	1.99	3.28	2.94	Yes (at 10%; inconclusive at 5%)
3	3.307559	2.04	1.8	2.08	2.80	Yes (at 5% and 10%)

Source: Authors' own elaboration based on the output of the software Eviews 10.

Table 5 reports all the long-term coefficients of the three systems. The results suggest that, in system 1, the one regarding Keynes-Harvey model base factors, growth rate differentials, liquidity, expectations of exchange rate changes and GDP growth have long-term effects on the current nominal exchange rate whereas the differentials of base interest rate differentials and inflation do not show long-term significant effects on the dependent variable. Thus, these outcomes are important because they make it possible to infer that expectations are statistically important to explain the exchange rate determination when the base factors are regressors of the exchange rate.

Based on the processes of Keynes-Harvey model, system 2 has Brazilian net exports, liquidity, GDP growth expectation (at 5% of significance) and foreign direct investment to Brazil (at 10%) as significant variables. Portfolio investment is not significant in explaining nominal exchange rate's long-term movements. In this system, variables more related to the real side, such as foreign direct investment, net exports and GDP growth, are more relevant to explain the nominal exchange rate. Lastly, expectation on exchange rate changes has no significance in the exchange rate determination. It is worth saying that liquidity has significance, so that it seems that when processes are considered individuals are rather concerned with having a convertible money in hands than with the future value of that very money.

Finally, all variables of system 3, which is the whole Keynes-Harvey model, have long-term significance; the only exception is GDP growth differential. This is the system that better represents the exchange rate determination, even because it is the most comprehensive one. GDP growth differential's absence of significance, in contrast to the significance of the expected Brazilian GDP growth, suggests that the absolute growth of each country matters more than GDP growth differentials across countries. Important to highlight that expectations about the future change of the exchange rate are significant

and so they help explaining the current nominal exchange rate. Once again, as in system 1, expectations play a role on explaining the current exchange rate.

Table 5 – Long-term coefficients

System	**1**		**2**		**3**	
Variable	Coefficient	Probability	Coefficient	Probability	Coefficient	Probability
DIFG	-0.84088	0.01600*	–	–	0.05798	0.47220
DIFI	-0.01104	0.81730	–	–	0.13025	0.00000*
DIFP	-10.90489	0.67220	–	–	49.56575	0.00150*
LIQ	-12.56418	0.01210*	-16.23805	0.01510*	10.86541	0.00000*
VEXPER	24.47339	0.04120*	-5.69547	0.61370	-12.57073	0.00900*
EXPG	-0.25441	0.00260*	-0.43649	0.01410*	0.13155	0.00220*
NX	–	–	-0.00008	0.04930*	0.00005	0.00000*
FDI	–	–	-0.00004	0.09400**	0.00012	0.00020*
PI	–	–	0.00031	0.10330	0.00016	0.00040*
Constant	5.01978	0.00060*	5.67035	0.00020*	-1.79246	0.00530*

Source: Authors' own elaboration based on the output of the software Eviews 10.
Note: * means significant at 5% and ** at 10%.

ECM is the second manner generally used to make diagnosis with coefficients of ARDL estimations, being used to identify both short-term interactions amongst the variables and the speed in which the cointegration association of the variables returns to equilibrium after a shock. ECM allows to analyze the adjustment dynamics of the current nominal exchange rate over time as a response to a punctual disturb it suffers from the first difference of the other explanatory variables. The coefficient of the cointegration equation is conjointly estimated with the regressors.

Table 6 reports ECM outcomes. If the variables are cointegrated, their expected coefficient must be negative and highly significant at 1% confidence, what was fulfilled. Coefficients of systems 1, 2 and 3 show that after a shock occurring in the first quarter in the nominal exchange rate, at each following quarter the dependent variable corrects its disturbance up to the equilibrium in 0.27%, 0.18% and 0.43%, respectively.

Table 6 – Results of the short-term dynamics (ARDL/ECM)

Error Correction – coefficient and probability										
ECM model outcomes	**System 1:**	-0.27	0.0000	**System 2:**	-0.18	0.0000	**System 3:**	-0.43	0.0000	
Lags with statistical significance										
System	NER	DIFG	DIFI	DIFP	LIQ	NX	FDI	PI	EXPG	VEXPER
1	1, 4	1, 2, 3, 4	0	1, 2	1, 2, 3, 4	–	–	–	1, 4	0, 1, 2, 3, 4, 5
2	5	–	–	–	1, 2, 3, 4	1, 2, 3	–	1, 2, 3, 4	1, 2, 5	0, 1, 2, 3, 4
3	1, 2, 3	0, 1	0, 1, 2	0, 1, 2	1, 2, 3	0, 1	0, 1, 2, 3	0, 1, 2, 3	0	0, 3

Source: Authors' own elaboration based on the output of the software Eviews 10.

In system 1, the one with base factors and expectations, liquidity and the differentials of GDP growth, base interest rate and inflation have significant positive relationship with nominal exchange rate, making them important elements to the short-run exchange rate determination in Brazil. The lags of GDP growth differential, inflation differential and liquidity are significant. Base interest rate differential showed only contemporary significance, without any relevant lag. GDP expectations are significant in lags 1 and 4, meaning that the relevant expectations to determine the actual exchange rate are those formed in the last quarter and in the last year, respectively. Expectations of exchange rate changes are significant in the first five lags and in the current period, though the coefficient is positive just for the contemporary expectation and for that made in the past four and five quarters, meaning that expectations of one year ago is also relevant for setting current exchange rates[17].

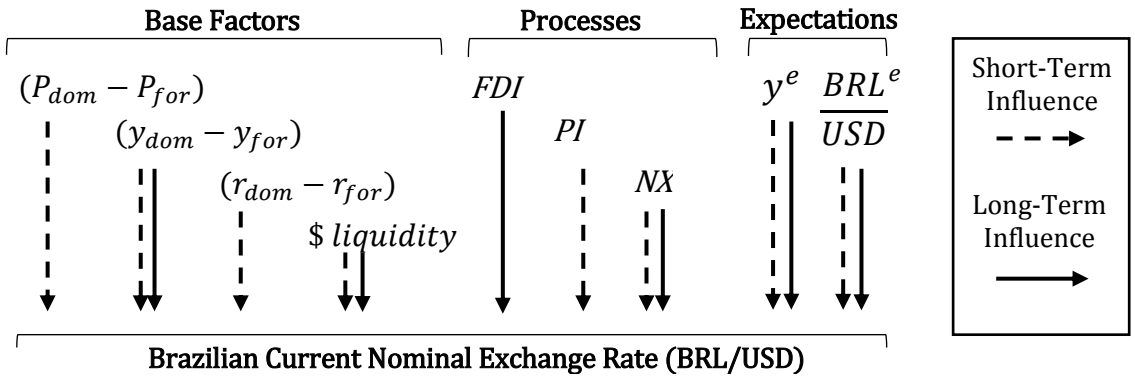
The results of system 2, that includes Keynes-Harvey processes, show that foreign direct investment is not a significant regressor. This can be related to the predominance of portfolio capital flowing into Brazil, what makes it more relevant to the short-run exchange rate determination than the direct investment fluxes. Liquidity and both expectations (exchange rate changes and GDP growth) are statistically significant, once again an important outcome regarding the role that expectations play on defining current exchange rate. Expectation on exchange rate changes is also a significant regressor in level (contemporary significance), such as happened in system 1. However, in system 2, expectations of exchange rate changes are significant for five following quarters, lags in which agents define the short-run relevant horizon through which they expect that the exchange rate moves.

System 3 synthesizes all variables of the Keynes-Harvey model, incorporating the base factors, processes and expectations to explain the current nominal exchange rate. Its results reveal that all variables have at least one significant regressor, with different lags. Moreover, liquidity is the only variable not significant in level, whilst the others, including the two measures of expectations, are significant. So, system 3 statistically confirms the relevance of expectations for exchange rate determination, such as suggested by the Keynes-Harvey model.

[17] In the Annex there is more information about the magnitude and the signal of the coefficients identified in the ECM model.

Figure 3 shows a summary of BTA and ECM ARDL estimations' outcomes. It is based on Figure 2, previously presented to sum up Keynes-Harvey model. The short- and long-run analysis pursue the following logic: base factors' outcomes are those founded by system 1, processes' results are based on system 2, and the complete model is the outcome of system 3. Figure 3 shows that, within the base factors, differentials of inflation and base interest rate exert short-term influence on the current nominal exchange rate. Liquidity and GDP growth differential have short- and long-run influence on the current nominal exchange rate. Amid the model's processes, foreign direct investment affects the current nominal exchange rate in the long-term, portfolio investment in the short-run and net exports in both. Lastly, the most relevant outcome of this analysis: expectations influence exchange rate determination both in the short- and long-run, as suggested by the Keynes-Harvey model.

Figure 3 – An analysis of short- and long-term results in a summary of Keynes-Harvey model



Source: Authors' own elaboration.

Final remarks

The theoretical framework of the exchange rate determination given by the Keynes-Harvey model, in which expectations play a major role, is corroborated by the empirical analysis of this paper. In this sense, it is possible to suggest that the model represents how an agent collects information about prices, interest rates, liquidity and GDP growth to form expectations of some future exchange rate. In turn, these elements shape, indeed, the current exchange rate.

ARDL estimations have explicit results showing that expectations of the exchange rate change and of GDP growth have, in both the short- and long-term, statistical significance in explaining the Brazilian BRL/USD exchange rate over 2002-2017. Base factors, namely liquidity and the differentials of inflation, base interest rate, and GDP

growth between Brazil and USA, are statistically related to the Brazilian current nominal exchange rate. However, they have different effects in the short- and long-run. Whilst in the short-run all base factors are significant to the BRL/USD rate, in the long-term, price and interest rate differentials are not significant. The same can be said about the processes of the Keynes-Harvey model, there is no consistence between foreign direct investment, portfolio investment and the net exports of international trade: the first only correlates to the exchange rate determination in the long-run, portfolio investments only in the short-run and international trade in both.

Capital flows as well as interest rate differentials, typical elements in a speculative demand for foreign money, are more significant in the short-term whereas they have mixed outcomes in the long-run, depending on the system that encompasses them. Nevertheless, factors like net exports and GDP growth are more strongly related to the long-term determination of the exchange rate, showing somehow that these are more structural aspects related to the long-run tendency of the exchange rate – that is why they are named fundamentals in a conventional analysis. Above all, in both the short- and long-run, expectations of future exchange rate change and of GDP growth are significant, what corroborates the fundamental role played by expectations on the BRL/USD exchange rate determination in Brazil from 2002 to 2017.

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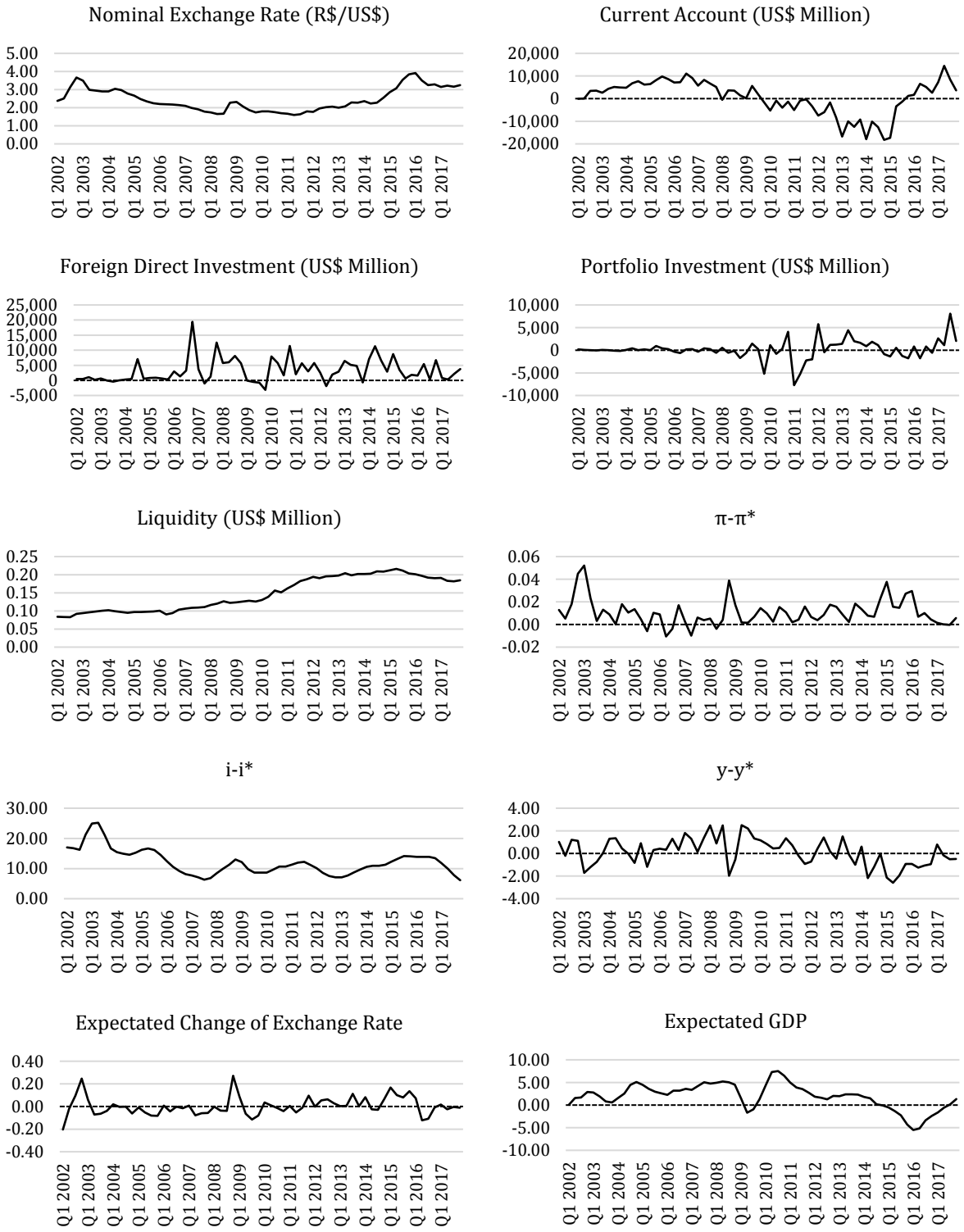
Annex

Table 1 – ARDL/ECM: Statistically significant regressors at 5%

System 1			System 2			System 3		
Regressors	Coeff.	Prob.	Regressors	Coeff.	Prob.	Regressors	Coeff.	Prob.
CointEq(-1)*	-0.2666	0.0000	CointEq(-1)*	-0.1752	0.0000	CointEq(-1)*	-0.4335	0.0000
D(NER(-1))	-0.5654	0.0026	D(NER(-5))	0.4993	0.0020	D(NER(-1))	-0.7366	0.0005
D(NER(-4))	-0.8821	0.0004	D(NX(-1))	0.0000	0.0002	D(NER(-2))	-0.7670	0.0006
D(DIFG(-1))	0.1373	0.0003	D(NX(-2))	0.0000	0.0008	D(NER(-3))	-0.4776	0.0034
D(DIFG(-2))	0.0958	0.0019	D(NX(-3))	0.0000	0.0009	D(DIFG)	-0.0368	0.0010
D(DIFG(-3))	0.1072	0.0004	D(LIQ(-1))	7.0325	0.0089	D(DIFG(-1))	-0.0336	0.0010
D(DIFG(-4))	0.0838	0.0006	D(LIQ(-2))	5.1949	0.0361	D(DIFI)	0.0455	0.0009
D(DIFG(-5))	0.0313	0.0279	D(LIQ(-3))	7.3874	0.0068	D(DIFI(-1))	-0.0401	0.0150
D(DIFI)	0.0399	0.0133	D(LIQ(-4))	5.8682	0.0306	D(DIFI(-2))	0.0508	0.0002
D(DIFP(-1))	-5.6326	0.0011	D(PI)	0.0000	0.0391	D(DIFP)	-3.8590	0.0131
D(DIFP(-2))	-5.0369	0.0073	D(PI(-1))	0.0000	0.0005	D(DIFP(-1))	6.9586	0.0162
D(EXPG(-1))	0.0482	0.0452	D(PI(-2))	0.0000	0.0011	D(DIFP(-2))	6.7958	0.0016
D(EXPG(-4))	0.0642	0.0071	D(PI(-3))	0.0000	0.0024	D(LIQ(-1))	16.9298	0.0000
D(LIQ(-1))	8.2061	0.0006	D(PI(-4))	0.0000	0.0009	D(LIQ(-2))	13.1753	0.0001
D(LIQ(-2))	6.1411	0.0074	D(EXPG(-1))	0.0482	0.0127	D(LIQ(-3))	13.0230	0.0001
D(LIQ(-3))	5.0369	0.0177	D(EXPG(-2))	0.0771	0.0015	D(NX)	0.0000	0.0034
D(LIQ(-4))	6.0197	0.0121	D(EXPG(-5))	0.0467	0.0124	D(NX(-1))	0.0000	0.0005
D(VEXPER)	2.2997	0.0000	D(VEXPER)	1.9292	0.0000	D(FDI)	0.0000	0.0243
D(VEXPER(-1))	-2.2051	0.0198	D(VEXPER(-1))	3.2260	0.0000	D(FDI(-1))	0.0000	0.0000
D(VEXPER(-2))	-1.9140	0.0105	D(VEXPER(-2))	3.2282	0.0000	D(FDI(-2))	0.0000	0.0000
D(VEXPER(-3))	-1.1561	0.0350	D(VEXPER(-3))	2.6374	0.0000	D(FDI(-3))	0.0000	0.0002
D(VEXPER(-4))	0.7430	0.0204	D(VEXPER(-4))	1.2212	0.0049	D(PI)	0.0000	0.0000
D(VEXPER(-5))	0.4932	0.0177				D(PI(-1))	0.0000	0.0003
						D(PI(-2))	0.0000	0.0489
						D(PI(-3))	0.0000	0.0001
						D(EXPG)	-0.1008	0.0000
						D(VEXPER)	2.8474	0.0000
						D(VEXPER(-3))	1.1235	0.0000

Source: Authors' own elaboration based on the output of the software Eviews 10.

Graph 1 – Descriptive analysis of the dataset: January 2002 to December 2017, in quarters



Source: Authors's own elaboration based on data from IMF, OCDE, BIS e BCB.