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Identifying Currency Bubbles using Markov-Switching Models:

The Latin American case

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Biographic Note

Dennis Ariza Virviescas was born and raised in Bogotá, Colombia. In 2012 he earned a BSc in Economics, with a Mention of Honor in the degree process, from the Externado University of Colombia. Following his undergraduate studies, Dennis worked for two years as an Investment Banking and Commercial Strategy Analyst at Asesorias e Inversiones Brokerage Firm in Bogotá. During this time, Dennis was responsible for analyzing clients' financial information for valuations, issuance of securities, mutual fund investment strategies, raise capital, lead consulting project, developing internal reports and commercial dashboards for decision making and increase profitability.

In 2014 Dennis decided to move to Porto to start his Master in Finance at the University of Porto. After the first year of the Master, Dennis spent nine months employed in an internship at Banco Carregosa in Porto. The internship focused on developing an automated trading model for the Forex Market through the use of technical analysis tools, money management strategies and risk control.

Abstract

This work examines whether the three regime model proposed by Panopoulou and Pantelidis (2015) based on Brooks and Katsaris' (2004) model can identify the presence of bubbles and explain the dynamics of the Colombian, Mexican and Brazilian exchange rates to the US Dollar for the period April, 1994 to December, 2015. We apply a two and three regime switching model that relates currency expected returns to a speculative factor (Bubble size) and one fundamental explanatory variable. We analyze several specifications considering five alternative explanatory variables (*Exports*, *Imports*, *International Rates*, *Interest Rates – proposed in the literature of Early Warning Indicators* – and *Oil Prices*).

We also test the predictive ability of our model to detect periods of extreme negative (Crash) or positive (Boom) movements in the aforementioned currency markets. Our results support the existence of speculative bubbles and overall are in line with the speculative behavior model. Additionally, in some cases, the regime models proposed seem to predict extreme market movements without jeopardizing the assumption of investor rationality.

Key-Words: Currency Crises, Regime-Switching, Speculative Behavior, Emerging Markets, Bubbles.

JEL Classification: F3, G1, C3

Resumo

A presente dissertação tem por objeto examinar se o modelo proposto por Panopoulou e Pantelidis (2015), baseado no modelo de Brooks e Katsaris (2004), permite identificar a presença de bolhas especulativas e explicar as dinâmicas das taxas de câmbio contra o dólar americano das moedas da Colômbia, México e Brasil no período temporal entre Abril de 1994 e Dezembro de 2015. Este estudo utiliza modelos *Markov-Switching* com dois e três regimes explicando os retornos cambiais por um fator de especulação (B*ubble size)*, juntamente com outra variável explicativa de caráter fundamental. Foram consideradas diferentes especificações usando variáveis explicativas propostas na literatura de Early Warning Indicators (*Exportações, Importações, Reservas Internacionais* e *as Taxas de Juro)* e o *Preço do Petróleo*.

No presente estudo testa-se ainda a capacidade de previsão do modelo para detetar períodos de fenómenos extremos no mercado cambial quer negativos (*Crash*) ou quer positivos (*Boom*). Os resultados obtidos suportam a existência de bolhas de origem especulativa nos mercados envolvidos e vão de encontro ao modelo de comportamento especulativo. Adicionalmente, em alguns casos, os modelos propostos preveem os movimentos extremos dos mercados, sem comprometer o pressuposto de racionalidade dos investidores.

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1. Introduction

Over the last years stock markets worldwide have been experiencing high level of uncertainty and volatility due to the recent financial crisis. Globalization has increasing the interconnectedness of different markets allowing businesses and investors to move overseas. However, this new environment of reduced trade facilities around the world exposes investors, companies and governments to foreign financial disruptions. Since the nineties, the financial world has experienced several bank and currency crises that have puzzled policy makers, economist, and market participants: Europe in 1992 – 1993 (the turmoil in the European Exchange Rate Mechanism), Mexico in 1994 – 1995, Turkey in 1994 and 2000 – 2001, East and Southeast Asia in 1997, Russia in 1998, and Argentina, Uruguay and Brazil starting in late 2001 (Ivashina, Scharftein, 2008).

The recent financial crisis that consensually had its genesis in the middle of 2007 with the subprime mortgage crisis in the US, followed by the collapse of Lehman Brothers (LM) bank in 2008 has brought instability to financial markets around the world. Nowadays, the Latin American currencies could still be suffering the consequences of the impact of this crisis. During 2015 the currencies of the principal economies in Latin America suffered a devaluation of around 22% on average against the American Dollar (USD); the Colombian Peso (COP) has been the most hit with a devaluation of 36% against the USD, followed by the Brazilian Real (BRL): 35%, the Mexican Peso (MXN): 19%, the Uruguayan Peso (UYU): 17%, the Peruvian Nuevo Sol (PEN): 12%, and finally the Argentinian Peso (ARS): 10%. These variations changed the funding of these economies, the international trade and the transactions in foreign currencies.

The huge impact that currency crises have on the economy in general has motivated researchers to develop models that try to understand and forecast the nominal exchange rate behavior. Engel and Hamilton (1990) presented a seminal contribution modeling exchange rates through the use of a two Markov-Switching process. Their results showed that this kind of models outperform the Random Walk (RW) models either in-sample and out-of sample. This model is one of the most important and relevant in econometrics as it allows for changes in mean and variance, detection of outliers in time series and accommodates for multiple breaks.

Following the contribution done by Engel and Hamilton, Markov-Switching models of exchange rates have been subsequently used in the literature. Engel (1994) tested the Regime-Switching (RS) for 18 different exchange rates and found that the model fits well in-sample for many exchange rates, but it is not able to generate a reliable forecast results. Kirikos (1998) examined the forecasting performance of the Markov-Switching process relative to that of random walk for three different currencies. He found that the Random Walk model gives consistently better in-sample forecasts but the Markov-Switching model predicts better for short out-of sample horizons when the post-sample period is narrowed towards the end of the full sample. Frommel, MacDonald, and Menkhoff (2005) provided evidence of a nonlinear relationship between exchange rates and fundamentals and found that the key determinant of regimes is the interest rate differential. Brunetti, Mariano, Scotti, and Tan (2008) used a Markov-Switching approach including a GARCH specification in which they account for the presence of two regimes: ordinary and turbulent. Their results show that real effective exchange rates and M2 ratios play and important role in understanding exchange rate turbulence, however they did not show any forecasting results. Klaassen (2005) follow a similar approach with a GARCH error structure, but do not find any positive forecasting results.

Van Norden (1996) using data for the Japanese yen, the German mark and the Canadian dollar exchange rates from 1977 to 1991 employs a two-state model that relates the future exchange rate to the deviation from fundamentals (bubble), where both the future return and the probability of appreciation or depreciations are functions of the bubble. His results show that in some cases there is no evidence of the existence of the bubble either because the bubble does not exist or because the test was not powerful enough to detect it. Van Norden and Vigfusson (1997) through the use of simulation methods try to examine the size and the power of Regime-Switching models for detecting bubbles. Their results show that their model is powerful enough to detect bubbles; however, they considered that the model is conservative since even with hundreds of observations the tests shows size distortions. Panopoulou and Pantelidis (2015) based their research on the contribution made by van Norden (1996) and provide evidence of periodically collapsing bubbles in the British pound to US Dollar exchange rate in the post-1973 period. They use two-state and three-state models that relate the future return of the exchange rate to the bubble size[1] and to an additional explanatory variable. They consider six explanatory variables based on the Early Warning Indicators literature, and four different bubble measures. Their results show that the Regime-Switching models are more accurate than the Random Walk models for exchange rate forecast and the three-regime model outperforms the two-regime model.

Given this background, the purpose of this work is to analyze if there is evidence of periodically collapsing bubbles in the foreign exchange markets, measure their duration and magnitude, and finally test the predicted ability of the model we propose. The analysis focus on three of the main Latin American exchange rates: the Colombian Peso, the Mexican Peso, and the Brazilian Real to US Dollar. The methodology proposed to follow is the one used by Panopoulou and Pantelidis (2015) using a two- and three-state Regime-Switching models that relate the expected exchange rate to some core explanatory variables proposed by the Early Warning System (EWS) theory as early warning indicators of a currency crisis, and to the size of the bubble. This work uses three bubble measures and four indicators provided by the EWS: Exports, Imports, International Reserves and Long Term Interest Rate. Additionally to these variables the model includes the West Texas Intermediate (WTI) oil price as we believe is an important variable that can explain the behavior of these currencies.

Chapter 2 contains a review of the relevant literature. Chapter 3 includes a description of data and of the tests proposed. Chapter 4 contains the empirical application with presentation and discussion of the main results for all the methodologies followed. Lastly, Chapter 5 includes the main conclusions of the work.

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[1] For the purposes of this work the term "bubble" is related with the deviation of the exchange rate from its fundamental value.

2. Literature Review

The literature on identifying bubbles in exchange rate markets is wide. Some of the papers written in this field report contradicting results regarding the existence of bubbles, claiming that there is not significance evidence to acknowledge the presence of a bubble or even that the deviation of an asset price from its fundamentals was caused by a bubble. Other researchers argue that the evidence regarding the existence of bubbles is real.

Research on speculative bubbles is wide, Flood and Garber (1980), Flood, Garber and Scott (1984), Cutler, Poterba, and Summers (1991), van Norden and Schaller (1999) developed tests trying to find the presence of a particular bubble specification on stock market returns. Authors as Blanchard (1979), Blanchard and Watson (1982), Diba and Grossman (1988), and West (1988) extended the research on the presence of bubbles in financial markets and proposed the study of periodically collapsing speculative bubbles. In the beginning of the bubble prices diverge from their fundamental value, and as time passes such divergence increases, and thus prices increase without a bound until achieve certain point when market participants believe that such price is unsustainable and therefore a sharp reversal is presented. The Blanchard and Watson (1982) model assumes that the collapsing state is induced by a positive bubble burst which does not regenerate. More recently other models were proposed, where both positive and negative bubbles are permitted and the probability of collapsing depends on the size of the bubble[2].

Blanchard and Watson (1982) investigate the nature and the presence of bubbles in financial markets, examining the probability of asset price deviations from its fundamentals when the behavior and expectations of market participants are rational. Their results show lack of power to explain whether the bubble appears or not. Evans (1986) tests the existence of a speculative bubble in the Sterling-Dollar exchange rate for the period 1981-1984. He states that the loss of value that the US Dollar presented to the Sterling Pound in that period of time cannot be explained by differential interest rates or inflation rates

[2] van Norden and Schaller (1993), van Norden (1996) and Schaller and van Norden (1999).

between the two countries. He concludes that the bubble found in the US Dollar to the Sterling Pound during 1981-1984 can be explained by non-rational expectations. Meese (1986) argues that the variations in the value of the US Dollar to the German Mark and to the Sterling Pound in the eighties were due to the presence of speculative bubbles.

Frankel and Froot (1990) test the rationality of foreign exchange rates and try to explain the deviations presented by the US Dollar on the basis of macroeconomic fundamentals, namely the "dramatic" period from January 1984 to February 1985, when the Dollar suffered an appreciation of 20%. They suggest two different approaches to this event; the first one is related with the shift in "tastes and technologies", and the second one makes reference to the existence of speculative bubbles. Wu (1995) argue that the evidence of speculative bubbles in Dollar exchange rates in the post Bretton-Woods period is weak, in contrast with the previous researches on this field. The tests were run for the US Dollar to the British Pound, the US Dollar to Japanese Yen and to the US Dollar to the Deutsche Mark exchange rates from January 1974 to December 1988. Wu divided his analysis in two sections; the first one uses the whole sample data where no significant component of a bubble was found, and the second one is a sub sample period between January 1981 and February 1985. In this latter period the US Dollar suffered a "dramatic" appreciation and the author states that if any bubble exists this would be the most likely period to find it. However, the results are in line with the first section and one once again no component of a bubble was found.

One of the main contributions to the development of Regime-Switching (RS) behavior models is from by van Norden (1996) using data from 1977 to 1991 for the Japanese Yen, the German Mark, and the Canadian Dollar to US Dollar exchange rates develops a new test for speculative bubbles following the assumption that bubbles displays a particular kind of Regime- Switching behavior. Van Norden uses a two RS model with two different states; survival and collapse. The results for the three aforementioned exchange rates appear to be sensitive to changes in the definition of the fundamental exchange rate or the measurement of exchange rates innovations. As it was already stated in the Introduction the results show that in some cases there is no evidence of a bubble either because the bubble does not exist or because the tests are not powerful enough to detect it. This paper is the starting point for our work. This is also the case in Panopoulou and Pantelidis (2015) that use van Norden approach as a benchmark for their analysis.

Ferreira (2006) investigates the hypothesis of a periodically collapsing bubble underlying the movement of the exchange rate for a set of four industrialized market economy countries; Canada, France, Germany and the United Kingdom for a period between January 1973 and April 1998. He concludes that the use of Markov-Switching regime models does not find robust evidence of a bubble driving the exchange rate away from fundamentals. More recently Bettendorf and Chen (2013) and Jiang *et al*. (2015), test for the existence of bubbles in the Sterling-US Dollar and Chinese RMB-US Dollar exchange rates, respectively. Their findings suggest doubts on bubbles presence as the explosive behavior in the nominal exchange rate coincides with explosive behavior in the relative prices of traded goods, so such explosiveness in the exchange rate is likely driven by either exchange rate fundamentals or the formation of rational bubbles.

3. Methodology and Data

3.1. Methodology

In this section we present the methodology used in this dissertation. In line with the methodology proposed by Panopoulou and Pantelidis (2015) this work starts analyzing the fundamental theory of exchange rate determination discussing the alternative solutions for the model proposed by van Norden (1996), in which he defines a bubble specification in order to define exchange rate expectations that satisfy the general model of exchange rate determination.

$$S_t = f(X_t) + a * E_t(S_{t+1}), \quad (1)$$

where S_t is the logarithm of the spot exchange rate, E_t is an operator of expectations that is conditional on information at time t, X_t is a vector of variables, and a is bounded between 0 and 1. Van Norden shows the general specification for this equation where the expected exchange rate depends on the current and the expected behavior of other macroeconomic variables. However, he proposes an alternative solution linking speculative bubbles to a two Regime-Switching model. His findings suggest that the possibility of appreciation or depreciation of a currency is related with the bubble size.

Following the approach proposed by Panopoulou and Pantelidis (2015), this work uses two different approaches to the work developed by van Norden (1996) while the van Norden's models will serve as a benchmark. The first one is a two-regime model that includes one explanatory variable taken from the EWS's theory that enters in both the conditional mean and the probability equations. The second model follows Brooks and Katsaris (2005), and Yuan (2011) along with the observation that exchange rates exhibit range-bound behavior for a sustained period of time. The basic model, the two-regime model, is extended to a three-regime one by allowing for a third trendless regime in the dynamics of the exchange rate.

The three proposed regimes are:

- *Survive*: in this state the asset price grows with explosive expectations;
- *Collapse*: in this state the asset price does not have any explosive expectations, therefore it reverses to fundamentals values;
- *Dormant*: in this state the bubble grows at the require rate of return without explosive expectations.

The fundamental variables used in this work; Imports, Exports; International Reserves, and Long Term Interest Rates, are variables that have shown a high popularity within the EWS theory[3]. Additionally to these variables we include the Western Texas Intermediate (WTI) oil price under the hypothesis that the volatility of this commodity can have an impact, either negative or positive, on the studied currencies. All the transactions done by sales and purchases oil/petroleum go through the currency market affecting directly the Current Account of the Balance of Trade. Therefore, in petroleum, exporter countries, an increase in the revenues due to a boom or simply due to a good performance of petroleum exports, could lead to a revaluation of the local currency due to the increase in the supply of the foreign currency; the effects will be the reverse if there is a decrease in trade revenues.

The steps to follow in order to develop our work are the following:

a. *Identify speculative bubbles*: we applied the Generalized Standard Augmented Dickey-Fuller (GSADF) test in order to identify the existence of speculative bubbles in the three markets studied.
b. *Measure the bubbles*: we will use three different approaches in order to identify how big these bubbles are.
c. *Apply the Regime-Switching Models*: in this work we use three different models; the first two (Model 1 and Model 2) are a two-regime models and the last one (Model 3) is a three-regime model.

[3] See for example: Berg, A. and C. Pattillo (1999), Inoue, A. and B. Rossi (2008), Kaminsky, G.L. (1999), Kaminsky, G., S. Lizondo, C.M. Reinhart (1998), Mariano, R.S., A.G. Abiad, B. Gultekin, T. Shabbir and A. Tan (2002), Osband, K. and C. van Rijckeghem (2000).

d. *Choose the best model*: the classification of the best model is done through the use of the likelihood ratio (LR) test. Additionally we use the Regime Classification Measure (RCM) to evaluate the ability of our Regime-Switching models to fit the data.

e. *Predict large swings in exchange rates:* the last part of this work evaluates the predictability power of the models in order to identify large movements, either negatives or positives, in the currency markets.

3.2. Data

The markets selected in this work are: Colombia, Brazil, and Mexico. These emerging market economies are the most representative in the region and their currencies suffered the highest devaluation in 2015. The information related with all the statistic series of the Colombian Peso, the Mexican Peso, the Brazilian Real and the WTI were obtained from Thomson Reuters' platform, while the information related with economic were obtained from certified national entities for each one of the countries analyzed. For Colombia the main source was the statistical information provided by Bank of the Republic, for Mexico were the Bank of Mexico and the Instituto Nacional de Estadística, Geografía e Informática, and for Brazil was the Brazilian Institute of Statistics and Geography (IBGE).

The time period analyzed goes from April 1st, 1995 to December 31st, 2015. However, due to a limitation on the historical information for some economic variables for Mexico, the period analyzed for this country is January 1st, 1995 to December 31st, 2015.

Price levels are proxy by the Consumer Price Index and inflation rates are calculated from y-o-y growth rate of prices. We use the Industrial Production Index and the M3 monetary aggregate for the income and money supply levels. However, for the United States we use the M2 as a proxy for the M3 due to on March 23, 2006, the Board of Governors of the

Federal Reserve System ceased the publication of the M3 monetary aggregate[4]. Exports, Imports, and International Reserves are expressed in US dollars, while the WTI is the annual growth rate expressed in percentage.

3.3. Model Specification

3.3.1. Identifying speculative bubbles

All the speculative bubbles have the same genesis; the inflation of any asset price. Normally they appear in some specific markets, as the stock market, and the real estate market, it isn't always that way, though. According to the Minsky model a speculative bubble follows a specific process with some specific stages. According to Kindleberger (1978) the process starts with a displacement of the demand due to an external variable (a war, the release of a new product, financial operations, etc.), this overheats the market and produces speculation over this asset. When the price begins to raise the number of buyers decrease and the bullish momentum losses strength, and the holders start to be more careful and sensitive about news, some of them (the most fear ones) start to settle their positions generating a selling pressure that makes the asset price to decrease and enter into the slowdown part of the curve. In this stage the market exhibits a high sensitivity to negative news that can cause panic and revulsion for that particular asset accelerating the asset price decrease.

Due to the well-known consequences of the housing bubble in the United States research on how to identify bubbles has gained a lot of popularity among academics and a wide range of research have been done on this topic. The asset pricing theory suggests that if a bubble exists, prices should inherit its explosiveness property. Diba and Grossman (1988) suggested the use of right-tailed unit root test in order to detect explosiveness processes. Later, Evans (1991) shows through the use of simulating methods that the approach

[4] www.stlouisfed.org

proposed by Diba and Grossman fails in detecting periodically collapsing bubbles. Phillips, Wu, and Yu (2011) (PWY hereafter), motivated by the previous works, proposed a new approach that conduct a series of right-tailed unit root tests based on an expanding window with a fixed start date. In the presence of a single bubble this model showed stable results, however, under the presence of multiple collapsing bubbles the results were not consistent. Phillips, Shi, and Yu (2011) (PSY hereafter) proposed a generalized model for the PWY model with a variable starting point. Both approaches use a variation of the Augmented Dickey-Fuller (ADF hereafter) unit root test wherein the null hypothesis is of a unit root and the alternative is of a mildly explosive process. PSY (2013) through a Monte Carlo study showed that PSY model perform much better than PWY model in the presence of multiple bubbles.

For the purposes of this work we will use the PSY approach that is the one that has shown better results in the presence of multiple bubbles.

Given a sample of T observations the PSY approach uses the following statistic[5]:

$$GSADF(r_0) = \sup\left\{ADF_{r_1}^{r_2}\right\}, \quad r_2 \in [r_0, 1], r_1 \in [0, r_2 - r_0],$$

where $r_0 = [Tr_0]$ is the size of the smallest window, and r_1 and r_2 are the starting and endings points of the sample over the statistic is performed.[6]

These models have been implemented actively in the research field, Phillips and Yu (2011) studied the presence of bubbles in the American housing market through the use of the *SADF*[7] model. Bettendorf and Chen (2013) as well as Panopoulou and Pantelidis (2015) used the *SADF* and *GSADF* tests for finding evidence for explosive behavior in the Sterling-Dollar exchange rate, the formers concluded that the presence of collapsing

[5] Generalized Standard Augmented Dickey-Fuller (GSADF)
[6] For a detailed description on how to implement this statistic on Eviews check Caspi (2013).
[7] Standard Augmented Dickey-Fuller, $SADF = sup_{r_2 \in [r_0, 1]}\left\{ADF_0^{r_2}\right\}$

bubbles in this market are probably driven by fundamentals and not by a rational bubble. Yiu, Yu, and Jin (2013) found evidence for multiple bubbles in the Hong Kong residential market applying the *GSADF* test.

3.3.2. Bubbles Measures

Once the bubble has been identified through the GSADF test, it is important to measure how big or how important it is. First of all it is important to define what will be understood in this work as a speculative bubble; following the most general definition provided by economics and quoted in the book "Manias, Panics, and Crashes" written by Kindleberger (2000) a bubble is a systematic deviation of asset prices from its fundamental value. As referred by Panopoulou and Pantelidis (2015) any model of exchange rate determination can be used to estimate a speculative bubble measure, which for the purposes of this work will be understood as the deviation of the logarithm of the nominal spot rate from its fundamental value.

$$b_t = e_t - f_t, \tag{2}$$

Equation (2) will be used it to measure the size of the bubble,

where e_t represents the nominal spot exchange rate, and f_t represents the fundamental value of such exchange rate. Once the bubble has been identified the next step is to measure it.

Following the methodology proposed by Panopoulou and Pantelidis (2015) we use three different measures of exchange rate deviations from fundamentals.

I. The first measure (Bubble 1) is related with the Purchasing Power Parity (PPP) that is often tested in the context of a cointegrating relationship between the nominal exchange rates and the relative prices expressed in logarithm terms.

$$e_t = \delta_0^A + \delta_1^A \times f_t + b_t^A, \tag{3}$$

where, A means that is the first measure used, and the first deviation from fundamental prices b_t^A is given by the cointegrating residual from equation (3).

The fundamental price is defined as

$$f_t = (P_t - P_t^*),$$

where, P_t is the domestic price level, P_t^* is the foreign price level, and f_t is measured in units of domestic currency per unit of the foreign currency.

II. The second measure (Bubble 2) used is based on a two variant of the flexible monetary model that include the domestic and the foreign money supply, the domestic and foreign income, and the domestic and foreign interest rate. Based on this, and assuming that the PPP holds, we can express the fundamental price as:

$$f_t = (m_t - m_t^*) - \alpha_1(y_t - y_t^*) + \alpha_2(i_t - i_t^*), \tag{4}$$

The nominal spot exchange rate is calculated through the following equation:

$$e_t = \delta_0^B + \delta_1^B(m_t - m_t^*) - \delta_2^B(y_t - y_t^*) + \delta_3^B(i_t - i_t^*) + b_t^B, \tag{5}$$

where, m_t (m_t^*) is the log of the domestic (foreign) money supply, y_t (y_t^*) is the log of the domestic (foreign) income, i_t (i_t^*) is the log of the domestic (foreign) nominal interest rate.

III. The last measure (Bubble 3) enriches the second one including the expectations of domestic (π_t) and foreign (π_t^*) inflation rates. Therefore, we can express the fundamental price as:

$$f_t = \alpha_1(m_t - m_t^*) - \alpha_2(y_t - y_t^*) + \alpha_3(i_t - i_t^*) + \alpha_4(\pi_t - \pi_t^*), \quad (6)$$

The nominal spot exchange rate is calculated through the following equation:

$$e_t = \delta_0^C + \delta_1^C(m_t - m_t^*) - \delta_2^C(y_t - y_t^*) + \delta_3^C(i_t - i_t^*) + \delta_4^C(\pi_t - \pi_t^*) + b_t^C, \quad (7)$$

3.3.3. Regime-Switching Models

The Regime-Switching models developed by Hamilton (1989) are the most appropriated ones to the empirical analysis of currency crises as they allow identifying multiple states, and explaining how the transition to one state to another occurs. In the currency market field these models allow modeling the likelihood of devaluation/appreciation or change from one regime to another one.

Panopoulou and Pantelidis (2015) analyze three different models, starting with the van Norden and Schaller' (Model 1) used as a benchmark for their analysis. The second model used is an extension of Model 1. Based on the EWS theory, the authors propose that the probability of collapsing is modeled as a function of both the size of the bubble and one of the indicators proposed by EWS models[8]. The third extension proposed follows the approach done by Brooks and Katsaris (2005). They propose and alternative third state "Dormant" which allows the bubble to growth at a steady rate without explosive

[8] For a detailed description of this models see Panopoulou and Pantelidis (2015)

expectations. Evans (1991) analyzed this state and affirmed that when the bubble crosses certain threshold value, such bubble erupts to an explosive regime in which the bubble can either continuing growing “Survive” or “Collapses”. Contrary to the approach done by Evans (1991) that chooses an arbitrary threshold value, Brooks and Katsaris (2005) model the probability of being in the “Dormant” state.

In order to identify the presence and size of a speculative bubble in the foreign exchange markets analyzed in this work we begin our analysis following the approach proposed by van Norden and Shaller (Model 1). Therefore the foreign exchange can be in two different regimes; *Survival (S)* or *Collapse (C).* In the Survival regime the bubble appears and grows, while in the second one the bubble collapses. The return of the exchange rate R_t is a function of one of the bubble measures (b_t) defined in Section 3.3.2., with different means, slopes and variances.

The equations for Model 1 are the following:

$$R_{c,t+1} = \beta_{c0} + \beta_{c1} b_t + \varepsilon_{c,t+1},$$

where, $\varepsilon_{c,t+1} \sim N(0, \sigma_c^2)$

$$R_{s,t+1} = \beta_{s0} + \beta_{s1} b_t + \varepsilon_{s,t+1}, \qquad (8)$$

where, $\varepsilon_{s,t+1} \sim N(0, \sigma_s^2)$

$$\Pr(State_{t+1} = C) = q_t = \Phi(\beta_{q0} + \beta_{q1} b_t),$$

Where q_t is the probability of collapse and is bounded between 0 and 1, R_t is the gross return of exchange rate, and Φ is the cumulative density function of the standard normal distribution.

The second model proposed is a generalization of Model 1 and based on the EWS theory we include five different early warning indicators that can act as a signal of changing market expectations about the evolution of the speculative bubble. The five variables used are: Imports, Exports, International Reserves, Long Term Interest Rates, and WTI. The first three variables capture the external sector of each country. We include the WTI as an important variable to analyze as this variable was one of the most debated variables when the current devaluation of the Latin American currencies began.

The second model calculates the probability of collapse as a function of both the bubble size and one of the five indicators listed before (z_t).

Model 2:

$$R_{c,t+1} = \beta_{c0} + \beta_{c1}b_t + \beta_{c2}z_t + \varepsilon_{c,t+1},$$

where, $\varepsilon_{c,t+1} \sim N(0, \sigma_c^2)$

$$R_{s,t+1} = \beta_{s0} + \beta_{s1}b_t + \varepsilon_{s,t+1}, \qquad (9)$$

where, $\varepsilon_{s,t+1} \sim N(0, \sigma_s^2)$

$$\Pr(State_{t+1} = C) = q_t = \Phi\big(\beta_{q0} + \beta_{q1}b_t + \beta_{q2}z_t\big),$$

The final approach proposed follows the research done by Brooks and Katsaris (2005). This model includes a third regime; *Dormant*, in this regime the market participants believe that the bubble will continue to grow at a steady rate and without explosive expectations. The assumption behind this model is that Model 1 and Model 2 focus only on identify explosiveness behavior periods in the currency market. However, according to these authors there are periods when the currency prices display constant growth or simple mimic the behavior of fundamentals.

The probability of being in the *Dormant* regime is represented by η_t as a function of the bubble size and the absolute value of the average six-month actual returns minus the absolute value of the average three-month returns of the estimated fundamental values (denoted as *spt*) implied by the three models presented in the previous section.

The equations for this model are the following:

$$R_{d,t+1} = \beta_{d0} + \varepsilon_{d,t+1},$$

where, $\varepsilon_{d,t+1} \sim N(0, \sigma_d^2)$

$$R_{c,t+1} = \beta_{c0} + \beta_{c1} b_t + \beta_{c2} z_t + \varepsilon_{c,t+1},$$

where, $\varepsilon_{c,t+1} \sim N(0, \sigma_c^2)$

$$R_{s,t+1} = \beta_{s0} + \beta_{s1} b_t + \varepsilon_{s,t+1}, \quad (10)$$

where, $\varepsilon_{s,t+1} \sim N(0, \sigma_s^2)$

$$\Pr(State_{t+1} = D) = \eta_t = \Phi\left(\beta_{\eta 0} + \beta_{\eta 1} b_t + \beta_{\eta 2} sp_t\right),$$

$$\Pr(State_{t+1} = C) = q_t = \Phi\left(\beta_{q0} + \beta_{q1} b_t + \beta_{q2} z_t\right),$$

This model is estimated by maximizing the following log-likelihood formula:

$$\ln(\prod_t \left[\eta_t \varphi\left(\frac{R_{t+1} - \beta_{d0}}{\sigma_d}\right) \sigma_d^{-1} + (1 - \eta_t) q_t \varphi\left(\frac{R_{t+1} - \beta_{c0} - \beta_{c1} b_t - \beta_{c2} z_t}{\sigma_c}\right) \sigma_c^{-1} + (1 - \eta_t)(1 - q_t) \varphi\left(\frac{R_{t+1} - \beta_{s0} - \beta_{s1} b_t}{\sigma_s}\right) \sigma_s^{-1}\right] \quad (11)$$

Even though investors believe that the bubble can continue growing without explosive expectations when is in the *Dormant* regime, there is a probability that the bubble might enter into an explosive state in which the bubble can continue for two different paths; the first one is to continue growing with explosive expectations, and the second one is to collapse to a smaller value. The probability of being in this explosive state is $1-\eta_t$. In this state are two underlying regimes: the *Collapse* and the *Survive* regime, the probability of being in the first one is q_t and the probability of being in the second one is $1-q_t$. In this explosive state, as the bubble increases, the probability of being in the *Survive* regime decreases and thus the probability of *Collapse* increases. When the bubble enters in this explosive state, investors take into account the possibility of a crash that was not being considered in the *Dormant* regime.

It is expected that the main variables take the following signs in order to affirm that the three regime model has explanatory power for gross returns:

- $\beta_{c1}<0$. If the bubbles increases in size, the expected returns in the *Collapse* regime should decrease (increase) if a positive (negative) bubble is present, since the bubble must collapse in regime *C*.
- $\beta_{s1}>\beta_{c1}$. As the bubble increases in size is expected that the difference between the expected returns across the surviving and the collapsing regimes increases as well.
- $\beta_{q1}>0$. The probability of the bubble collapsing is bigger (lower) when the bubble size increases (decreases).
- $\beta_{\eta1}<0$, $\beta_{\eta2}<0$). The probability of the bubble remain in the *Dormant* regime decreases (increases) either when the bubble size increases (decreases) and when investors observe larger (lower) average actual returns than average fundamental returns.

The same analysis could be done for Model 1 and Model 2.

3.4. Model Selection

3.4.1. Likelihood Ratio (LR)

For selecting the model that shows a better performance for our data, we applied the likelihood ratio test (LR) to choose among the specifications combining models 1 to 3 with the three bubble measures and the five alternative fundamental variables used. The use of the LR test allows us to calculate a *p-value* and decide whether to reject the model under the null hypothesis in favor of the model under the alternative hypothesis for nested models.

$$LR = -2ln\left[\frac{lr}{lu}\right], \quad (12)$$

where ln (lr) and ln (lg) stands for the maximized values of the log-likehood function of the restricted and unrestricted models, respectively. The probability function of the LR test follows a Chi-squared distribution with degrees of freedom equal to df2-df1, where the former is the number of parameters of the restricted model and the latter is the number of parameters of the unrestricted model.

3.4.2. Regime Classification Measure (RCM)

In order to evaluate the ability of a Regime-Switching model to fit the data used, in this section we apply the Regime Classification Measure[9]. An ideal RS model would have RCM values closer to zero; meaning that the model shows a perfect regime classification, while a weak RS model would have values closer to 100, implying that no information about regime classification is reveled.

[9] Ang and Bekaert (2002)

A general definition of the statistic for the K regime is:

$$RCM(K) = 100\, K^2\, \frac{1}{T} \sum_{t=1}^{T} \left(\prod_{i=1}^{K} p_{i,t}\right), \qquad (13)$$

where K is the number of regimes, T is the number of observations and p_t is the ex-ante regime probability.

For Regime-Switching models with three different regimes, the RCM statistic is defined as:

$$RCM(K) = 900 \frac{1}{T} [pi_1(1 - pi_1)pi_2(1 - pi_1)(1 - pi_2)],$$

where pi_1 is the ex-ante probability of the D*ormant Regime* and pi_2 is the ex-ante probability of the *Collapse Regime.*

3.5. Predictability ability

The last part of our analysis consists on testing the predictability ability that our models have. A good measure that provides useful insights about this is the probability of a crash or a boom in the currency market. This is a crude measure of the ability of the proposed models to determine optimal investment decisions, i.e. critical moments that can determinate optimal entry and exit times to the market. A crash is understood as a return more than two standard deviations below the mean return. Similarly, a boom is a return that is expected to be more than two standard deviations above the mean return.

The following equations describe how to calculate them.

Probability of a crash in the Currency Market

$$P_r(R_{t+1} < x) = \eta_t \Phi\left(\frac{x-\beta_{d0}}{\sigma_d}\right) + (1-\eta_t)q_t \Phi\left(\frac{x-\beta_{c0}-\beta_{c1}b_t-\beta_{c2}z_t}{\sigma_c}\right) + (1-\eta_t)(1-q_t)\Phi\left(\frac{x-\beta_{s0}-\beta_{s1}b_t}{\sigma_s}\right) \quad (14)$$

Probability of a boom in the Currency Market

$$P_r(R_{t+1} > x) = \eta_t \Phi\left(\frac{-x+\beta_{d0}}{\sigma_d}\right) + (1-\eta_t)q_t \Phi\left(\frac{-x+\beta_{c0}+\beta_{c1}b_t+\beta_{c2}z_t}{\sigma_c}\right) + (1-\eta_t)(1-q_t)\Phi\left(\frac{-x+\beta_{s0}+\beta_{s1}b_t}{\sigma_s}\right) \quad (15)$$

4. Empirical Application

4.1. Identifying Speculative Bubbles

Following the approach listed in Section 3.3.1 we applied the *GASDF* statistic to test the existence of a speculative bubble for the Colombian Peso, the Mexican Peso, and the Brazilian Real to the US Dollar exchange rate. The results of the *GASDF* suggest that for the COP and the BRL we reject the null hypothesis (no bubble in the exchange rate) at the 1% significance level and affirm that the results suggest the presence of speculative bubbles in these pairs for the period analyzed. For the MXN the rejection of the null hypothesis occurs at the 5% significance level.

Table 1 shows the results of the *GSADF* test for the Colombian Peso. Table 8 and Table 9 on the annexes show the results of the same test for the Mexican Peso and the Brazilian Real respectively.

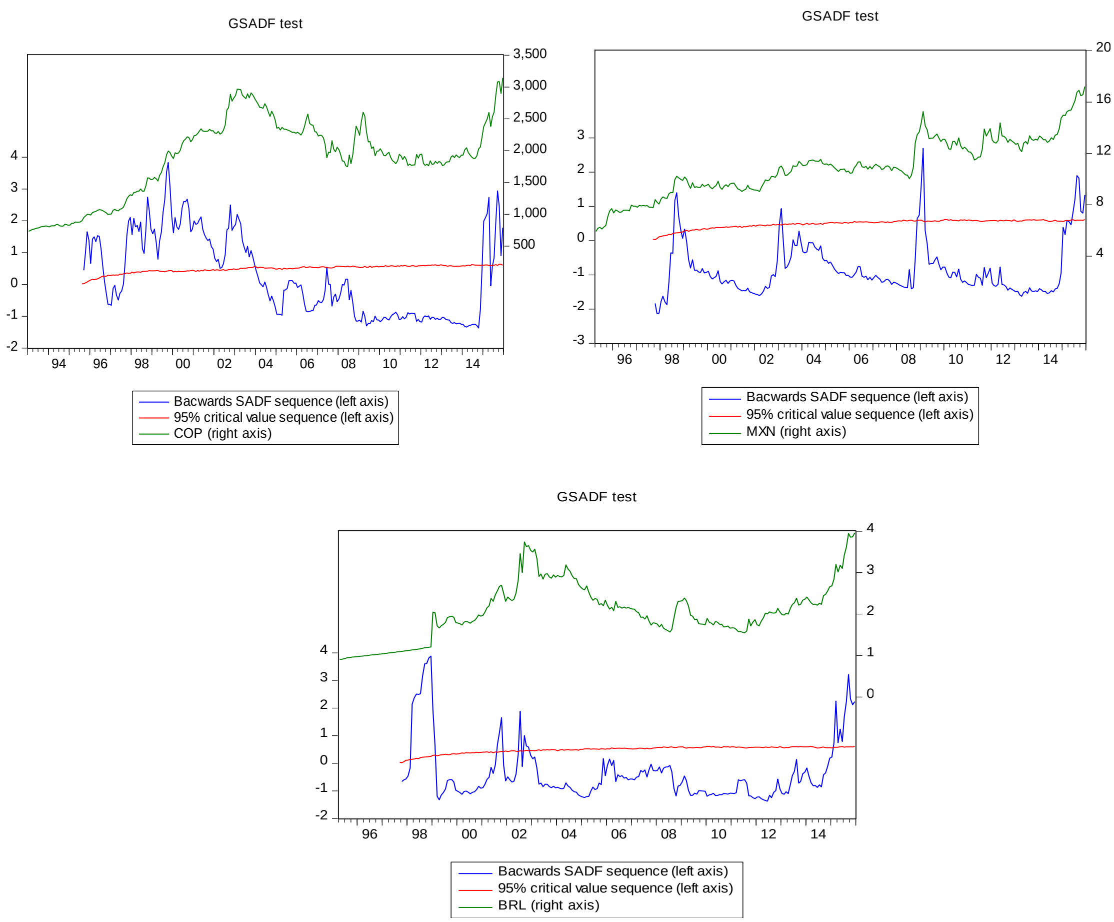
Table 1: Recursive right-tailed augmented Dickey-Fuller test of bubble detection, Colombian Peso.

		Critical Values		
		10%	5%	1%
	Statistic			
GASDF	3,8339 ***	1,8938	2,1430	2,7148

Null hypothesis: "No bubble in the exchange rate"
*** Rejection of the null hypothesis at 1% significance level

This analysis allows identifying the number, the dating and the duration of the bubble incidents for each one of the currency pairs studied. The *GASDF* statistic use Monte Carlo simulations in order to generate multiple critical values that will be the benchmark point to identify bubble incidents. Each time the statistic lies above the critical values indicate a bubble episode. Figure 1 the date-stamping bubble periods for our three currencies studied, and according to this methodology all of the currencies have presented multiple periods of bubble episodes. For the Colombian Peso we can highlight the one presented in the end of nineties and beginning of two thousands, and the one presented since the beginning of 2014 that remains nowadays.

Figure 1: Date-stamping bubble periods in the USD_COP, USD_MEX, and USD_BRL exchange rate.



For the Mexican Peso we can distinguish the bubble presented in the middles of 1998, beginnings of 2009, and the one presented since de second quarter of 2015. For the Brazilian Real we can highlight the bubble presented in 1998 and the one presented since the second quarter of 2015.

4.2. Bubbles Measures

In this section we are presenting the empirical work done for the three currency pairs analyzed.

The first part of this analysis is measuring the bubbles, for doing this we use the models presented in Section 3.3.2. These bubbles measures are calculated from the residuals of cointegration equations (3), (5) and (7), where equation (3) represents Bubble 1, equation (5) represents Bubble 2, and equation (7) represents Bubble 3. Table 2 reports the estimates parameters for the Colombian Peso for the three models. Table 10 and Table 11 on the annexes show the results of the same test for the Mexican Peso and the Brazilian Real respectively.

Table 2: Estimates of the exchange rate determination models for the Colombian Peso

	Bubble 1		Bubble 2		Bubble 3
δ_0^A	8.4077	δ_0^B	6.1286	δ_0^c	6.1633
	(0.0472)***		(0.1362)***		(0.1358)***
δ_1^A	0.9060	δ_1^B	-0.3412	δ_1^c	-0.3307
	(0.0488)***		(0.0253)***		(0.0255)***
		δ_2^B	0.2356	δ_2^c	0.2749
			(0.0788)***		(0.0799)***
		δ_3^B	-2.6506	δ_3^c	-3.1759
			(0.0721)***		(0.2372)***
				δ_4^c	0.9072
					(0.3915)**

Notes: Standard errors are reported in parentheses.

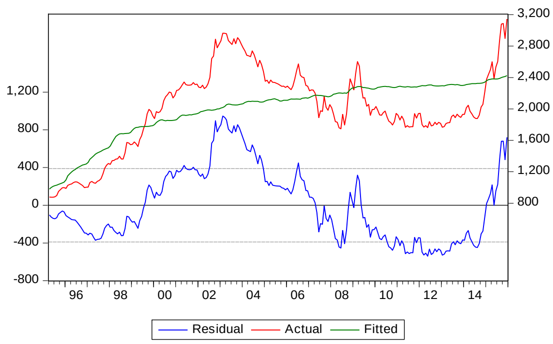
*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively.

Figures 2, 3, and 4 plots the three bubble measures together with the nominal exchange rate for Colombia, Mexico and Brazil, respectively.

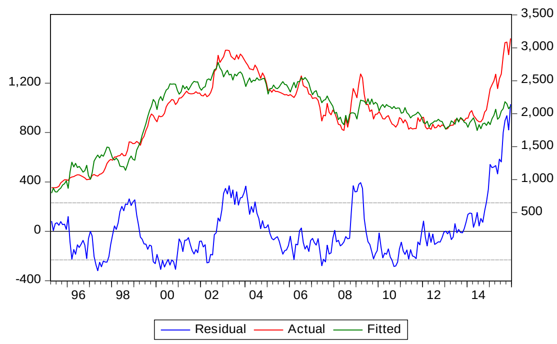
Figure 2 shows that the bubble measures exhibit a similar behavior revealing periods of positive and negative deviation from the USD_COP exchange rate from the fundamental values. The same behavior is observable for the pair USD_MXN (Figure3) and for the pair USD_BRL (Figure 4).

Figure 2: Bubble measures and the USD_COP exchange rate.

Exchange Rate vs. Bubble 1



Exchange Rate vs. Bubble 2



Exchange Rate vs. Bubble 3

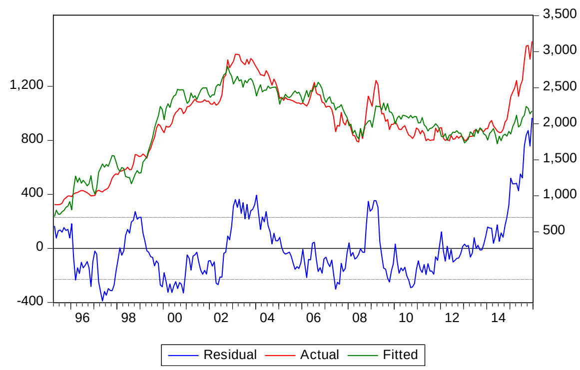
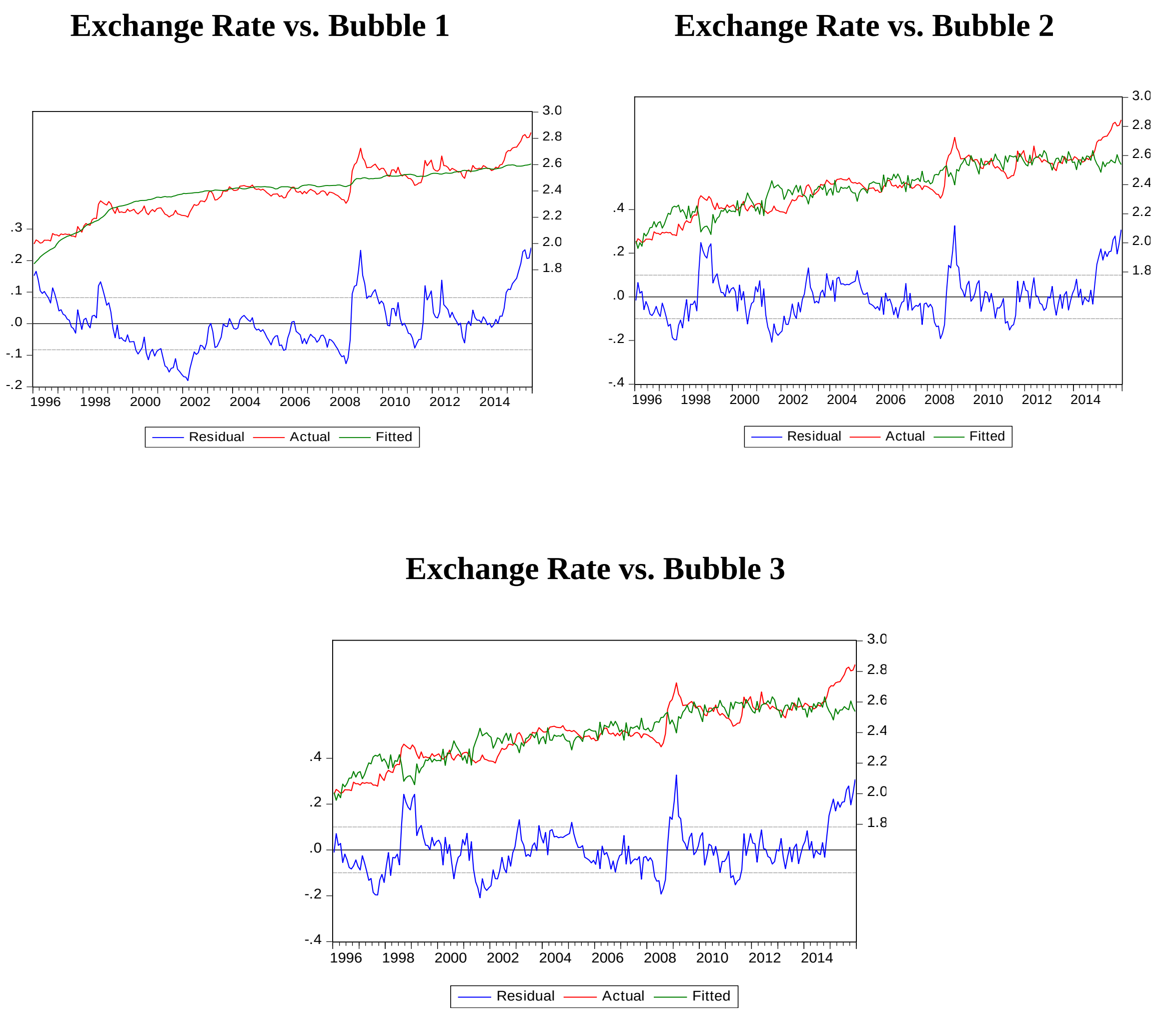
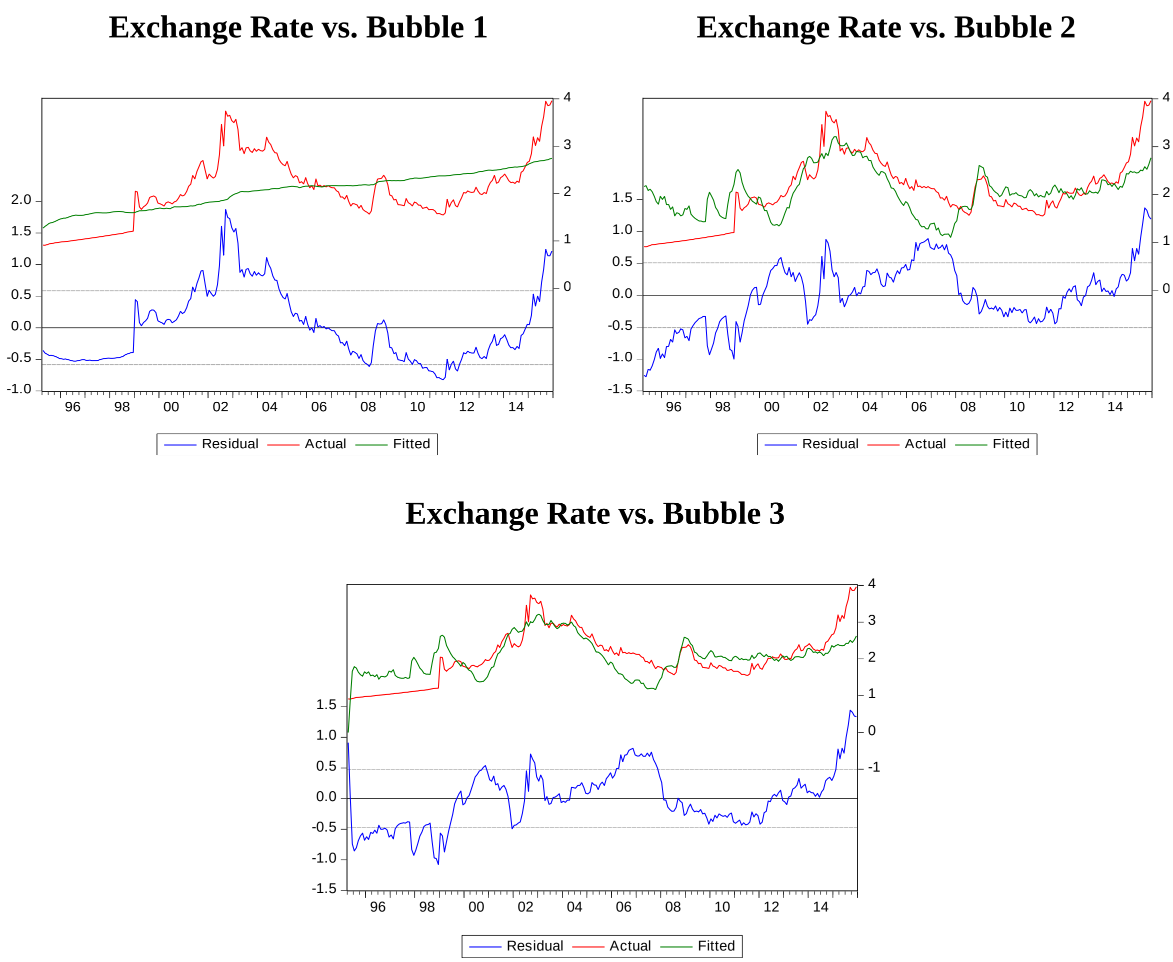


Figure 3: Bubble measures and the USD_MXN exchange rate.



After measuring all the bubbles the next step is to estimate the three different models for each one of the bubbles and for each one of the fundamental variables used. Using the models listed in Section 3.3.3 we first fit Models 1 – 3 for each one of the three bubble measures and for each one of the five explanatory variables. Chapter 4 reports the main results for each one of the currencies studied. Complete results can be found in the Annexes Section.

Figure 4: Bubble measures and the USD_BRL exchange rate.



4.3. Regime Models

After estimating 33 different models[10], we present the most relevant results for each one of the currencies studied. Complete results for each one of the models and each one of the currencies can be found in the Annexes Section.

[10] [(2 Models * 3 Bubbles * 5 Fundamentals) + (Model 1 * 3 Bubbles)]

4.3.1. Results for the Colombian Peso

The first results we are presenting correspond to the Colombian currency. In line with the results presented in Section 4.4 (Model Selection), Model 3 is the preferable one for the USD_COP according with the LR and the RCM. Table 3 reports the most relevant estimators for the Model 3 with the first bubble measure for the Colombian Peso. Results for the other models and bubbles measures can be found in the Annexes Section.

Table 3: Main results for Model3_Bubble1 USD_COP

	Exports	Imports	International Reserves	Interest Rate	WTI
$\boldsymbol{\beta_{d0}}$	0.0130	0.0407	0.04288	0.0067	0.0067
	(0.0051)**	(0.0128)***	(0.0120)	(0.0047)	(0.0050)
$\boldsymbol{\beta_{s0}}$	0.0043	-0.0023	0.0028	0.0096	0.0118
	(0.0051)	(0.0044)	(0.0037)	(0.0069)	(0.0083)
$\boldsymbol{\beta_{s1}}$	0.1467	-0.0569	-0.0323	0.0328	0.0118
	(0.0386)***	(0.0554)	(0.0529)	(0.0431)	(0.0468)
$\boldsymbol{\beta_{c0}}$	0.0419	0.0248	0.0181	-0.0121	-0.0030
	(0.0073)***	(0.0058)***	(0.0057)***	(0.0025)***	(0.0020)
$\boldsymbol{\beta_{c1}}$	-0.0984	-0.0668	-0.0637	-0.0656	-0.0819**
	(0.0318)***	(0.0229)	(0.0242)***	(0.0281)**	(0.0339)
$\boldsymbol{\beta_{c2}}$	0.0000	0.0000	0.0000	0.0403	-0.0303***
	(0.0000)***	(0.0000)***	(0.0000)***	(0.0114)***	(0.0060)
$\boldsymbol{\beta_{\eta 0}}$	-248.174	-0.8903	-0.8899	-2.5801	-11.7265
	(447461)	(0.3011)***	(0.2787)***	(2.6359)	(11.8844)
$\boldsymbol{\beta_{\eta 1}}$	-3180.46	4.4759	4.1602	-42.8544	-178.418
	(584138)	(1.3074)***	(1.2050)***	(38.9639)	(179.269)
$\boldsymbol{\beta_{\eta 2}}$	-2812.30	6.4158	6.3227	99.2284	591.793
	(287495)	(8.0156)	(7.2750)	(93.8332)	(610.880)
$\boldsymbol{\beta_{q0}}$	3.1372	1355.79	1539.77	-0.3046	0.2379
	(0.9199)***	(332.862)***	(215.341)***	(0.3163)	(0.2942)
$\boldsymbol{\beta_{q1}}$	-1.4885	4473.28	4401.60	-5.6936	-9.4778***
	(2.0408)	(257.898)***	(1306.27)***	(2.8682)**	(3.6355)
$\boldsymbol{\beta_{q2}}$	-0.0012	-0.3415	-0.0413	2.1110	-0.4544
	(0.0003)***	(0.0925)***	(0.0004)***	(1.4579)	(0.7175)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

It is important to highlight some of the results presented in Table 3, first of all not all the coefficients for all the fundamentals variables analyzed are statistically significant at a 10% nor have the expected sign or financially meaningful magnitude. The intercept for the *Dormant Regime* β_{d0} is highly significant for the first two fundamental variables and express the expected return in the *Dormant Regime*, which is equal to the required fundamental return. For instance, the estimate of the intercept in this regime for the *Exports* (β_{d0}) is 0.0130. This implies that the expected return in the D*ormant Regime* is 1.30%; this result is reasonable in terms of real fundamental results as it is in the percentile 65.

The coefficient β_{c1} that measures the relation between the bubble size and the expected return in the *Collapse Regime* has the expected sign in all the fundamentals variables used, as the relation between the expected return in the *Collapse* regime and the bubble size is negative; a larger speculative component (Bubble size) implies a larger loss of capital if the bubble collapses, and they are statistically significant at a 5% as well. The coefficient β_{s1} is statistically significant at 1% just for *Exports*, and has the expected value ($\beta_{s1} > \beta_{c1}$) for all the variables. These results are in line with the theory of speculative behavior.

As expected the effect of the bubble size on the probability (measure by $\beta_{\eta 1}$) of being in the *Dormant* state is negative for three out of five variables analyzed (*Exports*, *Interest Rates*, and *WTI*); as the bubble size increases the probability of being in the *Dormant* state in the next period falls, and the probability of entering in the explosive state (Collapsing or Surviving state) increases. In this explosive state, as the bubble increases the probability of being in the Collapsing state (β_{q1}) decreases when we consider the variable *Exports*, *Interest Rates* and *WTI*. For the other two variables such probability increases as the bubble size increases as well, therefore the probability of being in the Surviving regime decreases, this result is in favor of the presence of periodically collapsing speculative bubbles in the USD_COP. In the explosive state for these variables (*Imports,* and *International Reserves)*, investors perceive that the bubble can collapse and take into account the probability of a possible crash. According to the *GASDF* statistic (Figure 1, Section 4.1.) the USD_COP has evidenced periods of collapsing bubbles, nowadays this statistic shows that this pair is in a bubble.

When analyzing the intercept of the probability of being in the *Dormant* state ($\beta_{\eta 0}$) for the Model3_Bubble3 we can affirm that the probability of being in the steady state is negligible and once the variable enters in the explosive state it has a high probability of being in the *Surviving* regime, i.e. it will continue growing with explosive expectations. As we saw the probability of being in the *Dormant* state is almost null for this currency when there is no bubble and no divergence from the fundamental price, therefore we can affirm that the Colombian Peso will expend most of the time in the explosive state. This is evidenced in the Figure 5.

Contrary to the intuition behind the use of the term Spread (sp_t); when investors observe large spreads, i.e. larger average returns than average fundamental returns, they believe that the bubble has entered into the explosive state and the probability of being in the Dormant state falls, however, our results for the Colombian Peso show that the estimate $\beta_{\eta 2}$ is positive for almost all the variables and it does not have statistical significance for any of the variables analyzed, what makes us think that maybe is not a relevant variable for this pair. This result is contrary to the one obtained by Panopoulou and Pantelidis (2015) and the reason could be the difference in the sample size and the size used for the calculation of the spread, the authors used a six month differential while the period used in this work was three months[11].

In order to see in which regime the variable spends most of the time, we plot the ex-ante probability of R_{t+1} being in each regime. As Figure 5 shows the variable spends most of the time in the *Survive* regime with periods in it switches to the *Collapse* regime.

[11] "Chen, Hong and Stein (2001) found that the predictive power of past returns is larger is one considers the last six months" Brooks and Katsaris (2005).

Figure 5: Estimated Filtered Probabilities and Spot Exchange rate Colombian Peso.

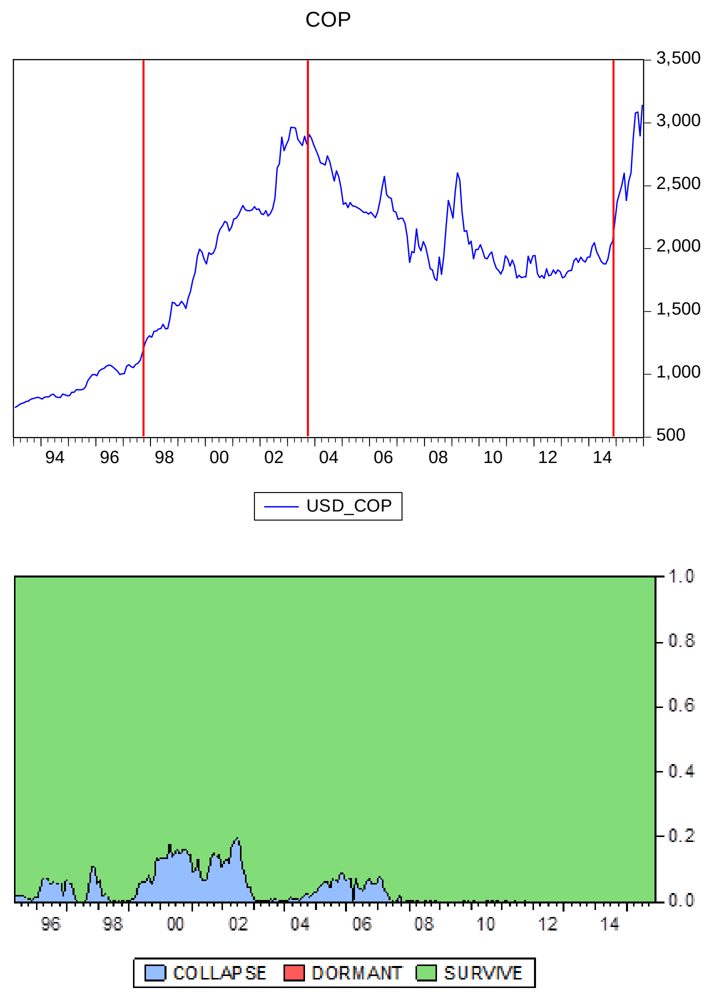
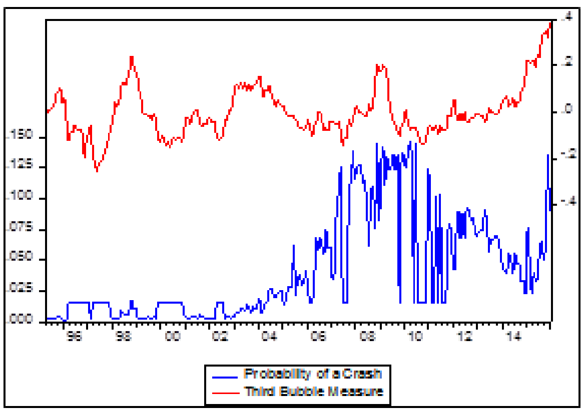


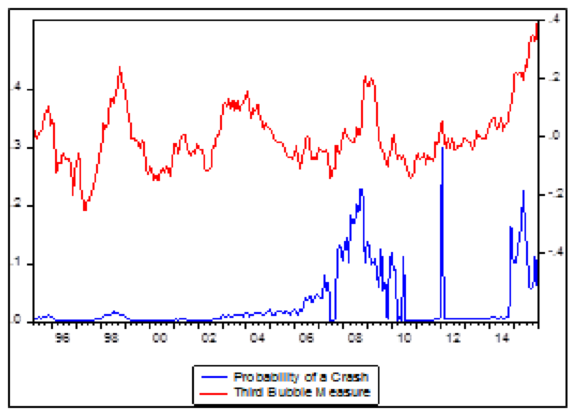
Figure 6 illustrates the estimated probability of a crash for the Model 3 for each one of the five fundamental variables used, together with the third bubble measure. For the event presented in the beginnings of 1996 just the variables *Interest Rates* and WTI register an increase in the probability of a crash, even though this probability is not too high (around 8%). For the collapse presented around 2004 we can observe that any of the variables present an increase in the probability of this event. Additionally for the bubble presented since the beginning of 2014 just the variable *Exports* show an increase in the probability of a crash in this period, around 13%. Although the results for the probability of a crash are not strong enough, the results for a boom are quite positive. All the variables register an increase in the probability of a boom in the period around 1999 and in the period around 2014 that is when the period of high devaluation stated. Results for the probability of a Boom can be found in the Annexes Section.

Figure 6: Estimated Probabilities of a Crash (Model 3) and the Bubble 1 measure, Colombian Peso

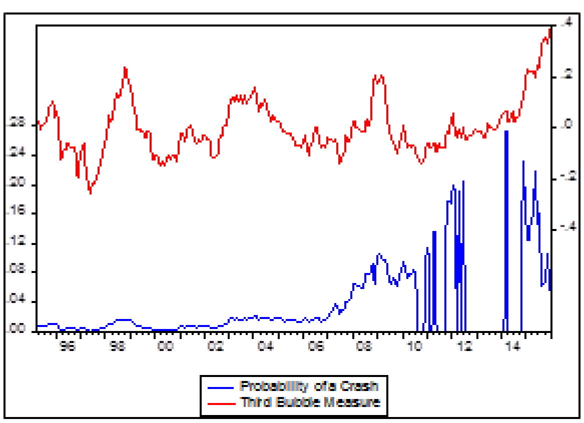
Exports



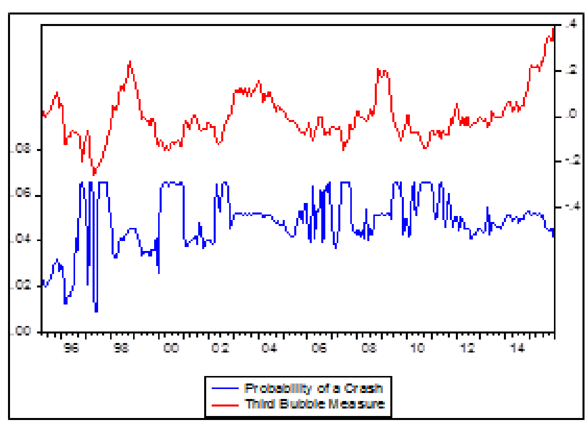
Imports



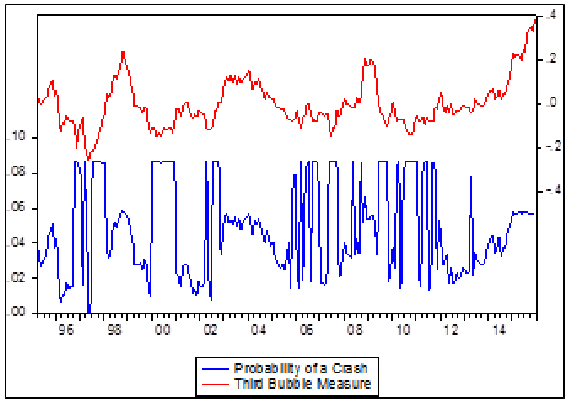
International Reserves



Interest Rates



WTI



4.3.2. Results for the Mexican Peso

According to the results of the LR statistic and the RCM (Table 14 and Table 12 in the Annexes Section) applied to the Mexican Peso, Model 3 is the preferable one. The LR statistic shows that when comparable with both Model 1 and Model 2, Model 3 is preferable to the other two in all the cases. In this section, we present the results for the third model and the first bubble measure; complete results for the other models are in the Annexes Section.

As occurred with the USD_COP for the Mexican Peso we can observe some similar results regarding either the statistically significance and the meaningful magnitude; not all the coefficients for all the fundamentals variables analyzed are statistically significant at a 10% nor have the expected sign or financially meaningful magnitude. The estimator β_{d0} for the *Dormant Regime* is not highly significant for all the fundamentals variables; we just can highlight the result for the variable *Interest Rate* that is statistically significant at a 10% confidence level. In this particular case β_{d0} is 0.0114, this implies that the expected return in the D*ormant Regime* is 1.14% per month; this result is considerable in terms of real fundamental results as it is under the percentile 65.

Table 4: Main results for Model3_Bubble1 USD_MXN

	Exports	Imports	International Reserves	Interest Rate	WTI
β_{d0}	-0.0011	-0.0020	-0.0016	0.0114	-0.0018
	(0.0016)	(0.0013)	(0.0016)	(0.0055)**	(0.0015)
β_{s0}	0.0165	0.0089	0.0195	0.2872	0.0162
	(0.0175)	(0.0322)	(0.0184)	(0.0142)***	(0.0164)
β_{s1}	0.0492	0.1015	0.0029	-1.3707	0.0536
	(0.1564)	(0.2621)	(0.1680)	(0.0698)***	(0.1499)
β_{c0}	0.0052	0.0434	-0.0333	0.0000	-0.0180
	(0.0003)***	(0.0027)***	(0.0011)***	(0.0032)	(0.0019)***
β_{c1}	0.1959	-0.1207	0.3974	0.0230	-0.0834
	(0.0025)***	(0.0512)**	(0.0067)***	(0.0285)	(0.0132)***
β_{c2}	0.0000	0.0003	0.0000	-0.0001	0.0559
	(0.0000)***	(0.0001)***	(0.0000)***	(0.0002)	(0.0041)***
$\beta_{\eta 0}$	0.7719	1.5216	1.0679	-0.9346	1.0280
	(0.2692)***	(0.2585)***	(0.3586)***	(0.3444)***	(0.2623)***
$\beta_{\eta 1}$	-10.5827	-12.7032	-17.9901	7.1457	-9.6402
	(3.7775)***	(4.2146)***	(6.0309)***	(3.1378)**	(3.9237)**
$\beta_{\eta 2}$	-1.7384	-17.9796	0.0000	29.0238	-18.9430
	(16.0037)	(18.4114)	(20.7299)	(23.2624)	(20.7530)
β_{q0}	-0.4567	1.0898	-0.6626	3.5802	-11.0389
	(0.6907)	(2.1658)	(0.6857)	(6.8344)	(36.2949)
β_{q1}	-7.7116	-42.4144	1.9331	-32.0650	-5.5189
	(3.7123)**	(42.4190)	(5.5123)	(58.2814)	(37.4394)
β_{q2}	0.0000	0.0237	0.0000	0.0608	41.7596
	(0.0000)	(0.0967)	(0.0000)	(0.2767)	(128.982)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

When the price series enters in the explosive regime, it behavior is a little bit more extreme. The equilibrium return in the *Survive* regime (β_{s0}) is significantly higher than in the *Dormant* regime for all the variables studied. For the equilibrium return in the *Collapse* regime, the results are statistically significant at a 1% for 4 out of 5 of the variables studied. For the *International Reserves* and the *WTI* the results are consistent with the theory of speculative bubbles since in this particular regime is expected to have a negative return as investors are selling their positions while the price falls.

The coefficient β_{c1} has the expected sign (negative) in two out of five of the fundamentals variables (*Imports* and *WTI*); however it is statistically significant at a 5% for 4 out of 5 of the variables. The coefficient β_{s1} that measures the relation between the expected return in the *Survive* regime and the bubble size is statistically significant at 1% just for the *Interest Rates*, and has the expected value ($\beta_{s1} > \beta_{c1}$) for *Imports* and *WTI*.

As expected the effect of the bubble size on the probability of being in the *Dormant* state (measure by $\beta_{\eta1}$) is statistically significant at a 5% for all the variables and is negative for four out of five variables analyzed (*Imports, Exports, International Reserves,* and *WTI*), as the bubble size increases the probability of being in the *Dormant* state in the next period falls, and the probability of entering in the explosive state (Collapsing or Surviving state) increases. In this explosive state, as the bubble increases, the probability of being in the Collapsing β_{q1} state decreases for almost all the variables indicating that the Mexican Peso expends most of the time in the *Survive* regime when the bubble size increases.

The results support the use of the term Spread (sp_t); when investors observe large spreads, i.e. larger average returns than average fundamental returns, they believe that the bubble has entered into the explosive state and the probability of being in the Dormant state falls, $\beta_{\eta2}$ is negative for three out of five variables (*Imports*, *Exports*, and *WTI)*, however it is not significant for any of the variables.

Figure 7 shows that the variable spends most of the time in the *Survive* regime with periods in it switches to the *Collapse* regime, as mentioned before.

Figure 7: Estimated Filtered Probabilities and Spot Exchange rate Mexican Peso.

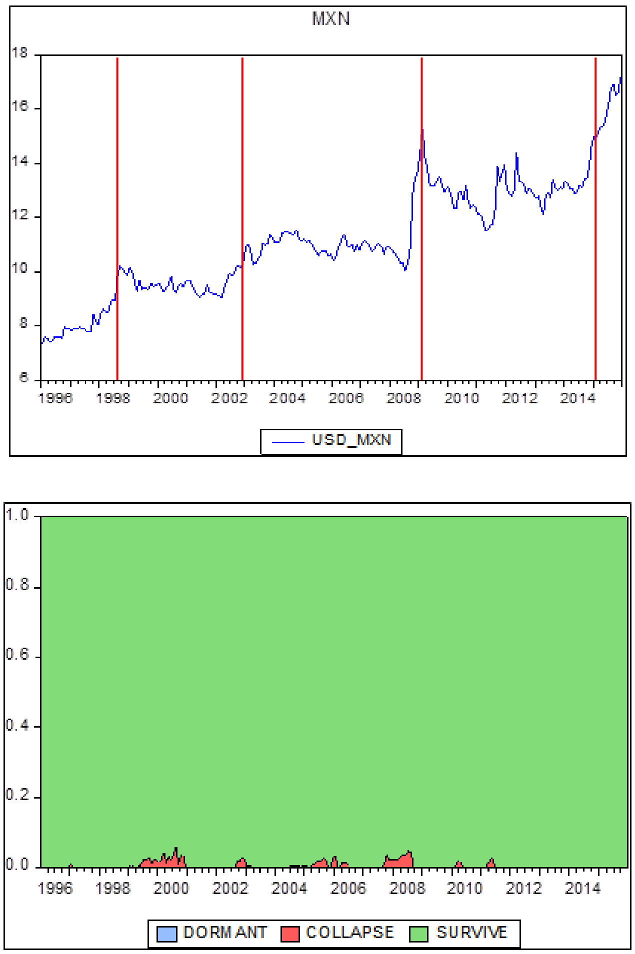
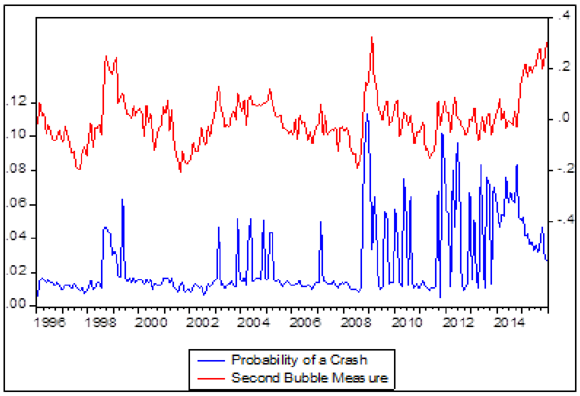


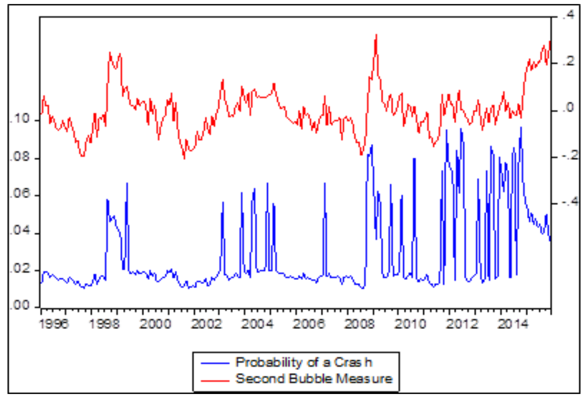
Figure 8 illustrates the calculated probability of a crash for the Model 3 for each one of the five fundamental variables considered, together with the second bubble measure. For all the variables we observe a significant increase in the probability of a crash around 1999 just before the collapse of the bubble. Similar results are evidenced around 2009, all models are able to increase the probability of a crash in this period, however this event is better registered by models that use the variables, *International Reserves*, *Interest Rates* and *WTI.* Finally models that use the aforementioned variables show an increase in the probability of a crash in the bubble that is presented in 2015, although it is not too high is a good signal of alert for investors. Results for the probability of a Boom can be found in the Annexes Section.

Figure 8: Estimated Probabilities of a Crash (Model 3) and the Bubble 2 measure Mexican Peso

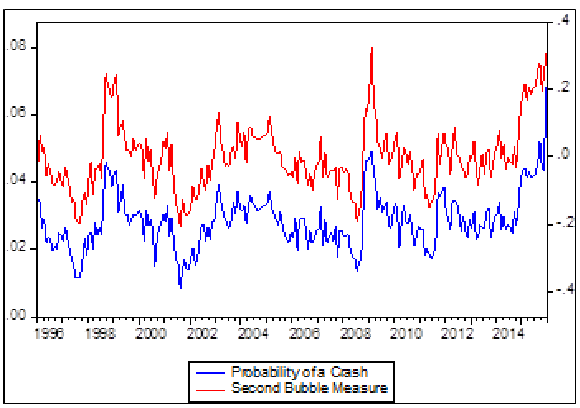
Exports



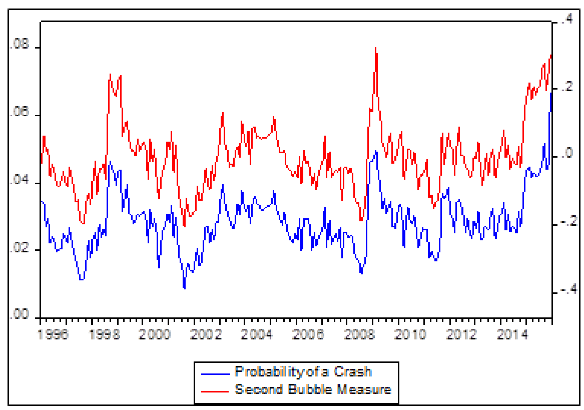
Imports



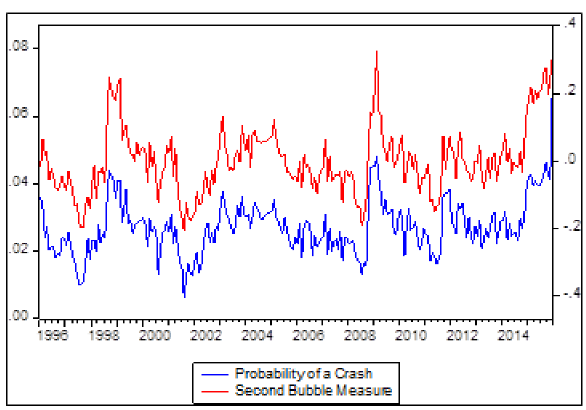
International Reserves



Interest Rates



WTI



4.3.3. Results for the Brazilian Real

In line with the results obtained for the Colombian Peso and the Mexican Peso, Model 3 is the preferred one for the Brazilian Real according to the results given by the LR statistic. When comparing to Model 1 just in one case this model is preferable to Model 3, and when comparing to Model 2 any time this model is better than Model 3 according to the LR statistic. When classifying the models by their ability to fit the data, Model 3 continues to be the better one for the Brazilian Real (see Table 13, Annexes Section). Therefore, we present the results for the third model and the second bubble measure; complete results for the other models are in the Annexes Section.

In terms of intercepts, the results for the *Dormant* regime and the Survive regime are not statistically significant for any of the variables studied. However, the results for the *Collapse* regime are highly significant for four out of five variables.

The coefficient β_{c1} has the expected sign (negative) in three out of five of the fundamentals variables (*Imports*, *International Reserves* and *WTI*); however it is statistically significant at a 1% just for the variable *Imports*. The coefficient β_{s1} is statistically significant at 5% for three out of five variables, and has the expected value ($\beta_{s1} > \beta_{c1}$) for all the variables. Is possible to affirm that it has the expected sign as well, as is expected that if the bubble size increases, investors will demand a higher return to compensate them for the increased risk of the bubble collapse.

The coefficient $\beta_{\eta1}$ is statistically significant at a 5% for four out of five variables and has the expected sign (negative) for three of the variables analyzed (*Exports*, *Interest Rate* and *WTI*). As the bubble' size increases the probability of being in the *Dormant* state in the next period falls, and the probability of entering in the explosive state (Collapsing or Surviving state) increases. In this explosive state, as the bubble increases, the probability of being in the Collapsing β_{q1} state decreases for almost all the variables indicating that the Brazilian Real like Mexican Peso expends most of the time in the *Survive* regime when the bubble size increases.

Table 5: Main results for Model3_Bubble1 USD_BRL

	Exports	Imports	International Reserves	Interest Rate	WTI
$\boldsymbol{\beta_{d0}}$	0.0403	0.0035	0.0049	0.0479	0.0395
	(0.0453)	(0.0035)	(0.0039)	(0.0553)	(0.0458)
$\boldsymbol{\beta_{s0}}$	-0.0022	0.0764	0.1451	-0.0023	-0.0020
	(0.0036)	(0.1997)	(0.9783)	(0.0035)	(0.0036)
$\boldsymbol{\beta_{s1}}$	0.0178	0.1095	0.1380	0.0176	0.0172
	(0.0075)**	(1.2154)	(1.4694)	(0.0076)**	(0.0074)**
$\boldsymbol{\beta_{c0}}$	0.0069	0.0060	0.0085	-0.0001	0.0051
	(0.0009)***	(0.0025)**	(0.0019)***	(0.0012)	(0.0006)***
$\boldsymbol{\beta_{c1}}$	0.0003	-0.0067	-0.0019	0.0054	-0.0007
	(0.0008)	(0.0020)***	(0.0019)	(0.0048)	(0.0009)
$\boldsymbol{\beta_{c2}}$	0.0000	0.0000	0.0000	0.4688	-0.0001
	(0.0000)	(0.0000)***	(0.0000)***	(0.1373)***	(0.0009)
$\boldsymbol{\beta_{\eta 0}}$	-1.4459	0.9402	3.6252	-1.5013	-1.4349
	(0.2937)***	(0.1651)***	(1.1979)***	(0.2867)***	(0.2948)***
$\boldsymbol{\beta_{\eta 1}}$	-1.0262	2.0807	9.3975	-0.4265	-1.0025
	(0.4905)**	(0.2943)***	(3.2194)***	(0.5174)	(0.4861)**
$\boldsymbol{\beta_{\eta 2}}$	24.9202	3.7551	0.0000	23.1601	24.0056
	(10.0736)**	(5.1596)	(10.0965)	(9.6812)	(9.9942)**
$\boldsymbol{\beta_{q0}}$	-2.6358	-6.8375	-505.684	-6.3159	-5.1635
	(1.7125)	(4.2129)*	(1.1000)	(2.2457)***	(1.9086)***
$\boldsymbol{\beta_{q1}}$	-8.9701	-3.7109	-145.163	-9.0104	-12.6574
	(4.3687)**	(3.0934)	(3.5100)	(4.5710)**	(4.7639)***
$\boldsymbol{\beta_{q2}}$	0.0000	0.0013	0.0093	208.597	-2.3498
	(0.0000)**	(0.0009)	(19367.1)	(94.4698)**	(1.2737)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

The coefficient β_{c2} is statistically significant at 1% for three out of the five variables (*Imports, International Reserves and Interest Rate*) and has the expected sign (positive) for all the variables. This implies that as the change in the fundamental variables increases, expected return for the next period increases as well, indicating that increased abnormal return is a sign of increased risk.

When analyzing the intercept of the probability of being in the *Dormant* state ($\beta_{\eta 0}$) for the Model 3, we can state that there is a probability of 50% of remain in this state if the size of the bubble and the spread of the actual returns are both equal to zero. Thus, there is a probability of 50% of switching to the explosive state. Once the variable enters in the explosive state if the bubble size and the spread are both equal to zero the variable has the same probability of being in the *Survive* or to reverses to the fundamental values i.e. enter in the *Collapse* regime.

Results for the coefficient Spread (sp_t) are similar to the ones obtained in the Colombian Peso, for the Brazilian Real the estimate $\beta_{\eta 2}$ is positive for all the variables and is statistically significant at a 5% just for two out of five variables (*Exports* and *WTI)*, what makes us think that maybe is not a relevant variable for this pair.

Figure 9 shows that the variable spends most of the time in the *Survive* regime with periods in it switches to the *Collapse* regime, as mentioned before.

Figure 9: Estimated Filtered Probabilities and Spot Exchange rate Brazilian Real.

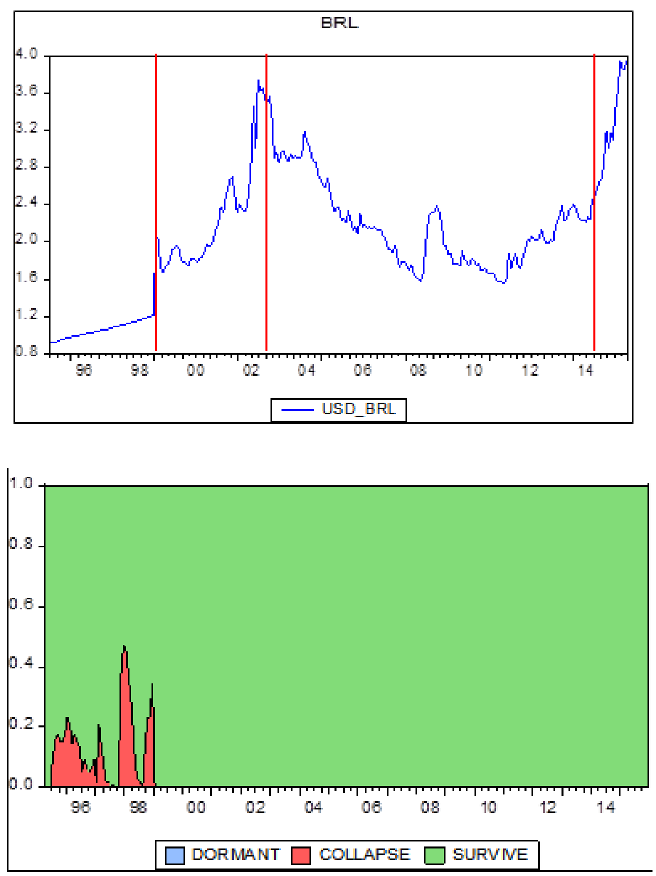
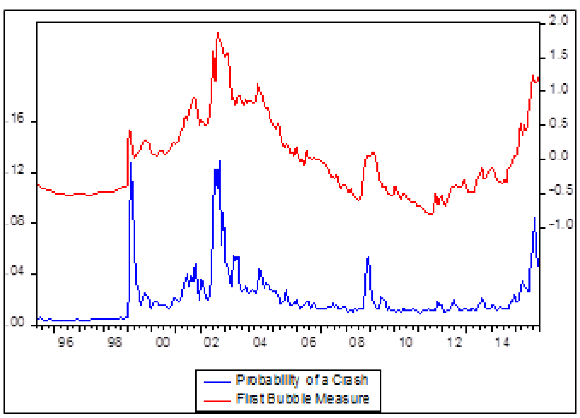


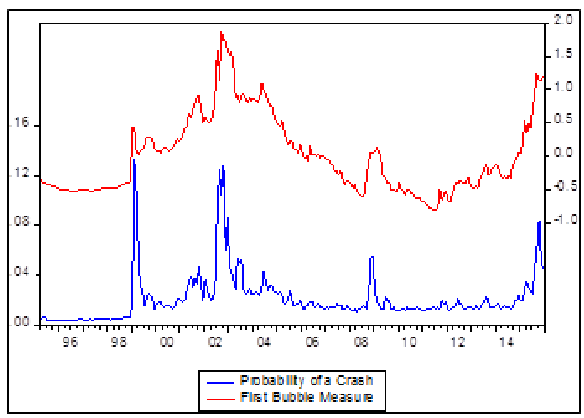
Figure 10 illustrates the calculated probability of a crash for the Brazilian Real using the Model 3 for each one of the five fundamental variables used in this work, together with the first bubble measure. For the variables *Exports*, *Imports* and *WTI* we observe a significance increase in the probability of a crash around 1999 just before the collapse of the bubble, however this event is not capture by the model that use the variable *International Reserves*. Similar results are evidenced around 2002, the probability of a crash in the aforementioned models increase considerable before the collapse of the bubble. Finally the same models show an increase in the probability of a crash in the bubble that is presented in 2015, which can be used as a signal of a possible collapse. Results for the probability of a Boom can be found in the Annexes Section.

Figure 10: Estimated Probabilities of a Crash (Model 3) and the Bubble 1measure Brazilian Real

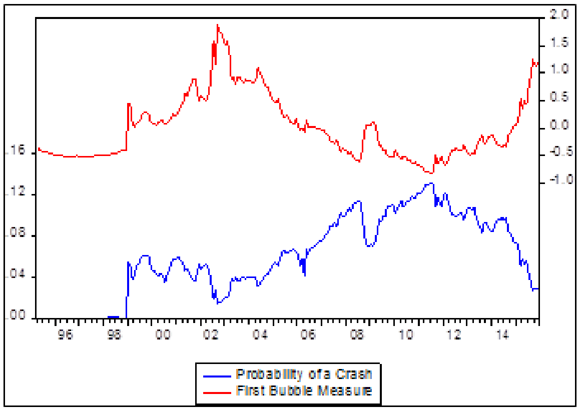
Exports



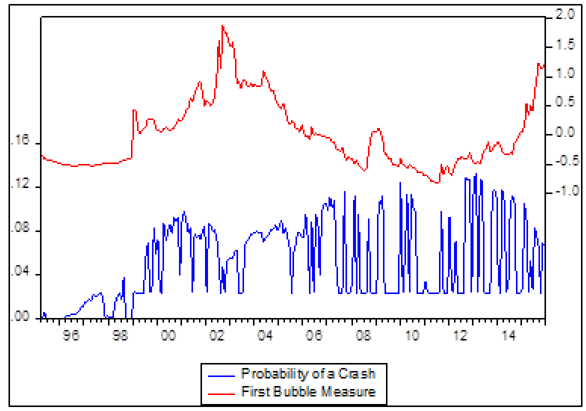
Imports



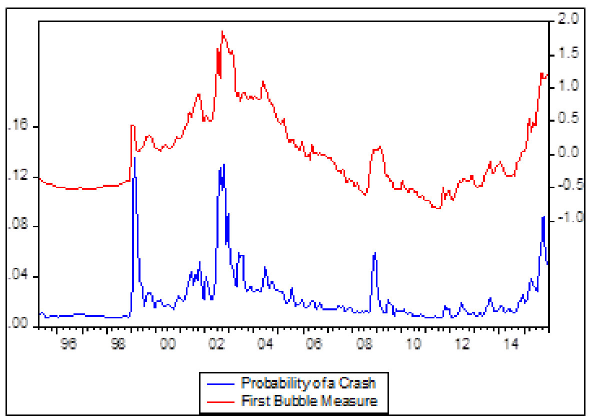
International Reserves



Interest Rates



WTI



4.4. Model Selection

4.4.1. Likelihood Ratio (LR)

Applying the LR test to the Colombian Peso and using a 5% significance level, LR test shows that Model 3 is preferable to Model 1 and Model 2 for almost all the possible combinations analyzed. We just identify three cases (using a 5% significance level) where the LR test selects Model 1 instead of Model 3; Model 3_Bubble3_Exports, Model 3_Bubble 3_Interest Rates, and Model 3_Bubble 3_Interest Rates. When we compare Model 1 with Model 2 we identify four cases (using a 5% confidence level) where the LR test selects Model 1 instead of Model 2; Model 2_Bubble 2_Imports, Model 2_Bubble 2_International Reserves, and Model 2_Bubble 3_Imports.

In total we consider 15 different combinations; three different bubble measures and five fundamental variables, results of the LR test for the Colombian Peso are presented in Table 6. Results for the Brazilian Real and the Mexican Peso can be found in the Annexes Section.

Table 6: LR Statistic for model selection USD_COP

	Model 1 vs. Model 2		Model 1 vs. Model 3		Model 2 vs. Model 3	
	LR	p-Value	LR	p-Value	LR	p-Value
Bubble 1						
Exports	29.391	0.000	630.576	0.000	601.185	0.000
Imports	8.755	0.003	30.046	0.000	21.291	0.000
International Reserves	6.677	0.010	27.562	0.000	20.885	0.000
Interest Rates	31.579	0.000	750.742	0.000	719.163	0.000
WTI	27.543	0.000	10.784	0.005	38.327	0.000
Bubble 2						
Exports	5.108	0.024	0.617	0.734	4.491	0.034
Imports	2.365	0.124	30.936	0.000	28.572	0.000
International Reserves	2.232	0.135	20.222	0.000	22.454	0.000
Interest Rates	19.683	0.000	0.908	0.635	20.591	0.000
WTI	19.683	0.000	9.639	0.008	35.709	0.000
Bubble 3						
Exports	20.029	0.000	16.870	0.000	36.899	0.000
Imports	1.157	0.282	21.006	0.000	19.849	0.000
International Reserves	3.623	0.057	18.774	0.000	22.398	0.000
Interest Rates	22.342	0.000	0.081	0.960	22.423	0.000
WTI	26.999	0.000	12.334	0.002	39.334	0.000

4.4.2. Regime Classification Measure (RCM)

The results for the Colombian Peso reported in Table 7, provide strong support for Model 3, since the majority of RCM values are closer to zero. For Bubble 1 the best models for regime classification are the ones that involve the fundamentals: *Exports*, *Interest Rates* and *WTI*. For Bubble 2 the best model according to the RCM test is the one that uses the *Imports* as a fundamental variable. Model 3 reports the best regime classification with four models reporting RCM values closer to zero; *Exports*, *Imports*, *International Reserves* and *WTI*. Results for the Mexican Peso and the Brazilian Real can be found in the Annexes Section.

Table 7: Regime Classification Measure USD_COP

	Bubble 1	**Bubble 2**	**Bubble 3**
Model 1	46.1308	40.9819	40.1081
Model 2			
Exports	23.6536	22.4804	25.8394
Imports	22.4623	28.8085	29.0408
International Reserves	34.0307	42.4775	43.1693
Interest Rates	20.7919	28.3362	28.9387
WTI	51.1944	17.2349	15.3852
Model 3			
Exports	0.1900	5.2522	0.0043
Imports	7.4063	0.0467	0.0265
International Reserves	7.2147	1.6487	0.0039
Interest Rates	0.4361	11.5360	5.8088
WTI	0.4482	5.6897	0.9279

5. Conclusions

The motivation of this dissertation stems from the phenomenon of high devaluation to the US Dollar that the Latin American currencies suffered in 2015, with values over 30% for the Colombian Peso and the Brazilian Real and close to 20% for the Mexican Peso. Through the use of the methodology proposed by Phillips, *et al*. (2001) for the identification of bubbles on the UK Pound to US Dollar, we found evidence of periodically collapsing bubbles for all the currencies involved. The Colombian Peso showed three periods of collapsing bubbles; the first one in the end of the nineties, the second one in the beginning of 2000, and the last one since the beginning of 2014. The Mexican Peso had three periods of collapsing bubbles as well; middle of 1998, beginning of 2009 and in the second quarter of 2015. Finally, the Brazilian Real evidenced two big periods of collapsing bubbles, the first one in 1998 and the second one in the second quarter of 2015.

After identifying the presence of speculative bubbles we applied different models of exchange rate determination in order to determine three different bubbles measures. The results evidence some divergence of actual prices from fundamental values for the three currencies analyzed, with some periods of reversals to the fundamental price. Bubble 1 which is the simplest one, seems to be the one which shows the biggest divergence to the fundamental values when comparing to the results of both Bubble 2 and Bubble 3.

We follow the methodology proposed by Pantelidis and Panopoulou (2015) and implement three different Regime-Switching models to examine whether speculative bubbles are a reliable driver for the behavior of the currencies under examination. The first model used is the simplest one and uses to different regimes: *Collapse* and *Survive.* In the latter the bubble continues to exists, and in the former the bubble collapses trying to return to the fundamental values. The second model (Model 2) is a generalization of Model 1 and includes an explanatory variable that enters in the return and the probability equations. Following the Early Warning system literature we use four variables that have been identified as currency crises indicators; *Imports, Exports; International Reserves and*

Interest Rates. Additionally we propose a specification that includes the annual variation of the West Texas Intermediate oil price. Finally the third model proposed (Model 3) is an extension of Model 2 allowing for a third regime (*Dormant*); in this regime the bubble will continue to grow at a steady rate and without explosive expectations.

The estimations results for the three currencies analyzed are mixed. First of all, it is important to highlight that for the three markets studied Model 3 is the preferred one. Model 3 when compared to both Model 1 and Model 2 through the use of the LR test, shows to be the best one for almost all the currencies. Model 3 was the one which better fitted our data. For that reason this model was the focus of our analysis. The results show that the difference between the actual prices and the fundamental ones (Bubble size) is an important predictor of returns.

The results obtained for each one of the currencies studied show that the speculative bubbles have explanatory power for the next period return. Yet the results do not have either statistically or economic significance for all the variables. As the bubble grows in size, the probability of remaining in the *Dormant* regime decreases and therefore the probability of entering in the explosive state increases. The expected returns in this state must compensate the higher risk exposure due to the higher likelihood of bubble collapse. Results for the Colombian Peso show that the bubble size is a good predictor of the future returns, for the three variations of Model 3 the economic significance is observed for almost all the models and in many cases the statistically significance is also considerably high. The probability of entering in the explosive state is better explained by the models that consider both *Bubble 1* and *Bubble 2*, however it lacks of statistically significance. Once the variable is in the explosive state, it is expected that the returns are higher than in the steady state. This phenomenon is well captured by the model using the third bubble measure, however the statistically significance is just observed for the specification using the variable *Exports*. According to these results the model which better describes the speculative behavior for the Colombian Peso is Model 3 with the *Bubble 3* measure and incorporating the variable *Exports.*

Results for the Mexican Peso show that the bubble size is also a good predictor of future returns, for the *Bubble 1* and *Bubble 3* measures, we observe economic significance for almost all the models and in many cases the statistically significance is also considerable high. The probability of entering in the explosive state is better explained by the model that considers the *Bubble 1* measure with a high statistical significance. The performance of the expected returns in the explosive state is better capture by the model using the *Bubble 1* measure, however only with the statistically significance for the variable *Interest Rate*. According to these results the model which better describes the speculative behavior for the Mexican Peso is the Model 3 with the first bubble measure and incorporating both variables *Imports* and *WTI.*

Results for the Brazilian Real are in line with the results obtained for the Mexican Peso, the models that better predict future returns regarding the speculative factor are the *Bubble 1* and *Bubble 3*, where the financial meaningful is accomplished for almost all the models and in many cases the statistically significance is considerable high. Similar results are obtained for the probability of entering in the explosive state and the expected returns in the explosive state. According to these results the model which better describes the speculative behavior for the Brazilian Real are the Model 3 with the *Bubble 1* and *Bubble 3* measures with the variables *Interest Rates* and *WTI.*

We find evidence that the probability of being in the steady state for all of the currencies studied is low, suggesting that the three currencies spend most of the time in the explosive regime, namely in the *Survive* regime with some periods in which the variable switches to the *Collapse* regime.

Furthermore, we also found that the use of the spread of the 3-month average of actual returns above the 3-month average of fundamental returns cannot help predict when a bubble will enter in the explosive state. These results differ to the ones obtained by Panopoulou and Pantelidis (2015) and Brooks and Katsaris (2004). This could stem from differences in sample size and the size used for the calculation of the spread. In contrast, the results of the specifications that include the variable *WTI* are stable for all the currencies with both economic and statistical significance.

When evaluating the ability of our models to predict large movements on the exchange rate, either positive or negative, the results show that our model has a decent performance in this field, capturing the main events in all the currencies. Furthermore, the results show some spikes in the probabilities of a crash and of a boom were not recognized by the market. These results are in line with Brooks and Katsaris (2004), and are in favor of the speculative behavior model, since if the time of the crash or the boom could be forecasted with great accuracy, this would rule out speculative bubbles: if investors knew what the future will be, they would react in advance, and the prices would not deviate from fundamental values.

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Annexes

Table 8: Recursive right-tailed augmented Dickey-Fuller test of bubble detection, Mexican Peso.

		Critical Values		
		10%	5%	1%
	Statistic			
GASDF	2,6964 **	1,8767	2,1502	2,7498

Note: Null Hypothesis, No bubble in the exchange rate
*** Rejection of the Null Hypothesis at 1% confident level

Table 9: Recursive right-tailed augmented Dickey-Fuller test of bubble detection, Brazilian Real.

		Critical Values		
		90%	95%	99%
	Statistic			
GASDF	3,8795 ***	1,8767	2,1502	2,7498

Note: Null Hypothesis, No bubble in the exchange rate
*** Rejection of the Null Hypothesis at 1% confident level

Table 10: Estimates of the exchange rate determination models for the Mexican Peso

	Bubble 1		Bubble 2		Bubble 3
δ_0^A	3.1875	δ_0^B	3.1143	δ_0^c	3.1012
	(0.0256)***		(0.1385)***		(0.1524)***
δ_1^A	0.8362	δ_1^B	0.2159	δ_1^c	0.2114
	(0.0264)***		(0.0533)***		(0.0578)***
		δ_2^B	1.2823	δ_2^c	1.2982
			(0.1617)***		(0.1791)***
		δ_3^B	-0.0062	δ_3^c	-0.0060
			(0.0014)***		(0.0019)***
				δ_4^c	-0.0472
					(0.2270)

Notes: Standard errors are reported in parentheses.
*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 11: Estimates of the exchange rate determination models for the Brazilian Real

	Bubble 1		Bubble 2		Bubble 3
δ_0^A	-1.7239	δ_0^B	0.9443	δ_0^c	0.7389
	(0.3882)***		(0.1911)***		(0.1807)***
δ_1^A	1.5216	δ_1^B	-0.5287	δ_1^c	-0.6895
	(0.1556)***		(0.0874)***		(0.0852)***
		δ_2^B	-1.1429	δ_2^c	-0.8576
			(0.3818)***		(0.3579)**
		δ_3^B	24.6557	δ_3^c	26.2098
			(1.7945)***		(1.6869)***
				δ_4^c	-2.4841
					(0.3959)***

Notes: Standard errors are reported in parentheses.
*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 12: Regime Classification Measure USD_MXN

	Bubble 1	Bubble 2	Bubble 3
Model 1	19.1875	24.9672	25.1300
Model 2			
Exports	36.4646	84.6522	84.6330
Imports	34.9041	84.7141	84.7076
International Reserves	41.1647	84.0347	84.0487
Interest Rates	40.3990	80.6387	80.7287
WTI	44.4620	69.2777	69.1913
Model 3			
Exports	6.9009	0.0004	0.0044
Imports	1.0728	0.0001	9.8075
International Reserves	4.6626	2.1472	2.2318
Interest Rates	1.2349	2.1677	2.2558
WTI	0.4900	0.0000	0.0000

Table 13: Regime Classification Measure USD_BRL

	Bubble 1	Bubble 2	Bubble 3
Model 1	5.6699	5.7498	2.2274
Model 2			
Exports	20.9012	32.3063	27.5163
Imports	31.1111	33.4327	35.4985
International Reserves	43.2757	34.5935	34.2133
Interest Rates	52.0291	33.8491	49.5643
WTI	39.4739	49.2239	51.5203
Model 3			
Exports	1.1110	1.7565	3.1827
Imports	1.9086	2.0677	7.6486
International Reserves	2.8111	0.0000	0.0370
Interest Rates	0.6627	1.3280	1.2278
WTI	2.6986	1.9904	0.3690

Table 14: LR Statistic USD_MXN

	Model 1 vs. Model 2		Model 1 vs. Model 3		Model 2 vs. Model 3	
	LR	p-Value	LR	p-Value	LR	p-Value
Bubble 1						
Exports	0.006	0.939	23.372	0.000	23.378	0.000
Imports	0.356	0.551	21.605	0.000	21.249	0.000
International Reserves	1.787	0.181	14.719	0.001	16.506	0.000
Interest Rates	0.435	0.509	24.410	0.000	24.845	0.000
WTI	2.026	0.155	13.182	0.001	15.208	0.000
Bubble 2						
Exports	8.101	0.004	15.549	0.000	23.650	0.000
Imports	8.410	0.004	19.293	0.000	27.704	0.000
International Reserves	8.578	0.003	18.972	0.000	27.550	0.000
Interest Rates	9.007	0.003	15.525	0.000	24.532	0.000
WTI	9.007	0.003	27.442	0.000	30.693	0.000
Bubble 3						
Exports	7.890	0.005	15.269	0.000	23.159	0.000
Imports	8.201	0.004	10.652	0.005	18.853	0.000
International Reserves	8.353	0.004	19.569	0.000	27.922	0.000
Interest Rates	8.820	0.003	16.138	0.000	24.958	0.000
WTI	3.097	0.078	26.896	0.000	29.993	0.000

Table 15: LR Statistic USD_BRL

	Model 1 vs. Model 2		Model 1 vs. Model 3		Model 2 vs. Model 3	
	LR	p-Value	LR	p-Value	LR	p-Value
Bubble 1						
Exports	15.370	0.000	86.319	0.000	101.690	0.000
Imports	31.492	0.000	63.261	0.000	94.753	0.000
International Reserves	104.858	0.000	17.703	0.000	122.561	0.000
Interest Rates	60.917	0.000	3.892	0.143	64.809	0.000
WTI	96.257	0.000	16.959	0.000	113.215	0.000
Bubble 2						
Exports	56.219	0.000	85.100	0.000	141.319	0.000
Imports	58.441	0.000	12.217	0.002	70.658	0.000
International Reserves	56.279	0.000	41.828	0.000	98.108	0.000
Interest Rates	51.521	0.000	79.601	0.000	131.123	0.000
WTI	51.521	0.000	75.893	0.000	146.297	0.000
Bubble 3						
Exports	39.623	0.000	59.502	0.000	99.125	0.000
Imports	63.530	0.000	34.329	0.000	97.859	0.000
International Reserves	41.897	0.000	68.908	0.000	110.805	0.000
Interest Rates	80.457	0.000	80.707	0.000	161.163	0.000
WTI	87.282	0.000	65.526	0.000	152.809	0.000

Table 16: Estimations Model 1 USD_COP

	Bubble 1	Bubble 2	Bubble 3
β_{c0}	0.0128	0.0128	-0.0015
	(0.0053)***	(0.0060)**	(0.0022)
β_{c1}	-0.0167	0.0047	-0.0525
	(0.0316)	(0.0376)	(0.0277)*
β_{s0}	-0.0012	-0.0015	0.0122
	(0.0022)	(0.0023)	(0.0059)**
β_{s1}	-0.0060	-0.0475	0.0123
	(206.456)	(0.0280)*	(0.0395)
σ_c^2	0.0464	0.0474	0.0194
	(0.0859)***	(0.0913)***	(0.1045)***
σ_s^2	0.0183	0.0195	0.0473
	(0.1084)***	(0.1064)***	(0.0887)***
β_{q1}	1.6850	1.9230	2.4208
	(0.4644)***	(0.7419)***	(0.5506)***

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 17: Estimations Model2_Bubble1 USD_COP

	Exports	Imports	International Reserves	Interest Rate	WTI
β_{s0}	0.0777	0.0342	0.0354	0.0805	0.0448
	(0.0139)***	(0.0073)***	(0.0071)***	(0.0132)***	(0.0120)***
β_{s1}	0.0059	0.1057	0.1058	-0.0027	0.1263
	(0.0719)	(0.0358)***	(0.0341)***	(0.0798)	(0.0546)**
β_{c0}	0.0124	0.0390	0.0345	-0.0051	-0.0093
	(0.0057)**	(0.0060)***	(0.0057)***	(0.0039)	(0.0051)*
β_{c1}	-0.0322	-0.0314	-0.0140	-0.0036	0.0227
	(0.0166)*	(0.0126)**	(0.0146)	(0.0136)	(0.0225)
β_{c2}	0.0000	0.0000	0.0000	0.0477	0.0197
	(0.0000)**	(0.0000)***	(0.0000)***	(0.0258)*	(0.0077)**
σ_s^2	0.0202	0.0349	0.0340	0.0187	0.0316
	(0.0071)***	(0.0034)***	(0.0032)***	(0.0073)***	(0.0041)***
σ_c^2	0.0288	0.0257	0.0250	0.0293	0.0287
	(0.0016)***	(0.0016)***	(0.0017)***	(0.0015)***	(0.0022)***
β_{q0}	1.8581	3.6695	2.3204	1.4116	0.9302
	(0.8279)**	(1.1511)***	(0.7382)***	(0.4165)***	(0.4714)**
β_{q1}	0.2034	3.0352	4.7736	0.8493	7.0121
	(1.8366)	(2.0044)	(1.6930)***	(1.1696)	(2.3500)***
β_{q2}	-0.0001	-0.0010	0.0000	1.8768	2.0411
	(0.0002)	(0.0003)***	(0.0000)***	(4.7670)	(0.7542)***

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 18: Estimations Model2_Bubble2 USD_COP

	Exports	Imports	International Reserves	Interest Rate	WTI
$\boldsymbol{\beta_{s0}}$	0.0105	0.0139	0.0154	0.0725	0.0848
	(0.0053)**	(0.0063)**	(0.0059)***	(0.0215)***	(0.0274)***
$\boldsymbol{\beta_{s1}}$	0.0917	0.0925	0.0820	-0.0942	-0.1384
	(0.0366)***	(0.0363)**	(0.0364)**	(0.0626)	(0.0926)
$\boldsymbol{\beta_{c0}}$	0.0366	0.0318	0.0310	-0.0089	-0.0013
	(0.0065)***	(0.0065)***	(0.0067)***	(0.0038)**	(0.0026)
$\boldsymbol{\beta_{c1}}$	-0.0683	-0.0512	-0.0299	-0.0886	-0.0927
	(0.0218)***	(0.0218)**	(0.0242)	(0.0263)***	(0.0304)***
$\boldsymbol{\beta_{c2}}$	0.0000	0.0000	0.0000	0.0511	0.0034
	(0.0000)***	(0.0000)***	(0.0000)***	(0.0210)**	(0.0073)
$\boldsymbol{\sigma_s^2}$	0.0374	0.0363	0.0366	0.0271	0.0266
	(0.0029)***	(0.0033)***	(0.0031)***	(0.0090)***	(0.0089)***
$\boldsymbol{\sigma_c^2}$	0.0248	0.0254	0.0245	0.0276	0.0299
	(0.0016)***	(0.0017)***	(0.0020)***	(0.0015)***	(0.0015)***
$\boldsymbol{\beta_{q0}}$	4.0802	3.4230	2.6166	1.3604	1.9785
	(1.8349)**	(1.1731)***	(0.8488)***	(0.3637)***	(0.5114)***
$\boldsymbol{\beta_{q1}}$	-1.1275	2.0370	4.6549	-6.1969	-6.2137
	(1.7629)	(1.9691)	(2.4094)*	(1.2793)***	(2.8292)**
$\boldsymbol{\beta_{q2}}$	-0.0015	-0.0011	-0.0001	1.4787	1.1185
	(0.0006)**	(0.0003)***	(0.0000)***	(2.4102)	(1.0952)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 19: Estimations Model2_Bubble3 USD_COP

	Exports	**Imports**	**International Reserves**	**Interest Rate**	**WTI**
$\boldsymbol{\beta_{s0}}$	0.06942	0.0134	0.0152	0.0725	0.0906
	(0.0216)***	(0.0061)**	(0.0057)***	(0.0234)***	(0.0292)***
$\boldsymbol{\beta_{s1}}$	-0.0892	0.0991	0.0830	-0.0987	-0.1701
	(0.0711)	(0.0381)***	(0.0383)**	(0.0727)	(0.1089)
$\boldsymbol{\beta_{c0}}$	0.0058	0.0320	0.0310	-0.0084	-0.0010
	(0.0042)	(0.0065)***	(0.0067)***	(0.0039)**	(0.0024)
$\boldsymbol{\beta_{c1}}$	-0.0876	-0.0473	-0.0292	-0.0785	-0.0823
	(0.0259)***	(0.0213)**	(0.0239)	(0.0260)***	(0.0024)***
$\boldsymbol{\beta_{c2}}$	0.0000	0.0000	0.0000	0.0495	0.0061
	(0.0000)**	(0.0000)***	(0.0000)***	(0.0223)**	(0.0068)
$\boldsymbol{\sigma_s^2}$	0.0283	0.0365	0.0369	0.0272	0.0262
	(0.0091)***	(0.0032)***	(0.0030)***	(0.0094)***	(0.0089)***
$\boldsymbol{\sigma_c^2}$	0.0282	0.0254	0.0244	0.0278	0.0303
	(0.0014)***	(0.0017)***	(0.0020)***	(0.0015)***	(0.0014)***
$\boldsymbol{\beta_{q0}}$	2.4482	3.4248	2.6025	1.3912	2.1545
	(0.8134)***	(1.1665)***	(0.8410)***	(0.3774)***	(0.5467)***
$\boldsymbol{\beta_{q1}}$	-7.9631	2.2549	4.7277	-6.4189	-7.2451
	(1.7304)***	(2.1207)	(2.5112)*	(1.4051)	(3.3392)**
$\boldsymbol{\beta_{q2}}$	-0.0002	-0.0011	-0.0001	1.3038	1.2496
	(0.0001)*	(0.0003)***	(0.0000)***	(2.4022)	(1.0782)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 20: Estimations Model3_Bubble1 USD_COP

	Exports	Imports	International Reserves	Interest Rate	WTI
β_{d0}	0.0747	0.0320	0.0310	0.0787	0.0132
	(0.0913)***	(0.0110)***	(0.0100)***	(0.0098)***	(0.0037)***
β_{s0}	0.0776	-0.0781	-0.0778	0.0920	-0.0806
	(2.9824)	(0.0073)***	(0.0075)***	(1.8364)	(0.0080)***
β_{s1}	0.0047	-0.3139	-0.3148	0.0111	-0.1806
	(2.6424)	(0.0356)***	(0.0367)***	(3.1489)	(0.1223)
β_{c0}	0.0124	0.0232	0.0212	-0.0051	-0.0015
	(0.0437)	(0.0066)***	(0.0074)***	(0.0076)	(0.0020)
β_{c1}	-0.0322	-0.0247	-0.0115	-0.0035	-0.0179
	(0.0604)	(0.0133)*	(0.0137)	(0.0194)	(0.0093)*
β_{c2}	0.0000	0.0000	0.0000	0.0478	-0.0229
	(0.0000)*	(0.0000)***	(0.0000)***	(0.0387)	(0.0074)***
σ_d^2	0.0213	0.0325	0.0327	0.0159	0.0392
	(0.0169)***	(0.0058)***	(0.0053)***	(0.0058)***	(0.0026)***
σ_s^2	0.0200	0.0142	0.0142	0.0230	0.0076
	(0.4909)	(0.0029)***	(0.0029)***	(0.9018)	(0.0142)
σ_c^2	0.0288	0.0180	0.0178	0.0293	0.0127***
	(0.0068)***	(0.0020)***	(0.0020)***	(0.0028)***	(0.0021)
$\beta_{\eta 0}$	1.8266	-0.5668	-0.5290	1.6326	-0.0661
	(96.1823)	(0.2773)**	(0.2702)*	(18.1433)	(0.2169)
$\beta_{\eta 1}$	0.1936	-1.1144	-1.1410	0.8271	-0.6533
	(23.9415)	(0.8904)	(0.8958)	(4.5814)	(0.7956)
$\beta_{\eta 2}$	0.0000	14.5539	14.9714	1.713068	29.8236
	(3.2524)	(6.9767)**	(6.8653)**	(12.5372)	(12.7194)**
β_{q0}	-0.0852	3.4085	3.1862	0.7614	17.2644
	(249.444)	(1.3231)**	(1.1898)***	(96.9603)	(52.1953)
β_{q1}	-0.0348	3.8078	5.5079	0.2582	26.0680
	(75.284)	(2.5957)	(2.7503)**	(40.7893)	(75.2304)
β_{q2}	0.0000	-0.0009	-0.0001	0.0000	39.3943
	(0.0004)	(0.0004)**	(0.0000)**	(2.1744)	(122.175)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 21: Estimations Model3_Bubble2 USD_COP

	Exports	Imports	International Reserves	Interest Rate	WTI
$\boldsymbol{\beta_{d0}}$	0.0387	0.0407	0.0260	0.0426	0.0096
	(0.0122)***	(0.0115)***	(0.0100)***	(0.0141)***	(0.0060)
$\boldsymbol{\beta_{s0}}$	-0.0071	-0.0029	-0.0008	-0.0019	0.0124
	(0.0049)	(0.0047)	(0.0049)	(0.0027)	(0.0079)
$\boldsymbol{\beta_{s1}}$	-0.1025	-0.0646	-0.0574	-0.0368	0.0088
	(0.0614)*	(0.0632)	(0.0577)	(0.0284)	(0.0424)
$\boldsymbol{\beta_{c0}}$	0.0332	0.0272	0.0332***	-0.0161	-0.0046
	(0.0072)***	(0.0055)***	(0.0063)	(0.0115)	(0.0020)**
$\boldsymbol{\beta_{c1}}$	-0.0759	-0.0579	-0.0589	-0.1636	-0.0855
	(0.0270)***	(0.0221)***	(0.0335)*	(0.0611)***	(0.0307)***
$\boldsymbol{\beta_{c2}}$	0.0000	0.0000	0.0000	0.1433	-0.0285
	(0.0000)***	(0.0000)***	(0.0000)***	(0.1125)	(0.0059)***
$\boldsymbol{\sigma_d^2}$	0.0355	0.0355	0.0450	0.0340	0.0402
	(0.0076)***	(0.0074)***	(0.0060)***	(0.0099)***	(0.0041)***
$\boldsymbol{\sigma_s^2}$	0.0225	0.0212	0.0223	0.0140	0.0421
	(0.0026)***	(0.0024)***	(0.0029)***	(0.0029)***	(0.0037)***
$\boldsymbol{\sigma_c^2}$	0.0212	0.0218	0.0217	0.0341	0.0121
	(0.0021)***	(0.0016)***	(0.0018)***	(0.0033)***	(0.0017)***
$\boldsymbol{\beta_{\eta0}}$	-0.8620	-0.9036	-0.7983	-1.3879	-2.9158
	(0.3063)***	(0.2752)***	(0.2924)***	(0.7278)**	(2.2652)
$\boldsymbol{\beta_{\eta1}}$	4.3212	4.4743	5.1705	6.9241	-35.3813
	(1.2209)***	(1.2123)***	(1.7875)***	(2.9098)**	(26.7446)
$\boldsymbol{\beta_{\eta2}}$	9.8777	12.9842	22.0651	2.8739	97.0400
	(8.4562)	(8.7933)	(11.8382)*	(10.2239)	(72.5725)
$\boldsymbol{\beta_{q0}}$	4.7332	610.960	11.0868	0.7186	0.1826
	(3.7781)	(16.6206)***	(11.2241)	(10.2239)	(0.3037)
$\boldsymbol{\beta_{q1}}$	19.0990	2435.25	49.1152	0.8524	-8.2778
	(16.6394)	(88.7486)***	(49.4953)	(3.3896)	(3.7235)**
$\boldsymbol{\beta_{q2}}$	-0.0015	-0.1568	0.0003	-4.0074	-0.3868
	(0.0011)	(0.0043)***	(0.0003)	(1.9295)**	(0.7312)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 22: Estimations Model 1 USD_MXN

	Bubble 1	**Bubble 2**	**Bubble 3**
$\boldsymbol{\beta_{c0}}$	-0.0066	0.0013	0.0013
	(0.0194)	(0.0014)	(0.0015)
$\boldsymbol{\beta_{c1}}$	0.2004	0.0598	0.0596
	(0.1583)	(0.0.151)***	(0.0151)***
$\boldsymbol{\beta_{s0}}$	0.0025	0.0151	0.0151
	(0.0016)	(0.0090)	(0.0111)
$\boldsymbol{\beta_{s1}}$	0.0598	-0.0106	-0.0118
	(0.0219)***	(0.0581)	(0.1117)
$\boldsymbol{\sigma_c^2}$	0.0516	0.0178	0.0178
	(0.1608)***	(0.0805)***	(0.0825)***
$\boldsymbol{\sigma_s^2}$	0.0199	0.0503	0.0503
	(0.0624)***	(0.1265)***	(0.0.1287)***
$\boldsymbol{\beta_{q1}}$	0.2424	0.0151	2.3187
	(0.9607)	(0.0090)*	(0.5527)***

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 23: Estimations Model2_Bubble1 USD_MXN

	Exports	**Imports**	**International Reserves**	**Interest Rate**	**WTI**
$\boldsymbol{\beta_{s0}}$	0.0171	0.0173	0.0168	0.0162	0.0164
	(0.0182)	(0.0178)	(0.0183)	(0.0185)	(0.0186)
$\boldsymbol{\beta_{s1}}$	0.0369	0.0356	0.0404	0.0497	0.0518
	(0.1585)	(0.1551)	(0.1597)	(0.1649)	(0.1677)
$\boldsymbol{\beta_{c0}}$	0.0047	0.0046	0.0017	0.0014	0.0000
	(0.0042)	(0.0042)	(0.0033)	(0.0032)	(0.0020)
$\boldsymbol{\beta_{c1}}$	0.0266	0.0230	0.0303	0.0311	0.0276
	(0.0266)	(0.0266)	(0.0282)	(0.0272)	(0.0259)
$\boldsymbol{\beta_{c2}}$	0.0000	-0.0002	0.0000	-0.0001	-0.0040
	(0.0000)	(0.0002)	(0.0000)	(0.0001)	(0.0056)
$\boldsymbol{\sigma_s^2}$	0.0465	0.0462	0.0462	0.0471	0.0480
	(0.0049)***	(0.0047)***	(0.0050)***	(0.0054)***	(0.0059)***
$\boldsymbol{\sigma_c^2}$	0.0.0183	0.0183	0.0181	0.0181	0.0180
	(0.0011)***	(0.0011)***	(0.0012)***	(0.0012)***	(0.0012)***
$\boldsymbol{\beta_{q0}}$	2.1526	2.3929	1.4288	0.8756	1.0934
	(0.8442)**	(0.8972)***	(0.5774)**	(0.3907)**	(0.3363)***
$\boldsymbol{\beta_{q1}}$	-15.2121	-16.1545	-13.1368	-13.6658	-10.3025
	(5.4159)***	(5.8109)	(4.9004)***	(5.2439)***	(5.0759)**
$\boldsymbol{\beta_{q2}}$	0.0000	-0.0520	0.0000	0.0270	0.1857
	(0.0000)	(0.0311)*	(0.0000)	(0.0279)	(0.8421)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 24: Estimations Model2_Bubble2 USD_MXN

	Exports	Imports	International Reserves	Interest Rate	WTI
β_{s0}	0.0112	0.0121	0.0122	0.0135	0.0157
	(0.0064)*	(0.0064)*	(0.0065)*	(0.0074)*	(0.0087)*
β_{s1}	0.0167	0.0183	0.0170	0.0222	0.0122
	(0.0689)	(0.0696)	(0.0707)	(0.0841)	(0.0944)
β_{c0}	0.0034	0.0029	0.0012	-0.0002	0.0000
	(0.0041)	(0.0042)	(0.0029)	(0.0025)	(0.0018)
β_{c1}	0.0522	0.0505	0.0533	0.0434	0.0447
	(0.0186)***	(0.0186)***	(0.0185)***	(0.0183)**	(0.0188)**
β_{c2}	0.0000	-0.0001	0.0000	0.0000	-0.0056
	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0055)
σ_s^2	0.0417	0.0417	0.0420	0.0433	0.0452
	(0.0033)***	(0.0033)***	(0.0033)***	(0.0037)***	(0.0046)***
σ_c^2	0.0141	0.0142	0.0143	0.0151	0.0160
	(0.0015)***	(0.0015)***	(0.0015)***	(0.0015)***	(0.0014)***
β_{q0}	0.3784	0.4305	0.3512	0.5771	0.6249
	(0.3983)	(0.3968)	(0.3208)	(0.2873)**	(0.2275)***
β_{q1}	-3.6218	-3.5789	-3.6551	-3.2025	-1.7861
	(1.9427)***	(1.9589)*	(2.0093)*	(2.0595)	(2.2495)
β_{q2}	0.0000	-0.0016	0.0000	-0.0057	1.0014
	(0.0000)	(0.0170)	(0.0000)	(0.0176)	(0.6103)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 25: Estimations Model2_Bubble3 USD_MXN

	Exports	Imports	International Reserves	Interest Rate	WTI
$\boldsymbol{\beta_{s0}}$	0.0121	0.0122	0.0123	0.0135	0.0158
	(0.0064)*	(0.0064)*	(0.0065)*	(0.0074)*	(0.0087)*
$\boldsymbol{\beta_{s1}}$	0.0158	0.0173	0.0159	0.0211	0.0112
	(0.0693)	(0.0699)	(0.0709)	(0.0839)	(0.0950)
$\boldsymbol{\beta_{c0}}$	0.0034	0.0029	0.0013	-0.0002	0.0000
	(0.0041)	(0.0042)	(0.0029)	(0.0025)	(0.0018)
$\boldsymbol{\beta_{c1}}$	0.0523	0.0506	0.0536	0.0437	0.0447
	(0.0185)***	(0.0185)***	(0.0184)***	(0.0182)**	(0.0187)***
$\boldsymbol{\beta_{c2}}$	0.0000	-0.0001	0.0000	0.0000	-0.0055
	(0.0000)**	(0.0001)	(0.0000)	(0.0000)	(0.0055)
$\boldsymbol{\sigma_s^2}$	0.0418	0.0417	0.0421	0.0433	0.0453
	(0.0033)***	(0.0033)***	(0.0034)***	(0.0037)***	(0.0046)***
$\boldsymbol{\sigma_c^2}$	0.0142	0.0142	0.0143	0.0150	0.0160
	(0.0015)***	(0.0033)***	(0.0015)***	(0.0015)***	(0.0014)***
$\boldsymbol{\beta_{q0}}$	0.3825	0.4338	0.3519	0.5760	0.6280
	(0.3978)	(0.3962)	(0.3202)	(0.2870)***	(0.2274)***
$\boldsymbol{\beta_{q1}}$	-3.5910	-3.5523	-3.6341	-3.1931	-1.7539
	(1.9389)*	(1.9545)*	(2.0037)*	(2.0511)	(2.2526)
$\boldsymbol{\beta_{q2}}$	0.0000	-0.0017	0.0000	-0.0057	1.0010
	(0.0000)**	(0.0170)	(0.0000)	(0.0175)	(0.6108)*

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 26: Estimations Model3_Bubble2 USD_MXN

	Exports	Imports	International Reserves	Interest Rate	WTI
β_{d0}	0.0045	0.0052	0.0050	0.0051	0.0053
	(0.0025)*	(0.0026)*	(0.0030)*	(0.0031)*	(0.0030)*
β_{s0}	0.0275	0.0283	0.1758	0.1758	0.1749
	(0.0234)	(0.0309)	(0.0268)***	(0.0296)***	(0.0235)***
β_{s1}	0.0486	0.0493	-0.7444	-0.7635	-0.7437
	(0.2988)	(0.4070)	(0.2008)***	(0.2152)***	(0.1876)***
β_{c0}	0.0077	0.0073	0.0028	-0.0045	-0.0023
	(0.0057)	(0.0050)	(0.0036)	(0.0034)	(0.0027)
β_{c1}	0.0469	0.0586	0.0591	0.0481	0.0409
	(0.0304)	(0.0252)**	(0.0233)**	(0.0238)**	(0.0257)
β_{c2}	0.0000	-0.0005	0.0000	0.0001	-0.0072
	(0.0000)***	(0.0002)**	(0.0000)**	(0.0002)	(0.0066)
σ_d^2	0.0240	0.0254	0.0286	0.0287	0.0284
	(0.0015)***	(0.0018)***	(0.0023)***	(0.0023)***	(0.0021)***
σ_s^2	0.0591	0.0661	0.0104	0.0104	0.0101
	(0.0129)***	(0.0215)***	(0.0088)	(0.0115)	(0.0087)
σ_c^2	0.0096	0.0089	0.0108	0.0112	0.0113
	(0.0017)***	(0.0016)***	(0.0017)***	(0.0019)***	(0.0019)***
$\beta_{\eta 0}$	0.5124	0.4068	0.1626	0.1672	0.1683
	(0.2527)**	(0.2383)*	(0.2567)	(0.2775)	(0.2425)
$\beta_{\eta 1}$	3.5077	3.5365	4.2680	4.4104	4.2933
	(2.0341)*	(2.0756)*	(2.1105)**	(2.2590)*	(2.1194)**
$\beta_{\eta 2}$	-22.6815	-8.7449	10.5044	9.7354	15.3677
	(13.8810)	(12.9450)	(16.1810)	(16.422)	(17.6931)
β_{q0}	285.763	15154.9	3.0556	2.3186	520.390
	(239990)	(248.086)***	(1.3356)**	(2.8331)	(5.3200)
β_{q1}	-1741.99	-90751	-24.874	-24.869	-7157.30
	(143278)	(112369)	(19.8204)	(18.0382)	(7.2400)
β_{q2}	-0.0105	-496.853	0.0000	0.0079	1129.77
	(8.8015)	(0.0009)***	(0.0000)	(0.2535)	(1.1400)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 27: Estimations Model3_Bubble3 USD_MXN

	Exports	Imports	International Reserves	Interest Rate	WTI
β_{d0}	0.0047	0.0219	0.0050	0.0051	0.0053
	(0.0025)*	(0.0144)	(0.0030)**	(0.0031)**	(0.0029)**
β_{s0}	0.0280	0.0035	0.1730	0.1728	0.1716
	(0.0249)	(0.0028)	(0.0238)***	(0.0264)***	(0.0214)***
β_{s1}	0.0452	0.0024	-0.7363	-0.7333	-0.7147
	(0.3127)	(0.0297)	(0.1731)***	(0.1857)***	(0.1969)***
β_{c0}	0.0075	0.0091*	0.0029	-0.0045	-0.0027
	(0.0056)	(0.0054)	(0.0036)	(0.0034)	(0.0028)
β_{c1}	0.0466	0.0695	0.0596	0.0483	0.0379
	(0.0300)	(0.0257)	(0.0232)**	(0.0236)**	(0.0262)
β_{c2}	0.0000	-0.0006	0.0000*	0.0001	-0.0067
	(0.0000)***	(0.0002)**	(0.0000)	(0.0002)	(0.0067)
σ_d^2	0.0242	0.0552	0.0287	0.0287	0.0281
	(0.0015)***	(0.0117)***	(0.0023)***	(0.0024)***	(0.0020)***
σ_s^2	0.0604	0.0228	0.0097	0.0097	0.0093
	(0.0147)***	(0.0024)***	(0.0082)	(0.0104)	(0.0057)
σ_c^2	0.0095	0.0079	0.0108	0.0112	0.0112
	(0.0017)***	(0.0020)***	(0.0017)***	(0.0018)***	(0.0019)***
$\beta_{\eta 0}$	0.4864	-1.6108	0.1522	0.1550	0.2144
	(0.2446)**	(0.4345)***	(0.2551)	(0.2763)	(0.2277)
$\beta_{\eta 1}$	3.5154	2.3491	4.1772	4.3460	4.4972
	(2.0689)*	(2.5023)	(2.1067)**	(2.2672)*	(2.1359)**
$\beta_{\eta 2}$	-17.6550	46.938	11.9147	11.3548	14.4716
	(12.2023)	(26.516)*	(16.4338)	(16.7520)	(17.8845)
β_{q0}	198.218	-0.3659	2.9660	2.2673	79.4292
	(11443.4)	(0.6371)	(1.3837)**	(2.5564)	(6.4800)
β_{q1}	-1231.38	-5.3678	-23.8249	-23.7734	-1195.58
	(70580.4)	(2.8769)**	(18.8122)	(16.9430)	(1.0600)
β_{q2}	-0.0072	-0.0137	0.0000	0.0073	238.735
	(0.4241)	(0.0242)	(0.0000)	(0.2357)	(2.1400)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 28: Estimations Model1 USD_BRL

	Bubble 1	Bubble 2	Bubble 3
β_{c0}	0.0045	0.0082	0.0081
	(0.0045)	(0.0004)***	(0.0005)***
β_{c1}	0.0147	0.0032	0.0033
	(0.0076)*	(0.0006)***	(0.0008)***
β_{s0}	0.0090	0.0042	0.0044
	(0.0068)***	(0.0047)	(0.0047)
β_{s1}	0.0627	0.0131	0.0125
	(0.0513)***	(0.0101)	(0.0107)
σ_c^2	0.0464	0.0014	0.0015
	(0.0513)***	(0.1123)***	(0.1172)***
σ_s^2	0.0014	0.0631	0.0633
	(0.1174)***	(0.0514)***	(0.0516)***
β_{q1}	3.1453	-0.1187	-0.9916
	(0.4919)***	(0.3330)	(1.6138)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 29: Estimations Model2_Bubble1 USD_BRL

	Exports	Imports	International Reserves	Interest Rate	WTI
β_{s0}	0.0044	0.0058	0.0316	0.0058	0.0280
	(0.0061)	(0.0064)	(0.0365)	(0.0067)	(0.0408)
β_{s1}	0.0147	0.0143	0.0227	0.0162	0.0253
	(0.0070)**	(0.0075)*	(0.0403)	(0.0078)**	(0.0483)
β_{c0}	0.0083	0.0001	-0.0018	-0.0163	0.0022
	(0.0006)***	(0.0001)	(0.0044)	(0.0011)***	(0.0024)
β_{c1}	0.0065	-0.0274	0.0012	-0.0209	0.0019
	(0.0012)***	(0.0022)***	(0.0060)	(0.0016)***	(0.0044)
β_{c2}	0.0000	0.0000	0.0000	0.5462	-0.0194
	(0.0000)**	(0.0000)***	(0.0000)	(0.0454)***	(0.0073)***
σ_s^2	0.0623	0.0642	0.1226	0.0655	0.1274
	(0.0011)***	(0.0012)***	(0.0114)***	(0.0012)***	(0.0117)***
σ_c^2	0.0011	0.0023	0.0290	0.0030	0.0289
	(0.0001)***	(0.0002)***	(0.0018)***	(0.0003)***	(0.0015)***
β_{q0}	0.4543	0.7618	1.5938	-2.1834	1.2344
	(0.3111)	(0.3149)**	(0.3741)***	(0.2262)***	(0.2028)***
β_{q1}	-3.1186	-3.2826	-0.9732	-1.2852	-0.8194
	(0.6035)***	(0.5646)***	(0.3222)***	(0.2956)***	(0.2059)***
β_{q2}	-0.0002	-0.0002	0.0000	103.716	1.2291
	(0.0000)	(0.0000)***	(0.0000)*	(10.6440)***	(0.5307)**

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 30: Estimations Model2_Bubble2 USD_BRL

	Exports	Imports	International Reserves	Interest Rate	WTI
β_{s0}	0.0034	0.0032	0.0032	0.0032	0.0046
	(0.0067)	(0.0067)	(0.0068)	(0.0061)	(0.0071)
β_{s1}	0.0171	0.0173	0.0173	0.0169	0.0167
	(0.0120)	(0.0121)	(0.0121)	(0.0110)	(0.0127)
β_{c0}	0.0093	0.0115	0.0099	-0.0007	-0.0042
	(0.0031)***	(0.0029)***	(0.0024)***	(0.0009)	(0.0013)***
β_{c1}	-0.0018	-0.0005	0.0001	0.0064	-0.0128
	(0.0022)	(0.0019)	(0.0019)	(0.0041)	(0.0019)***
β_{c2}	0.0000	0.0000	0.0000	0.5257	0.0076
	(0.0000)***	(0.0000)***	(0.0000)***	(0.1225)***	(0.0031)**
σ_s^2	0.0648	0.0649	0.0651	0.0635	0.0671
	(0.0015)***	(0.0015)***	(0.0015)***	(0.0013)***	(0.0016)***
σ_c^2	0.0039	0.0041	0.0041	0.0023	0.0055
	(0.0002)***	(0.0003)***	(0.0015)***	(0.0002)***	(0.0006)***
β_{q0}	-1.0987	-1.1158	-1.1906	-1.5560	-0.8946
	(0.4743)**	(0.4529)**	(0.3903)***	(0.2954)***	(0.1953)***
β_{q1}	-3.4953	-3.5026	-3.4871	-3.1510	-2.5905
	(0.8543)***	(0.8092)***	(0.7690)***	(0.8799)***	(0.5518)***
β_{q2}	0.0000	0.0000	0.0000	1.3217	0.4711
	(0.0000)	(0.0000)	(0.0000)	(29.7241)	(0.4199)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 31: Estimations Model2_Bubble3 USD_BRL

	Exports	Imports	International Reserves	Interest Rate	WTI
$\boldsymbol{\beta_{s0}}$	0.0046	0.0044	0.0049	0.0054	0.0284
	(0.0057)	(0.0063)	(0.0058)	(0.0067)	(0.0300)
$\boldsymbol{\beta_{s1}}$	0.0121	0.0132	0.0116	0.0137	0.0319
	(0.0104)	(0.0116)	(0.0105)	(0.0125)	(0.0628)
$\boldsymbol{\beta_{c0}}$	0.0060	0.0116	0.0104	-0.0066	0.0021
	(0.0009)***	(0.0021)***	(0.0007)***	(0.0016)***	(0.0025)
$\boldsymbol{\beta_{c1}}$	-0.0009	0.0000	0.0019	-0.0157	-0.0010
	(0.0013)	(0.0027)	(0.0011)	(0.0029)***	(0.0060)
$\boldsymbol{\beta_{c2}}$	0.0000	0.0000	0.0000	0.1173	-0.0212
	(0.0000)**	(0.0000)***	(0.0000)***	(0.1019)	(0.0073)***
$\boldsymbol{\sigma_s^2}$	0.0623	0.0642	0.0628	0.0659	0.1187
	(0.0011)***	(0.0015)***	(0.0013)***	(0.0017)***	(0.0132)***
$\boldsymbol{\sigma_c^2}$	0.0011	0.0034	0.0012	0.0044	0.0272
	(0.0001)***	(0.0003)***	(0.0001)***	(0.0006)***	(0.0017)***
$\boldsymbol{\beta_{q0}}$	-1.0149	-1.0541	-1.1901	-1.5897	0.9762
	(0.4597)**	(0.4285)**	(0.3463)***	(0.3145)***	(0.1870)***
$\boldsymbol{\beta_{q1}}$	-3.0138	-3.2869	-2.8656	-1.8644	-0.4002
	(0.6319)***	(0.6652)***	(0.5332)***	(0.5050)***	(0.3428)
$\boldsymbol{\beta_{q2}}$	0.0000	0.0000	0.0000	52.7278	1.0628
	(0.0000)**	(0.0000)	(0.0000)*	(22.3546)**	(0.4683)**

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 32: Estimations Model3_Bubble2 USD_BRL

	Exports	Imports	International Reserves	Interest Rate	WTI
$\boldsymbol{\beta_{d0}}$	0.0403	0.0035	0.0049	0.0479	0.0395
	(0.0453)	(0.0035)	(0.0039)	(0.0553)	(0.0458)
$\boldsymbol{\beta_{s0}}$	-0.0022	0.0764	0.1451	-0.0023	-0.0020
	(0.0036)	(0.1997)	(0.9783)	(0.0035)	(0.0036)
$\boldsymbol{\beta_{s1}}$	0.0178	0.1095	0.1380	0.0176	0.0172
	(0.0075)**	(1.2154)	(1.4694)	(0.0076)**	(0.0074)**
$\boldsymbol{\beta_{c0}}$	0.0069	0.0060	0.0085	-0.0001	0.0051
	(0.0009)***	(0.0025)**	(0.0019)***	(0.0012)	(0.0006)***
$\boldsymbol{\beta_{c1}}$	0.0003	-0.0067	-0.0019	0.0054	-0.0007
	(0.0008)	(0.0020)***	(0.0019)	(0.0048)	(0.0009)
$\boldsymbol{\beta_{c2}}$	0.0000	0.0000	0.0000	0.4688	-0.0001
	(0.0000)	(0.0000)***	(0.0000)***	(0.1373)***	(0.0009)
$\boldsymbol{\sigma_d^2}$	0.1375	0.0455	0.0503	0.1498	0.1381
	(0.0232)***	(0.0021)***	(0.0017)***	(0.0314)***	(0.0231)***
$\boldsymbol{\sigma_s^2}$	0.0380	0.2060	0.1859	0.0381	0.0380
	(0.0024)***	(0.2543)	(0.1969)	(0.0024)***	(0.0024)***
$\boldsymbol{\sigma_c^2}$	0.0011	0.0032	0.0023	0.0021	0.0012
	(0.0001)***	(0.0004)***	(0.0002)***	(0.0001)***	(0.0001)***
$\boldsymbol{\beta_{\eta 0}}$	-1.4459	0.9402	3.6252	-1.5013	-1.4349
	(0.2937)***	(0.1651)***	(1.1979)***	(0.2867)***	(0.2948)***
$\boldsymbol{\beta_{\eta 1}}$	-1.0262	2.0807	9.3975	-0.4265	-1.0025
	(0.4905)**	(0.2943)***	(3.2194)***	(0.5174)	(0.4861)**
$\boldsymbol{\beta_{\eta 2}}$	24.9202	3.7551	0.0000	23.1601	24.0056
	(10.073)**	(5.1596)	(10.0965)	(9.6812)	(9.9942)***
$\boldsymbol{\beta_{q0}}$	-2.6358	-6.8375	-505.684	-6.3159	-5.1635
	(1.7125)	(4.2129)*	(1.1000)	(2.2457)***	(1.9086)***
$\boldsymbol{\beta_{q1}}$	-8.9701	-3.7109	-145.163	-9.0104	-12.6574
	(4.3687)**	(3.0934)	(3.5100)	(4.5710)**	(4.7639)***
$\boldsymbol{\beta_{q2}}$	0.0000	0.0013	0.0093	208.597	-2.3498
	(0.0000)**	(0.0009)	(19367.1)	(94.4698)**	(1.2737)

Notes: Standard errors are reported in parentheses.

*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Table 33: Estimations Model3_Bubble3 USD_BRL

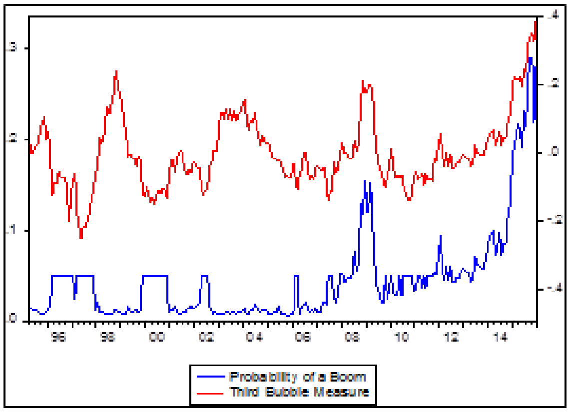
	Exports	**Imports**	**International Reserves**	**Interest Rate**	**WTI**
$\boldsymbol{\beta_{d0}}$	0.0599	0.0019	0.0048	0.0540	0.0398
	(0.0599)	(0.0031)	(0.0038)	(0.0561)	(0.0429)
$\boldsymbol{\beta_{s0}}$	-0.0013	0.0546	0.2234	-0.0019	-0.0017
	(0.0032)	(0.0700)	(0.4369)	(0.0033)	(0.0034)
$\boldsymbol{\beta_{s1}}$	0.0142	0.0807	0.2937	0.0179	0.0170
	(0.0071)**	(0.3292)	(0.6465)	(0.0071)**	(0.0073)**
$\boldsymbol{\beta_{c0}}$	0.0107	0.0104	0.0096	0.0016	0.0039
	(0.0014)***	(0.0014)***	(0.0021)***	(0.0015)	(0.0017)**
$\boldsymbol{\beta_{c1}}$	0.0005	-0.0001	0.0008	0.0039	-0.0045
	(0.0018)	(0.0020)	(0.0020)	(0.0037)	(0.0024)**
$\boldsymbol{\beta_{c2}}$	0.0000	0.0000	0.0000	0.3218	0.0004
	(0.0000)***	(0.0000)***	(0.0000)***	(0.0635)***	(0.0023)
$\boldsymbol{\sigma_d^2}$	0.1540	0.0380	0.0500	0.1559	0.1433
	(0.0284)***	(0.0022)***	(0.0017)***	(0.0364)***	(0.0223)***
$\boldsymbol{\sigma_s^2}$	0.0379	0.1544	0.1651	0.0378	0.0372
	(0.0024)***	(0.0633)**	(0.0556)***	(0.0023)***	(0.0023)***
$\boldsymbol{\sigma_c^2}$	0.0012	0.0015	0.0012	0.0020	0.0026
	(0.0001)***	(0.0002)**	(0.0001)***	(0.0001)***	(0.0003)***
$\boldsymbol{\beta_{\eta 0}}$	-1.4609	0.9366	8.9451	-1.5852	-1.4007
	(0.1877)***	(0.2145)***	(3.6949)**	(0.2971)***	(0.2347)***
$\boldsymbol{\beta_{\eta 1}}$	-0.0436	2.3852	22.1927	0.5206	-0.7061
	(0.4361)	(0.4237)***	(9.3286)**	(0.7083)	(0.6344)
$\boldsymbol{\beta_{\eta 2}}$	-0.6369	-1.6109	0.0000	24.3976	22.4242
	(0.5026)	(3.7030)	(21.3265)	(11.1591)**	(8.4774)***
$\boldsymbol{\beta_{q0}}$	1.0292	-0.2707	-20.5688	-7.6748	-90.4283
	(0.6268)*	(1.0557)	(14.5856)	(2.8196)***	(194.981)
$\boldsymbol{\beta_{q1}}$	-3.9483	-2.8855	-5.8418	-12.4715	-226.597
	(0.9740)***	(1.4509)**	(6.4206)	(5.1003)**	(487.591)
$\boldsymbol{\beta_{q2}}$	0.0000	0.0000	0.0003	179.225	-52.3457
	(0.0000)**	(0.0000)	(0.0003)	(79.623)***	(123.479)

Notes: Standard errors are reported in parentheses.

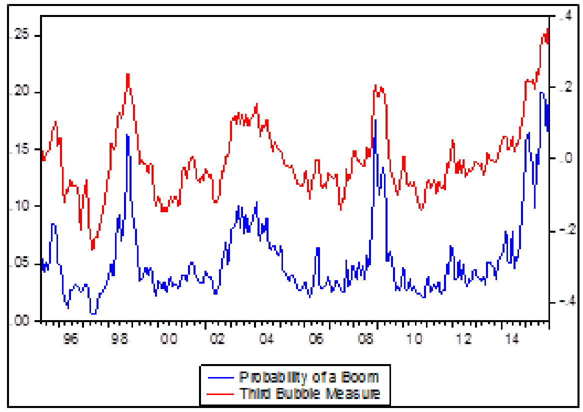
*, **, *** indicate that the null hypothesis can be rejected at the 1%, 5% and 10% significance levels respectively

Figure 11: Estimated Probability of a Boom, Colombian Peso

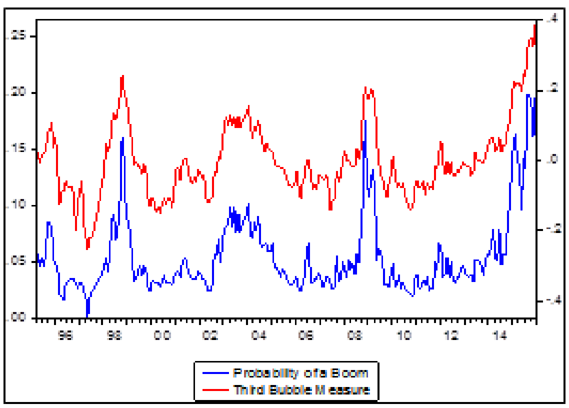
Exports



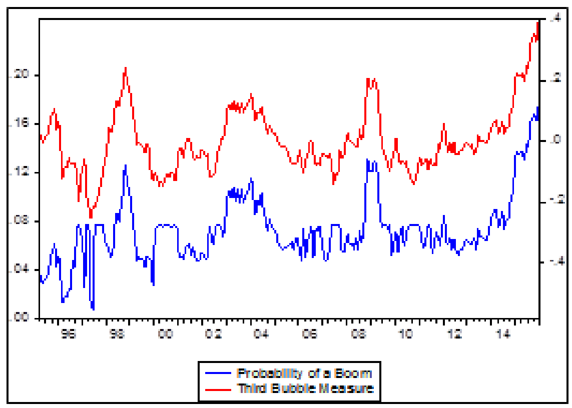
Imports



International Reserves



Interest Rates



WTI

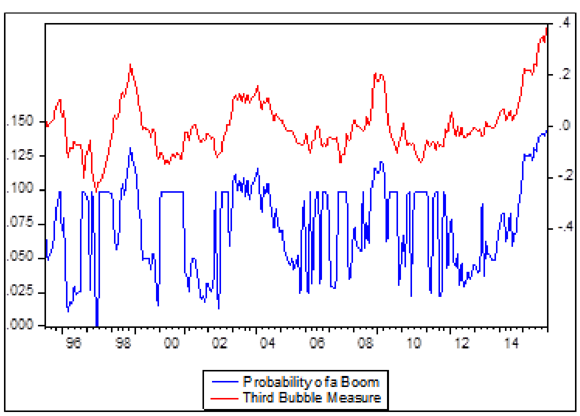
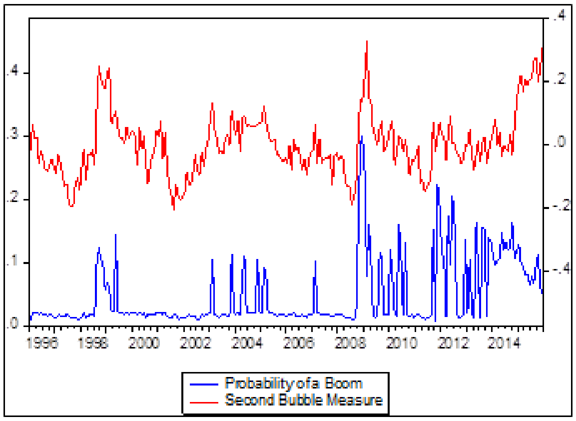
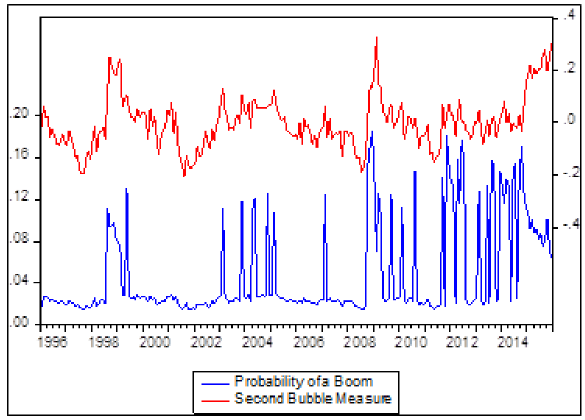


Figure 12: Estimated Probability of a Boom, Mexican Peso

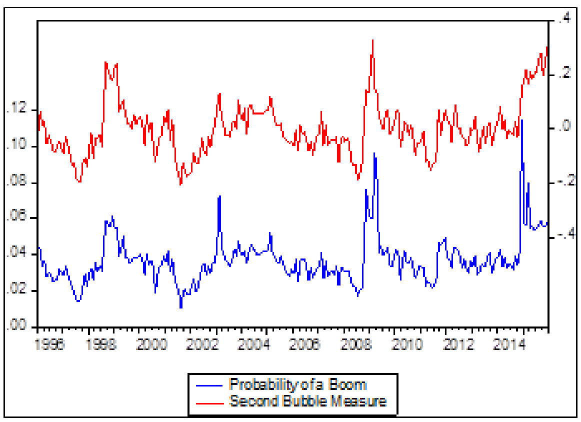
Exports



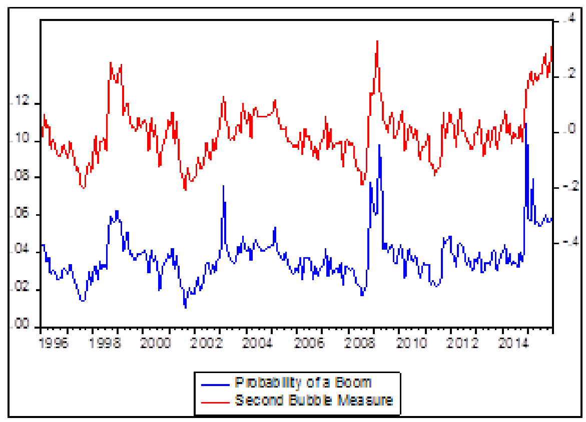
Imports



International Reserves



Interest Rates



WTI

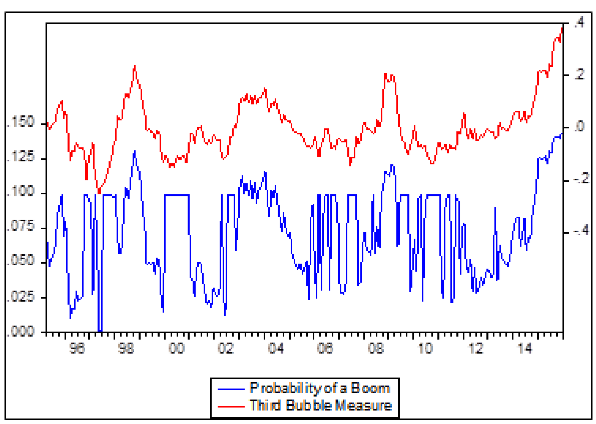
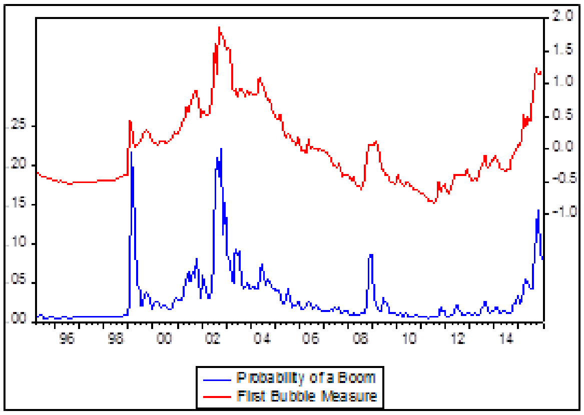
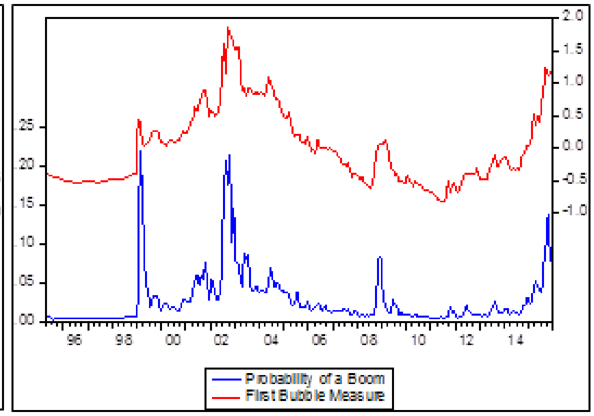


Figure 13: Estimated Probability of a Boom, Brazilian Real

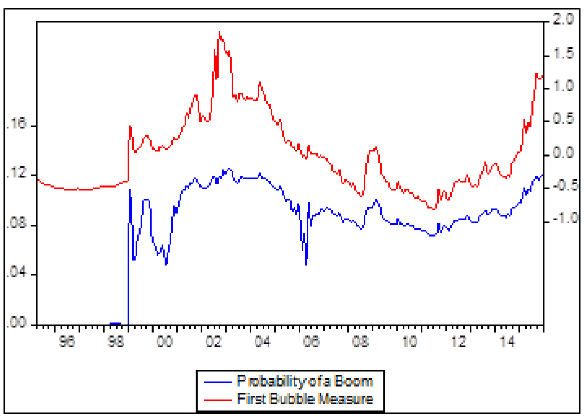
Exports



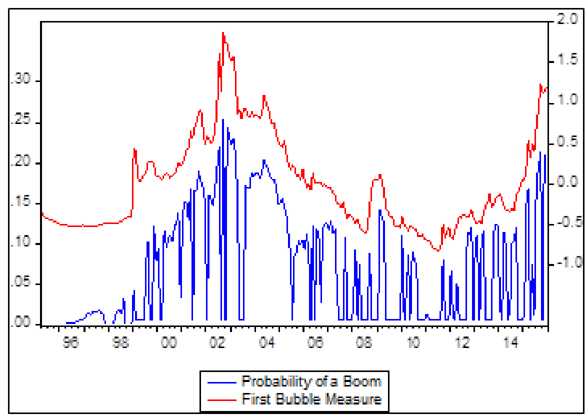
Imports



International Reserves



Interest Rates



WTI