Journal of Applied Economics and Business

OPEN ACCESS ARTICLE

ON THE ROLE OF CONTAGION EFFECTS IN TOTAL RESERVES IN SOUTH AMERICA

Paulo Matos[1*], Felipe Reis[1]

[1]Graduate Program in Economics, University Federal of Ceará, Brazil - CAEN/UFC

[*]paulomatos@caen.ufc.br

Abstract

With the growth of international reserves in the last decades, the existence of contagion and financial integration between Argentina, Brazil, Chile, Colombia and Peru is found by Matos et al., (2014). We add to the international reserve literature using the Frenkel and Jovanovic (1981) buffer stock model. Our fundamental innovations are the consideration of the cross-effects of conditional volatilities, spreads and imports on the model. The joint estimation of this framework allows a considerable increase in the explanatory power in addition to detecting the relevant role of the volatility of the Colombian reserves, Argentine spreads and imports from Brazil and Chile in the modeling of reserves in other countries. In this period, too, one can see oscillation between a more daring and a conservative stance on the accumulation of international reserves in these countries.

Key words:

South America; International Reserves; Buffer Stock; Cross-Effects; VEC.

INTRODUCTION

The reserve stock of a country is the sum of all the net assets in foreign currency held by the central bank as a guarantee for the payment of the obligations of that nation. According to Souza and Triches (2013), reserves are instruments of security for the direction of a monetary and exchange rate policy, providing an interventionist capacity and aiming to achieve the desired exchange rates. Therefore, international reserves serve as a buffer against crises or emergencies.

According to Jeanne (2007), the emerging market international reserves have increased since the 1990s; for example, China has the largest stock of international reserves in the world, having surpassed Japan at the end of 2005 and being responsible for part of the accumulation of reserves in emerging markets. Alfaro and Kanczuk (2009) argue that this reserve increase is not unique to China or the East Asian

countries but is a widespread phenomenon among emerging markets, including countries with a large amount of external debt.

The cost and benefit of these reserves from emerging countries are a point of discourse among policy makers, such as Jeanne and Rancière (2011), and Hur and Kondo (2016). These large reserve balances are necessary to avoid or mitigate the impacts of a financial crisis, and their cost is negligible in the face of a crisis. However, Aizenman and Marion (2003), Soto and García (2004), and Rodrik (2006) conduct a cost–benefit analysis of the accumulation of reserves, in which they evaluate the impact of these reserves on a probable default and compare it with the opportunity cost, noting that, for a country to have a high level of reserves, it requires a high maintenance cost.

An important aspect of the discussion is to note that emerging and developed countries are affected by crises in different ways and thus seek different solutions. The database constructed by Lane and Ferreti (2007), and Pina (2015) shows clear divergence in the relationship between the international reserves and the GDP for emerging and developed economies. In 1987, the average of 24 developed countries was approximately 10%, very close to the 11% obtained as the average of 154 emerging countries.

In this scenario, the following question arises: what is the optimal level of international reserves for a developing country? Many authors, such as Jeanne and Rancière (2011), Summers (2006), and Matos (2016), consider this question as a puzzle in international finance. Faced with this question, we add to this debate by proposing a methodological innovation aiming to model the optimal time path of the amount of international reserves in Argentina, Brazil, Colombia, Chile and Peru, which enables us to answer the question of whether there is excess conservatism or not and thus whether there is a puzzle in South America or not.

More specifically, this article aims to contribute to the theoretical–empirical literature on international reserves, following conceptually and in theoretical terms the basic notions of Heller (1966). It is aligned with Ben-Bassat and Gottlieb (1992), and Chakravarty (2009), aiming to propose an innovative framework based on idiosyncratic extensions to the model developed by Frenkel and Jovanovic (1981), entitled the buffer stock model. This model considers the associated adjustments to the exchange rate and monetary policy, besides the opportunity cost of holding such a volume of reserves. In terms of application, we follow Jeanne (2007), Pina (2015), Ford and Huang (1994), and Ramachandran (2004), whose related studies analyze reserves in emerging economies, and especially Matos et al., (2016), who apply the buffer stock model with an extension to the BRICS.

Our methodological innovation in relation to the other studies, which empirically address the question of these reserves in each of these individual emergent economies, is based on Frenkel and Jovanovic's (1981) buffer stock framework. However, we

consider the significant cross-effects of conditional volatilities, spreads and imports given the strong financial and trade relationship between Argentina, Brazil, Colombia, Chile and Peru. In addition, we especially consider the evidence reported by Mejía-Reyes (2000), Hecq (2002), and Matos et al., (2014) that, despite their heterogeneity, the financial markets and commercial transactions of these emerging countries have strong relationships in the short and long term.

The article is organized as follows. Section 2 provides a historical discourse about the reserve levels of Argentina, Brazil, Chile, Colombia and Peru. Section 3 reviews the buffer stock literature and its extensions. In Section 4, we present the variables used and the methodology adopted, while in Section 5 we perform the empirical exercise and discuss the results. Finally, the conclusion of the work is outlined in Section 6.

SOUTH AMERICAN RESERVES

There is a trend for the accumulation of international reserves in the economies of the world. Steiner (2013) notes in his study that, between 1970 and 2010, the official reserves worldwide grew at an average annual rate of 15% and finds that this accumulation of reserves was mainly due to developing economies and economies in transition. The share of these economies in the total world reserves increased from 22% in 1970 to 65% in 2010, and the phenomenon of reserve accumulation is not restricted to some isolated places but occurs in most countries. Furthermore, Steiner (2013) notes that, from 1982 to 1996, on average 58% of countries increased their reserves in real terms and that this share increased to 67% in the period from 1997 to 2010.

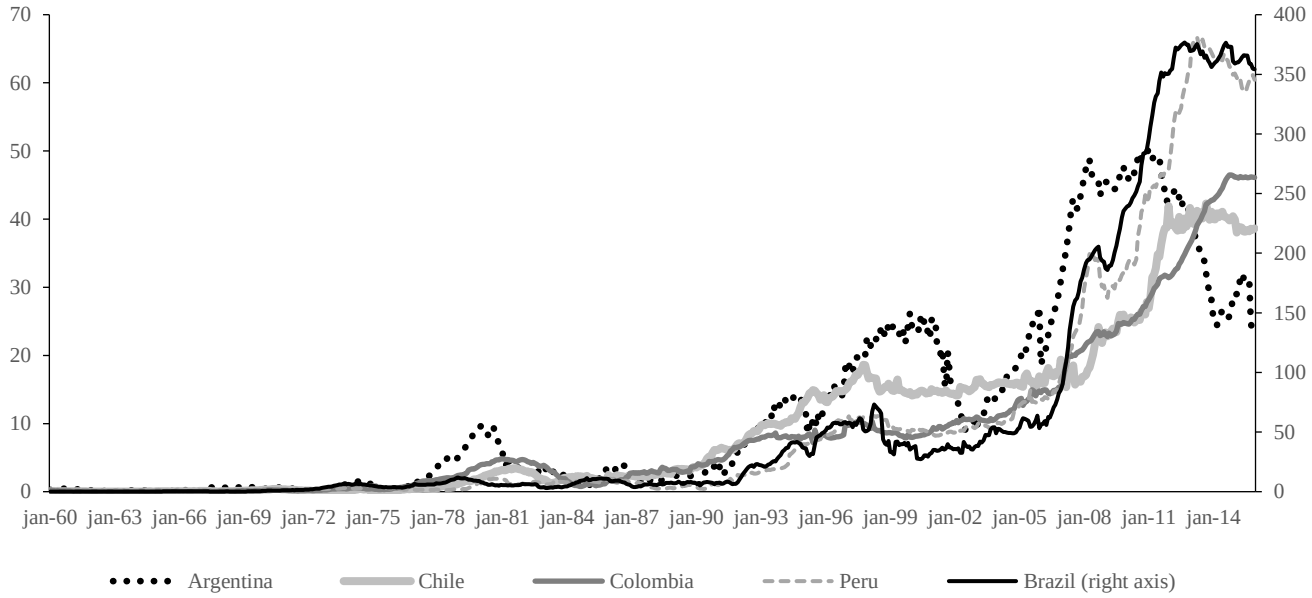


FIGURE 1. TOTAL RESERVES EXCLUDING GOLD (US$ MILLION)
Data Source: FRED

In South America, the stock of reserves does not differ. Figure 1 shows the stock of reserves in billions of dollars of Argentina, Brazil, Chile, Colombia and Peru from January 1960 to December 2015. Based in Figure 1, we identify stability in the first decade, and from the 1970s and with the end of the Bretton Woods system, there was an increase in the international reserves in these countries. This growth has become much more pronounced since the 1990s, which, according to Rodrik (2006), is the decade identified as the beginning of the era of globalization.

From the 1990s, there was a considerable drop in the South American international reserves, which may have been influenced by the international financial crisis. Bandeira (2002) reports that the crisis began in Asia in 1997 and reached Brazil in 1999, more strongly in 2002 in Argentina, and with it political instability, the fall of the president and the request for default. This may be one of the factors contributing to the fall in the Argentine reserves between 2000 and 2002.

Figure 2 shows the monthly evolution of the absolute volume of reserves in millions of dollars for Argentina, Brazil, Chile, Colombia and Peru over the period from January 2004 to December 2015. With the exception of Argentina, we can see an apparently growing movement of countries, with average growth rates ranging from 0.44% in Argentina to 1.4% in Brazil. The discrepancies are due to the order of magnitude of the Brazilian reserves, which in total for this period was more than ten times the Peruvian volume; however, this evidence is expected due to the size of this economy vis-à-vis the others.

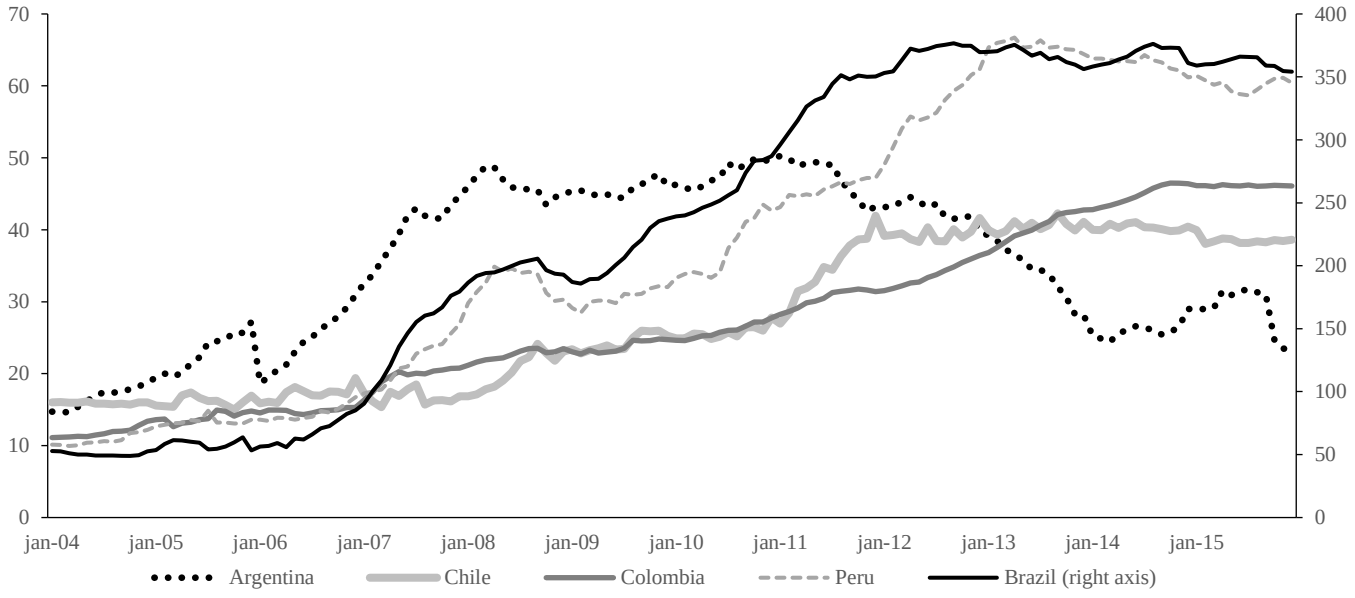


FIGURE 2. TOTAL RESERVES EXCLUDING GOLD (US$ MILLION)
Data Source: FRED

Scale discrepancies can be removed when we use other indicators, considering the level of reserves in ratio to the other important variables, such as imports and GDP. Figure 3 shows the annual international reserves of the same economies in ratio to the

GDP from 1965 to 2014, which also shows a tendency to increase the reserves. A small decline is apparent in the late 1990s and early 2000s, which agrees with Dominguez et al., (2012), who observe that the countries that suffered crises and a loss of reserves in the late 1990s were in the process of recomposing their reserves in the years before the global crisis of 2008.

In comparison with the G7 country reserves, according to Luna (2016), the reserves declined continuously from 1989, when they accounted for 43.2% of the world's total reserves, and in 1999, they reached 29% and in 2010 beat the level of 15%. According to Matos et al., (2016), the G7 countries' reserves remained below 10% of the GDP with the exception of Italy, which reached 25% of its GDP at the end of 2014.

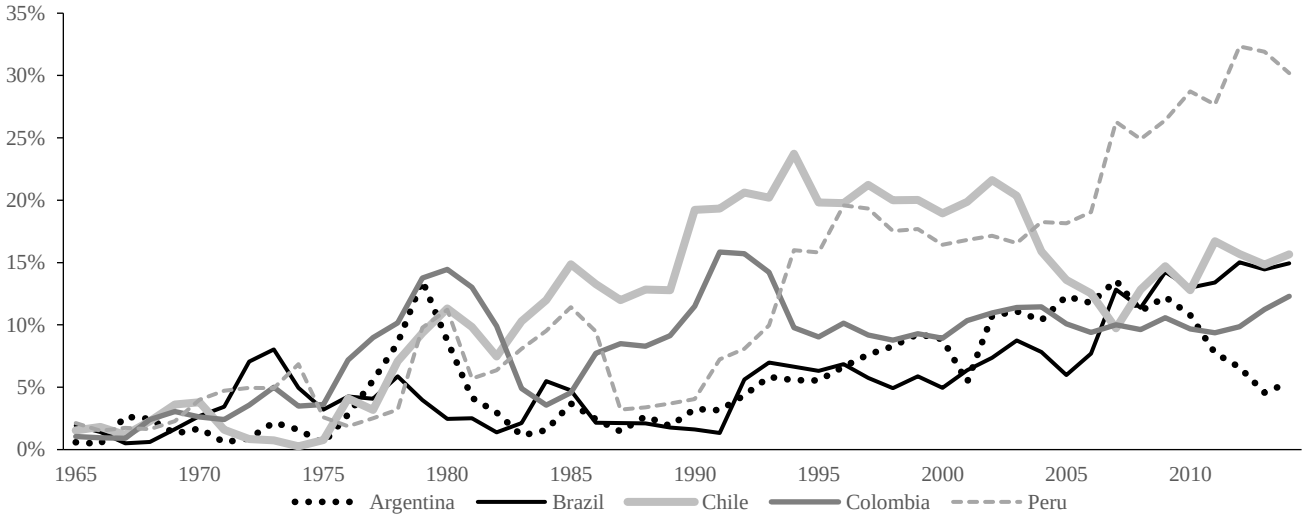


FIGURE 3. TOTAL RESERVES EXCLUDING GOLD (PERCENTAGE OF GDP)
Data Source: FRED

Another indicator for the accumulation of international reserves takes into account the participation of each country in international trade. According to Rodrik (2006), and Bird and Rajan (2003), the reserve accumulation in ratio imports equivalent to three months of imports is considered an adequate level. Rodrik (2006) finds that this proportion oscillated around three during the 1990s in almost all developing countries.

Figure 4 shows the accumulation of reserves in ratio for the last 3 months of imports from January 2005 to December 2015. In the beginning, we observe behavior close to 3 times the imports and in 2007 a highlight for the growth of Brazil that comes close to 6 due to the growth in imports and GDP. In 2008, with the crisis, all the countries suffered a decrease, with Chile reaching in October 2008 the level of 1.2 times the volume of imports and Brazil and Peru registering approximately 5 times the imports at the beginning of 2008 and almost 3.7 times their reserves in relation to imports.

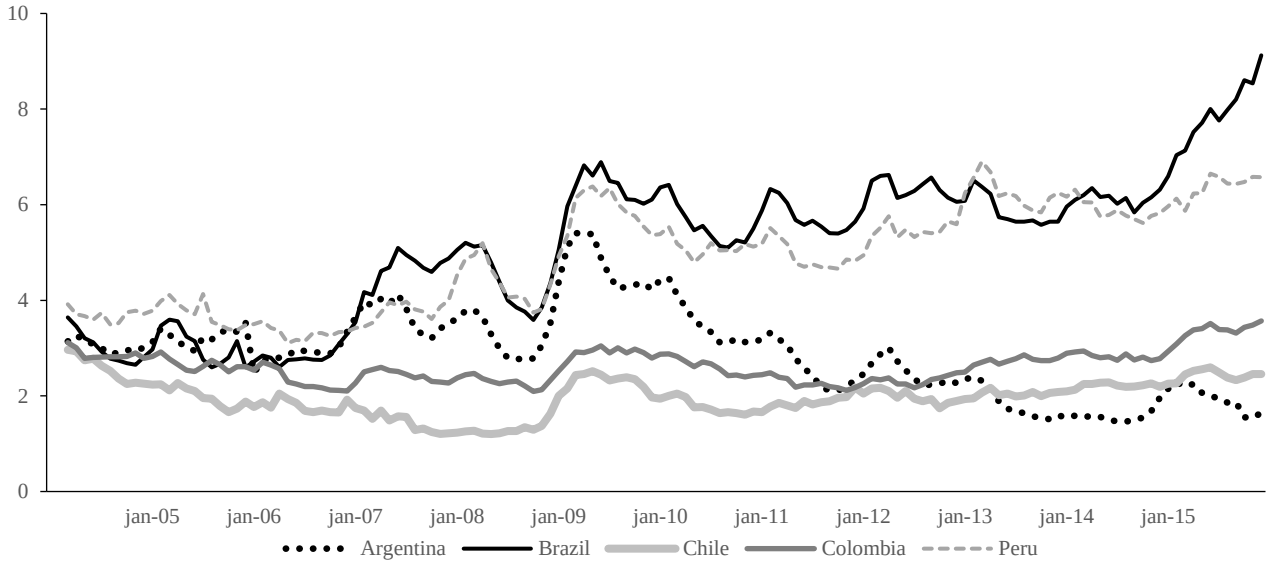


FIGURE 4. TOTAL RESERVES EXCLUDING GOLD (PERCENTAGE OF 3 MONTHS OF IMPORTS)
Data Source: FRED

After this period, we observe a recovery of reserves by the year 2009, with Brazil and Peru reaching almost 6.5 times, Argentina 5 times and Chile and Colombia almost 3 times. All of them maintained these levels until the end of 2014 and registered an increase during the year 2015 with the exception of Argentina, which is the only one to reduce its reserves in ratio to 3 months of imports (1.6 times).

Graphically, there is very similar behavior in these economies with small differences in magnitude, given the size of the reserves and the volume of the imports in some periods. This behavior can be explained by the contribution of Lewis (1980), which suggests that the growth engine of underdeveloped countries is trade; moreover, while most Latin American countries have weak domestic markets, the only option for these countries to grow would be increased interregional cooperation through trade in underdeveloped countries.

RELATED LITERATURE

Most of the initial studies about international reserves indicate that the demand for international reserves is attributable to the necessity of softening trade balance instability. However, with the changes in the global financial environment, in which there is increasing capital mobility, greater exchange rate flexibility, rapid growth in financial market innovations and increased global financial integration, a buffer stock approach to international reserves emerges. In this context, Heller (1966) is possibly one of the pioneers in promoting the debate on the topic. He associates the optimal level of reserves with a protection instrument to cushion imbalances in the balance of payments and incorporation of variables related to the adjustment cost and opportunity cost of reserves.

Some related contributions at this time include Kenen and Yudin (1965), who introduce the use of econometric techniques. At the beginning of the 1970s, with the end of the Bretton Woods system, there was renewed interest in the theme, with the contribution of Kelly (1970) highlighting the differences in the demand for reserves between economies that are more and less open. Frenkel (1974) emphasizes the differences in developed and developing nations. Further contributions include those by Heller and Kahn (1978), Saidi (1981), Edwards (1983), Frenkel (1984), and Lizondo and Mathieson (1987). The third moment of greater intensity in the literature arises only as a consequence of the exchange crisis, the crisis of the European Monetary System and the crisis of the "

Asian tigers" in the 1990s.

Based on this literature, we stratify the models into first, second and third generations. The first generation is exemplified by Krugman (1979), and Flood and Garber (1984), who emphasize the role of reserves as a tool for postponing crises. The second generation of models is known as exchange rate crises, instituted by Obstfeld (1994). The third generation, inaugurated by Furman et al., (1990) with Ben-Bassat and Gottlieb (1992), is a model aligned with that developed by Frenkel and Jovanovic (1981) to base the optimum level on the balance between the costs of macroeconomic adjustment and the opportunity costs.

The derivations of these frameworks and their respective empirical applications are numerous, so this discussion about the adequacy of the models in each situation or economy is extensive and not consensual. It is common sense that all frameworks are grounded in some cost–benefit relationship based on macroeconomic variables, like the financial ones by Krugman (1979), exchange by Calvo and Reinhart (2002) or politically and institutionally aligned with Cheung and Ito (2009).

In this context, this article follows the approach proposed by Frenkel and Jovanovic (1981) of a denominated buffer stock. They consider the adjustments associated with exchange and monetary rate policies as a counterpart to the opportunity cost measured by alternative options vis-à-vis the composition of the volume of international reserves. Among the recent applications of this framework, it is worth mentioning Ramachandran (2004), Flood and Marion (2002), and Luengo-Prado and Sörensen (2004), who associate this model with the use of panel data.

Methodologically, the present article is aligned with Cifarelli and Paladino (2009), who use the model to analyze the dynamics of the countries of South America with Asian countries, and Chakravarty (2009), who makes a simple, more relevant extension of the model buffer stock. More recently, Matos (2016) makes use of the model with an extension of breaks for Brazil. Specifically, we follow Matos et al., (2016), who follow the buffer stock model with cross-effects for the BRICS.

METHODOLOGY

Assuming that the balance of payments of economy i is in equilibrium and that the reserves follow a stochastic Wiener process, one can derive the optimal path, $R^*_{i,t}$, to minimize the macroeconomic adjustment costs and opportunity costs. Assuming that $R^*_{i,t}$ follows a second-order Taylor approach suggests that the optimal level of reserves held by economy i at time t (in log) depends linearly on the standard deviation of the change in reserves (in log), given by $ln(\sigma_{i,t})$, on the opportunity cost of holding reserves (in log), given by $ln(r_{i,t})$, and on the imports (in log), given by $ln(I_{i,t})$. This optimal level can be described as:

$$ln(R^*_{i,t}) = \beta_0 + \beta_1\, ln(\sigma_{i,t}) + \beta_2\, ln(r_{i,t}) + \beta_3\, ln(I_{i,t}) + \varphi_{i,t} \quad (1)$$

In this relation $\varphi_{i,t}$ means the residual. Although simple, the implementation and possible extensions are not consensual, motivating some routes in this literature. Frenkel and Jovanovic (1981) report estimated elasticities close to the theoretical predictions of the model, $\beta_1 = 0.5$ and $\beta_2 = -0.25$, and Cifarelli and Paladino (2009) initially assume $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$, but many studies, such as Ramachandran (2004) and Flood and Marion (2002), obtain different values for the elasticities. Chakravarty (2009) argues that the reason is that these estimates are highly sensitive to the proxy used to represent the opportunity cost, model specification, estimation methods and additional variables included in the original equation.

The most promising route, following Frenkel and Jovanovic (1981), suggests extensions to their benchmark framework in the sense of incorporating some idiosyncratic additional variables, which are important in the determination of the level of reserves for specific emerging economies. Chakravarty (2009), for instance, takes into account the positive correlation between the reserve holdings and the size of international transactions, while Matos (2016) adds the expectations of the most relevant macroeconomic variables in Brazil. We follow them by proposing an extension that incorporates contagion effects on the reserves in Argentina, Brazil, Chile, Colombia and Peru by estimating a joint buffer stock benchmark model for these economies. To summarize, we propose a joint estimation model for the reserves of the country that can be described as follows:

$$ln(R^*_{i,t}) = \varphi_0 + \gamma_{i,i}\, ln(\sigma_{i,t}) + \delta_{i,i}\, ln(r_{i,t}) + \emptyset_{i,i}\, ln(I_{i,t}) + \sum_{j\neq i} \gamma_{i,j}\, ln(\sigma_{j,t}) + \sum_{j\neq i} \delta_{i,j}\, ln(r_{j,t}) + \sum_{j\neq i} \emptyset_{i,j}\, ln(I_{j,t}) + \varepsilon_{i,t} \quad (2)$$

$$\varepsilon_{i,t}|\psi_{t-1} \sim N(0, \sigma^2_{i,t}) \quad (3)$$

$$\sigma^2_{i,t} = \theta_0 + \sum_{l=1}^{q} \theta_l \varepsilon^2_{i,t-l} + \sum_{s=1}^{p} \tau_s \sigma^2_{i,t-s} + \xi_{i,t} \quad (4)$$

Regression (2) suggests that the optimal level of reserves held by economy i at time t depends not only on the respective standard deviation of the change in reserves and the opportunity cost of holding reserves but also on the standard deviation,

opportunity cost and imports of all the other countries, given by $ln(\sigma_{j,t})$, $ln(r_{j,t})$ and $ln(I_{j,t})$.

In this sense, to incorporate these effects, the intuition that they are not negligible lies in the recent empirical evidence that there is contagion and financial integration in the countries of South America. The estimation is suggested here of relation (1), in a system for the five emerging economies following a vector auto regressive (VAR) model or its natural extension, in the case of cointegration in the time series in question, that is, a vector error correction model (VEC).

The second step is the adoption of a framework for modeling the volatility. Engle (1982) suggests conditional variance heteroskedasticity as a linear function of the square of past innovations, giving rise to the famous framework entitled autoregressive conditional heteroskedasticity (ARCH). Aiming to obtain a more parsimonious framework, no major problems with signal parameters and both a long memory and a more flexible lag structure, we follow the extension suggested by Bollerslev (1986) entitled generalized ARCH (GARCH).

Here, we follow West and Cho (1995), who show that, for short time horizons, exercises following the GARCH family of frameworks are more accurate and appropriate to predict volatility than a constant standard deviation or even compared with other frameworks of conditional volatility. A recent application of this very interesting framework for Brazil and other Latin American countries is reported by Hegerty (2014).

Concerning the GARCH model, $\varepsilon_{i,t}$ is the demeaned series of reserves, which follows a normal distribution, and of which the conditional variance $\sigma_{i,t}^2$ is expressed by equation (4). Regarding this equation of variance, as is usual in the GARCH specification, we have that $p > 0, q > 0, \theta_0 > 0, \theta_l \geq 0, \tau_s \geq 0$ and $0 \leq \sum_{l=1,s=1}^{\max(p,q)}(\theta_l, \tau_s) < 1$. As reported in this literature, low-order GARCH is used in most applications. Therefore, we have to find the best specification for GARCH by defining the number of lags, p and q, respectively. $\xi_{i,t}$ is the residual of the variance equation.

EMPIRICAL EXERCISE

The data used in this study consist of time series of monetary, financial and exchange rate variables with monthly frequency for the economies of Argentina, Brazil, Chile, Colombia and Peru, according to their original formation. In the case of reserves, aiming at uniformity, all the series are converted into US dollars using the official spot exchange on the last business day of the month.

The series of spreads is the ratio of the gross nominal returns of the respective domestic interest rates, a proxy for which is given by the ratio between the heading immediate interest rate. These data are available from the Organization for Economic

Co-operation and Development (OECD Statistics) and the US rate, calculated through the open parity applied to the monthly series of Treasury bills (T-bills).

The data for these countries are restricted to the sample from January 2004 to December 2015 in the 144 monthly observations. The sources of these data, the series of spot exchanges of international reserves in the domestic currency, imports of goods and the interest rate in the US economy were extracted from the Federal Reserve Economic Data (FRED), International Monetary Fund (IMF)/International Fund Statistic (IFS). The rates set by central banks in the very short term were extracted from the OECD Statistics.

A basic condition to guarantee the reliability of the autoregressive vector method (VAR) is the performance of specific tests for stationarity, which are based on the unitary root test. These can be analyzed through different tests, including the augmented Dickey–Fuller (ADF) test. The results reported in Table 1 are obtained through the augmented version (ADF) of the test originally proposed by Dickey and Fuller (1979, 1981).

TABLE 1. UNIT ROOT TEST[a,b]

Variable	Test	Level		First difference	
Ln(Reserves)		Test statistic	p-value	Test statistic	p-value
Argentina	ADF	-2.207	0.204	-10.280	0.000
Brazil	ADF	-1.904	0.330	-5.057	0.000
Chile	ADF	-0.772	0.824	-13.562	0.000
Colombia	ADF	-1.609	0.476	-9.847	0.000
Peru	ADF	-2.072	0.256	0.256	0.000

[a]Unit root tests of the time series of the Naperian logarithm of international reserves in US dollars during the period from January 2004 to December 2015. [b] Results based on the Dickey–Fuller unit root test, for which the reported t statistics refer to the specification with trend and intercept. These results are robust to changes in this specification. The critical values reported at 5% follow McKinnon (1996). The choice of lags follows the Schwarz criterion.

We observe that all the time series (in log) of the reserves in this block of emergent countries are non-stationary, and they are stationary in the first difference, a result that is robust to a change in technique, since each is more adequate due to the power of the test. Because of this result, we can proceed to the estimation of the econometric vector error correction (VEC) framework.

Besides this result, the accumulation of international reserves adopted by a country is questioned by its maintenance cost, which is linked to the spread between the interest received with the application of reserves in the international markets and the abdicated returns for not investing in some alternative applications of these resources.

If there are costs and benefits, it is very probable that there is an optimal volume of international reserves, which equals the marginal costs and benefits of asset maintenance, so the variable of the buffer stock model seeks to capture the social cost associated with this maintenance of international reserves. In addition, the spread is nothing more than the interest difference.

Rodrik (2006) observes two types of costs involved in accumulating international reserves. First is the spread between the cost of short-term private sector loans abroad and the yield that the Central Bank earns on its net foreign assets, such as T-bills. Second is the loss from buying T-bills instead of increasing the capital stock or social expenditures like programs to combat poverty.

The series for this spread from January 2004 to December 2015 in South America are reported in Figure 5.

The Argentine spread, unlike that of the other economies, clearly shows increasing behavior over the period, rising from a value close to zero, 0.19% in March 2004, to reach 22.65% in December 2015. It is also important to highlight that, after the application of exchange control on October 31, 2011, there was a jump in the spread charged by the Government.

In the other economies, we observe that apparently similar behavior occurs, only with different magnitudes, whereby, after the American subprime crisis in 2008, there was a strong reaction of the economies in this period. As international investors withdrew their investments from several emerging countries at that time, followed by an increase in the spreads, Brazil and Argentina arrived at the beginning of 2009 at approximately 13%, Chile and Colombia at around 8% and Peru at around 6%.

The empirical literature based on this model commonly makes use of the techniques that make up the autoregressive conditional heteroskedasticity (ARCH) family, introduced by Engle (1982), to extract the volatility series of the reserve variation. This family ranges from simple and parsimonious specifications to others, such as the exponentially weighted moving average (EWMA) and other extensions, like the generalized ARCH, exponential GARCH and threshold GARCH models.

Table 2 reports the main results based on the estimate of the buffer stock model, including the cross-effects. In the first step are the results of the estimation of the volatility frameworks of the reserve variations of Argentina, Brazil, Chile, Colombia and Peru, in which all the GARCH specifications are estimated up to two residual lags and variance lags.

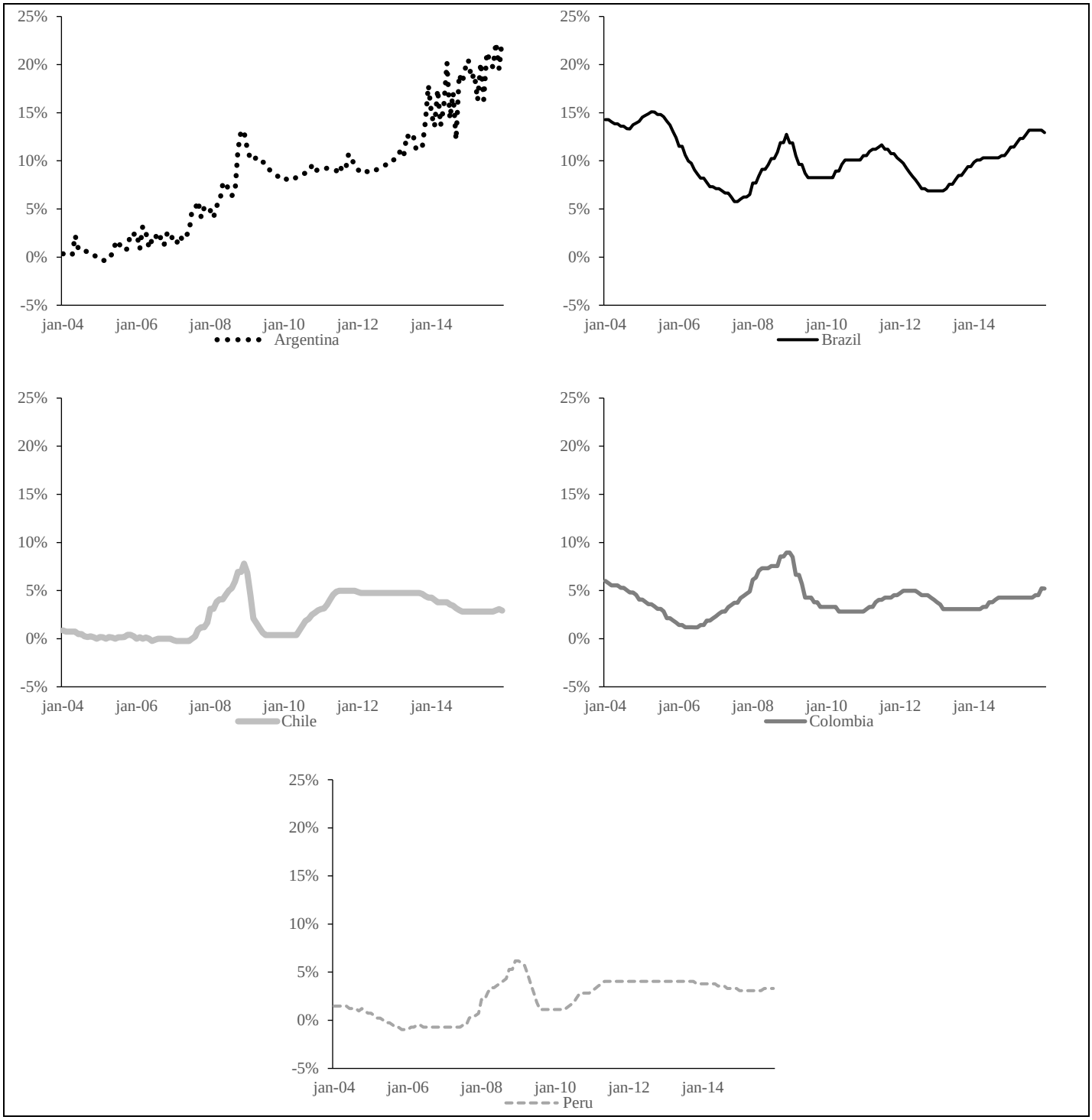


FIGURE 5. SPREAD OF INTEREST FROM SOUTH AMERICAN COUNTRIES[a]

[a]The series consist of the Naperian logarithm in the ratio between the gross interest of the emerging economy in question and the US economy.

As observed in Table 2, for all the countries, the specifications present individual significance for the parameters at the 5% level, except for only two coefficients, these

being significant at the 10% level, highlighting the most parsimonious specification possible for the economy of Colombia.

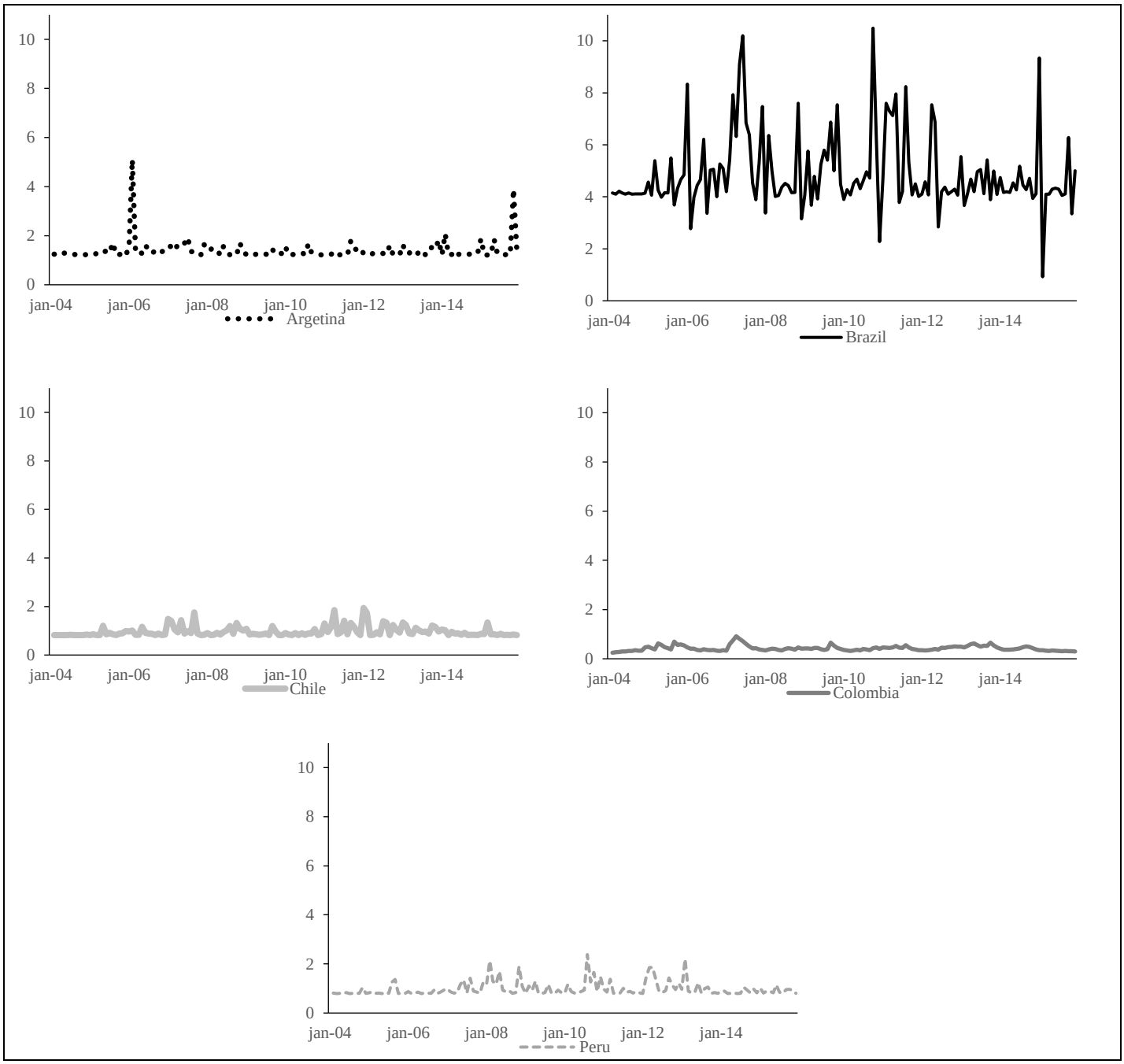


FIGURE 6. CONDITIONAL VOLATILITY OF RESERVES' VARIATION (02/2004–12/2015)[a]

[a] Methodology: the series are extracted using the procedure of identification of the best specification, according to the Akaike criterion, among the parsimonious specifications until GARCH (2,2), in which the variables with a greater lag are significant individually.

As a consequence, these estimates can be visualized in a more concrete and comparative way through Figure 6. We perceive a great difference in the behavior of the curves. The first and most notable observation is that the curve of Brazil shows

several periods of volatility, the orders of magnitude of which are greater than those in the other countries, by the order of magnitude of the Brazilian reserves. This volatility in part depends on the aid that this potential economy offers to the other economies of South America and on the contagion of external crises in emerging partners of this economy. The volatility of the Argentine reserves shows a "softer" behavior in relation to Brazil, mostly oscillating close to 1, with a strong variation in February 2006, leaving the level of 1.1 and reaching 5.1. The Colombian reserves have the lowest oscillations in their volatility around zero; this small oscillation is due to the policy adopted by the Colombian Bank of the Republic, which, according to Gómez (2006), has a type of intervention that is called accumulation or disaccumulation of reserves following a volatility control rule. According to the same author, the bank buys international reserves when the exchange rate is below the moving average of the last twenty days minus 4% and sells reserves when the exchange rate is above the moving average of the last twenty days beyond 4%.

The estimation of the system of equations that compose the modeling of the monthly evolution from 2004 to 2015 of the reserves in US dollars of Argentina, Brazil, Chile, Colombia and Peru via restricted VEC, based on the premise of exogeneity of the explanatory variables of the buffer stock model, which are shown to be stationary, are reported in the second step of Table 2. Initially we consider the explanatory power, an important factor in our research. We observe an improvement over the buffer stock model with no cross-effect for all the countries. It is important to observe an increase in the adjusted R^2, for which the explanatory power of Argentina leaves 7% in the buffer stock model with no cross-effect for approximately 12% in the buffer stock with cross-effects, which is still a low level for the specification of the model, and the same is true for Colombia, which reaches 11% for the model with cross-effects.

TABLE 2. ESTIMATION OF THE BUFFER STOCK MODEL WITH CROSS-EFFECTS[a,b,c]

	Endogenous variables: reserves (in log)				
Exogenous	Argentina	Brazil	Chile	Colombia	Peru
First step: estimations					
Variance equation based on the parsimonious GARCH model					
Constant	1.47e+18	1.69e+19	6.76e+17	3.87e+16	6.33e+17
	(0.000)	(0.000)	(0.000)	(0.070)	(0.000)
ε_{t-1}^2	0.339	0.696	0.301	0.248	0.441
	(0.000)	(0.015)	(0.039)	(0.059)	(0.014)
ε_{t-2}^2		0.558			

		(0.037)			
σ_{t-1}^2			0.558		
			(0.000)		
Second step: estimations and complementary results					
Joint buffer stock model: cointegration vector					
Constant	0.443	-1.361**	1.100 **	-0.606**	-0.221
	[0.523]	[-2.052]	[1.651]	[-1.842]	[-0.473]
Coint. #1	-0.029 ***	-0.010 *	-0.044***	-0.007 *	-0.034***
	[-2.396]	[-1.292]	[-4.589]	[-1.477]	[-5.063]
Joint buffer stock model: spread					
Argentina	-0.375 ***	-0.140 *	-0.578 ***	-0.096 *	-0.458***
	[-2.375]	[-1.351]	[-4.646]	[-1.566]	[-5.257]
Brazil	-0.052	-0.327 ***	0.090	-0.038	-0.235**
	[-0.280]	[-2.701]	[0.619]	[-0.530]	[-2.305]
Chile	-0.188	-0.335	0.960***	-0.108	-0.144
	[-0.359]	[-0.978]	[2.332]	[-0.531]	[-0.500]
Colombia	0.159	-0.057	-0.551**	-0.075	-0.381**
	[0.433]	[-0.238]	[-1.914]	[-0.523]	[-1.891]
Peru	0.061	0.047	0.873*	0.165	0.888***
	[0.088]	[0.105]	[1.609]	[0.615]	[2.340]
Joint buffer stock model: conditional volatility					
Argentina	-0.015	0.007	-0.003	-0.001	0.002
	[-0.670]	[0.478]	[-0.143]	[-0.056]	[0.138]
Brazil	-0.0280**	0.0129*	0.002	-0.007	-0.002
	[-1.847]	[1.297]	[0.178]	[-1.259]	[-0.253]
Chile	0.014	0.016	-0.065***	0.016**	-0.001
	[0.571]	[1.047]	[-3.497]	[1.765]	[-0.100]
Colombia	0.018	0.015	0.0357**	0.0145**	0.012
	[0.859]	[1.118]	[2.187]	[1.801]	[1.066]
Peru	-0.004	0.006	-0.020*	0.009	0.004
	[-0.240]	[0.518]	[-1.447]	[1.242]	[0.434]

Continued on the next page…

Joint buffer stock model: imports					
Argentina	0.078*	0.049	-0.060	0.005	-0.107***
	[1.322]	[1.254]	[-1.271]	[0.230]	[-3.262]
Brazil	-0.070*	-0.009	-0.023	0.029*	0.057**
	[-1.315]	[-0.263]	[-0.544]	[1.420]	[1.961]
Chile	-0.038	0.045*	-0.048	-0.057***	0.065***
	[-0.758]	[1.387]	[-1.215]	[-2.975]	[2.382]
Colombia	0.060	-0.026	-0.004	0.038**	-0.041
	[1.007]	[-0.664]	[-0.086]	[1.666]	[-1.239]
Peru	-0.045	-0.012	0.097**	-0.005	0.009
	[-0.827]	[-0.348]	[2.283]	[-0.238]	[0.332]
Adj. R-squared	0.116	0.229	0.200	0.106	0.288
F-statistic	2.170	3.650	3.231	2.057	4.595

[a] Estimate based on results over the period from February 2004 to December 2015. [b] GARCH models estimated through ARCH with normal distribution errors, using the Bollerslev–Wooldridge robust heteroskedasticity coefficient of covariance of residues. P-values are in brackets, while t-statistics are bracketed. [c] The Newey and West method (1987) covariance coefficients aim to obtain robustness to heteroskedasticity in the averaged equation based on the MQO method estimates. * indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

However, for Brazil, Chile and Peru, the explanations reach higher levels for the buffer stock model with cross-effects of the order of magnitude of almost 23%, 20% and 28%, respectively. Regarding the cointegrating vectors, for all the economies in question, according to the maximal eigenvalue test, the null hypothesis of a cointegrating vector is not rejected; that is, there is significance of the parameters, in all these cases with a negative sign. The most relevant analysis, however, lies in the significance of individual effects and cross-effects. It is shown in the second stage of Table 2 that the Argentine economy reacts negatively to the spread and positively to the imports from its own country and reacts negatively to fluctuations in volatility and imports from Brazil, which is to be expected.

Brazil's reserves react negatively to oscillations in its own spreads and those from Argentina, and it reacts positively to movements in its volatility and Chilean imports. The Chilean economy is influenced by the spreads of all the other countries, with the exception of the Brazilian spread, reacts negatively to fluctuations in its own reserves and Peruvian reserves and reacts positively to fluctuations in Colombian reserves and imports. The Colombian economy reacts negatively to the spread of Argentine and Chilean imports and positively to its own volatility and imports, and it reacts to Chilean volatility and Brazilian imports. The Peruvian economy, counterintuitively, is not influenced by any one fluctuation in reserves; however, it is influenced negatively by the Brazilian, Argentine and Colombian spreads and positively by its

own spreads, and it is affected by imports from Argentina (negatively) and from Brazil and Chile (positively).

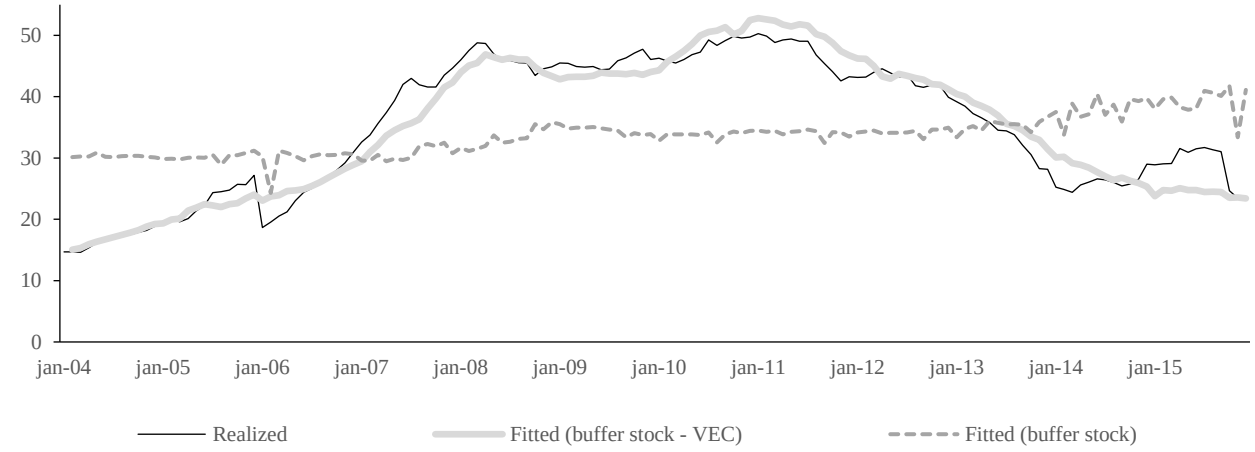
The results of the estimations and inferences of this framework can be visualized in the graphs reported in Figure 7. In these graphs the stock of reserves in each economy is considered at the end of January 2004 as a starting point, and from this month the optimal trajectory is based on the accumulated theoretical variations suggested by the buffer stock model with cross-effects.

Chang (2008) observes a policy of reserve accumulation as one of the measures used by the Brazilian Government to deal with the problem of increasing appreciation of the real despite growth observed since 2004. This Brazilian reserve policy presents a phase very close to the optimum that extends from the beginning of the period until March 2011; from that date onwards, it has more international reserves than the optimum until April 2013, during the fiscal instability of the European countries, when it adopts a conservative stance until the end of 2015.

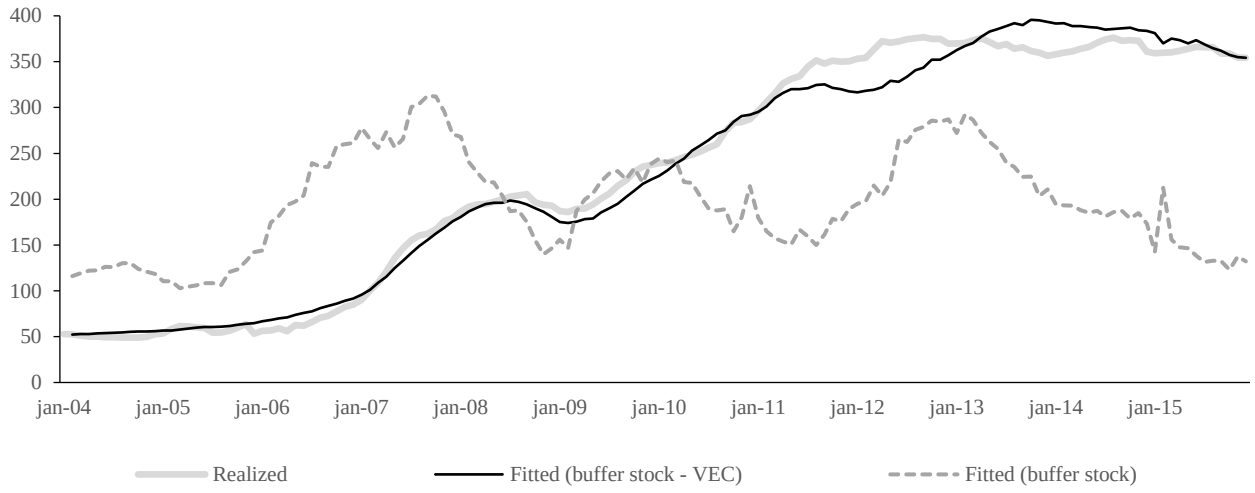
The Argentine reserves up to 2010 show an oscillation in the posture in relation to the optimum; from this date until the end of 2014, there is a conservative relationship in its reserves that may be related to the policy adopted by the Government. According to Schincariol and Fernandez (2014), this policy had as its objective the containment of the dollar price, restricting its official commercialization, with the intention of controlling inflation, thus producing an illegal market of dollars and in turn causing an escape of the international reserves. From 2014 onwards, it returned to a greater amount of reserves in relation to the optimum, which can be explained by the government policy that in January 2014 managed a resumption of the appreciation of the dollar against the local currency, thus bringing a strong preference for the dollar as the reserve currency.

The reserve policy practiced by Colombia is very close to the composition of optimal reserves, oscillating in a conservative stance until March 2006, followed by a sequence up to April 2009 characterized by a lower than optimal protection level and returning to conservatism until 2014. This closeness to the optimum can be explained by the type of intervention of the central bank, the prior announcement of the accumulation or depletion of reserves mentioned by Echavarría et al., (2010).

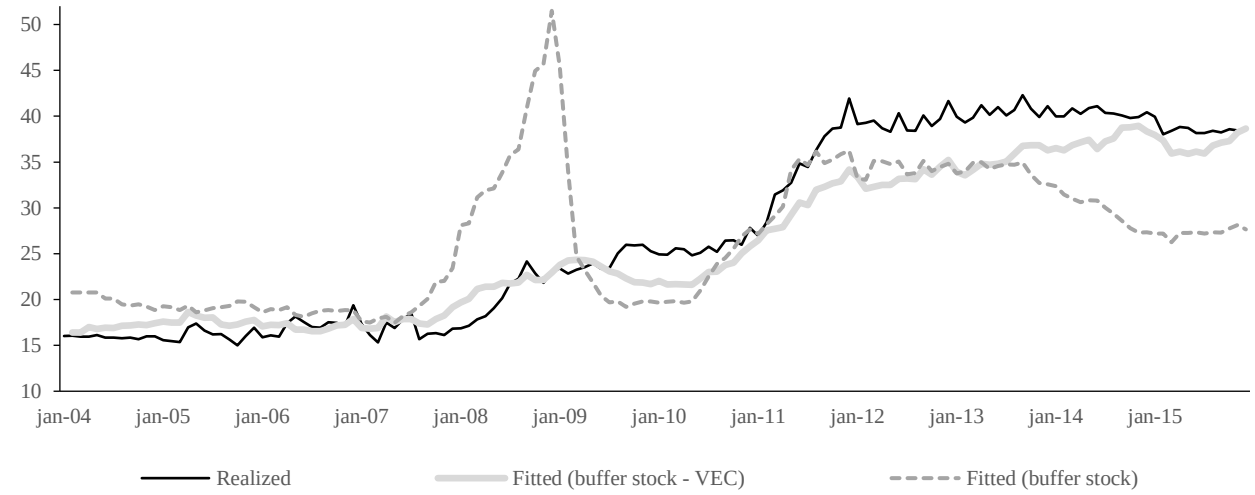
a. Argentina



b. Brazil



c. Chile



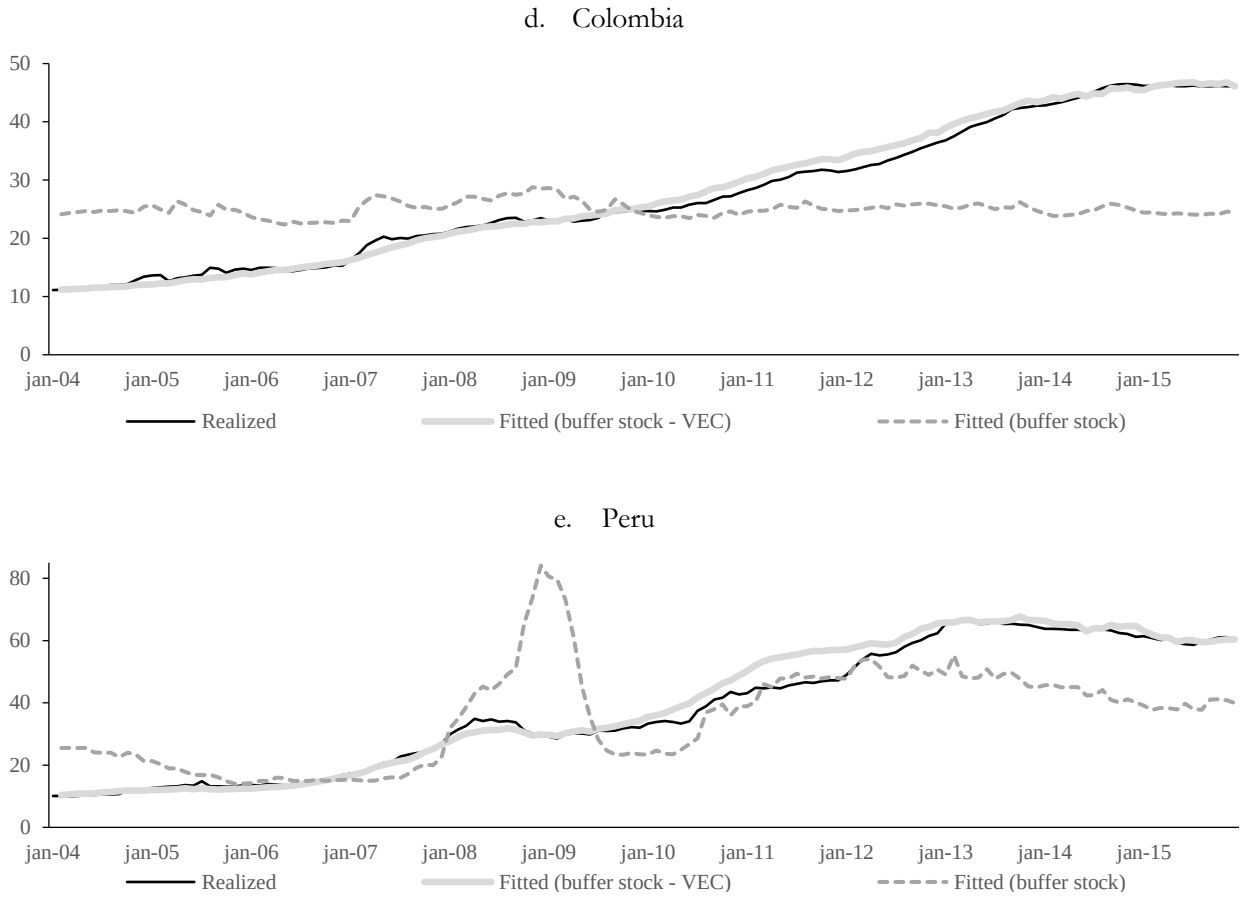


FIGURE 7. MONTHLY REALIZED AND FITTED TOTAL RESERVES (US$ BILLION) FOR THE SOUTH AMERICAN ECONOMIES[a]

[a] This figure plots the series of monthly realized reserves and the predictions based on the original buffer stock model and its extended version, taking into account cross-effects, during the period from January 2004 to December 2015.

In Chile, we observe two stages in the accumulation of reserves, one before 2008 characterized by the oscillation of the optimal reserves with those practiced by the Government and one after 2008 with a conservative stance characterized by a surplus of its reserves in relation to the optimal one until 2015. This oscillation can be explained by the two programs adopted by the Central Bank in 2008 and in 2011, which, according to De Gregorio (2011), had as a priority the purchase of reserves and the issuance of foreign currency readjustable bonds.

In contrast to this race, the reverse applies to Peru, with a slightly more conservative moment before 2008 and after the crisis with a stance resulting in its reserve accumulation being less than optimal. In practice, this was due to the policy of the Peruvian Central Bank, which adopted the position to reduce the degree of dollarization of the economy as it attempted to recover the value of the Peruvian

currency, causing domestic institutions to substitute foreign currency assets and liabilities for domestic currency.

To confirm the results of Table 2, we determine the impulse response effect of the VEC method based on the cross-effect buffer stock model for the same countries, reported in Figure 8. We can confirm that apparently the contagion effects of the countries of South America do not seem to be relevant to the Brazilian and Colombian reserves. Already the reserves in Argentina, Peru and Chile are more dependent on the impacts of the other South American economies.

DISCUSSION

We believe that our framework is useful for supporting Argentine, Brazilian, Chilean, Colombian and Peruvian policy makers' decisions about driving the stock of international reserves because of the good performance of fitting, the assumptions of our micro-fundamented model and the results based on the individual and joint significance. We can infer, based on the trajectories reported in Figure 7 and the forecasting errors, which the behavior of the monetary authority in practice has been close to that provided by the theoretical framework.

Firstly, according to Lanteri (2013), from the second term of President Cristina Kirchner in 2010, Argentina introduced a policy of restrictions on the purchase of foreign currency in the official foreign exchange market, limitations on turning profits abroad, increasing payments made by Argentine tourists abroad, import barriers, government bond sales in dollars and others. This policy was aimed at accumulating reserves and limiting the outflow of capital. However, the Argentine reserves declined in net terms, and, according to our model, in this period the economy was in a process of conservatism. We believe that this event was due to the distrust of the economic agents and the monetary and fiscal policies, which were expansionist and fed the inflation in that period.

In Chile economic interventions were implemented in the years 2008 and 2011; mainly the second intervention had the objective of bringing the reserves from 13% to 17% of the GDP to affect the exchange rate. We believe that these policies were crucial for the reserves to be above the optimum for 78 months, generating an average conservative excess of US$3.71 billion. At this time the Chilean Government could be less conservative in its accumulation of reserves, seeking an alternative with lower costs, to reach the exchange rate, for example using commodity hedges, which would be a more convenient financial instrument.

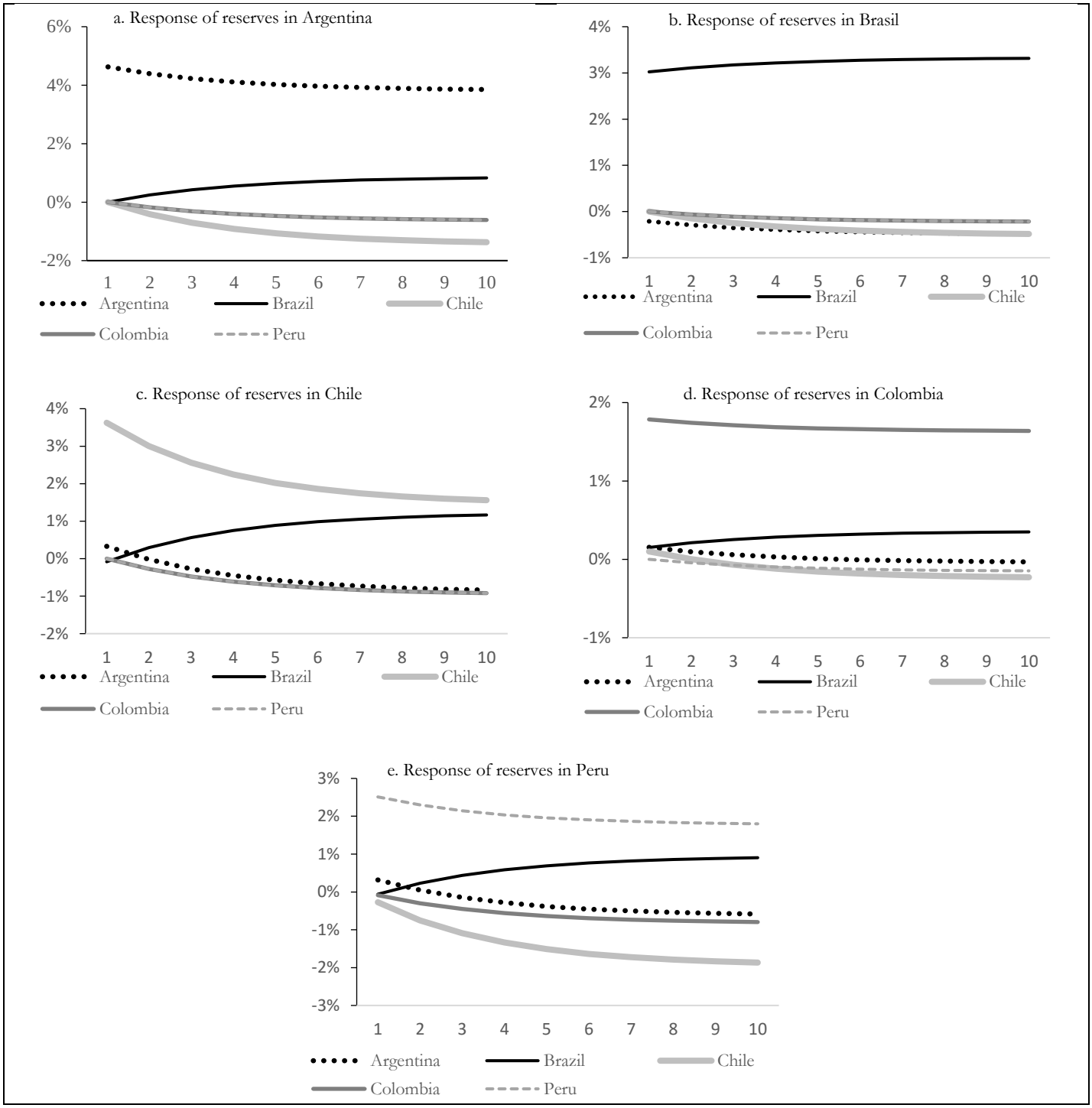


FIGURE 8. IMPULSE AND RESPONSES OF THE TOTAL RESERVES (US$ BILLION) FOR SOUTH AMERICAN ECONOMIES[a]

[a] This figure plots the series of monthly impulse responses based on the extended version of the buffer stock model, taking into account cross-effects, during the period from January 2004 to December 2015.

Following the crisis of 2008, our model observes that in the Peruvian economy there was an excess of reserves for 81 months, with a monthly average of R$1.09 billion dollars. This excess can be explained by the policy of the Central Bank of Peruvian Reserves, which actively intervened in the foreign exchange market to reduce the exchange rate fluctuations and build international reserves. According to Rossini, Armas and Quispe (2014), as of 2008 this accumulation of reserves was used as a monetary control tool and was intended to contain the impact of capital flows on internal credit conditions, both in the national currency and in foreign currencies. In addition, as a tool to address liquidity and foreign currency credit risk, a high level of mandatory reserves on liabilities in foreign currencies was also established.

Colombia, during the analyzed period, generated a very small excess of reserves of an average of R$382 million monthly dollars; we find that the accumulation of reserves realized was very close to the optimum. The policy for the purchase of reserves was due to the Board of Directors of the Banco de la República, which is responsible for the exchange rate policy in Colombia and is chaired by the finance minister, who is the government representative in the council that is responsible for the interventions. This Government adopted automatic and explicit rules of intervention, and we believe that this closeness to the optimum was caused by the transparent interventions made by the council. According to Ramírez (2004), it is possible to estimate the number of interventions, because each week the reserve levels are published along with the monetary base.

Brazil was the economy that suffered the least from the changes in the other South American economies at the significance level of 5%. In the Brazilian reserves, we observe that, during the period from January 2014 to December 2015, it is possible to evidence more than six months without interruption, characterized by a conservative sequence in excess or a sequence of reserve deficiency. This evidence may support decisions on the use of Brazilian reserves for which, according to the Brazilian press, there are recent signs that the Brazilian Federal Government intends to make use of this indispensable level of for-profit reserves to deal with deficits or debts.

However, we maintain that the policy of the Central Bank of Brazil is the way indicated for the maintenance of reserves along with the trajectory of the current indicators involving transactions with external agents. For in our model during the months of January 2011 to December 2015 there was an average value of excess reserves of R $ 2.02 billion and if we consider all periods there will be an average value of excess reserves of R $ 1.61 billion, Which are very distant from the primary deficit of R $ 111 billion (1.88% of GDP) and insignificant compared to the nominal deficit, R $ 613 billion (10.34% of GDP), which corroborates the results found by Matos (2016).

CONCLUSION

In the last two decades, the central banks of the emerging countries have accumulated an unprecedented level of reserves. This stock of international reserves should be seen as a useful public good to ensure the continuity of economic activity and preserve financial stability, especially for emerging economies.

In this article, we explore the discourse of the theoretical–empirical literature regarding the optimal level of international reserves, conceptually following the basic notions of Heller (1966). We innovate in the methodological buffer stock through the significant cross-effects of conditional volatilities, their respective spreads and the imports among the countries of South America, given the strong financial and commercial relationship existing between these emerging economies.

One of the main results of our research is the increase in the explanatory power of the model in relation to the buffer stock model without cross-effects. That is, there is an increase in the adjusted R^2 for all the countries. Other results are the strong influence of the Argentine spreads on the reserves of the South American countries and the fact that the Brazilian reserves are less affected by the other economies.

In short, it is not possible to infer from these figures whether or not the level of reserves for the countries of South America is appropriate given the cross-stock buffer model unless an optimum theoretical path can be drawn considering the relevant and robust idiosyncrasies of the behavior of the monetary authority. In this context, due to the adequate performance, the assumptions of our model and the results based on the individual and joint meaning, we believe that our microfinance framework is useful for supporting the decisions of South American politicians on the conduct of international reserves.

Our contribution is especially relevant to the discussion on the ideal level of reserves for South America, especially for Brazil, given its independence from the other South American countries and the recent context that was characterized by a severe local crisis and a nominal deficit in December 2015 of R$613 billion, more than 10% of the GDP, and given the lack of prospects for improvement of the main economic fundamentals, such as inflation, GDP, employment and investment. In this scenario we affirm that Brazilian society needs to be protected by the current level of caution in international reserves, a conquest of the Brazilian people through the efforts of the Brazilian monetary authority.

REFERENCES

Aizenman, J. & Marion, N. (2003). The high demand for international reserves in the Far East: What is going on?. Journal of the Japanese and International Economies, 17(3), 370-400.

Alfaro, L. & Kanczuk, F. (2009). Optimal reserve management and sovereign debt. Journal of International Economics, 77(1), 23-36.

Bandeira, L. A. M. (2002). Neoliberal policies and the crisis in South America. Brazilian Journal of International Politics, 45(2), 135-146.

Ben-Bassat, A. & Gottlieb, D. (1992). Optimal international reserves and sovereign risk. Journal of International Economics, 33(3), 345-362.

Bird, G. & Rajan, R. (2003). Too much of a good thing? The adequacy of international reserves in the aftermath of crises. The World Economy, 26(6), 873-891.

Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. Journal of Econometrics, 31(3), 307-327.

Calvo, G. & Reinhart, C. (2002). Fear of floating. Quarterly Journal of Economics, 117(2), 379-408.

Chakravarty, S. (2009). The optimal level of international reserves: The case of India. Journal of Social and Management Sciences, 38, 81-98.

Chang, H. J. (2008). Bad Samaritans: The guilty secrets of rich nations and the threat to global prosperity. Random House, Business books.

Cheung, Y. & Ito, H. (2009). A cross-country empirical analysis of international reserves. International Economic Journal, 23(4), 447-481.

Cifarelli, G. & Paladino, G. (2009). The buffer stock model redux? An analysis of the dynamics of foreign reserve accumulation. Open Economies Review, 20(4), 525-543.

De Gregorio, J. (2011). Acumulación de reservas internacionales en economías emergentes. Cuadernos de Economía, 30(55), 77-89.

Dickey, D. A. & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica: Journal of the Econometric Society, 1057-1072.

Dickey, D. A. & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74(366a), 427-431.

Dominguez, K. M., Hashimoto, Y. & Ito, T. (2012). International reserves and the global financial crisis. Journal of International Economics, 88(2), 388-406.

Echavarría, J. J., Vásquez, D. & Villamizar, M. (2010). Impact of exchange rate interventions on the level and volatility of the exchange rate in Colombia. Essays in Economic Policy, 28(62), 12-69.

Edwards, S. (1983). The demand for international reserves and exchange rate adjustments: the case of ldcs, NBER Working Paper No. 1063, 1964-1972.

Engle, R.F. (1982). Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation. Econometrica: Journal of the Econometric Society, 987-1007.

Flood, R. P. & Garber, P. M. (1984). Collapsing exchange-rate regimes: some linear examples. Journal of International Economics, 17(1), 1-13.

Flood, R. & Marion, N. (2002). Holding reserves in an era of high capital mobility. IMF working paper, No. 62.

Ford, J. & Huang, G. (1994). The demand for international reserves in China: An ECMmodel with domestic monetary disequilibrium. Economica, 61, 379-397.

Frenkel, J. A. (1974). The demand for international reserves by developed and less developed countries. Economica, 41, 14-24.

Frenkel, J. A. (1984). The demand for international reserves under pegged and flexible exchange rate regimes and aspects of the economics of managed float. Floating exchange rates and the state of world trade payments, Beard Books, 161.

Frenkel, J. A. & Jovanovic, B. (1981). Optimal international reserves: a stochastic framework. Economic Journal, 91(362), 507-514.

Furman, J., Stiglitz, J. E., Bosworth, B. P. & Radelet, S. (1998). Economic crises: evidence and insights from East Asia. Brookings papers on economic activity, No. 2, 1-135.

Gómez, J. (2006). Monetary policy in Colombia. Economy drafts, 394, 1-33.

Hecq, A. (2001) Common cycles and common trends in Latin America. Medium Econometrische Toepassingen, 10(3).

Heller, R. (1966). Optimal international reserves. Economic Journal, 76(302), 296-311.

Heller, H.R. & Kahn, M.S. (1978). The demand for international reserves under fixed and floating exchange rates. IMF staff papers, 25, 623-649.

Hegerty, S. (2014). Output volatility in Latin America, evidence from a multivariate Garch model. International Journal of Applied Economics, 11, 10-18.

Hur, S. & Kondo, I. (2014). A theory of rollover risk, sudden stops, and foreign reserves. FRB International Finance Discussion Paper, (1073).

Jeanne, O. (2007). International reserves in emerging market countries: too much of a good thing?. Brookings papers on economic activity, No. 1, 1-55.

Jeanne, O. & Ranciere, R. (2011). The optimal level of international reserves for emerging market countries: a new formula and some applications. Economic Journal, 121(555), 905-930.

Kelly, M. G. (1970). The demand for international reserves. American Economic Review, 60(4), 655-667.

Kenen, P. B. & Yudin, E. B. (1965). The demand for international reserves. Review of Economics and Statistics, 242-250.

Krugman, P. (1979). A model of balance-of-payments crises. Journal of Money, Credit and Banking, 11(3), 311-325.

Lane, P. R. & Milesi-Ferretti, G. M. (2007). The external wealth of nations mark II: Revised and extended estimates of foreign assets and liabilities, 1970–2004. Journal of International Economics, 73(2), 223-250.

Lanteri, L. N. (2013).Vulnerabilidad externa y reservas internacionales. Evidencia para Argentina. Análisis Económico, 28(69), 37-54.

Lewis, W. A. (1980). The slowing down of the engine of growth. American Economic Review, 70(4), 555-564.

Lizondo, J. & Mathieson, D. J. (1987). The stability of the demand for international reserves. Journal of International Money and Finance, 6(3), 251-282.

Luengo-Prado, M. J. & Sorensen, B. E. (2004). The buffer-stock model and the aggregate propensity to consume: a panel-data study of the US states. Discussion paper series n. 4474.

Luna, V. M. I. (2016). Brics' bank: possibilities and constraints. Economía informa, 398, 3-22.

MacKinnon, J. G. (1996). Numerical distribution functions for unit root and cointegration tests. Journal of Applied Econometrics, 601-618.

Matos, P. (2016). On the forward-looking behavior of Brazilian central bank regarding the total reserves. Caen working paper nº.3.

Matos, P., Rebouças, M. & Jesus Filho, J. (2016). On the relationship between total reserves and contagion effects of BRIC financial markets. Empirical Economics Letters (forthcoming).

Matos, P., Siqueira, A. & Trompieri, N. (2014). Analysis of integration and financial contagion in South America. Brazilian Journal of Economics, 68(2), 277-299.

Mejía-Reyes, P. (2000). Asymmetries and common cycles in Latin America: evidence from Markov switching models. Economía Mexicana. Nueva Epoca, 189-225.

Newey, W. K. & West, K. D, (1987). A simple positive semi-definite heteroskedasticity and autocorrelation consistent covariance matrix. Econometrica, 55, 703-708.

Obstfeld, M. (1994). Evaluating risky consumption paths: the role of intertemporal substitutability. European Economic Review, 38(7), 1471-1486.

Pina, G. (2015). The recent growth of international reserves in developing economies: a monetary perspective. Journal of International Money and Finance, 58, 172-190.

Ramachandran, M. (2004). The optimal level of international reserves: evidence for India. Economics Letters, 83(3), 365-370.

Ramírez, J. M. (2004). Foreign Exchange Market Intervention through Options: the Case of Colombia. Document presented during the Congress on Practical Aspects of Inflation Targets conducted by the National Bank of the Czech Republic.

Rodrik, D. (2006). The social cost of foreign exchange reserves. International Economic Journal, 20(3), 253-266.

Rossini, R., Armas, A. & Quispe, Z. (2014). Global Policy Spillovers and Peru's Monetary Policy: Inflation Targeting, Foreign Exchange Intervention and Reserve Requirements. Foreign Exchange Intervention and Reserve Requirements (August 2014). BIS Paper, No. 78p.

Saidi, N. (1981). The square-root law, uncertainty and international reserves under alternative regimes: Canadian experience, 1950–1976. Journal of Monetary Economics, 7(3), 271-290.

Schincariol, V. E. & Fernandez, R. G. (2014). Economic Growth and Government Policies in Argentina, 2003-2014. Paranaense Development Magazine, 35(127), 59-78.

Soto, C. & García, P. (2004). Large Hoardings of International Reserves: Are They Worth It?. Documentos de Trabajo (Banco Central de Chile), (299), 1.

Souza, R. G. & Triches, D. (2013). Analysis of the level of international reserves of emerging countries from 2000 to 2010. Electronic Journal in Environmental Management, Education and Technology, 16(16), 3200-3212.

Steiner, A. (2013). How central banks prepare for financial crises–an empirical analysis of the effects of crises and globalisation on international reserves. Journal of International Money and Finance, 33, 208-234.

Summers, L. H. (2006) Reflections on global account imbalances and emerging markets reserve accumulation. Harvard University.

West, K. D. Cho, D. (1995). The predictive ability of several models of exchange rate volatility. Journal of Econometrics, 69(2), 367-391.