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FELIPE ALVES REIS

ESSAYS ON THE ROLE OF CONTAGION AND INTEGRATION IN INTERNATIONAL ISSUES OF SOUTH AMERICA

FORTALEZA

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Tese apresentada ao Programa de Pós-Graduação em Economia - CAEN, da Faculdade de Economia, Administração, Atuária e Contabilidade da Universidade Federal do Ceará, como requisito parcial à obtenção do título de Doutor em Ciências Econômicas. Área de concentração: Finanças Internacionais Aplicadas.

Orientador: Prof. Dr. Paulo Rogério Faustino de Matos.

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Aprovada em: ___/___/_____.

BANCA EXAMINADORA

_____
Prof. Dr. Paulo Rogério Faustino de Matos (Orientador)
Universidade Federal do Ceará (UFC)

_____
Prof. Ricardo Antônio de Castro Pereira
Universidade Federal do Ceará (UFC)

_____
Prof. Dr. Sérgio Aquino de Souza
Universidade Federal do Ceará (UFC)

_____
Prof. Dr. Nicolino Trompieri Neto
Instituto de Pesquisa e Estratégia Econômica do Ceará (IPECE)

_____
Prof. Dr. Leonardo Andrade Rocha
Universidade Federal Rural do Semi-Árido (UFERSA)

A Deus.

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RESUMO

As economias emergentes da América do Sul atraem comumente a atenção de pesquisadores, mesmo que por razões pontualmente distintas entre as economias em questão. Dentre essas economias pode-se destacar o sólido mercado financeiro chileno, a consolidada demanda interna da população brasileira, a convergência antidemocrática argentina, o processo de pacificação interna colombiana, ou mesmo as elevadas taxas de crescimento da economia peruana. Adicionalmente a isso, ressaltamos os resultados de Matos, Siqueira & Trompieri (2014) que evidenciam a existência de um elevado nível de integração e o contágio financeiro entre os índices do Brasil, Argentina, Colômbia, Chile, Peru e Venezuela. À luz dessas evidências, essa tese faz três ensaios acerca de dados financeiros e econômicos do Brasil, Argentina, Colômbia, Chile e Peru. No primeiro ensaio faz-se a análise do mercado de risco dessas economias através da metodologia Value at Risck - VaR condicional, onde o valor crítico que caracteriza o VaR foi associado à distribuição que apresentar melhor fitting e incorporamos os efeitos da média e da volatilidade, ambas condicionais, obtidas pelo arcabouço ARMA-GARCH mais bem especificado. Onde observa-se que os modelos condicionais *best fitting* tem uma menor quantidade de violações. No segundo ensaio, buscou a análise das reservas internacionais seguindo conceitualmente noções da metodologia *Buffer Stock*, porém considerando os efeitos cruzados significativos das volatilidades condicionais, dos respectivos spreads e das importações intrablocos. Os resultados apontam uma melhoria significativa no poder explicação do modelo e que as reservas brasileiras são a menos afetadas pelas economias da América do Sul. No último ensaio foi analisado as opções de carteiras diversificadas disponíveis para um investidor brasileiro, que enfrenta um cenário livre de oportunidades no mercado financeiro, com o objetivo de mensurar ganhos com diversificação da posição adquirida nos índices de mercado da América do Sul vis-à-vis um carteira doméstica. Os resultados mostram a possibilidade que estratégias de composição de carteira simples e não dinâmica, composta somente de índices dos mercados dos países vizinhos do Brasil, se traduzam em resultados muito satisfatórios em termos de ganho e risco esperados.

Palavras-chave: América do Sul. Value-at-Risck. Reservas. Diversificação de carteiras.

ABSTRACT

The emerging economies of South America commonly attract the attention of researchers, even if for punctually different reasons among the economies in question. These economies include the strong Chilean financial market, the consolidated domestic demand of the Brazilian population, the Argentine anti-democratic convergence, the process of internal pacification in Colombia, or even the high growth rates of the Peruvian economy. In addition to this, we highlight the results of Matos, Siqueira & Trompieri (2014) that show the existence of a high level of integration and the financial contagion among the indices of Brazil, Argentina, Colombia, Chile, Peru and Venezuela. In light of these evidences, this thesis presents three essays on financial and economic data from Brazil, Argentina, Colombia, Chile and Peru. In the first essay, we analyze the risk market of these economies using the Value at Risck - VaR conditional methodology, in which the critical value that characterizes the VaR is associated to the distribution that presents the best fitting, and we incorporate the effects of the mean and the volatility, both conditional, obtained by the best-specified ARMA-GARCH model, showing that the best fitting conditional models have a smaller number of violations. The second essay presents the analysis of international reserves, conceptually following the notions of the Buffer Stock methodology, but considering the significant cross-effects of conditional volatilities, their respective spreads and intra-block importation. The results point to both a significant improvement in the explanatory power of the model and that the Brazilian reserves are the least affected by South American economies. In the last essay, we analyze some diversified portfolio options available to a Brazilian investor, who faces a scenario with no opportunities in the financial market, with the purpose of measuring gains with diversification of the position acquired in the South American market indices vis-à-vis the domestic portfolio. The results show the possibility that simple and non-dynamic portfolio composition strategies, composed only of indexes of the markets of the neighboring countries of Brazil, translate into very satisfactory results in terms of expected gain and risk.

Keywords: South America. Value-at-Risk. Reserves. Portfolio Diversification.

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LIST OF ABBREVIATIONS AND ACRONYMS

AGDCC	Asymmetric Generalized Dynamic Conditional Correlation
ALADI	Latin American Integration Association
ARMA	Autoregressive Moving Avarege
CAN	Andean Community of Nations
CASA	South American Community of Nations
CEPAL	Economic Commission for Latin America and Caribbean
FOCEM	Mercosur Structural Convergence Fund
FRED	Federal Reserve Economic Data
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
GDP	Gross Domestic Product
IBOVESPA	Index of the São Paulo Stock Exchange
IFS	International Fund Statistic
IGBC	Colombia Stock Exchange General Index
IGBVL	Lima Stock Exchange General Index
IPSA	Santiago Stock Exchange Index
LAFTA	Latin American Free Trade Association
MERCOSUR	Common Market of the South
MERVAL	Buenos Aires Stock Exchange Index
OECD	Organization for Economic Co-operation and Development
UNDP	United Nations Development Program
VaR	Value at Risk
VAR	Vector Autoregressive
VEC	Vector Error Correction
WFE	World Federation of Exchanges

CONTENTS

1 GENERAL INTRODUCTION

South America has been the subject of a vast amount of literature since its discovery in the early fifteenth century, but there is a broad consensus in this literature that the colonization of South American was done on the basis of exploitation, in which Spain and Portugal stand out. According to Simões (2011), their discovery created a navigation route that produced an economic and social transformation in the world, by moving the focus of the world economy from the Mediterranean to the Atlantic, from Italy to Spain and Portugal, which ascended to great wealth in the following centuries.

According to Ferrer (1998), between the sixteenth and nineteenth centuries, Portugal and Spain instituted the massive exploitation of slave labor of Africans and indigenous peoples of the region. It is estimated that about ten million slaves from Africa were taken to South America, with the vast majority being exploited in industries related to metals, sugar cane and other tropical crops. Indigenous enslavement, caused by *encomienda*[1] and *mita*[2], gave the Spaniards a supply of labor for mining, but it had disastrous consequences for indigenous populations. It caused the abandonment of subsistence crops, widespread famine, mass mortality of these workers in the mines, either because of the excess work or unhealthy conditions to which these Indians were subjected.

The exploitation of the mines gave impetus to agriculture, cattle raising and weaving in several Hispano-American colonies, whose main function was to supply the mining areas. Regions such as northern Argentina produced agricultural crops, draft animals and coarse cloth. Júnior (1945) states that in this period Brazil was totally subordinated to the Portuguese metropolis. Its economy was based only on the passage of profits to Portugal, leaving Brazil dominated by monoculture, export and slave labor with a small domestic market.

The process of independence of the South American countries began in the late eighteenth and early nineteenth centuries, when the first major anti-Spanish revolts, the so-called First War of Independence, the transfer of D. João and his entire court to Brazil in 1808 and other events culminated in the independence of the principal countries of the Americas. Although these movements of political freedom were a reality, the colonial socioeconomic

[1] The system of exploitation of indigenous labor for the extraction and beneficiation of ores.
[2] The indigenous slave labor system used by the Spaniards, for the development of agricultural activities or the extraction of precious metals. (Ruiz Rivera, 1975).

structures did not undergo any major alteration, maintaining a strong economic dependence of the metropolis.

Colonization and independence generated some similarities and differences between the countries of South America. The greatest and most visible diversity was the territorial extension of its geographical units. It can be seen that Brazil, the only Portuguese colony, has become the largest territory of the continent in extent (48% of the continent). In the case of colonies of Spanish origin, the territories were divided into smaller countries like Paraguay, Ecuador and Argentina, which experienced early urbanization and has been marked by European influence.

In the period of colonization there was an intense influx of international immigrants, such as the significant entry of the African population as slaves and also the large number of natives from the colonizing countries. In Brazil, this led to a great cultural diversity in some regions. In the nineteenth century, with independence and labor shortages in the Latin American countries, and given the socio-political crises and unprecedented demographic growth of Europe there was a new wave of immigration to the region, the so-called "great immigration." According to Patarra (2002), Argentina, Brazil, Uruguay and Chile were the main countries to receive these immigrants, mostly from Italy, whose cultural, social and economic influence was quite significant.

Despite this diversity in terms of population and territory, after World War II, regionalism in the Americas persisted and the potential gains from free trade at the regional level, based on the utilization of productivity and allocation of production factors in the region, were clear. In 1948 the Economic Commission for Latin America and the Caribbean (CEPAL) was created, which created studies on industrialization, trade and the possibility of expanding markets for Latin products, inspiring future attempts at integration of Latin America. These studies served as the basis for various processes of economic integration in South America.

One of the first integration processes in South America was the Latin American Free Trade Association (LAFTA), which was formalized in 1960 by the Treaty of Montevideo, signed by Argentina, Brazil, Chile, Uruguay, Paraguay and Peru. Bolivia, Colombia, Ecuador and Venezuela, which gave rise to the current ALADI-Latin American Integration Association of 1980, which is nothing more than an update of the Treaty of Montevideo. LAFTA was an economic cooperation organization that sought to create, over a period of 12 years, a free trade area that would reduce tariffs between member countries.

In May 1969, the CAN-Andean Community of Nations (CAN) was created with the signing of the "Cartagena Agreement," which was initially composed of Bolivia, Colombia, Chile, Ecuador and Peru, and later incorporated Venezuela in 1974, followed by Chile in 1976. The treaty had projects for the implementation of agricultural programs, a better vision for foreign investment, among other things, the main one being the common trade program. Recognizing the smaller economies with their specific vulnerabilities and the existence of sensitive products, the liberalization program proposed a complex framework of tariff exemption between regions, as well as the adhesion of a Common External Fee (PINTO; BRAGA, 2006).

However, none of these processes were able to effectively form an integrated market for the region. As highlighted by Braga (2002), the main causes of the failure were the difficulties in distributing the benefits and costs of integration in a group of countries with different degrees of industrial development and the instability in the macroeconomic conditions of the countries involved during the 1970's.

The 1980's were marked by the resumption of integration between the two most important nations of South America, when Brazil and Argentina signed cooperation, development and integration treaties. This movement originated in 1991, the Common Market of the South known as MERCOSUR, with the signing of the Treaty of Asunción, between Argentina, Brazil, Paraguay and Uruguay, and, in 2012, Venezuela.

Dathein (2004) found that the integration coefficient grew considerably after the creation of MERCOSUR, where the participation of Argentina, Brazil, Uruguay and Paraguay in trade in MERCOSUR rose substantially, positively influencing the GDP growth rates of the four countries between 1991 and 1998. However, in the late 1990's and early 2000's, the integration coefficient narrowed sharply for Argentina, Brazil, and Uruguay, repeating previous experiences of economic crises negatively affecting integration. In 2003 and 2004, this relationship stopped reducing to Brazil and Argentina, but has not yet recovered substantially.

In order to finance the MERCOSUR programs and strengthen the integration process, the MERCOSUR Structural Convergence Fund (FOCEM) was created in 2004 and was an extremely important system in which the main objective was to reduce differences between members of the bloc. It followed the same principles as the EU cohesion funds, that is, the largest contributors to the fund were the countries with the largest economies, and the smallest economies benefited the most. Its function was to transfer resources, aimed at

structural investment, thus stabilizing the integration process by reducing the dissatisfaction of smaller members (TESSARI, 2012).

With the objective of bringing the countries closer to the Andean community and the common market of the South, an agreement was signed in April 1998 to create a free trade area and in 2004 the South American Community of Nations CASA. According to Gomes (2005), CASA had the initial objective of increasing political and diplomatic coordination to strengthen relations between MERCOSUR, the Andean Community and Chile through infrastructure integration and the improvement of the free trade zone between countries.

Costa and Gonzales (2015) report that in Brasilia in September 2000, during the First Meeting of South American Presidents, another program was created for the Integration of Southern Regional Infrastructure - American (IILRSA). Its main objective was to overcome the infrastructure deficit in the areas of transport, energy and communication, which would increase regional integration, offering better conditions for the region to enter the global market. This agreement proposed 335 projects, of which 97% were in the area of transport (286) and energy (40). However, only 20 projects were completed by 2014.

Given this major attempt to integrate the South American countries, the continent has attracted the attention of researchers, investors and policy makers alike, even for reasons that are distinct between the economies in question. Carvalho (2010) argued that the improvement in international reserves coupled with the success of the economic policies adopted in some Latin American countries has allowed a greater resilience to crises in some Latin American economies. Hecq (2001) studied the existence of common cycles among Latin American economies based on three types of cyclical resource models, concluding that Brazil, Argentina, Mexico, Peru and Chile have similar movements in the long and short term, based on macroeconomic variables.

Our research aims at integrating the empirical evidence of Matos, Siqueira and Trompieri (2014) according to which there is both contagion and financial integration in the economies of this continent, focusing on Brazil, Argentina, Colombia, Chile and Peru. And for a better reflection of this whole framework of economic integration, it is necessary to analyze current data on the recent productive and socioeconomic character of these countries, with a view to a better conjunctures view of the integration of productive factors, land, labor and capital.

The international context of generalized economic prosperity before the recent financial crisis, characterized by excess liquidity and strong demand for agricultural commodities and minerals, was the basis for growth in the economies of South America.

On the one hand, this boom drew the attention of the world to the solid Chilean financial market, to the consolidated Brazilian domestic demand, to the degree of investment obtained by Colombian public bonds, to the Argentine wave of privatizations and reforms in the 1990s, to the Venezuelan oil deposits or to the high growth rates of the Peruvian economy, which reached 9.8% and 8.8% in 2008 and 2010 respectively.

On the other hand, this "euphoria" may have obscured the difficulties and especially the heterogeneity in social and economic terms in these countries.

Taking into account the already specified sample of economies, it is possible to identify common patterns of time evolution in the series of GDP growth rates, caused by some of the fundamentals of these economies. Argentina and Peru appear with more volatile trajectories, characterized by extreme upper and lower values throughout most of the time, while the Chilean economy behaves more moderately.

In political terms, despite the increasingly frequent Argentine state interventions that have been set against the rest of the world, these economies are all classified as democratic according to the scale proposed in Cheibub, Gandhi & Vreeland (2010). However, the historical or political and growth similarities are not consensual in other areas, which is important, since several aspects should be analyzed when building economic blocs.

Table 1.1 shows relevant indicators of the United Nations Development Program (UNDP) Human Development Report for the years 2010 and 2011.

In economic terms, while Argentina and Chile have GDP per capita at levels above $14,000, in Peru and Colombia it is less than $9,000.

When compared in absolute terms, the Brazilian economy has a GDP of more than $2trillion, a size well above all others, more than three times the Argentine GDP of almost $600 billion, and a level higher than those observed for the Chilean and Peru, whose aggregate wealth is around $250 billion. Chile's trade liberalization, driven more by exports, is higher than the levels of the main Asian countries, with almost 60% of GDP, while China, for example, has a 44% opening economics. This level is much higher than those observed for Peru, Colombia, Argentina and Brazil, which range from 38% to 18%. As expected, the admittedly closed Venezuelan economy has less than 7% of its GDP associated with commercial operations with other countries.

Table 1.1 – Descriptive statistics: social, demographic, financial and macroeconomic variables of the countries of South America [a, b, c, d, e, f, g, h, j, k, l, m ,n]

	Chile	Argentina	Peru	Brazil	Colombia
Variables associated with human capital					
Average years of schooling [a]	9,70	9,30	9,60	7,20	7,40
Population with secondary education [b]	51,80%	44,60%	50,50%	21,90%	31,30%
Adult literacy rate [c]	98,60%	97,70%	89,60%	90,00%	93,20%
Social variables					
HDI 2010 [d]	0,78	0,78	0,72	0,70	0,69
Ranking of HDI	45º	46º	63º	73º	79º
Annual average growth rate of HDI	0,65%	0,55%	0,69%	0,73%	0,79%
Gini [e]	52,00	48,80	50,50	55,00	58,50
Population below poverty line [f]	15,10%	x	34,80%	21,40%	46,50%
Demographic variables and the labor market					
Total population [g]	17,10	40,70	29,50	195,40	46,30
Percentage of urban population [h]	89,00%	92,40%	76,90%	86,50%	75,10%
Employed population [i]	49,60%	56,50%	53,40%	63,90%	62,00%
Financial variables					
Foreign direct investment (% of GDP) [j]	7,80	1,30	3,70	1,60	3,10
International Reserves [k]	$25,20	$46,04	$31,97	$236,64	$24,68
International Reserves (% of GDP)	15,67%	14,91%	25,21%	14,86%	10,58%
Macroeconomic variables					
GDP per capita (US$) [l]	$14.311,00	$14.538,00	$8.629,00	$10.367,00	$8.959,00
GDP (bilhões of US$)	$244,72	$591,70	$254,56	$2.025,71	$414,80
Exportation F.O.B. (% PIB) [m]	32,30%	18,16%	21,20%	9,61%	14,06%
Importation C.I.F. (% PIB) [n]	25,71%	12,67%	16,52%	8,39%	14,11%

Notes: [a] Period: 2010. Source: Barro e Lee (2010). [b] Percentage of population aged 25 or over, with at least secondary education. Period: 2010. Source: UNESCO Institute for Statistics (2010). [c] Adult literacy rate: Percentage of the population aged 15 and over who can read and write, with full understanding, a short and simple statement in their daily lives. Period: 2010. Source: UNESCO Institute for Statistics (2011).[d] Human development Index. Source: DAESNU (2009), Barro and Lee (2010), UNESCO Institute for Statistics (2010), World Bank (2010b) and IMF (2010). [e] Gini coefficient of income inequality. Period: 2000 to 2010. Source: World Bank (2010a). [f] Percentage of the population living below the national poverty line (considered appropriate for a country by its authorities). National estimates are based on weighted estimates of population subgroups obtained from household surveys. Period: 2010. Source: World Bank (2011). [g] Total population in millions of people. Period 2010. Source: DAESNU (2009). [h] Percentage of total population residing in urban area. Since the data were based on national definitions of what constitutes a city or metropolitan area, comparisons between countries should be made with caution. Period: 2010. Source: DAESNU (2009). [i] Population rate between 15 and 64 years old employed. Period: 2008. ILO (2010). [j] Sum of social capital, reinvested earnings, other long-term capital and short-term capital, expressed as a percentage of gross domestic product (GDP). Period: 2009. Source: World Bank (2011). [k] Total international reserves, including gold, in billions of US $. Period: 2010. Source: IFS / IMF. [l] Gross domestic product (GDP) expressed in US $ under purchasing power parity, divided by the population in the middle of the year. Period: 2009. Source: World Bank (2011). [m] Export of goods and services (free on board). Period: 2010. Source: IFS / IMF. N Import of goods and services (cost, insurance and freight). Period: 2010. Source: IFS / IMF.

This Chilean macroeconomic supremacy is maintained when variables of human capital are observed, an essential element in the development framework. Chile has 9.7 years

of schooling on average, followed by Peru and Argentina, which have levels close to Chile's. This evidence is robust when the metric is adult literacy or when the proportion of the population with secondary education is observed. Almost 52% of Chileans have this level of education, much higher than the level of approximately 22% and 28% respectively for the Brazilian and Venezuelan populations.

The heterogeneity remains under a social prism, except for the Human Development Index (HDI), whose amplitude is not so high. Colombia has the lowest HDI, 0.69, while Chile and Argentina have a level of 0.78, which are the 45th and 46th places in the world ranking respectively. The growth rates of this social indicator already show marked differences, with Venezuela, 75th in the ranking, growing at a stronger pace, at around 0.9% per year on average between 2000 and 2010. The Colombian economy, followed by Brazil, appears as the most unequal of all, with a Gini Coefficient of 58.5, and having the highest percentage of the population below the poverty line, over 45%, a much higher level than observed in Chile, for instance, where approximately 15% of the population are considered poor.

Demographically, despite Brazilian superiority in absolute terms as the largest country in territory and in population, with approximately 200 million inhabitants, while the others have populations between 17 and 46 million people, these economies have approximate levels in terms of urban population, with the lowest levels in Colombia and Venezuela. There is still some homogeneity in the employed population between 15 and 64 years old, with Chile having the lowest level, with almost 50%, while in Brazil this indicator reaches 64%. From a financial point of view, Chile stands out with 7.8% of GDP in foreign direct investments, whereas Brazil has total international reserves, including gold, in excess of $230 billion and Peru with more than 25% of its GDP in this type of reserves.

In short, despite the diversity in the macroeconomic fundamentals of this continent, the results reported by Hecq (2002) and Matos, Siqueira and Trompieri (2014) suggest that the financial systems of these countries should not be analyzed individually, since the deviations of long- Any of the financial markets are able to influence the other markets in question between the economies of Brazil, Argentina, Chile, Colombia and Peru. In this sense, three essays on the financial and economic data of these countries. In all the tests, we use specific statistical or econometric theoretical models, which have in common only the use of conditional volatility estimates through the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model suggested in Bollerslev (1986), but in its multivariate

version, aiming to accommodate exactly the contagion effects and financial integration of the continent.

Chapter two is titled “On the Risk Management of South American Financial Markets: Do Integration and Contagion Matter?” This first essay of the dissertation was published with Professor Paulo Rogério Faustino de Matos in *Journal of International and Global Economic Studies* and presented at the Universidade Federal do Ceará- CAEN. In this study, we add to the discussion about risk management by testing different specifications of Value at Risk (VaR) measures for the main stock market indices in South America: MERVAL (Argentina), IBOVESPA (Brazil), IPSA (Chile), IGBC (Colombia), and IGBVL (Peru). As a benchmark VAR, we rely on the hypotheses of unconditional moments of a Gaussian probability distribution. We relax these assumptions by allowing for time-varying specifications for the moments of a well-specified probability distribution in terms of fitting. Finally, we take into account the evidence reported in Matos, Siqueira and Trompieri (2014) by measuring the effects of contagion and integration on risk management, based on the conditional time-varying moments of the best-fitting distribution, which are extracted from a multivariate GARCH approach. We compare all these specifications based on relevant backtesting models.

Chapter three is titled “On the role of contagion effects in total reserves in South America.” This second essay of the dissertation was published with Professor Paulo Rogério Faustino de Matos in *Journal of Applied Economics and Business* and presented at the Universidade Federal do Ceará- CAEN. 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.

The third chapter is “On the relationship between home bias in Brazil and financial integration in South America.” This third essay of the dissertation was submitted with Professor Paulo Rogério Faustino de Matos in *Economical Empirical Letters*. We enter the debate about the ability of Brazilian investors to diversify risk and improve performance by allocating resources to international stock market indices, taking into account the evidence of financial integration and contagion in the countries of South America reported by Matos,

Siqueira and Trompieri (2014). Based on unleveraged strategies of portfolio composition using five of the most relevant South American stock market indices, we find that simple strategies as equal- or value-weighted portfolios and optimization-based portfolios – minimization of risk, maximization of performance and principal component analysis – were able to reach higher levels of cumulative return between January 1999 and December 2013. Another common feature of these international portfolios is a lower level of risk than the IBOVESPA, even based on the most sophisticated measures, such as semivariance or drawdown. Risk-return performance measures also suggest that Brazilian investors should be motivated to think of feasible strategies to reduce their exposure to the political or macroeconomic risk sources that comprise the systemic risk of the domestic financial market.

2 ON THE RISK MANAGEMENT OF SOUTH AMERICAN FINANCIAL MARKETS: DO INTEGRATION AND CONTAGION MATTER?

2.1 Introduction

Kose *et al*. (2009) provide evidence that emerging countries have received growing capital flows during the past decade. Regions such as Latin America and eastern Europe have experienced financial liberalization from the 1990s onwards, and have moved towards an open, market-based development model in place of one that relied on the state and was closed regarding capital flows and foreign trade, as emphasized by Stallings (2006).

However, over the last decades, the financial markets have been characterized by the incessant search for better returns and lower risks, and this has led to a continuing race for the international markets. In this context, one should also mention that the main stock markets of the emerging economies are able to offer higher levels of expected return, even if these are accompanied by higher levels of risk.

Another relevant issue is that the emerging economies are more likely to experience periods of turmoil due to economic crises, not only local ones but also global crises or crises occurring in other economies. According to Fidrmuc and Korhonend (2010) and Ozkan and Unsal (2012), one possible reason is the greater intensity of contagion effects among emerging economies, for which there is robust empirical evidence. Within this context, we address risk management modelling that considers the cross-effects for the main South American stock market indices, because of their relevance for domestic and foreign investors.

More specifically, South American economies have commonly come to the attention of researchers, investors and policy makers, although for quite distinct reasons. One can highlight the solid Chilean financial market, the internal demand of the Brazilian population as a whole, the antidemocratic convergence in Argentina, the Colombian process of internal peace-making, and even the elevated growth rates of the Peruvian economy. To summarize, one can see great differences between these countries, with their similarities most commonly identified under an historical prism.

Methodologically, we deal with risk management by following the literature about modern risk management theory, commonly associated with the concept established by J.P. Morgan in 1994 called Value at Risk (VaR). This metric seems to be able to capture an extreme total risk, taking into account only the moments of the asset's own probability distribution functions. In its most commonly used versions, VaR depends on a parametric

statistical framework that is based on some unreliable assumptions. Unconditional Gaussian VaR – used by the Basel Committee as the legal framework for its signatory countries – depends on the premise that one should not reject the null hypothesis that the net return on financial assets follows a normal probability distribution function (pdf), with moments fixed over time.

A promising route of related research has discussed the suitability of an unconditional normal distribution rather than a more appropriate distribution function. Another step relates to deal with the issue of conditional moments and, specifically, the mean and standard deviation used to measure VaR, by extracting both as time-varying series.

Our main contribution is to provide an empirical exercise that can be used to answer the question of whether these current risk measures are able to capture cross-effects and thus to provide good predictions. In other words, we aim to discover whether or not the cross-effects are second order effects. In South American financial markets, this issue is relevant, since there is robust evidence of contagion and integration effects, as recently reported by Matos, Siqueira and Trompieri (2014). Aligned to our main issue, we also mention the research of Hegerty (2014), which uses multivariate conditional volatility models to verify the contagion effect between South American countries.

Here, we aim to address these effects on risk management for the main South American stock market indices, by employing an innovative VaR suggested by Matos, Fonseca and de Jesus Filho (2016), which depends on the time-varying moments of a best-fitting distribution that is derived to capture the cross-effects associated with common risk drivers.

We apply three different specifications of VaR (Basel VaR, and conditional best-fitting VaR in its univariate and multivariate versions) to daily series of nominal returns on the main stock market indices of Argentina, Brazil, Chile, Colombia and Peru during the period from January 07, 1998 to December 31, 2013.

This paper is structured so that in section 2 we offer a brief review of related literature. In section 3 we detail the methodology proposed, while in Section 4 we present the empirical exercise and discuss the results. The final considerations are in the fifth section.

2.2 Related literature

The literature identifies several contributions to risk measures. More specifically, it is necessary to progress methodologically and to analyze the statistical frameworks aligned

to the evaluation of ratings and the Basel agreements. When J.P. Morgan proposed RiskMetrics by defining VaR as a simple and unique metric for the risk, assuming normality in the returns and modeling the volatility as the standard deviation using an exponential smoothing, this science has evolved. In practice, even financial market procedures have changed to a point at which this metric had been widely used, so that the Basel Committee established it as a standard for risk calculations, making it part of the legal framework in its signatory countries.

Nonetheless, inherent to the evolution of this science is the necessity to achieve a better accommodation of the basic violations that are characteristic of the series of net returns of financial assets. First, as can be seen in several samples of returns over the course of time, one can evidence heteroscedasticity and leptokurtosis, making it impossible to use the unconditional Gaussian VaR. Danielsson and de Vries (2000) showed the importance of incorporating this point in VaR.

A second step in this literature was taken by Lee and Lee (2011) and Jánský and Rippel (2011) that suggested innovation through using Autoregressive Moving Average (ARMA) modeling for return on the asset in association with the use of Generalized Autoregressive Heteroscedasticity (GARCH) for volatility and thus created the VaR ARMA-GARCH family. On the other hand, Berkowitz and O'Brien (2002) analyzed the VaR models of large North American banks and compared them with the VaRs measured by the ARMA-GARCH models of conditional volatility, concluding that the VaRs of the analyzed banks do not capture the changes.

Within this context, West and Cho (1995) demonstrated that, in the short run, models using the GARCH family framework, which was initially developed by Engle (1982) and then generalized by Bollerslev (1986), are more precise and better at predicting volatility than models with the constant standard deviation alone or even other frameworks of conditional volatility.

In Cappielo, Engle, and Sheppard (2006), this model was improved by the inclusion of the crossed effects of one asset into another by the use of the GARCH multivariate model, obtaining multivariate volatilities. These extensions, although very robust, still suffer from the same problem: the probability distribution function is not adequate. Actually, another research stream aims to deal with this by incorporating the statistical benefits of modeling the fitting correctly through non-normal distributions such as the hyperbolic secant, in Vaughan (2002) and Klein and Fischer (2003).

In articles closer to this study, it is necessary to list the contribution of Matos *et al*.

(2015), who analyzed the returns series for BRIC countries, and Hegerty (2014), who used a multivariate GARCH to analyze product volatility in a set of Latin American countries. Here we aim to build on the literature, not only by applying the techniques used in these empirical works, but also by suggesting innovation, using the empirical evidence for the Latin American economies obtained in Matos Siqueira, and Trompieri (2014), who analyzed integration and financial contagion in South America. We also follow Mejías-Reyes (2000), who showed that Latin American business cycles are modeled from macroeconomic variables, through the frameworks of Markovian chains and using real GDP per capita, for a sample containing data from Argentina, Bolivia, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela between 1950 and 1995.

Given this literature overview, our main intention is to measure the conditional risk of the main South American financial markets by considering the crossed effects between the conditional volatility series of these economies through the GARCH multivariate framework. Another related contribution is that by Silva *et al*. (2010), who applied the VaR metric for the stock exchange indices of Latin American countries using the volatility forecasting models EWMA and EQMA.

2.3 Methodology

2.3.1 VaR

Taking the Gaussian distribution as an example, the relation of the unconditional VaR to a determined level of confidence, $c(\%)$ (which is usually 95% or 99%), is simply given by:

$$VaR^{G,I}(c\%) = \mu - \alpha_{c(\%)}\sigma, \quad (1)$$

Where μ is the population mean parameter, σ is the parameter that measures the population standard deviation, and $\alpha_{c(\%)}$ is the characteristic critical alpha in a standard normal distribution, assuming the value 2.32630 for a 1% accumulated probability and 1.64485 for a 5% accumulated probability, for example.

This relation is merely the quantile function of the normal – that is, the inverse of the cumulative distribution function associated with a one-tailed probability, 5% or 1%, which is related to the confidence level according to the relation given by $1 - c(\%)$. In this relation,

note that the insertion of the time-varying moments is trivial, since the mean and standard deviation, which are both no longer obtained from the sampling but are obtained by means of the ARMA-GARCH modeling and are given, respectively, by μ_t and σ_t, will replace the constant population parameters, producing the following relation for the VaR ARMA-GARCH univariate Gaussian:

$$VaR^{G,C}(c\%) = \mu_t - \alpha_{c(\%)}\sigma_t \quad (2)$$

The extension to the multivariate framework consists only in using, in relation (2), the mean and standard deviation of the time series now obtained via the ARMA-GARCH multivariate model of the AGDCC (Asymmetric Generalized Dynamic Conditional Correlation) type, whose specification meets the best Schwarz criterion and does not have the unwanted violations of this type of model.

The question then becomes is how to obtain the analogous relation to this conditional Gaussian VaR, incorporating the information that the most appropriate distribution in terms of fitting is not the normal distribution. In this case, the search for the distribution needs to impose a certain limitation on the range of continuous distribution families, for the only distributions that can be used are those in which the standard deviation and the mean are given by univariate bijective functions (functions that have as their argument only one of the respective distribution parameters). In short, it is necessary to identify exactly which parameter is time-varying so that the mean can also be time-varying; the same applies for the standard deviation. Otherwise, the evidence that the mean and the deviation are both time-varying does not have an exact counterpart, on the assumption that the distribution parameters will also be exactly time-varying. A better way of putting this, assuming that the mean is conditional but depends on two or more parameters of the distribution in question, is to consider how to carry out the necessary bijection so that the parameter can be substituted by the mean in the quantile function formula.

For example, in the Dagun function (4p), which is well suited to banks' returns in Brazil, the standard deviation function has, as its arguments, all four parameters of the distribution; these parameters also appear in the quantile function, making it impossible to establish a relation between the inverse of the accumulated function and the standard deviation, which is replaced by the conditional standard deviation.

This happens because in most probability distributions the parameters are not exactly given by the mean and the deviation in the same way as they are given in the normal.

Therefore, it is necessary to obtain a bijection such that the parameters become a function of the mean and the deviation, respectively, and allow the inverse cumulative function to be expressed by the mean and the standard deviation and, finally, to insert them as time-varying.

The ultimate goal is therefore to obtain two relations at the same level of confidence $c\%$, both based on a probability distribution with a proper fitting. Consider the parametric quantile, the VaR best-fitting unconditional univariate, $VaR^{BF,I}(c\%)$, given by:

$$VaR^{BF,I}(c\%) = F_{BF}^{-1}(1 - c|\boldsymbol{\Theta}), \tag{3}$$

The ARMA-GARCH univariate conditional best-fitting VaR will be given by a quantile function, but it is no longer a function of the parameter vector itself; it has as arguments the time-varying mean and standard deviation, according to the following relation:

$$VaR^{BF,C}(c\%) = F_{BF}^{-1}(1 - c|\mu_t, \sigma_t) \tag{4}$$

Using the Laplace probability distribution function as the best-fitting distribution, whose parameters are μ and λ, in which the standard deviation is given by $\sigma = \sqrt{2}/\lambda$, and incorporating the extracted conditional moments of an ARMA-GARCH multivariate, VaR^{MLapC} can be generated and is given by:

$$VaR^{MLapC}(c\%) = \mu_t + \sigma_t \frac{\ln(2.(1-c\%))}{\sqrt{2}} \tag{5}$$

2.3.2 Validating backtesting framework

Finally, for each VaR specification used herein, predictions are made one step forward in the sample for each return series, so they can be compared. The methods of Basel backtesting and those set out in Lopez (1999), Kupiec (1995), and Christoffersen (1998) are used to compare the series, each of these having certain features that will help in verifying whether the effects of financial interconnection incorporated into the VaR influence the risk calculation and with what magnitude.

More specifically, as Jorion (2006) says, when VaR models cannot predict the risk precisely, they lose their usefulness. Adhesion tests (backtesting) are employed to check the performance of these models in order to examine whether the losses foreseen by VaR are consistent with the reality of the data series. Backtesting is important from two perspectives, risk management and statistics, according to Campbell (2006). Campbell discusses various

types of testing methodologies and explains how all of them have weaknesses and that more than one should therefore be applied to find a diagnosis closer to reality.

2.4 Empirical exercise

2.4.1 Database

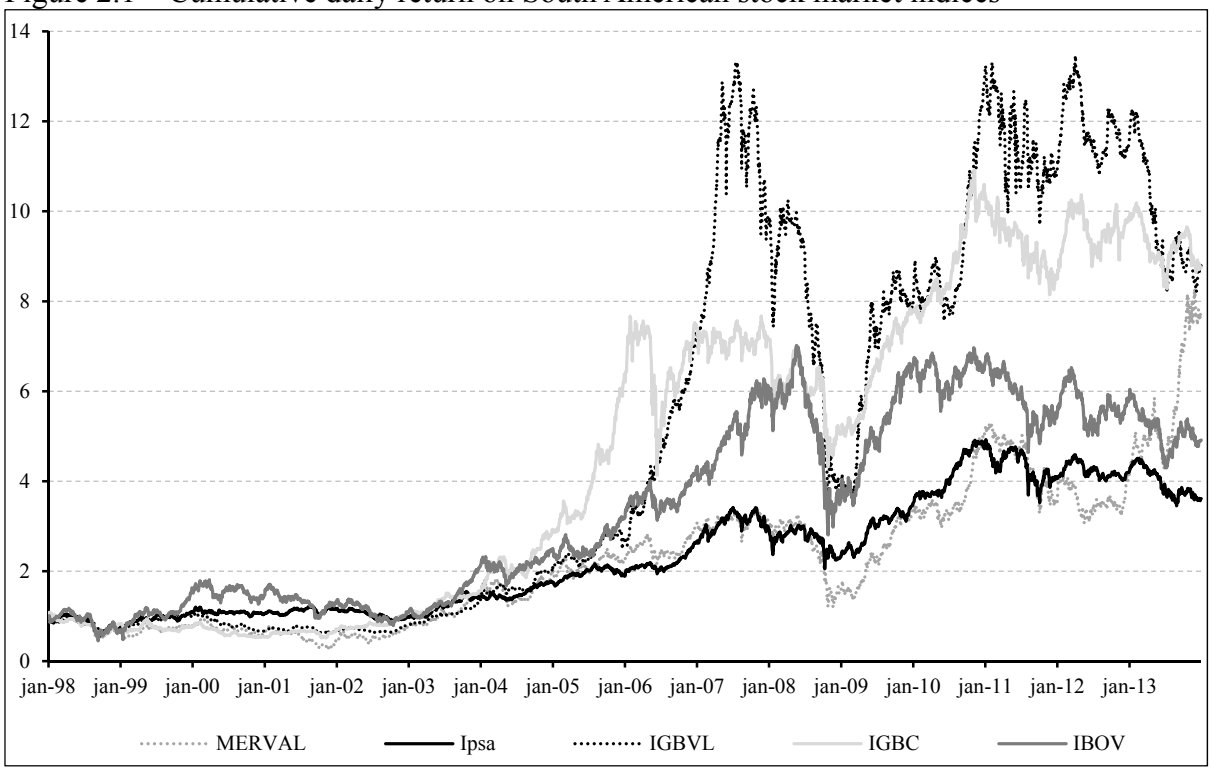
In an attempt to analyze the risk of the major financial indices of Latin America, it is necessary to use a long and consistent time series of returns of these indices. For this reason, the financial markets suggests that, because of their transaction volume and composition, the major indices are: i) IBOVESPA (Index of the São Paulo Stock Exchange, Brazil), ii) IGBC (Colombia Stock Exchange General Index, Colombia), iii) MERVAL (Buenos Aires Stock Exchange Merval Index, Argentina), iv) IGBVL (Lima Stock Exchange General Index, Peru), and v) IPSA (Santiago Stock Exchange IPSA Index, Chile). In terms of time series, 4,118 observations of nominal daily net returns on these indices from January 07, 1998 to December 31, 2013 were extracted from the CMA Trade.

The use of this set of indices is aligned with the research of Matos, Siqueira and Trompieri (2014), where the presence of integration and financial contagion was detected. The indices differ in their maturity. The most traditional is the IBOVESPA, which began in 1968 and underwent a change in its calculation methodology in 2013; on the other hand, the IGBC's calculation methodology only became official in 2001, but there are data available at Economática from 1991. The Argentinian index is composed from the stock price and thus differs from the others, which have a methodology in common that includes a rebalancing on the basis of composition weighted by the capitalization of the stock markets.

2.4.2 Summary statistics

From the visual analysis shown in graph 1, there is similar behavior for periods of growth and decline, which can especially be seen for the Brazilian index from June 1999 to June 2002; for almost this entire period, this was above the other indices as a consequence of the currency depreciation policy that favored the growth of the industrial sector, according to Cardoso (2007).

Figure 2.1 – Cumulative daily return on South American stock market indices [a]



Source: CMA Trade.
Note: [a] Cumulative daily return on South American major market indices, during the period from January 07, 1998 to December 31, 2013, 4118 observations.

The Peruvian index shows a much higher growth trend than the others between the second half of 2006 and the second half of 2007; this growth reflects foreign capital inflows for investment in the mining sector as a result of a new policy in relation to international trade agreements.

The Argentinian index had a very similar performance to the Chilean index, until December 2012; however, from January 2013, an opposite shift to the others can be observed, particularly in the second half of 2013, when it started to show greater gains, reaching a cumulative return of 676.79%, while the others showed a downward trend. During 2008, there was, overall, a declining trend in the South American indices, especially in the second half of that year. This period of decline had a greater effect on the Peruvian stock exchange, where there was a drop of approximately 74.62% due to strong economic dependence on foreign capital, whereas the maximum loss for the IBOVESPA was 61.3%.

After this period of a general fall in the South American indices, it is clear that the Peruvian index recovered more strongly, achieving an average daily gain, from the beginning of January 2009 until the end of the sample period, of around 0.073%; this is second only to the Argentinian index, which recovered to show an average daily gain of 0.141% as a result of the almost exponential growth seen in 2013. The presence of clusters of volatility in the daily

return series would be expected, for observations of returns show several non-linear patterns, according to Gourieroux and Jasiak (2001).

Table 1 shows the main descriptive statistics for the indices. Throughout the sample period, the Argentinian index accumulated a net gain of 676.79%, while the IPSA showed a gain of only 261.28%. The MERVAL had the highest standard deviation and the highest average daily return among the analyzed indices, but its performance, according to the Sharpe ratio, was similar to that of the Chilean index.

Table 2.1 – Summary statistics and violation tests applied to returns on South American stock market indices [a]

Statistics/ Index	MERVAL	IPSA	IGBVL	IGBC	IBOV
Gain					
Mean	0.073%	0.037%	0.063%	0.061%	0.060%
Cumulative	676.794%	261.278%	781.886%	776.445%	391.526%
Risk					
Standard deviation	2.143%	1.109%	1.423%	1.317%	2.079%
Downside risk	1.523%	0.779%	1.019%	0.928%	1.428%
3rd e 4th moments					
Asymmetry	0.014	0.324	-0.197	0.282	1.118
Kurtosis	8.593	12.417	13.529	16.120	24.580
Gaussian Distribution					
Jarque Bera [b]	5.370	15.294	19.059	29.606	80.804
P-value.	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Stationarity					
Phillips-Perron test [c]	-60.334	-53.705	-55.266	-54.520	-64.274
P - value	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
ARCH LM test					
F Statistic [d]	217.318	195.754	908.633	289.053	95.987
P - value	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

Notes: [a] Panel containing daily time series of nominal net returns on major stock exchanges in Latin America countries from 1998 to 2013. (4118 observations); [b] Jarque-Bera test for series normality, the test statistics measure the difference between skewness and kurtosis of the series with a normal distribution under the null hypothesis that the series follows a normal distribution; [c] Phillips-Perron unit root test, at a level with constant and trend, spectral estimation method Default (Bartlett Kernel); [d] Engle's ARCH LM Test, the "Lagrange multiplier" type, for the hypothesis of residuals from ARMA models returns having an ARCH structure, under the null hypothesis that there is no ARCH with a lag. Null Hypothesis: There is no ARCH effect.

The performance of the Colombian and Peruvian indices was very similar, with the Peruvian index having the largest metric associated with a gain, while the Colombian index, compared with the Peruvian, showed better measures of risk, which resulted in the highest Sharpe ratio among the indices observed. In its turn, the IBOVESPA had the worst Sharpe ratio and the second lowest downside risk, while the Chilean index had the lowest values for both the standard deviation and the downside risk.

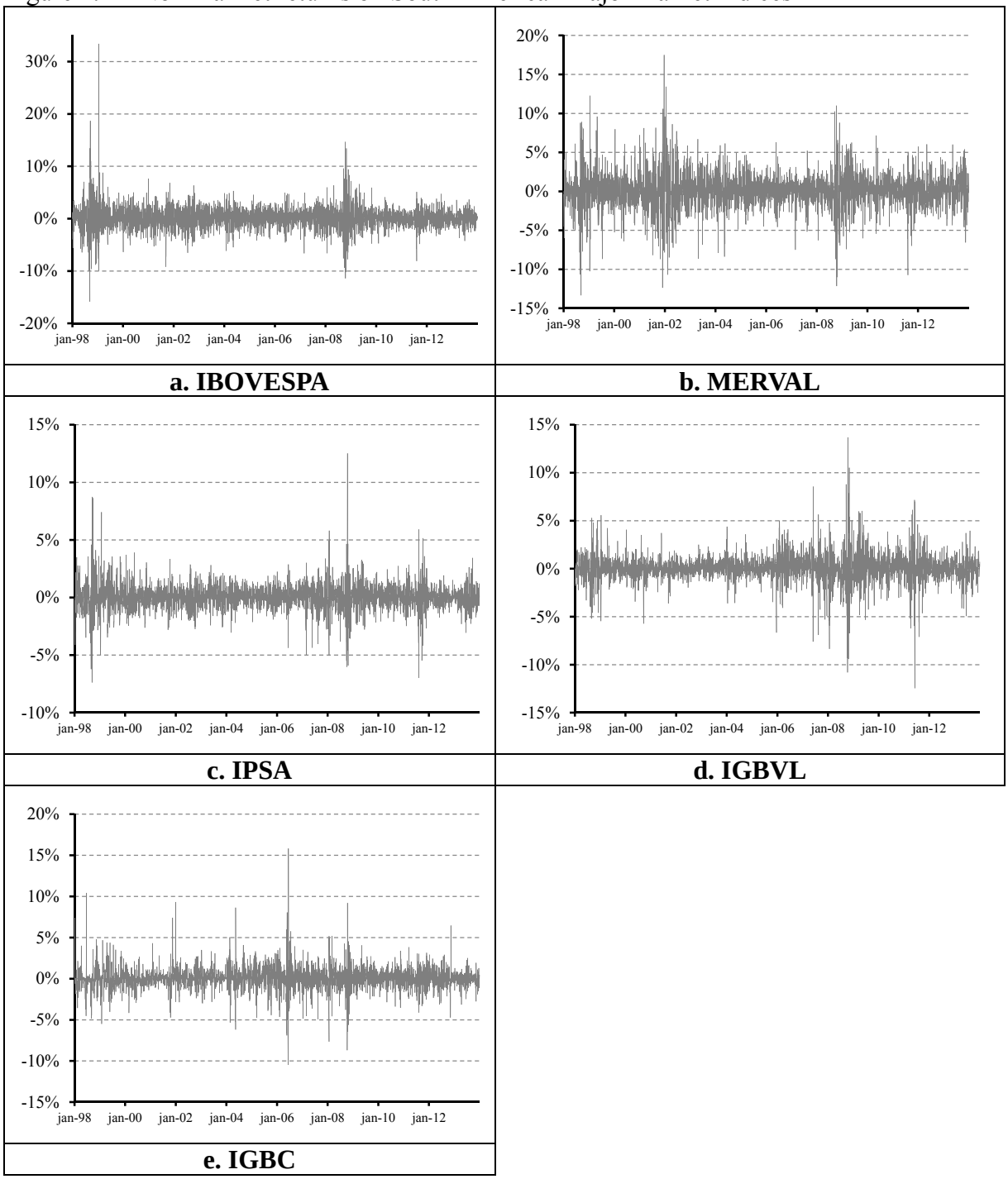
All the indices, except for the IGBVL, showed asymmetry to the right, with this being more pronounced for the IBOVESPA and less pronounced for the MERVAL.

All the indices feature leptokurtosis, since they show a kurtosis greater than the normal distribution, which is 3, and the magnitude is greatest for the Brazilian index and lowest for the Chilean one. This evidence suggests a priori the non-normality of the index return series. In this sense, with the aim of verifying the Gaussian nature more properly, the Jarque-Bera test was used; the result of this test indicates the rejection of the null hypothesis of normality for all the series at a 1% level of significance. According to Mahadeva and Robinson (2004), the biggest problem of using regression models when there are non-stationary variables is that the standard error obtained is biased. Non-stationary series are not suitable if the final purpose is to make predictions, as they have little practical value because the behavior of the series is conditional on time. To examine whether the series are stationary, the Dickey and Fuller (1979) unit root test, in its augmented version, also known as the ADF test, was performed, and also the Phillips and Perron (1988) test. According to Mahadeva and Robinson (2004), the Phillips and Perron test (1988) is used as an alternative to the ADF test because, being a non-parametric test, it has advantages in various applications.

Thus, it was verified that for all the series, at a 1% significance level in both tests, the null hypothesis of the presence of a unit root is rejected; this is expected in returns seriesAlso, in order to determine whether or not there is heteroscedasticity to be modeled in the residues, Engle's ARCHLM test was performed, and the results are shown in Table 1. It can be seen that for all series, at a 99% confidence level, the null hypothesis of the homoscedasticity of the residues is rejected. According to Engle (2001), in the presence of heteroscedasticity the regression coefficients estimated by the ordinary least squares method remain unbiased, but they give a false sense of precision. Engle (2001) argues that the autoregressive conditional heteroskedasticity (ARCH) and Generalized Autoregressive Heteroskedasticity (GARCH) models treat heteroscedasticity as a variance to be modeled, instead of considering it as a problem to be fixed.

Graph 2 shows the behavior of the returns series for the indices. From a visual analysis of these graphics, it is possible to highlight the presence of volatility clusters (volatility clustering), and large swings, which can particularly be seen at the end of 2008 and between 1998 and 1999, when there were common fluctuations: in 2008, as a result of the subprime crisis peak and from 1998 to 1999 as a result of the 1999 currency crisis.

Figure 2.2 – Nominal net returns on South American major market indices [a]



Source: CMA Trade

Notes: [a] Daily series of nominal net return obtained from the time series closing price (end-of-day) of the indices in question during the period from January 07, 1998 to December 31, 2013, 4,118 observations.

It can also be seen that the Colombian index shows turbulence even before the crisis, with the largest negative peaks in June 2006. The Argentinian index has its most turbulent period in 2002.

Finally, Table 2 reports the initial ranking positions in terms of the fitting of a wide range of distribution functions for the probability present, using the EasyFit software. It

is not exactly surprising that the normal distribution does not perform very well in the fitting rankings reported in this table. It can be observed that, in the aggregate ranking that considers the more than 50 continuous distributions that make up the Easy database, the normal distribution occupies positions like 10th and 17th, with the best distributions being identified as the Laplace for the Brazilian, Chilean and Argentinian indices. The best distribution for the Peruvian and Colombian indices is the Johnson SU.

Table 2.2 – Identification of the best fitting probability distribution function [a]

Index	Country	Best Fitting probability distribution function(pdf)[a]	Anderson -Darlin statistic test	Parameters	Best fitting pdf critical value (1%)	Global ranking (best fitting pdf)[b]	Global ranking (normal distribution)
IBOVESPA	Brazil	Laplace	3.002	l= 68.033; μ=6.00 E-4	-5.690%	1st	17th
IGBC	Colombia	Laplace	13.789	l= 107.35; μ=6.1360 E-4	-3.583%	2nd	15th
IGBVL	Peru	Laplace	13.306	l= 99.367; μ=6.3003 E-4	-3.874%	2nd	10th
IPSA	Chile	Laplace	2.040	l= 127.49; μ=3.73 E-4	-3.031%	1st	16th
MERVAL	Argentina	Laplace	4.085	l= 65.991; μ=7.27 E-4	-5.855%	1st	12th

Notes: [a] The best-fitting pdf is identified and the ranking is done based on Anderson and Darling (1952) statistic. Our search for this specific and idiosyncratic distribution needs to impose a limitation on the range of continuous distribution families, because we can only use pdf's in which the standard deviation and the mean are given by univariate bijection, i.e., each moment depends on only one pdf parameter. [b] This is an unrestricted ranking, considering all continuous timing distributions.

Thus, for only these two indices, among the subset of distributions that can establish the bijection necessary for the quantile function to have a time-varying mean and standard deviation as arguments, it is noted that the Laplace function, which occupies second place in the overall ranking, presents the most appropriate fitting. Other distributions that satisfy this condition and have adequate fitting for the sector indices and for shares in the Brazilian capital markets are the logistic distribution and the secant hyperbolic distribution, among others.

2.4.3 Results: ARMA-GARCH

Based on Table 3, the series have different specifications, both in terms of the ARMA modeling, and in terms of the GARCH modeling, with the IGBC showing the simplest linear framework.

Table 2.3 – Estimation ARMA-GARCH model. [a,b]

$$y_t = \phi_0 + \sum_{i=1}^{m} \phi_i\, y_{t-i} + \varepsilon_t - \sum_{j=1}^{n} \theta_j\, \varepsilon_{t-j}, \qquad \varepsilon_t = v_t \sigma_t, \qquad \sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i\, \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j\, \sigma_{t-j}^2.$$

Period: from 1998:01 to 2013:12 (4120 observations)

Index	Best ARMA-GARCH	Estimation	Log verossim.	Akaike	Schwarz	p-value
IBOVESPA	ARMA(2,2)-GARCH(1,1)	$y_t = \underset{(0.0000)}{0.000905} + \underset{(0.0000)}{1.525010}\, y_{t-1} \underset{(0.0000)}{- 0.723076}\, y_{t-2} \underset{(0.0000)}{- 1.529007}\, \varepsilon_{t-1} \underset{(0.0000)}{+ 0.712479}\, \varepsilon_{t-2}$ $\sigma_t^2 = \underset{(0,0000)}{0.000007} + \underset{(0,0000)}{0,.087503}\, \varepsilon_{t-1}^2 + \underset{(0,0000)}{0.894567}\, \sigma_{t-1}^2$	10797.06	-5.2400	-5.2277	0.0051
IGBC	AR(1)-GARCH(1,1)	$y_t = \underset{(0.0000)}{0.000705} + \underset{(0.0000)}{0.180992}\, y_{t-1}$ $\sigma_t^2 = \underset{(0.0000)}{0.0000116} + \underset{(0.0000)}{0.202787}\, \varepsilon_{t-1}^2 + \underset{(0.0000)}{0.732474}\, \sigma_{t-1}^2$	12752.38	-6.1896	-6.1819	0.0000
IGBVL	ARMA(2,2)-GARCH(1,1)	$y_t = \underset{(0.0000)}{0.000949} + \underset{(0.0000)}{0.957639}\, y_{t-1} \underset{(0.7850)}{- 0.030871}\, y_{t-2} \underset{(0.0000)}{- 0.760778}\, \varepsilon_{t-1} \underset{(0.2383)}{- 0.120363}\, \varepsilon_{t-2}$ $\sigma_t^2 = \underset{(0.0000)}{0.00000615} + \underset{(0.0000)}{0.186704}\, \varepsilon_{t-1}^2 + \underset{(0.0000)}{0.784090}\, \sigma_{t-1}^2$	12754.09	-6.1904	-6.1781	0.0000
MERVAL	ARMA(1,2)-GARCH(2,2)	$y_t = \underset{(0.0002)}{0.001109} + \underset{(0.0005)}{0.730897}\, y_{t-1} \underset{(0.0014)}{- 0.677681}\, \varepsilon_{t-1} \underset{(0.3011)}{- 0.024087}\, \varepsilon_{t-2}$ $\sigma_t^2 = \underset{(0.0005)}{0.00002} + \underset{(0.0033)}{0.059806}\, \varepsilon_{t-1}^2 + \underset{(0.0001)}{0.106012}\, \varepsilon_{t-2}^2 + \underset{(0.3743)}{0.195203}\, \sigma_{t-1}^2 + \underset{(0.0026)}{0.593848}\, \sigma_{t-2}^2$	10513.34	-5.1004	-5.0866	0.0000
IPSA	ARMA(2,1)-GARCH(1,1)	$y_t = \underset{(0.0000)}{0.000719} + \underset{(0.0000)}{0.908219}\, y_{t-1} \underset{(0.0002)}{- 0.143530}\, y_{t-1} \underset{(0.0000)}{- 0.721234}\, \varepsilon_{t-1}$ $\sigma_t^2 = \underset{(0.0000)}{0.0000025} + \underset{(0.0000)}{0.130792}\, \varepsilon_{t-1}^2 + \underset{(0.0000)}{0.850493}\, \sigma_{t-1}^2$	13454.33	-6.5310	-6.5203	0.0062

Notes: [a] ARMA models estimated via OLS using the Newey-West coefficient for heteroscedasticity. [b] ARMA-GARCH models estimated via ARCH, with normal errors distribution (Gaussian), using the Bollerslev-Wooldridge covariance coefficient for heteroscedasticity.

The parameters of the models estimated for the IBOVESPA, IGBC and IPSA indices are individually significant, even at the 1% level, both in the ARMA specification and in the GARCH framework. The IGBVL index obtained some parameters that were individually insignificant even at the 10% significance level in the ARMA specification, but the estimated GARCH parameters showed no problem with individual significance, even at the 1% level. However, the estimated model for the MERVAL presented a problem of individual significance in some parameters, for both the ARMA specification and the GARCH framework.

Still considering Table 3, the p-value of the F statistic for the estimated ARMA-GARCH models is reported. The results demonstrate, in all the models estimated, that the null hypothesis that the slope coefficients of the estimated equations are jointly statistically insignificant is rejected at a 99% confidence level. Thus, the F-test confirms that the estimated models can be used to represent the return series of the South American indices for both the models estimated for the IGBVL and MERVAL indices, which showed some individual insignificant parameters, as well as for the other indices. The GARCH models obtained, except for the Argentinian index, are aligned with the results of Ferreira (2013), who states that "financial series are often better adjusted to low order GARCH models, with GARCH (1.1) being a very popular choice."

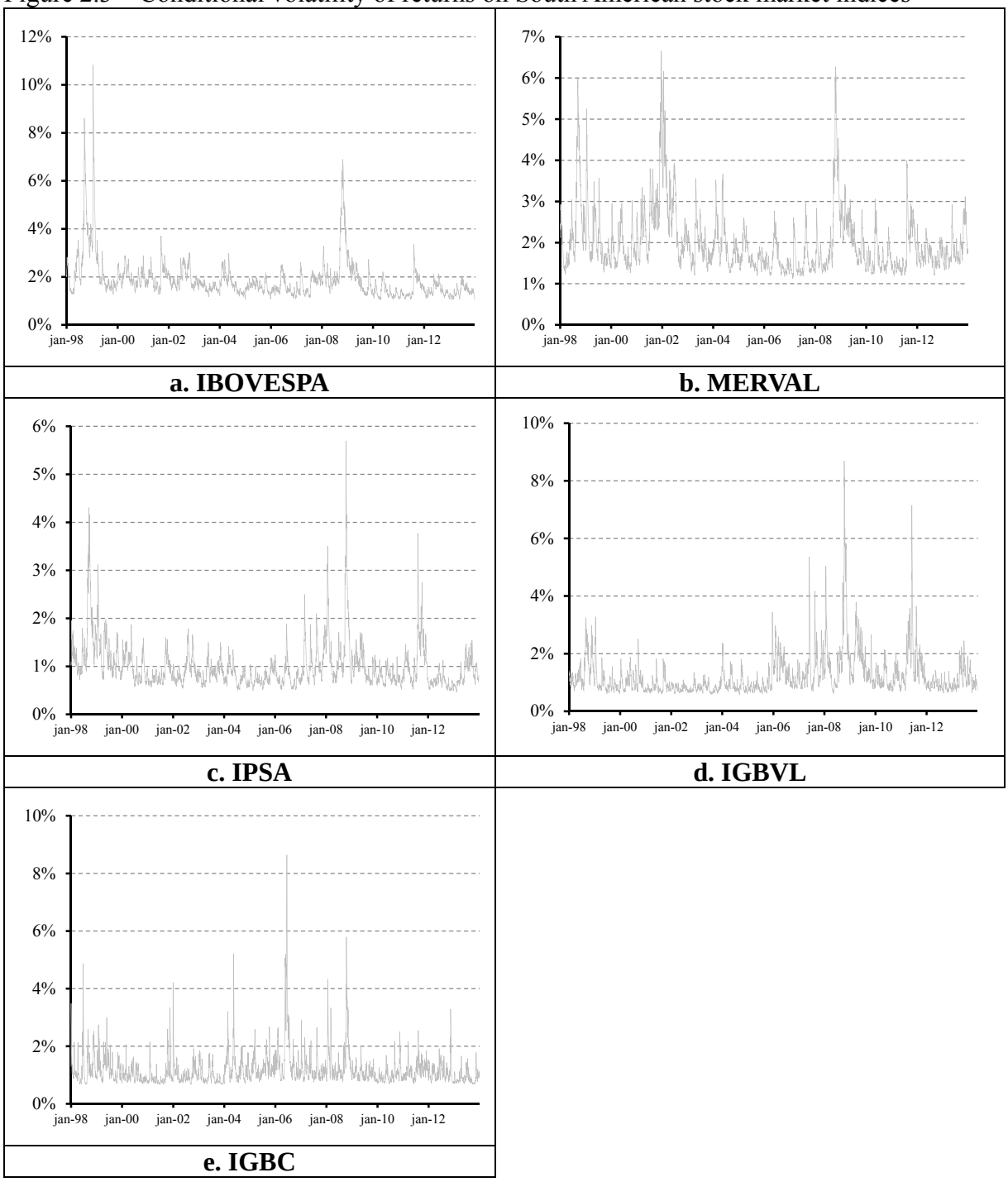
2.4.4 Results: joint estimation

As a result of the contagion and financial integration for the main market indices in South America highlighted in Matos, Siqueira, and Trompieri (2014), it is intuitively clear that there can be benefits in risk modeling when considering the cross-effects in estimating the ARMA-GARCH frameworks. This happens through the joint estimation of this framework, that is, by using a multivariate GARCH of the AGDCC type (Asymmetric Generalized Dynamic Conditional Correlation). Theoretically, this framework accommodates all the major criticism of the unconditional Gaussian VaR used in most parametric approaches to risk management.

In practice, the estimation results of the conditional risk series show, as can be seen in graph 3, a pattern of conditional volatility very similar to the ARMA-GARCH estimations in a univariate and isolated way. The peaks occur on the same days, with rare exceptions, and the orders of magnitude are also similar. However, this apparently negligible difference does not translate into exactly identical VaRs, since the return series fitted change

greatly within the univariate and multivariate frameworks. In short, it is possible to observe a pattern of an inferior envelope being provided by the Laplace Multivariate Conditional VaR, with more extremes, that is, with an excess of conservatism that apparently provides a model with fewer exceptions.

Figure 2.3 – Conditional volatility of returns on South American stock market indices [a,b]



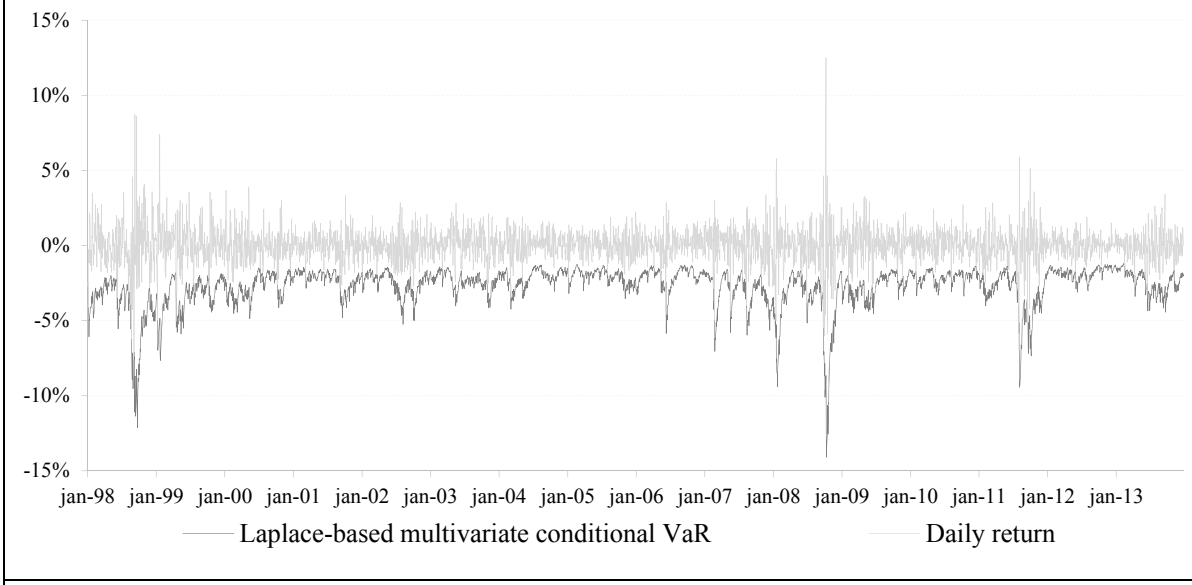
Source: CMA Trade.

Notes: [a] Daily series of nominal net return obtained from the time series closing price (end-of-day) of the indices in question during the period from January 07, 1998 to December 31, 2013, 4,118 observations. [b] One-step-ahead prediction performed using the ARMA-GARCH models estimated jointly.

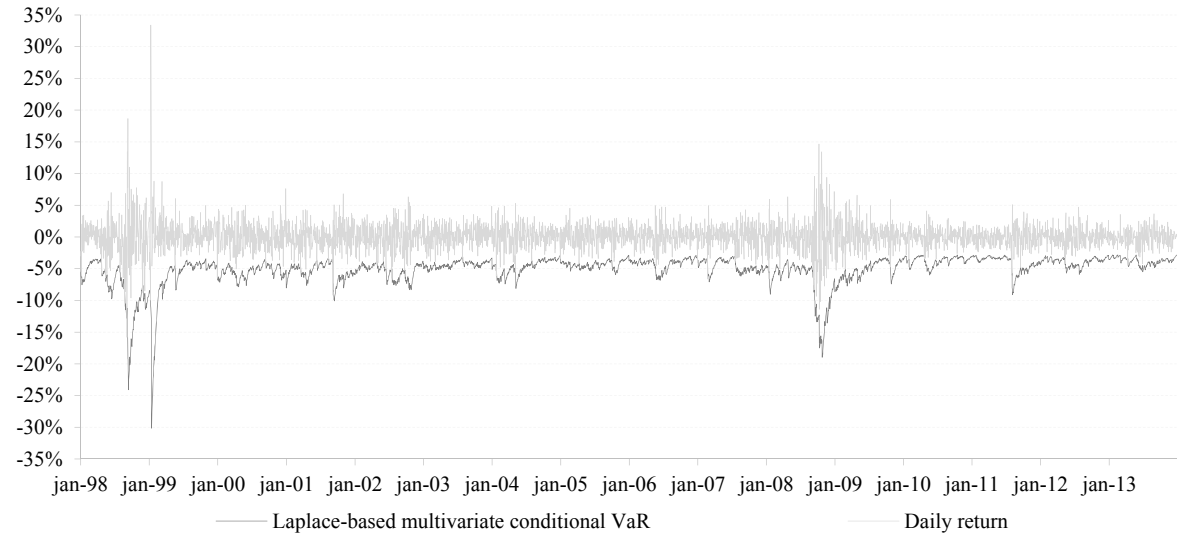
2.4.5 Results: validation of models through backtesting

Aiming to analyzing cross-effects due to contagion and integration, in Graph 4 we plot the time evolution of the VaR series generated by following the multivariate metric, with a confidence level of 99% and a horizon of one day, as well as the daily return series for each banking index. Visual analysis allows us to suggest that, for all series, the maximum expected losses predicted by the multivariate VaR are closer to the realized losses than those predicted by the base VaR.

Figure 2.4 – Laplace-based absolute VaR (99%, 01 day) of South American stock market indices



a. IPSA (Chile)

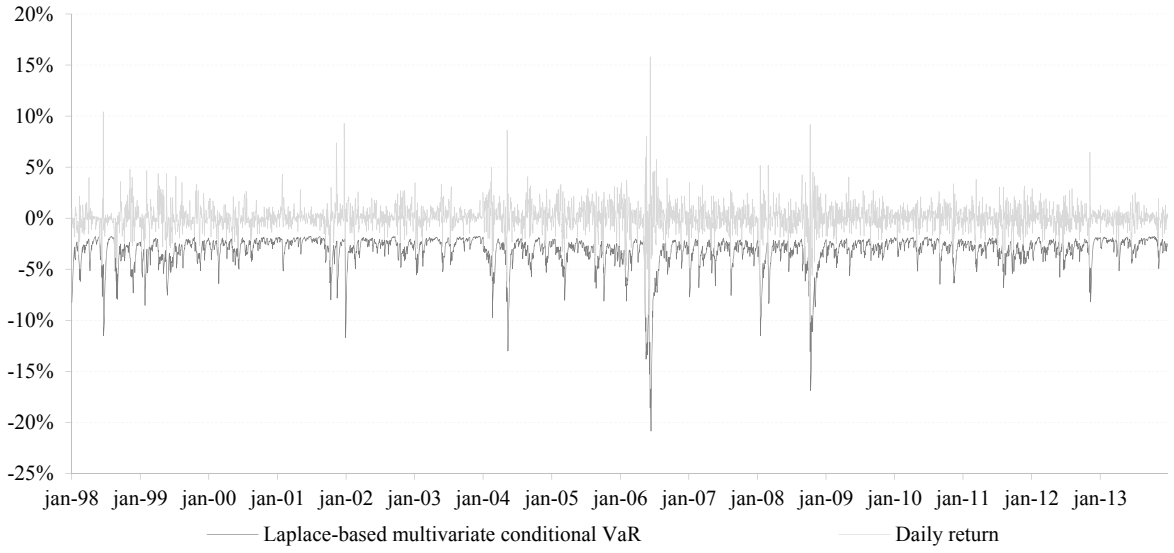


b. IBOVESPA (Brazil)

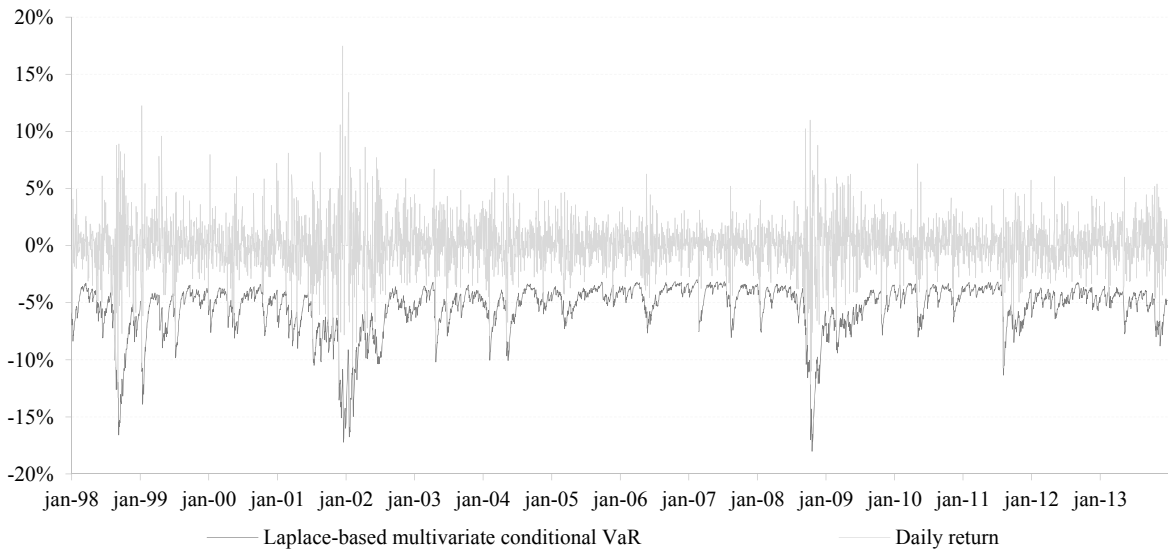
Continue

Continuation

Figure 2.4 – Laplace-based absolute VaR (99%, 01 day) of South American stock market indices



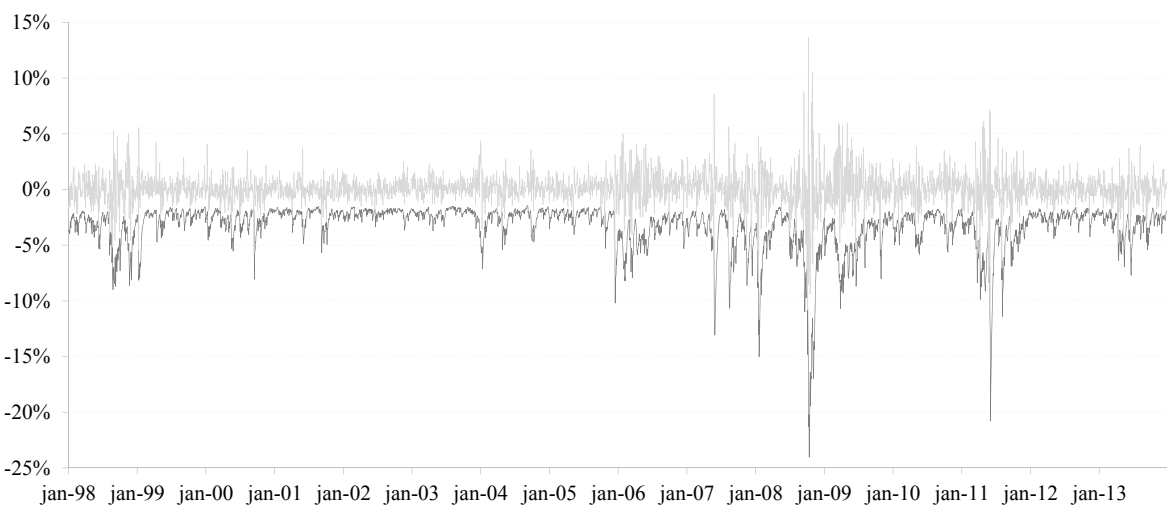
c. IGBC (Colombia)



d. MERVAL (Argentina)

Continue

Figure 2.4 – Laplace-based absolute VaR (99%, 01 day) of South American stock market indices



e. IGBVL (Peru)

Source: CMA Trade

According to Graph 4, there are three moments for all the South American markets when the highest values of VaR are seen, and these match the times of greatest volatility: i) the first half of 2009, still reflecting the subprime crisis in the United States; ii) the first half of 2010, as a result of a time of instability in the euro zone due to the first signs of the sovereign debt crisis; and iii) the second half of 2011, with the emergence of the same crisis signaling the possibility of some government defaults. Our purpose is to draw inferences about the relevance of contagion and financial integration effects between the South American stock market indices, and therefore multivariate conditional best-fitting VaR, which incorporates these cross-effects, is compared with the corresponding univariate version.

These models are similar in all aspects, except for the conditional moments incorporated into the distribution with the better fitting, which, in the latter VaR, are estimated from a univariate ARMA-GARCH, instead of a multivariate framework. To continue this comparison we must use the backtesting methods defined in the previous section. We report the results of the proposed backtesting in Table 4.

Using Basel backtesting, which takes into account violations in the absolute or relative amounts over the 4,118 daily observations, we reject Basel VaR for all economies, while univariate VaR is rejected for Argentina. Multivariate VaR fails for Colombia, Argentina, and Peru. For all the economies, the number of violations is higher for Basel VaR than for

univariate or multivariate VaR. Using backtesting that takes into account the frequency and conditionality of losses exceeding the VaR (the tests proposed by Kupiec (1995) or Christoffersen (1998) or the joint test proposed by these authors), while Basel VaR is rejected for all five economies, we fail to reject univariate conditional best-fitting VaR for all markets, while the multivariate version is rejected only for Peru and Chile. Since for most of the indices there are no successive violations when we use the univariate or multivariate VaR measures, we cannot measure a value for the statistical test proposed by Christoffersen (1998) or for the joint test.

Table 4 also reports useful partial metrics to measure the average violation and the excessive conservatism. For the IBOVESPA in Brazil and the MERVAL in Argentina, multivariate VaR shows the best performance regarding both partial statistics, supporting a conclusion that contagion and integration effects are relevant for these two financial markets, which are the largest in the continent.

Table 2.4 – Backtesting methods applied to VaR of returns on South American stock market indices [a,b]

Index (country)	VaR specification	Basel test (4118 observations)			Partial statistics		Kupiec Test [c] (crít. value $X^2(1) = 6.63$)		Christoffersen Test [d] (crit. value $X^2(1) = 6.63$)		Kupiec-Christoffersen Test [d] (crit. value $X^2(1) = 9.21$)	
		Number of violations	%	Result	Average violation	Excess conservatism	Statistic	Result	Statistic	Result	Statistic	Result
IBOVESPA (Brazil)	Gaussian-based unconditional	57	1.384%	reject	0.331%	5.253%	5.48	no reject	14.93	reject	20.41	reject
	Laplace-based univariate conditional	31	0.753%	no reject	0.147%	6.076%	2.78	no reject	- x -	no applic	- x -	no applic
	Laplace-based multivariate conditional	29	0.704%	no reject	0.146%	6.075%	4.06	no reject	- x -	no applic	- x -	no applic
IGBC (Colombia)	Gaussian-based unconditional	74	1.797%	reject	0.287%	3.320%	21.37	reject	39.94	reject	61.31	reject
	Laplace-based univariate conditional	38	0.923%	no reject	0.083%	3.835%	0.25	no reject	- x -	no applic	- x -	no applic
	Laplace-based multivariate conditional	48	1.166%	reject	0.092%	3.845%	1.08	no reject	5.45	no reject	6.54	no reject

Continue

Continuation

Table 2.4 – Backtesting methods applied to VaR of returns on South American stock market indices [a,b]

Index (country)	VaR specification	Basel test (4118 observations)			Partial statistics		Kupiec Test [c] (crít. value $X^2(1) = 6.63$)		Christoffersen Test [d] (crit. value $X^2(1) = 6.63$)		Kupiec-Christoffersen Test [d] (crit. value $X^2(1) = 9.21$)	
		Number of violations	%	Result	Average violation	Excess conservatism	Statistic	Result	Statistic	Result	Statistic	Result
MERVAL (Argentina)	Gaussian-based unconditional	74	1.797%	reject	0.383%	5.414%	21.37	reject	6.28	no reject	27.65	reject
	Laplace-based univariate conditional	46	1.117%	reject	0.170%	6.276%	0.55	no reject	0.37	no reject	0.92	no reject
	Laplace-based multivariate conditional	44	1.068%	reject	0.183%	6.271%	0.19	no reject	0.46	no reject	0.65	no reject
IGBVL (Peru)	Gaussian-based unconditional	78	1.894%	reject	0.348%	3.587%	26.34	reject	47.62	reject	73.96	reject
	Laplace-based univariate conditional	38	0.923%	no reject	0.104%	4.134%	0.25	no reject	- x -	no applic	- x -	no applic
	Laplace-based multivariate conditional	45	1.093%	reject	0.131%	4.139%	0.35	no reject	10.32	reject	10.67	reject

Continue

Table 2.4 – Backtesting methods applied to VaR of returns on South American stock market indices [a,b]

Index (country)	VaR specification	Basel test (4118 observations)			Partial statistics		Kupiec Test [c] (crít. value $X^2(1) = 6.63$)		Christoffersen Test [d] (crit. value $X^2(1) = 6.63$)		Kupiec-Christoffersen Test [d] (crit. value $X^2(1) = 9.21$)	
		Number of violations	%	Result	Average violation	Excess conservatism	Statistic	Result	Statistic	Result	Statistic	Result
IPSA (Chile)	Gaussian-based unconditional	68	1.651%	reject	0.199%	2.802%	14.75	reject	38.88	reject	53.63	reject
	Laplace-based univariate conditional	35	0.850%	no reject	0.073%	3.219%	0.99	no reject	- x -	no applic	- x -	no applic
	Laplace-based multivariate conditional	40	0.971%	no reject	0.084%	3.228%	0.03	no reject	12.11	reject	12.15	reject

Notes: [a] We performed the backtestings reported here on the daily series of absolute measures of VaR, with 99% confidence level one day ahead, during the period from January 07, 1998 to December 31, 2013, 4,118 observations. We may reject the VaR specification where the test statistic is higher than the critical value. [b] Unconditional coverage test proposed by Kupiec (1995), with confidence around 99% defined by a ratio of log-likelihood having chi-square asymptotic distribution with one degree of freedom under the null hypothesis that the level of VaR confidence is the real likelihood of losses. [c] Unconditional coverage test proposed by Christoffersen (1998), with the region of confidence of approximately 99%, defined by a ratio of log-likelihood that has asymptotic chi-square with one degree of freedom under the null hypothesis that the exceptions are independent serially. [d] Joint test of conditional and unconditional coverage, with confidence of approximately 99%, defined by a ratio of log-likelihood having chi-square asymptotic distribution with two degrees of freedom under the null hypothesis that the confidence level of the VaR is the real likelihood of losses and the exceptions are serially independent.

2.5 Conclusion

Risk management, whether on the local scene for a particular company, or in a broader and more complex international context that involves, for example, a country's index, requires a statistical framework that can accommodate the characteristics of the time series in question. What can be seen from the commonly used parametric frameworks is the adoption of assumptions that prove invalid, such as the Gaussian nature of the returns and homoscedasticity. In this context, this study follows Matos *et al*. (2015) in order to accommodate these two violations in a VaR framework that is described as univariate best-fitting. Subsequently, this study follows Matos, Fonseca, and de Jesus Filho (2016) by adding the possible cross-effects associated with contagion and the existing financial integration of this group of countries.

The results, in summary, suggest that the statistical refinement associated with the use of the Laplace probability distribution generates a risk management model with the lowest number of violations and with the average violation having a lower order of magnitude, but yet with the absence or small incidence of violation clusters, so avoiding excessive conservatism.

The insertion of the cross-effects does not generally translate into improvements if the model is validated through backtesting, except in relation to the IBOVESPA.

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

3.1 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, Rebouças and Jesus Filho (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, Siqueira and Trompieri (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.

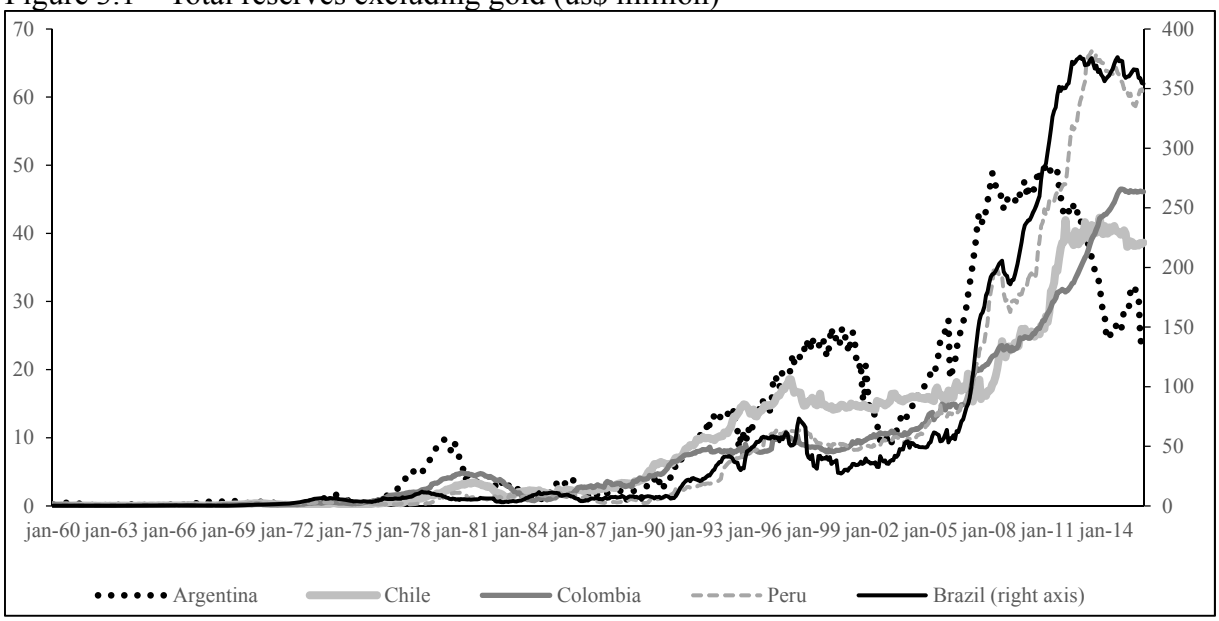
3.2 South American reserves

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. The same author 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.

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. In this figure 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.

Figure 3.1 – Total reserves excluding gold (us$ million)



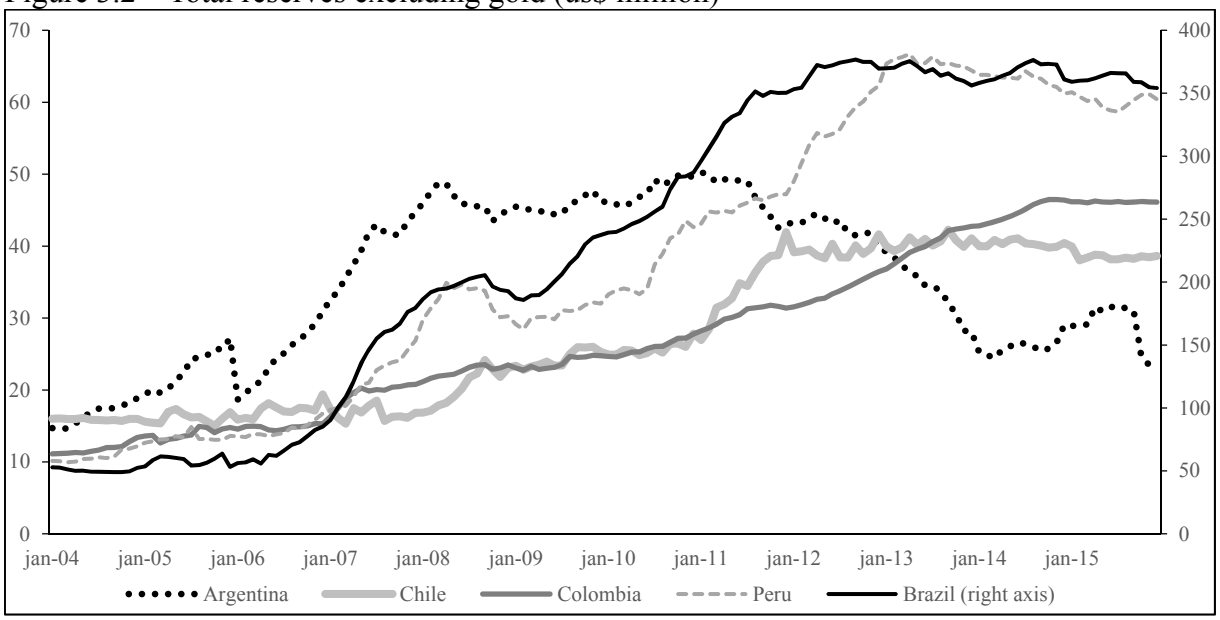
Source: fred

From the 1990's 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 3.2 – Total reserves excluding gold (us$ million)



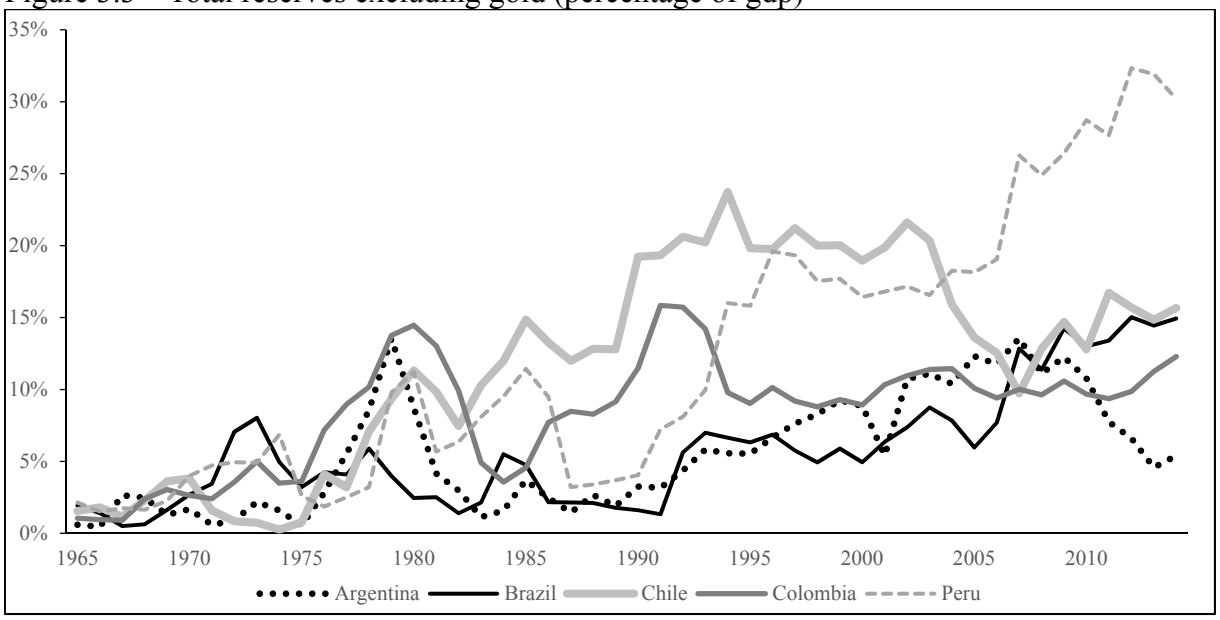
Source: fred

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, Hashimoto and Ito (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, Rebouças and Jesus Filho (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 3.3 – Total reserves excluding gold (percentage of gdp)

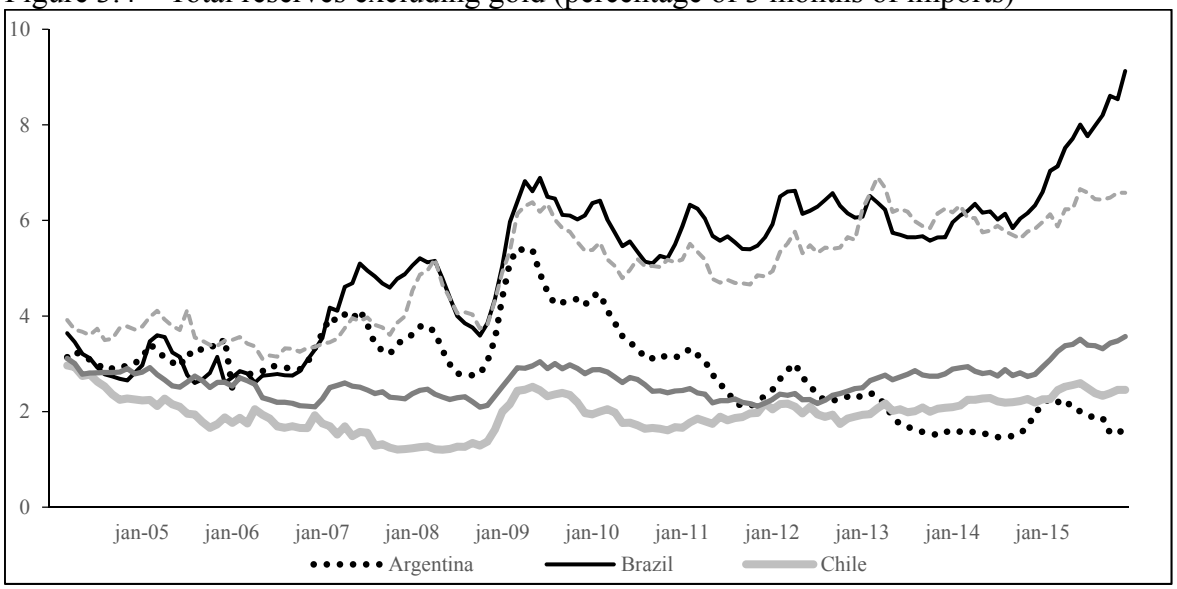


Source: fred

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 3.4 – Total reserves excluding gold (percentage of 3 months of imports)



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.

3.3 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, Rebouças and Jesus Filho (2016), who follow the buffer stock model with cross-effects for the BRICS.

3.4 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.

3.5 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 Organisation 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 Organization for Economic Co-Operation and Development (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 3.1 – Unit root test[a,b]

Variable Ln(Reserves)	Test	Level		First difference	
		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

Notes: [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.

Figure 3.5 – Spread of interest from South American countries[a]

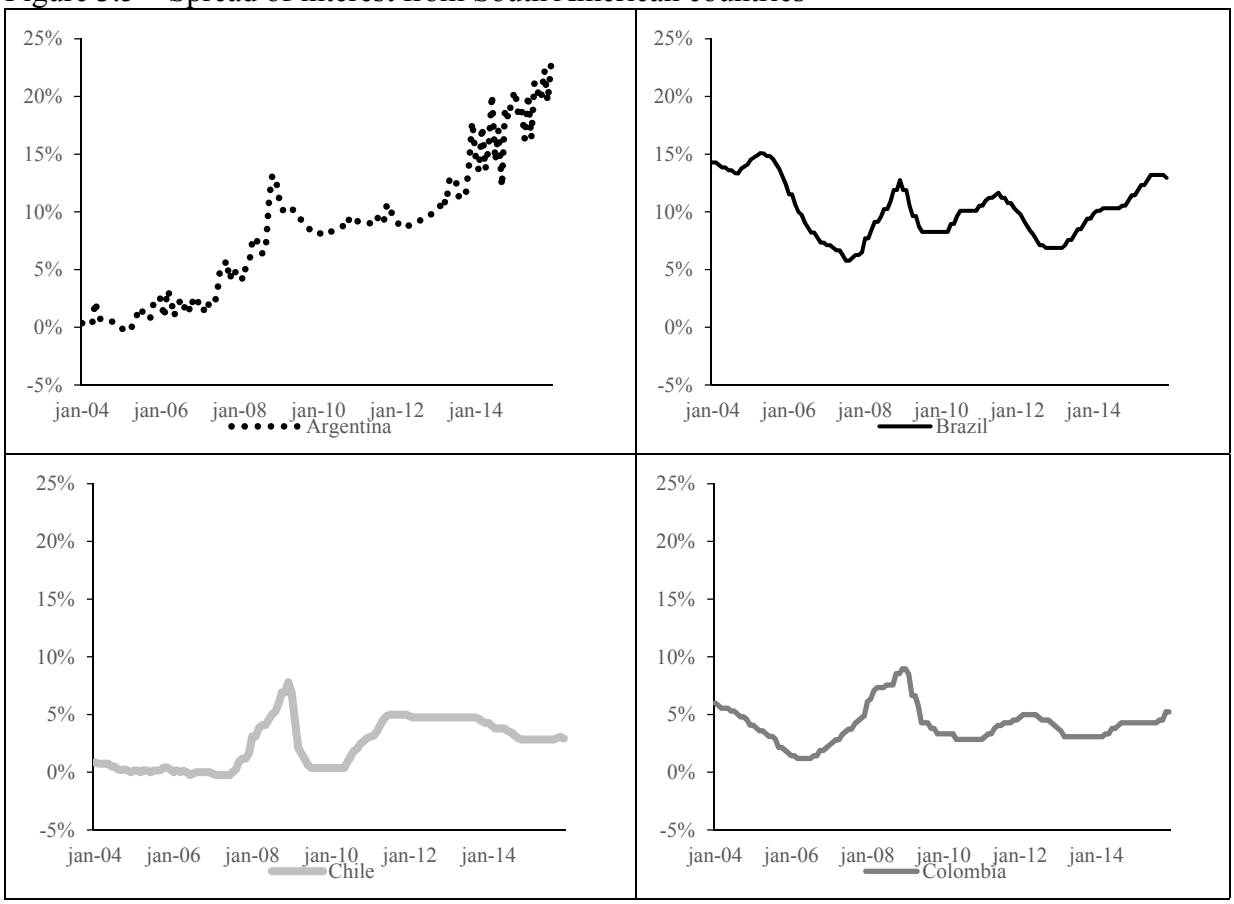


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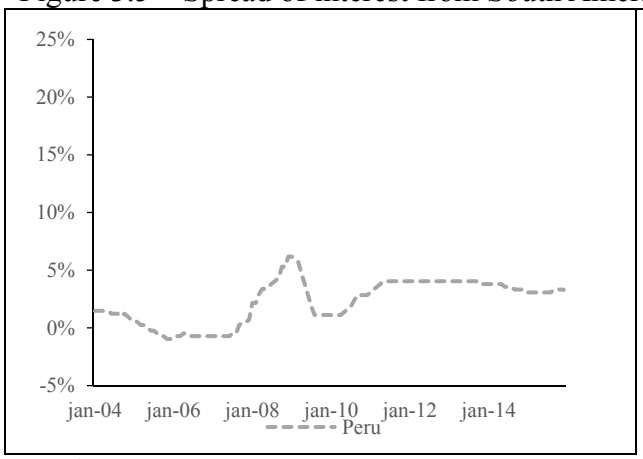
Figure 3.5 – Spread of interest from South American countries[a]

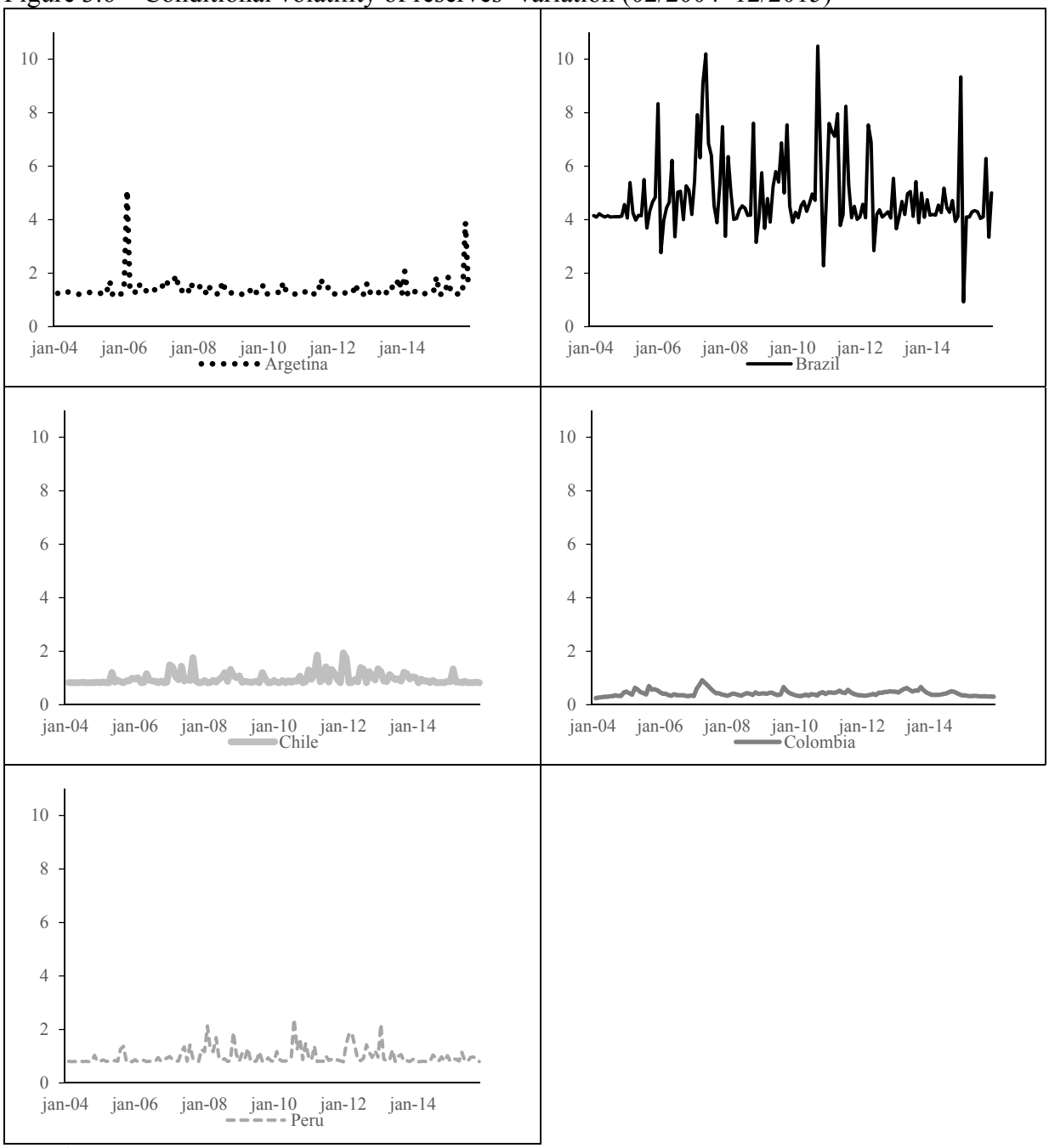


Note: [a] The series consist of the Naperian logarithm in the ratio between the gross interest of the emerging economy in question and the US economy.

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. 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.

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.

Figure 3.6 – Conditional volatility of reserves' variation (02/2004–12/2015)[a]



Note: [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.

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.

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).

Table 3.2 – Estimation of the buffer stock model with cross-effects[a,b,c]

Exogenous	Endogenous variables: reserves(in log)				
	Argentina	**Brazil**	**Chile**	**Colombia**	**Peru**
First step: estimations					
Variance equation based on parsimonious GARCH model					
Constant	1.47e+18 (0.000)	1.69e+19 (0.000)	6.76e+17 (0.000)	3.87e+16 (0.070)	6.33e+17 (0.000)
ε_{t-1}^2	0.339 (0.000)	0.696 (0.015)	0.301 (0.039)	0.248 (0.059)	0.441 (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 [0.523]	-1.361** [-2.052]	1.100 ** [1.651]	-0.606** [-1.842]	-0.221 [-0.473]
Coint. #1	-0.029 *** [-2.396]	-0.010 * [-1.292]	-0.044*** [-4.589]	-0.007 * [-1.477]	-0.034*** [-5.063]
Joint buffer stock model: spread					
Argentina	-0.375 *** [-2.375]	-0.140 * [-1.351]	-0.578 *** [-4.646]	-0.096 * [-1.566]	-0.458*** [-5.257]
Brazil	-0.052 [-0.280]	-0.327 *** [-2.701]	0.090 [0.619]	-0.038 [-0.530]	-0.235** [-2.305]
Chile	-0.188 [-0.359]	-0.335 [-0.978]	0.960*** [2.332]	-0.108 [-0.531]	-0.144 [-0.500]
Colombia	0.159 [0.433]	-0.057 [-0.238]	-0.551** [-1.914]	-0.075 [-0.523]	-0.381** [-1.891]
Peru	0.061 [0.088]	0.047 [0.105]	0.873* [1.609]	0.165 [0.615]	0.888*** [2.340]
Joint buffer stock model: conditional volatility					
Argentina	-0.015 [-0.670]	0.007 [0.478]	-0.003 [-0.143]	-0.001 [-0.056]	0.002 [0.138]
Brazil	-0.0280** [-1.847]	0.0129* [1.297]	0.002 [0.178]	-0.007 [-1.259]	-0.002 [-0.253]
Chile	0.014 [0.571]	0.016 [1.047]	-0.065*** [-3.497]	0.016** [1.765]	-0.001 [-0.100]
Colombia	0.018 [0.859]	0.015 [1.118]	0.0357** [2.187]	0.0145** [1.801]	0.012 [1.066]
Peru	-0.004 [-0.240]	0.006 [0.518]	-0.020* [-1.447]	0.009 [1.242]	0.004 [0.434]

Continue

Table 3.2 – Estimation of the buffer stock model with cross-effects[a,b,c]

Exogenous	Endogenous variables: reserves(in log)				
	Argentina	**Brazil**	**Chile**	**Colombia**	**Peru**
Joint buffer stock model: imports					
Argentina	0.078* [1.322]	0.049 [1.254]	-0.060 [-1.271]	0.005 [0.230]	-0.107*** [-3.262]
Brazil	-0.070* [-1.315]	-0.009 [-0.263]	-0.023 [-0.544]	0.029* [1.420]	0.057** [1.961]
Chile	-0.038 [-0.758]	0.045* [1.387]	-0.048 [-1.215]	-0.057*** [-2.975]	0.065*** [2.382]
Colombia	0.060 [1.007]	-0.026 [-0.664]	-0.004 [-0.086]	0.038** [1.666]	-0.041 [-1.239]
Peru	-0.045 [-0.827]	-0.012 [-0.348]	0.097** [2.283]	-0.005 [-0.238]	0.009 [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

Notes: [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.

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, Vásquez and Villamizar (2010).

Figure 3.7 – Monthly realized and fitted total reserves (us$ billion) for the South American Economies[a]

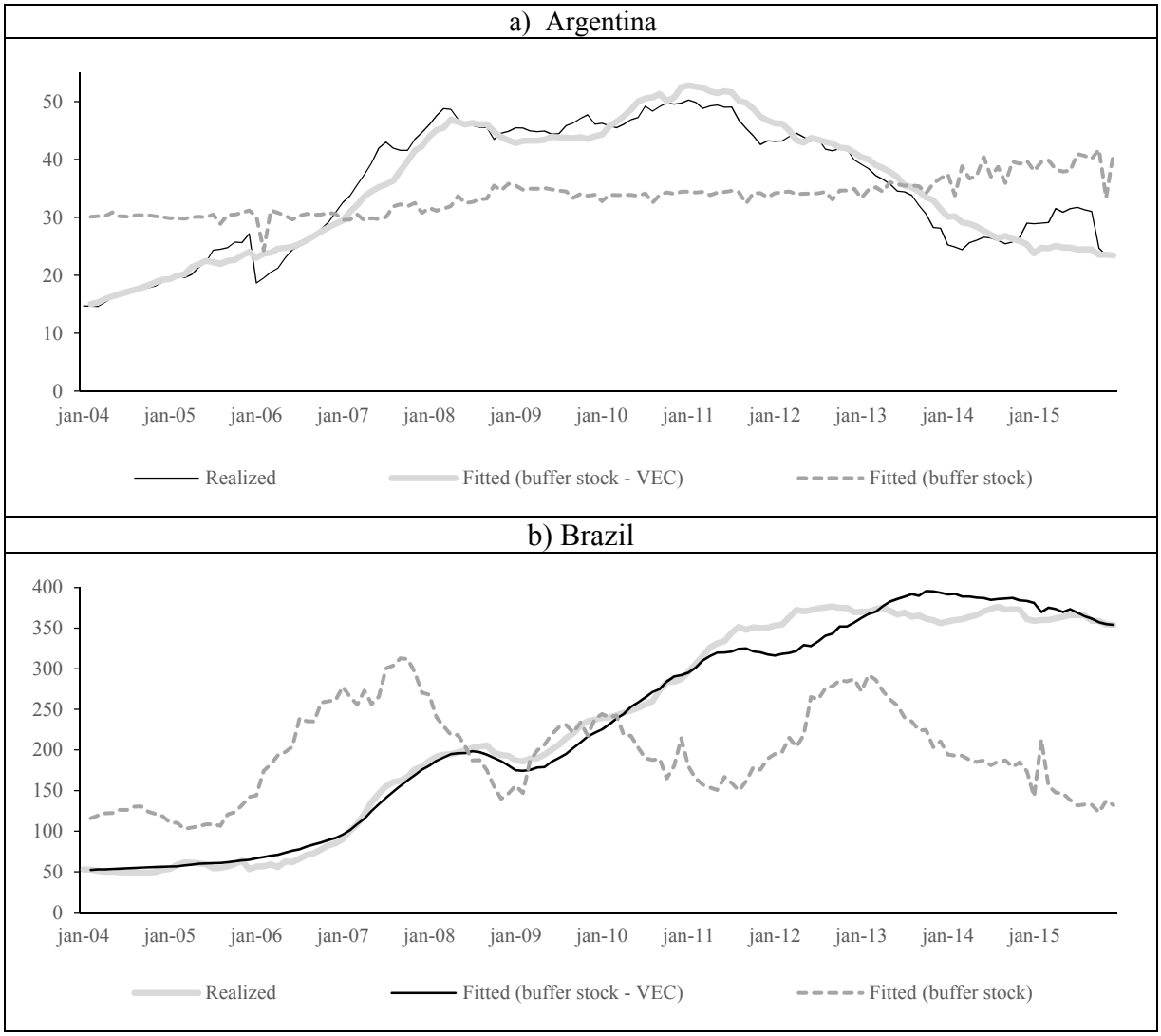


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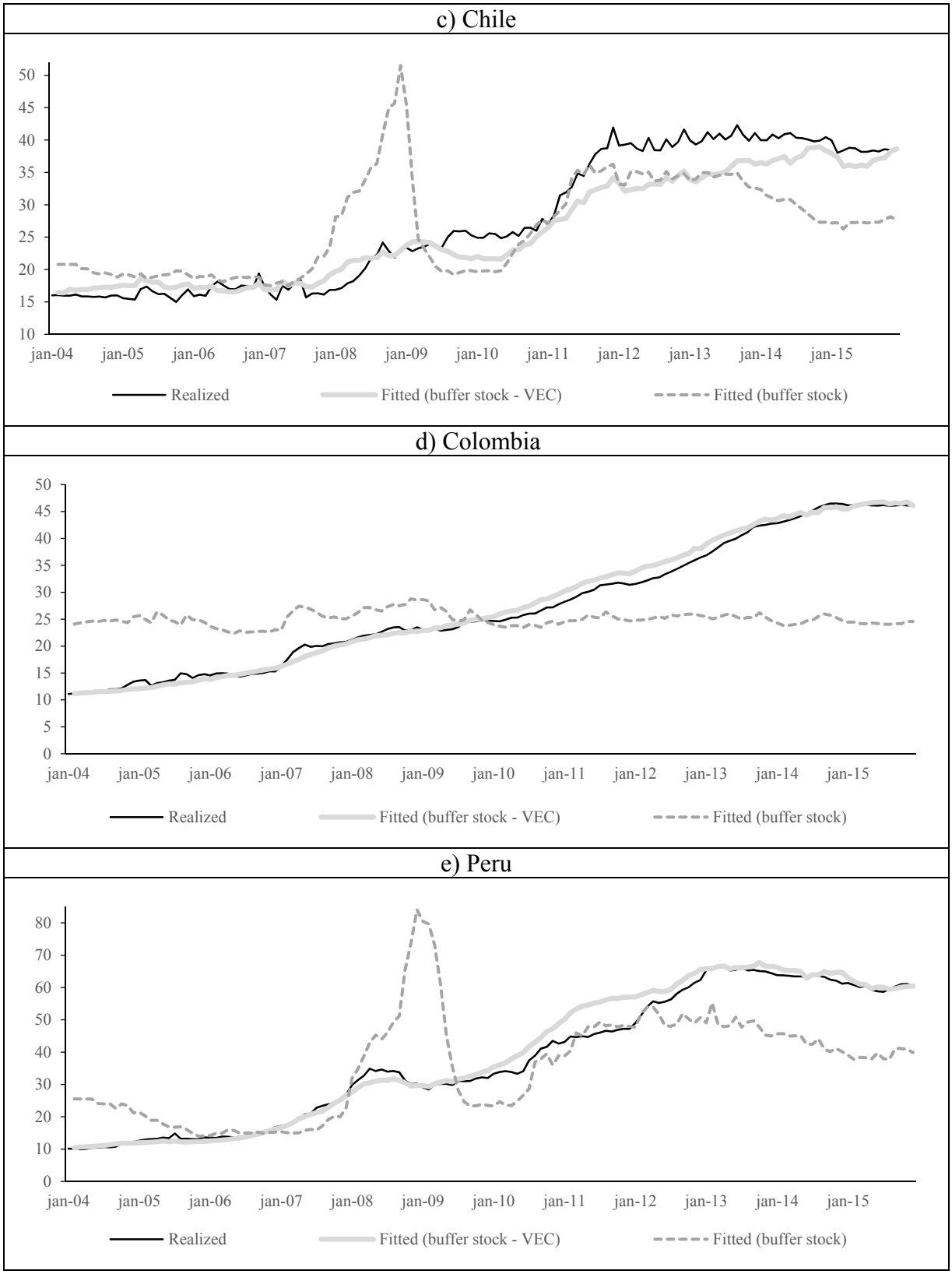
Figure 3.7 – Monthly realized and fitted total reserves (us$ billion) for the South American Economies[a]



Note: [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.

3.6 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 microfundamented 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, that 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 3.8 – Impulse and responses of the total reserves (us$ billion) for South American Economies[a]

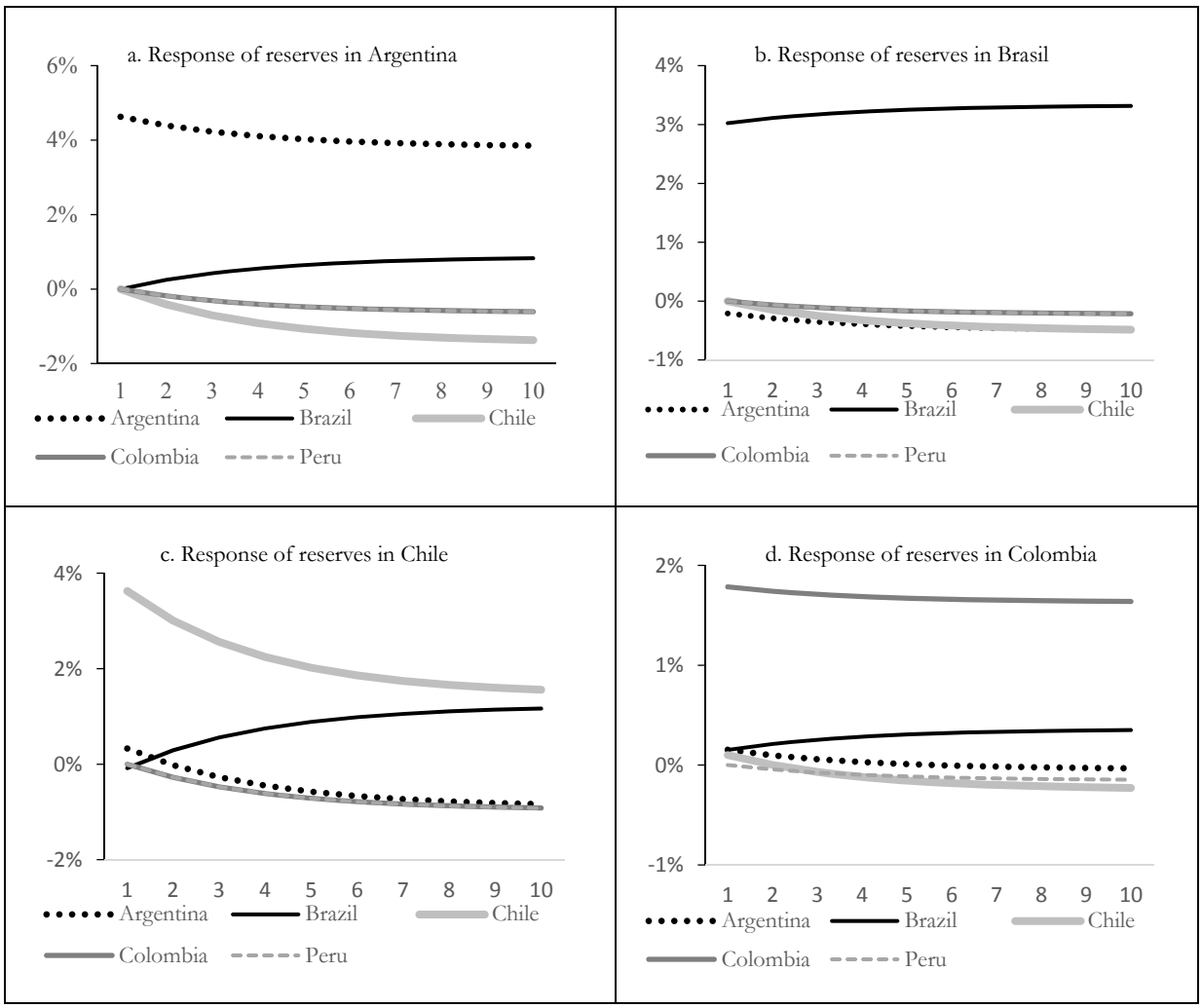


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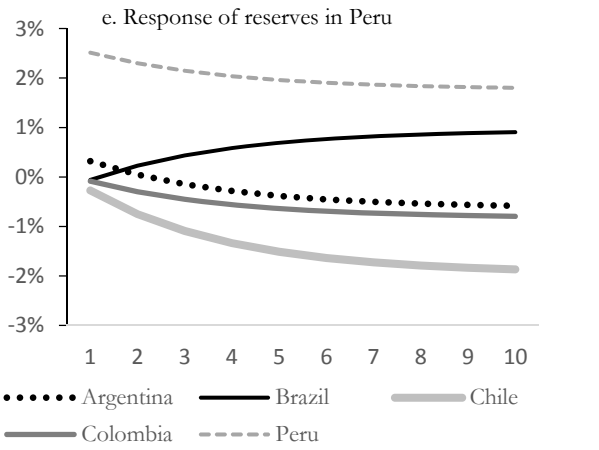
Figure 3.8 – Impulse and responses of the total reserves (us$ billion) for South American Economies[a]



Note: [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).

3.7 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.

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4. ON THE RELATIONSHIP BETWEEN HOME BIAS IN BRAZIL AND FINANCIAL INTEGRATION ON SOUTH

4.1 Introduction

Rationality and convexity of preferences of economic agents imply in an optimal smooth trajectory of consumption over time and in the face of possible uncertain states of nature. Under this assumption of modeling involving consumer theory and its savings and investment decisions, what can determine the strategy of an investor in terms of timing composition and rebalancing of his portfolio? Which characteristics of the probability distribution moments are relevant? Are there patterns or anomalies in the composition of portfolios of investors in terms of the allocation of domestic and foreign assets?

Specifically on the diversification of risk and its trade-off with the expected level of gain, there are insights from the classic work of Markowitz (1952), besides Evans and Archer (1968), Fisher and Lorie (1970) Elton and Gruber (1977) and Tole (1982). They conclude that portfolio risk is a decreasing function in the number of assets. Observing, for example, the Brazilian case Oliveira and Paula (2008) infer to the São Paulo Stock Exchange (BM&FBOVESPA) that 12 assets would be necessary to reach a minimum risk portfolio, reducing the diversifiable portfolio risk by 87%. However, investor does not necessarily need to prioritize a certain amount of assets or even limit himself to the assets traded on the stock exchanges of his own country. How a Brazilian investor should behave when faced, for example, with more than 50 exchanges around the world with more than 50,000 listed companies, with a value of share trading worldwide close to $ 114 trillion and a total number of trades of 23.7 billion in 2015, according to World Federation of Exchanges (WFE)? In comparison, in Brazil in 2015, there were 510 listed companies, with a trading value of R$ 132 million and a total number of trades of 230.2 million.

These questions are addressed in the literature for more than two decades, which describes the home bias puzzle as the phenomenon associated with the biased behavior of investors in allocating large portions of their investments in domestic assets, considering as a second best gains associated with international diversification. Some of the pioneers are French and Porteba (1991) and Tesar and Werner (1992), according to whom 94% of US investors concentrated their investments on domestic assets.

In this context, we add to this debate by analyzing diversified portfolios options available to a Brazilian investor, who faces a scenario free of arbitrage opportunities that

ignores market frictions, with the purpose of measuring gains with diversification from the position purchased in South American market indices vis-à-vis a domestic portfolio. Our empirical exercise is especially relevant due to evidences about financial contagion and integration reported in Matos, Bueno and Trompieri (2014).

The article is structured, so that literature is presented in section 2, while the empirical exercise is in section 3. Our final considerations are in section 4.

4.2 Literature review

Lewis (1995) is one of the first to describe home bias puzzle as a robust finding about the behavior of investors who allocates large portions of their investments in domestic assets vis-à-vis foreign assets. In this research field, French and Porteba (1991) argue that institutional constraints can explain home bias, increasing the uncertainty of the foreign investor, leading him to focus his investment on household assets. Baxter and Jerman (1997) argue that the main factors that could be associated with this puzzle would be the slow adjustment of the institutions responsible for regulating and encouraging the flow of capital, transaction costs and the cost of information.

Obstfeld and Rogoff (2000) and Lane and Ferretti (2007) are aligned with Lewis (1995) by pointing to transaction cost as the main barrier to international diversification. Grubel (1968), Levy and Sarnat (1970) and Solnik (1988) expanded related studies for the United States, United Kingdom, France, Germany, Italy, Belgium, Holland and Switzerland. They argue that a number of 20 domestic assets are sufficient in the composition of the minimum risk portfolio, and a considerable reduction of the total risk is still possible by adding foreign assets to form a portfolio of the same size.

Reinforcing the gain with international diversification, we also must mention Eun and Resnick (1988) and Hunter and Coggin (1990).

We add to this debate from the perspective of a Brazilian investor who can reach higher levels of gain with a continental diversification. Our choice is motivated, since Brazilian stock exchange is the largest stock market in South America and is the thirteenth largest in the world. Its main index, IBOVESPA, provides an average monthly real return of 0.7832% during the period from 1999 to 2013, one of the highest levels worldwide. Some of the few markets capable of hitting IBOVESPA are located in South America, although none of them can dominate it in terms of mean-variance. To finish, we also need to take into account

the effects of financial integration and contagion in the countries of South America reported in Mejía-Reyes (2000) and Matos, Bueno and Trompieri (2014).

We aim to measure if simple and optimization-based strategies, considering only major South American stock market indices, are able to beat IBOVESPA, during the period from January 1999 to December 2013. We then propose an empirical exercise taking into account that a Brazilian investor can transact other indexes besides the main index of the domestic market, IBOVESPA: MERVAL (Argentina), IPSA (Chile), IGBC (Colombia) and IGBVL (Peru). We assume that Brazilian investor can follow continental diversified nonleveraged portfolio composition strategies: i) equal-weighted, ii) value weighted, iii) maximizing the Sharpe Index; iv) minimizing the risk measured by the standard deviation and v) using weights obtained through principal components analysis.

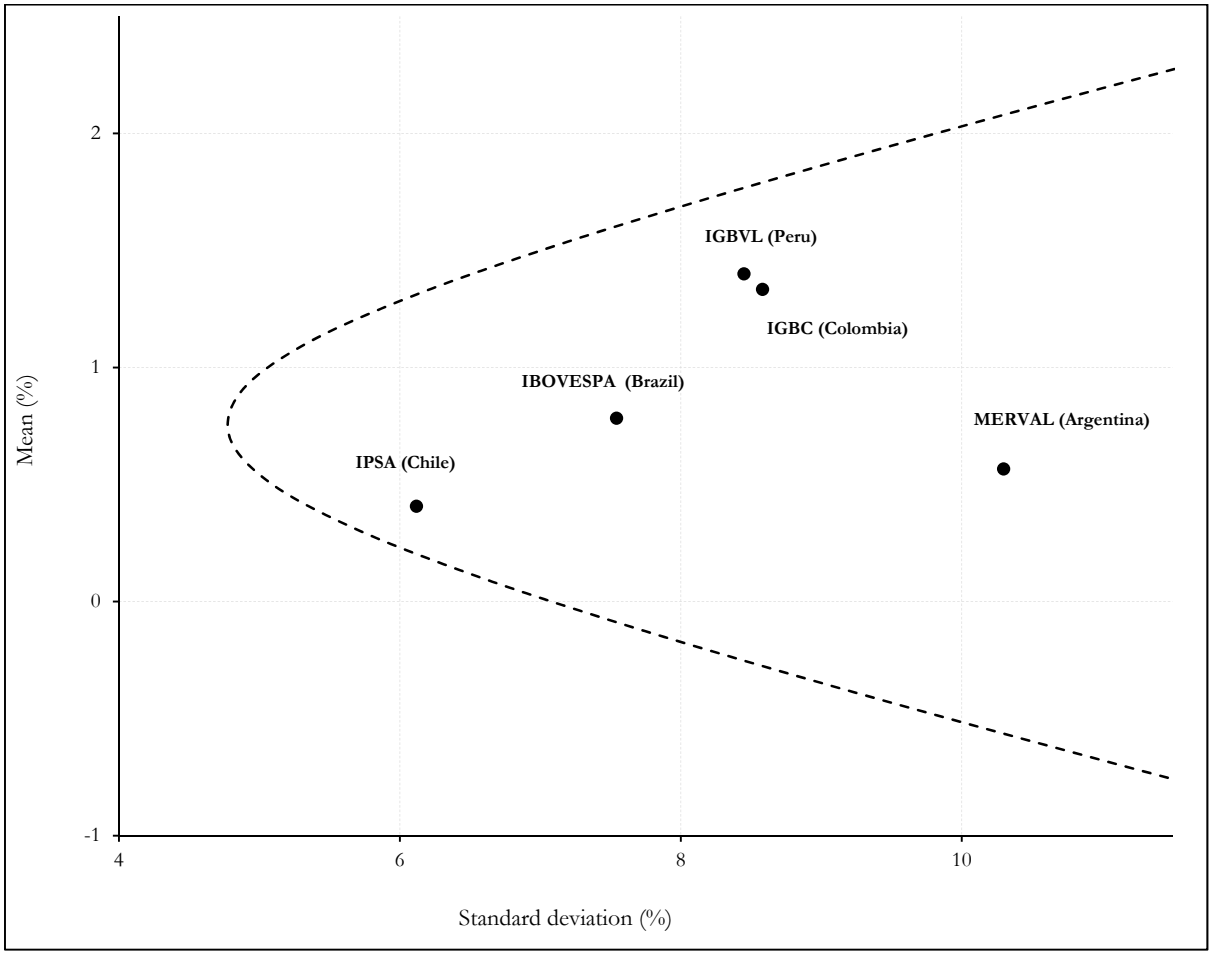
4.3 Empirical exercise

4.3.1 Database and summary statistics

All risk and performance metrics are calculated from monthly real net returns from the Brazilian investor's perspective. The end-of-day prices of a given index on the last business day of each month of the city where the respective exchange operates are used to calculate the nominal returns from the local investor's perspective. This information is obtained from Economática. From nominal monthly series of end-of-day spot exchange rates of the last business day available mainly in the databases of the respective central banks, the nominal return series are constructed from the perspective of the Brazilian investor. Finally, for the calculation of the real return in t of the financial asset $i, r_t^i, t = 1, \ldots, T$, the gross nominal returns at t are divided by the inflation indicator at t +1, Extended Consumer Price Index (IPCA).

Figure 1 shows the mean-variance frontier based on the real monthly returns from the perspective of the Brazilian investor on IBOVESPA, IGBC, MERVAL, IGBVL and IPSA indices, during the period from January 1999 to December 2013.

Figure 4.1 – Mean–variance frontier based on the major South American stock market indices[a]



Source: Economática and respective central banks.
Note: [a] Real monthly returns from the perspective of Brazilian investors on the major South American stock market indices from January 1999 to December 2013.

The descriptive statistics of real monthly returns from the perspective of Brazilian investors on South American indices are reported in Table 1.

Table 4.1 – South American stock market indices: summary statistics[a, b]

	IBOVESPA (Brazil)	IGBC (Colombia)	MERVAL (Argentina)	IGBVL (Peru)	IPSA (Chile)
Preliminary tests: stationarity					
Statistic	-11.2951	-13.5208	-13.1111	-13.9985	-15.2369
P-value	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Summary statistics: gain					
Mean	0.7832%	1.3338%	0.5666%	1.4004%	0.4076%
Minimum	-25.0661%	-25.0126%	-40.8273%	-33.3880%	-26.3520%
Maximum	23.2812%	30.2284%	33.1997%	36.7126%	20.1498%
Cummulative net return	143.8084%	464.7938%	3.5218%	547.4166%	47.6118%

Continue

Table 4.1 – South American stock market indices: summary statistics[a, b]

	IBOVESPA (Brazil)	IGBC (Colombia)	MERVAL (Argentina)	IGBVL (Peru)	IPSA (Chile)
Summary statistics: risk					
Standard deviation	7.5432%	8.5830%	10.2984%	8.4506%	6.1190%
Semivariance	5.3311%	5.9032%	7.3360%	5.7468%	4.4295%
Drawdown	59.8123%	53.1046%	82.7419%	67.6365%	42.0257%
Summary statistics: other moments					
Asymmetry	-0.0670	0.1936	-0.2083	0.2439	-0.3326
Semikurtosis	1.8728	1.6115	3.1801	2.2637	3.4983
Kurtosis	3.3940	3.9073	5.2157	5.2664	5.3952
Summary statistics: performance					
Sharpe index	0.1077	0.1588	0.0578	0.1691	0.0714
Sortino index	0.1524	0.2309	0.0812	0.2487	0.0986
Calmar index	0.0136	0.0257	0.0072	0.0211	0.0104

Source: Economática and respective central banks. Stationarity test proposed by Phillips and Perron (1988), whose null hypothesis is non-stationarity.
Note: [a] Real monthly returns from the perspective of Brazilian investors on the major South American stock market indices from January 1999 to December 2013.

Except for Argentina, all the others have composition given by a weighting of the market value of the companies in question in the calculation of the quotation of each index. The IBOVESPA is the oldest, having been created in 1968, while the IGBC had its methodology suggested only in 2001. Considering IBOVESPA as a reference, with a cumulative return of approximately 144%, MERVAL with a net accumulated gain almost zero during the analyzed period, and positively the Peruvian index, which gave Brazilians a nearly 550% gain. The returns of these indices have no common pattern of asymmetry, presenting high kurtosis, as usually reported in this literature. As usual, we show that all series of monthly real returns are stationary.

Observing average gain and standard deviation through Figure 1, we corroborate the figures presented in Table 1, in which, while the Peruvian and Colombian indices hit the IBOVESPA at a cost associated with a higher risk, on the other, MERVAL and IPSA Are less volatile than the Brazilian index, but have a lower average gain. That is, none of them can dominate IBOVESPA in terms of mean-variance. Summarizing these moments through the performance metrics in Table 1, only the Peruvian and Colombian indices present higher indices of Sharpe, Sortino and Calmar. The central question is whether there is any nonleverage strategy based only on long positions in the South American indices such that if one achieves a point in the quadrant that dominates the IBOVESPA in a medium-variance term, thus adding to the debate about the home Bias of the Brazilian investor.

4.3.2 Methodology: portfolio composition

Aiming to analyze the international diversification capacity associated to a basket of South American stock indices vis-à-vis the main Brazilian index, we suggest as the first strategy to the Brazilian investor the simplest possible, in which each stock exchange has the same weight in the composition of the portfolio, i.e., an equal-weighted portfolio. The second strategy, following indices composition methodology, is the value-weighted strategy, in which, based on market capitalization of listed domestic companies in current US$ 2015 extracted from World Bank database, we calculate each share.

In terms of strategies based on optimization, we suggest the following portfolios. First, Min Risk Strategy, whose weights result in a theoretically lower risk portfolio. We also propose Max Performance Strategy, in which weighting aims at constructing a portfolio theoretically with better risk-return performance. Finally, we also test Principal Component Analysis Strategy, in which weighting is associated with the extraction of the largest possible portion of the risk contained in the variance-covariance matrix of the index returns. Aiming to propose feasible portfolios for a common Brazilian investor, we avoid sold positions and leverage, by imposing non negative weights as a restriction on optimization problem. For this reason, in the specific case of the principal components, we need to use the second principal component, which explains 19% of the risk in the continent, because the first component, which explains 42% of the risk, has negative weights.

4.3.3 Results

The central point of this article is to analyze if there are opportunities for global index portfolios built in a simple way or via optimization capable of providing the Brazilian investor who invests only in the domestic market index itself, improvements in terms of diversification without compromising the levels of gain expected.

In order to summarize the information on the five portfolios suggested vis-à-vis the IBOVESPA, the evolution of the accumulated gains are reported in Figure 2. The descriptive statistics of these portfolios strategies composed of South American indices are described in Table 2.

Figure 4.2 – Cumulative gross monthly returns on the IBOVESPA and continental strategies

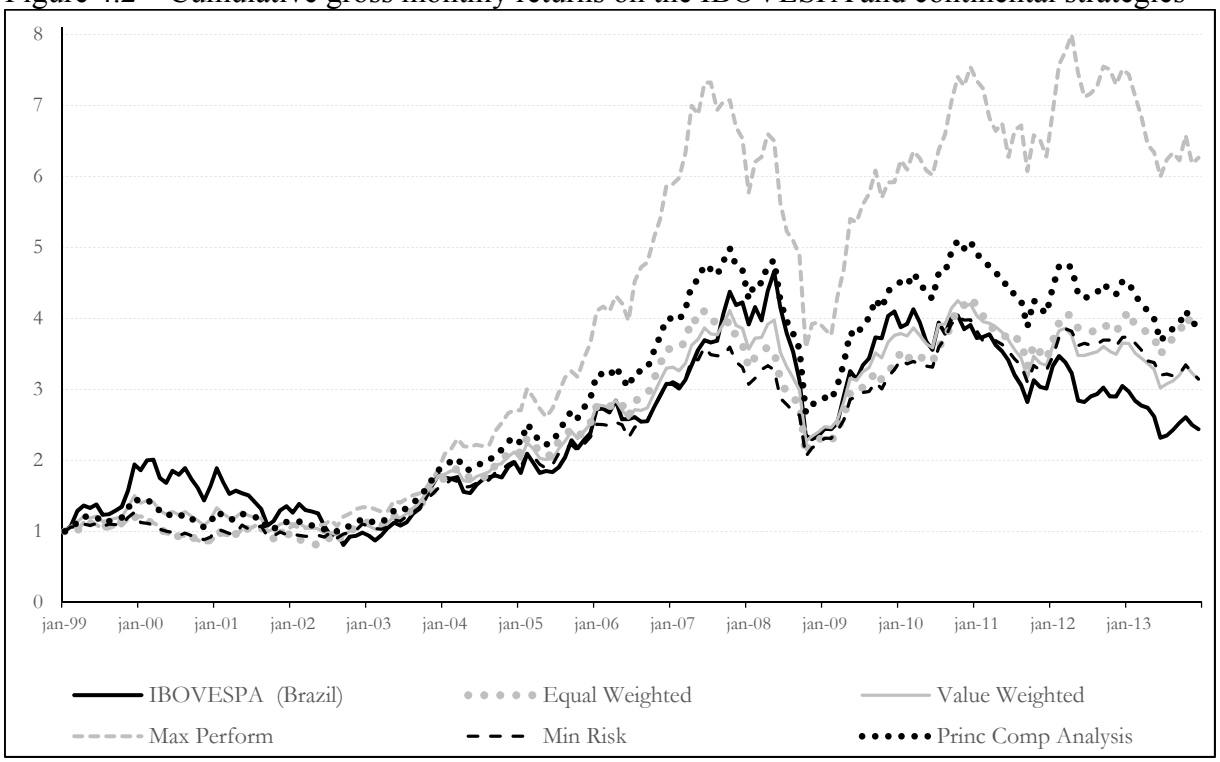


Table 4.2 – The IBOVESPA and continental strategies: summary statistics[a, b, c]

	IBOVESPA (Brazil)	Portfolio Strategy				
		Equal Weighted	Value Weighted	Max Performance	Min Risk	Princ Comp Analysis
Summary statistics: gain						
Mean	0.7832%	0.8983%	0.7815%	1.1971%	0.7576%	0.9036%
Minimum	-25.0661%	-26.2289%	-24.1018%	-26.7044%	-22.1160%	-25.2653%
Maximum	23.2812%	14.5218%	14.0669%	15.2167%	12.0676%	13.3915%
Cumulative net return	143.8084%	283.1771%	213.5795%	526.2101%	214.5748%	287.9007%
Summary statistics: risk						
Standard deviation	7.5432%	5.3536%	5.2801%	5.7574%	4.7723%	5.3210%
Semivariance	5.3311%	3.8469%	3.8491%	4.1284%	3.4994%	3.8879%
Drawdown	59.8123%	49.4214%	44.7719%	51.0408%	42.8881%	46.4583%
Summary statistics: other moments						
Asymmetry	-0.0670	-0.4991	-0.5060	-0.4261	-0.6123	-0.5716
Semikurtosis	1.8728	4.5803	3.8855	3.9378	4.3377	4.2839
Kurtosis	3.3940	5.9416	5.0513	5.2045	5.4691	5.3937
Summary statistics: performance						
Sharpe index	0.1077	0.1732	0.1535	0.2130	0.1648	0.1753
Sortino index	0.1524	0.2411	0.2106	0.2970	0.2248	0.2399
Calmar index	0.0136	0.0188	0.0181	0.0240	0.0183	0.0201

Note: [a] Real monthly returns from the perspective of Brazilian investors in the IBOVESPA and continental strategies from January 1999 to December 2013.

Short-sighted risk-averse or risk-neutral investors can infer from the evolution of cumulative gains on the success of all the strategies suggested in this article, since all of them beat the IBOVESPA at the end of the sample. One should emphasize the strategy that maximizes performance, whose accumulated gain takes off the IBOVESPA's accumulated earnings as of January 2004. In the last three years of the sample, all strategies have already hit the Brazilian index definitively. Cumulative gains reported in Table 2 show that while IBOVESPA provided an accumulated real net gain of approximately 144%, a Brazilian investor could reach in the same period a cumulative net real gain ranging from 214% (value-weighted strategy) to 526% (maximizing performance).

Still according to Table 2, all strategies with South American indices have lower risk levels than the IBOVESPA, based on different risk measures, as standard deviation, semivariance or drawdown. In contrast, these portfolios have a much higher level of semikurtosis in relation to IBOVESPA.

However, the correct and more complete way of analyzing how these continental portfolios are superior to the IBOVESPA and thus indicated to ordinary Brazilian investors, is considering joint gain and risk through performance indices. Based on the Sharpe index, while the Brazilian market index has a performance lower than 0.11, the portfolios have Sharpe higher than 0.15. Based on the Sortino index, IBOVESPA's performance is close to 0.15, half of Sortino's performance-maximizing strategy, whose value is almost 0.30. Finally, the Calmar index of the most representative market portfolio in Brazil is less than 0.014, while the Calmar values of the strategies range from 0.018 to 0.024.

4.4 Conclusion

Institutional constraints, the slow adjustment of institutions responsible for regulating and encouraging capital flows, transaction costs, the cost of information and the asymmetry of information are pointed out as factors capable of contextualizing the apparent irrational and anomalous position of investors in several countries characterized by the concentration in domestic assets.

Intuitive, reasonable, and defensible, it is possible that such aspects may be a hindrance to investors in both achieving satisfactory performances and discouraging them from trying, analyzing data and thinking of feasible strategies to reduce exposure to sources of Risk of a political or macroeconomic character that compose the systemic risk of the national financial market and that usually influence all the assets of the domestic market.

Obviously considering the issue of exchange rate risk, but not considering costs associated with market frictions, this article suggests that in times of financial crisis one should not resort to scarce fundamentals, but that in periods of recovery or economic boom, investing in assets of others countries. It is possible that simple and non-dynamic portfolio composition strategies composed only of indices of the markets of countries neighboring Brazil already translate into very satisfactory results in terms of expected gain and risk.

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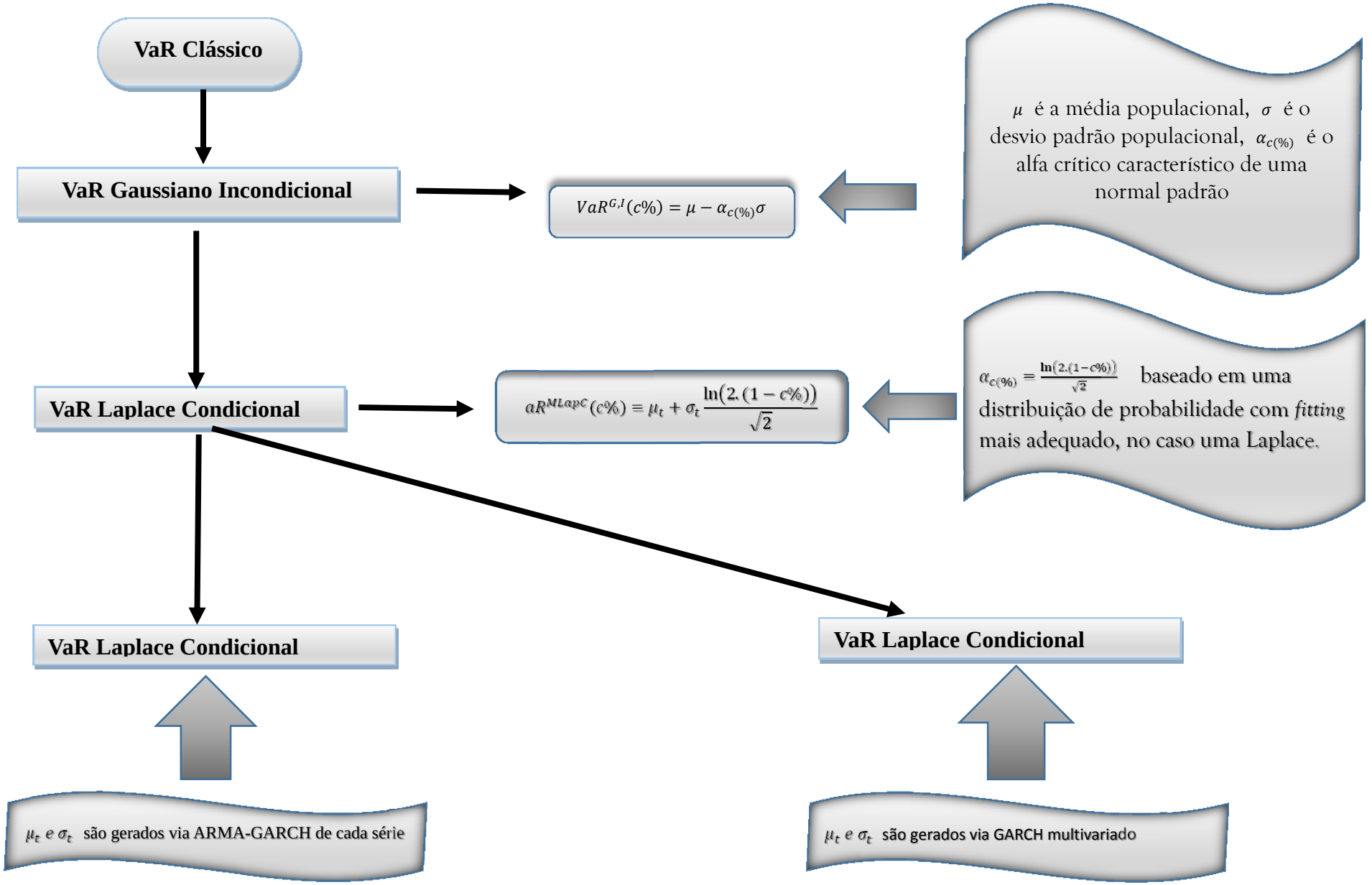
APPENDIX A - FLUXOGRAMA DA CONSTRUÇÃO DO VALUE-AT-RISK



- No primeiro ensaio foi utilizado a função quantílica da normal, ou seja, a inversa da função de distribuição acumulada associada a uma probabilidade unilateral, 5% ou 1%, a qual está relacionada ao nível de confiança segundo a relação dada por $1 - c(\%)$, logo após fez-se o uso de função de distribuição de probabilidade Laplace com o melhor *fitting,* uma sugestão para futuros artigos seria a utilização do métodos de Monte Carlos, no qual pode-se produzir uma aproximação da função de distribuição para as séries e a partir desta distribuição quaisquer parâmetros estatísticos, incluindo o resultado da medição, a incerteza de medição padrão associada e a respectiva probabilidade de abrangência intervalo de confiança, podem ser obtidos.
- Sugerimos também o emprego de métodos não paramétricos de inferência estatística para determinar a inversa da função de distribuição acumulada utilizada no VaR, que segundo Wasserman (2005) pode-se utilizar os métodos não paramétricos de bootstrap e o jackknife para calcular o desvio padrão e o intervalo de confiança.
- No artigo três por se tratar de um estudo de mercado financeiros da América do Sul, uma sugestão de uma nova linha de trabalho é a discursão sobre características institucionais que apresentam uma aderência muito particular para estes países, podendo assim ajudar a explicar padrões de desenvolvimento financeiro nesses países.
- Uma outra linha de pesquisa é a discursão de que os modelos de previsibilidade na américa latina, que são apresentados no ensaio um, quase sempre são prejudicados em decorrência de fatores culturais e institucionais que afetam a dinâmica mercados.