# UNIVERSITY OF MACEDONIA

Interdepartmental Programme of Postgraduate Studies in Economics
*Applied Economics and Finance*

**MASTER THESIS**

# Periodically Collapsing Bubbles in Exchange Rates

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## Abstract

Nowadays, it is an undeniable fact that forecasting exchange rates are of great interest to all participants in international financial markets. Despite the efforts of many economists to examine and explain the phenomenon of the financial bubble, its identification seems to be very difficult. The objective of this paper is to examine the existence, duration, and size of financial bubbles in three exchange rate markets by using various two-state switching regime models. More in detail, we use these models to describe the dynamics in three exchange rates. These currencies are the British Pound/US Dollar, Canadian Dollar /US Dollar and the Japanese Yen/US Dollar. Moreover, we test the predictive ability of our models to detect unusual positive or negative movements in these exchange rates. Given that our findings provide evidence supporting the existence of financial bubbles in the exchange rate markets, in most cases, our regime-switching models seem to predict extreme market movements.


**Keywords:** Financial Bubbles, Foreign Exchange, Regime Switching, Forecast

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# CHAPTER 1

# Introduction

## 1.1 Motivation and Background

The topic of bubbles in financial markets has a long history because of their difficulty in being interpreted. Over the years many economists tried to examine the phenomenon of the bubble by using different methods but their results are still questionable. This is the reason why financial bubbles have often led to heated debate in the industry, the media, and academics. An important factor that led to the resurgence of the matter of the financial bubble is the financial crisis which followed economic stagnation and monetary policy response. Today, there are many questions about whether the monetary policy around the globe is prudent and whether there is a possibility of an increase of expensive asset purchasing schemes and easy credit in giant asset bubbles. So, economic analysis of financial bubbles is full of difficulties and states reasonable the fact that for every economic model which identifies a bubble type situation, another one exists that dismisses the claim.

The model that is able to offer a possible solution to these difficulties is the Johansen- Ledoit- Sornette Log-Periodic Power Law model as it is not based on challenging definitions of fundamental asset price value. Resulting from positive feedbacks, the model determines a bubble as a period of faster than exponential growth. Up to a critical point, growth which accelerates very fast is sustainable, but after this point, a changing market dynamic must be created. Indeed, with the log-periodic power law framework, we are able to identify bubbles in real time and make predictions of changes in the current market regime and finally to avoid a potential crash.

## 1.2 Chapter Overview

The thesis is organized as follows. Chapter 2 provides an overview of financial bubbles by starting with the definition of the term and then analyzing the causes of them. Finally, we can understand the dimension of this phenomenon by observing some historical examples of irrational bubbles. Foreign exchange market is discussed in Chapter 3 with the factors that may affect them. Market participants and their objectives are referred and a market structure takes place in order to understand how the liquidity is transported. Chapter 4 introduces the monetary model and the estimation methodology, while the data that are used are outlined in Chapter 5 and the results that are obtained are discussed in Chapter 6.

## 1.3 Literature Review

In academic literature, which is growing very fast, there is a great dispute regarding the definition of a common bubble or whether bubbles can actually subsist in the markets. By testing the existence of bubbles with plenty of economic approaches, Gurkaynak (2005) was led to the conclusion that for every paper which finds evidence of bubbles in asset prices, another one exists which argues the claim. Following the dot-com bubble, Alan Greenspan (former chairman of the U.S. Federal reserve) stated in 2002: … "We … recognized that, despite our suspicions it was very difficult to definitely identify a bubble until after the fact, that is when it's bursting confirmed its existence".

As far as bubbles are concerned, the early literature was based on the rational bubbles except for Flood and Garber (1980) that tested for deterministic bubbles by creating the first econometric test for price-level bubbles of the German hyperinflation (no significant evidence of a bubble found). Rational bubbles are characterized by an explosive path which is created because of the belief of speculators and investors that it is still profitable to purchase units of the currency even though it is overvalued. Essentially, the existence of bubbles means that market participants are not distributing their savings to the best possible investment. Moreover, it is an undeniable fact that the analysis of rational bubbles cannot be determined easily because of the dependence of agents on the current market price and on their expectations of future prices (Obstfeld and Rogoff, 1997).

The traditional literature in empirical research has followed three different methods in order to investigate bubbles. The first one is the variance bound test (volatility test), which was originally proposed by Shiller (1981), the second is the Hausman specification test, which was originally published by Kenneth West in 1987 and was based on the Hausman (1978) test and the third method is the use of unit root and co-integration test (see MacDonald and Taylor, 1993). Despite the great efforts of many economists it is still very difficult to identify a bubble prior to large price falls and that it is why many empirical tests had limited success and their results are contradicted.

To begin with, West (1987b) did not find bubble evidence in the Dollar-British Pound exchange rate by using the volatility test, but he found significant evidence of bubbles by using the Hausman's specification test in the Dollar-Deutsche Mark and Dollar-British Pound exchange rates (West 1987a). Evans (1986) has also found significant evidence of bubbles for the same exchange rate in the early 1980s. Meese (1986) used the hybrid monetary exchange rate model (Dornbusch (1976), Frenkel (1976), Bilson (1978, 1979), Frankel (1979), Mussa (1982)) and the Hausman's specification test for the Dollar-British pound, Dollar-Deutsche Mark and Dollar-Japanese Yen exchange markets for the period 1973-82. He examines the possibility of the observed deviations from values of major bilateral exchange rates which are implied by market fundamentals to be a consequence of rational asset market bubbles. For the investigated exchange rates the joint hypothesis of no bubbles is rejected, when a new econometric methodology is used to discern asset market bubbles. The same also applies to stable autoregressive processes for real incomes and relative money supplies and this is the reason why the bubble findings should be interpreted with caution. Many economists concluded that the main problem of the West/Meese methodology is the fact that there are many factors such as misspecification of the market fundamental process, rational speculative bubbles, other irrational behaviors etc which may lead to the rejection of the joint null hypothesis.

On the other hand, Wu (1995) yield mixed results by using the Kalman filter technique (monetary model used by Meese, 1986) and unit root test to investigate stochastic bubbles for the Dollar-British Pound and Japanese Yen-Deutsche Mark exchange rates. By using the monetary model of exchange rate determination (exchange rate is equal to fundamental solution plus stochastic bubble), he was aiming to estimate the unobserved component of the bubble and test whether it is significantly different from zero. Finally, his results were in sharp contrast with previous findings because he was not able to find significant evidence of bubbles which creates some doubts on those who claim that in the post-Bretton Woods period there were many bubbles in the dollar exchange rates.

Another interesting approach is that of Lucas (1977) who based on Knight's (1921) and distinct risk, which is measurable, from uncertainty, which is not measurable. According to Lucas, rational agents would be able to configure a probability with regard to the occurrence of a phenomenon, if it is “a fairly well-defined recurrent event”. This uncertainty distinction of the risk was made by Keynes(1936) who proposes that in situations where the “existing knowledge does not provide a sufficient basis for a calculated mathematical expectation”, “rational economic man” would suppose “that the existing state of affairs will continue indefinitely except in so far as [they] have specific reasons to, expect a change”.

Adopting Knight's terms and Keyne's martingale proposal, Woo (1987) estimated a version of the portfolio-balance model in order to investigate speculative bubbles in Dollar-Japanese Yen (1978-1979), Dollar-Deutsche Mark (1979-1980) and in Dollar-French Franc (1978-1980) exchange rates. He tested 1) the two-sided scenario, where agents in both countries hold both bonds in their portofolios and 2) the one-sided scenario ((Branson Halttuten and Masson (1977), Dooley and Isard (1982), Hooper and Morton (1982)), where agents in two countries hold uneven bonds in their portofolios, of the portofolio balance equation. After distinguishing two types of deviations from the value imposed by the fundamentals (speculative bubbles and error terms), he referred that the trend term of rational speculative bubbles is a precise function of the structural parameters of the asset demand equation. Finally, he found reasonable evidence of a bubble and his results agreed with Friedman's (1953) argument that destabilizing speculation does not constitute the behavioral norm in foreign exchange markets.

Recently, there are many new tests that have been developed in order to detect speculative bubbles in asset prices such as Al-Anaswah and Wilfling (2011), Lammerding et al. (2012). Based on the type of indirect stationary tests, which are initiated by Diba and Grossman (1984), Hamilton and Whiteman (1985), Phillips et al. (2011a; 2011b) proposed the sequential unit root tests. The advantage of these indirect tests is their ability to detect speculative bubbles despite a possible misspecification of the market fundamentals process. After creating two types of fundamentals (the relative prices of non-traded and traded goods) and by using the above-mentioned test, Betttendorf and Chan (2013) investigated for bubbles in the Dollar-British Pound exchange rate (1972-2012). In order to shed light on the causes of the explosiveness, they also tested for explosive behavior in the underlying fundamentals. They found strong evidence of explosive behavior in the examined exchange rate and their results indicated that the traded goods fundamental may explain this explosiveness, thus their results create doubts on claims that the Dollar-British Pound exchange rate is driven by speculative bubbles. The outcome of their examination was that this explosive behavior should not be simply determined as evidence of rational bubbles because this behavior might be driven by the relative prices of traded goods (Engel, 1999). Finally, they concluded that the “nominal exchange rate must be viewed as an asset price” (Obstfeld and Rogoff, 1997), which means that it is defined by current and expected values of fundamentals.

In order to examine the existence of periodically collapsing rational bubbles in exchange rates, Ferreira (2006), used the Markov-switching regime model for the Dollar-British Pound, Dollar-Canadian

Dollar, Dollar-French Franc and Dollar-Deutsche Mark for the period 1973-1998. Unfortunately, he was not able to find robust evidence which can approve that a bubble drives the exchange rate away from fundamentals. A rational bubble that collapses periodically is designated as an eruptive deviation from fundamentals with distinguishable expansion and contraction stages infinite time. Significant non-linearities and different regimes are revealed with his results which propose that linear models may not be able to examine exchange rate movements. On the other hand, Simon's Van Norden (1995) test was based on a kind of stochastic bubble which each period is anticipated either to persist growing or to collapse. He made some assumptions regarding the probability and size of these collapses and because of the fact that such behaviors should result in a particular kind of regime-switching behavior; he used some switching-regression techniques (the regime-switching model) for Dollar-Japanese Yen and Dollar-Australian Dollar exchange rates at 1977-1991. Finally, he was led to the conclusion that his results are sensitive to the specification of exchange rate fundamentals and other factors.

Trying to explain stock market crashes, Van Norden and Schaller (1996) use regime-switching models and they present two different explanations in order to account for historical crashes. The first model, which is characterized by an accelerating increase in asset prices and an abrupt decrease, is a model of speculative behavior and is based on historical accounts of "manias and panics". This model proves that the huge difference in expected returns between the two regimes (between speculative component and collapse) increases the size of the apparent overvaluation. Based on switches in fundamentals, the second model can lead markets to imitate speculative behaviors. After using data of the U.S for 1926-1989, their results show that despite the fact that the degree and variability of the apparent market overvaluations are higher in the real time than in the simulations, there is evidence of regime-switching in the simulated returns, which means that the degree of obvious overvaluation influences expected returns. On the other hand, Hall, Psaradakis, and Hola (1999), proposed a methodology based on a generalization of the Augmented Dickey-Fuller (ADF) unit root test and tested for the existence of periodically collapsing bubbles in time series. This methodology, which makes use of dynamic Markov regime-switching models, analyses the following terms: namely monetary base, consumer prices and exchange rates in Argentina for 1983-1989 in terms of US dollar. According to their results, the rapid growth in money supply can explain the hyperinflation in Argentina at 1989 and the explosive behavior only in consumer prices can interpret the existence of a rational bubble in consumer prices at 1988 and in 1984-1985.

While studying the October 1987 US stock market crash, Sornette et. al (1996), Feigenbaum and Freund (1996) discovered the Log-periodic structures in financial markets. The LPPL model was suggested by Sornette (2003a) who applied the model to the Dollar-Deutsche Mark and Dollar-Japanese Yen at 1971-1999 and he proved that with this model can someone identify bubbles and predict their most potential end. Moreover, Johansen and Sornette (2004) were in the position to detect in large set of financial assets the most extreme cumulative losses and to indicate that these losses (drawdowns) pertain to a probability density distribution, which is not similar to the distribution of normal market regime (of 99%) of the smaller drawdowns. Furthermore, it was shown, as confirmed by a calibration of LPPL model, that for two-third of these extreme losses, a super-exponential behavior characterizes the market prices before their occurrences. In Sornette (2009), these specific outliers (drawdowns) are called “dragon kings” and they cannot be described by an extrapolation of the distribution of intermediate and small losses.

As far as more recently literature is concerned, many papers such as Drozdz et. al (1999) and Johansen et. al (2000) have identified ex-post the LPPL structure before crashes, while a number of other papers such as Zhou and Sornette (2003) and oil Sornetee et. al, 2009 have also identified crashes in market ex-ante including real estate. The LPPL was used by Johansen and Sornette (1999) in order to examine for bubbles in Dollar-Swiss Franc and in Dollar-Deutsche Mark exchange rates in 1985. In a successful way, they identified anti-bubbles in gold and equity markets, while further evidence was found by Sornette and Zhou (2002). It was also used to forecast the termination of bubbles in order to create an early bubble alarm indicator (Sornette and Zhou 2006). A newer stand of literature used this alarm system in order to produce a trading model and estimate appearance across 10 different equity markets. The term of negative bubbles, which bubbles are characterized by accelerating price falls, was introduced by Yan et. al, (2010), while most recently, an early warning system for bubbles was tested by Vakhtina and Wosnitza (2015) in credit default swap markets.

**CHAPTER 2**

# Financial Bubbles

## Introduction

It is an undeniable fact that financial bubbles are very important in modern society because of their configuration and the dramatic bursts that follow. We can comprehend through the many examples of irrational bubbles, which are mentioned below in this chapter, that bubbles have a great impact globally on the majority of the people.

Despite the efforts of many economists to examine and explain this phenomenon, its identification remains to be very difficult which prevents us to understand and to forecast this phenomenon and eventually to avoid it. William C. Dudle once said in 2010 that: “... what I am proposing is that we try to identify bubbles in real time, try to develop tools to address those bubbles, try to use those tools when appropriate to limit the size of those bubbles and, therefore, try to limit the damage when those bubbles burst...”.

In this chapter, we will start the discussion of financial bubbles by addressing the meaning of the bubble (2.1) and its causes (2.2) in order to understand better how a bubble can be created. Then we will state the two types (2.3) that a bubble can be and consequently refer some examples of the irrational bubble (2.4). Finally, we will discuss the calculation of a bubble (2.5) and whether there is a way to diagnose a bubble ex-ante (2.6).

## 2.1 What are Bubbles?

As declared in the book «Manias, Panics and Crashes» historical economist Charles Kindleberger and professor emeritus Robert Aliber, a bubble is determined as a steep increase in the price of an asset, which has a continuation, producing expectations for continued increment of prices, alluring, in this way, new investors. It is reasonable that this sharp increase can be criticized by the variation of the current value of the fundamental value of the asset (fundamental value is the present value of anticipated benefits, counted on the actual one-year rates). It could also be featured as a situation in which asset prices are based on irrational and inconsistent predictions for the future.

We could, therefore, divulge that the bubble is the outcome of a speculative mania since people are more concerned about the profits that will come off the price increases in spite of the profits that may result from the conservation of assets. Therefore, the price raise is not excused by the fundamental characteristics (fundamentals) of the asset and is powered by the inclination of investors to purchase and sell rapidly and at an even higher price in order to scythe short-term gains. It would be sensible, therefore, the allegation that the bubbles disclose the incapacity of market participants (agents) to assess judicially certain assets.

## 2.2 What are the causes of Bubbles?

A probable reason for the creation of the bubble is the monetary slackness. That is the immoderate supply of liquidity in the financial system, with the concurrent introduction of unsuitable lending standards, making markets vulnerable to inflation in asset prices provoked by short-term speculation. For instance, Axel Weber, former president of the Deutsche Bundesbank, has mentioned that "The past has shown that overly generous provision of liquidity in global financial markets in conjunction with very low-interest rates promotes bubble formation". Another reason is named extrapolation which is a situation in which investors have the belief that the price of an asset will increase merely because it happened in the past.

Moreover, we should not disregard another interpretation, which is widely utilized in behavioral economics is the “herd behavior”. “Psychology of the herd” or “herd behavior” is the way it operates and an investor group behaves without planned direction, like a herd, imitating comportment of other investors in the markets. In finance, psychology herd regards cases in which many investors are turning to unnecessarily determinate investments during the same period, merely forced by the fact that a great number of traders indicated interest in them. In their exertion to emulate one another, these megatrends end up either in bubbles (similar massive equity markets) or crash (abrupt sales of securities or other assets).

Investors sell or buy, depending on the market trend. Of course, all this should be regarded alongside the enthusiasm and investor ignorance, the complexity of the financial system and asymmetric information. In this way, we are led to soaring prices of assets over what in economics is called “fair value” but it comes at some point that the holders of the assets begin to feel insecure as to how much more can raise the price and start mass sales. So, it becomes a brutal market correction and prices are precipitated. Then we say that the bubble “pops” (bursts).

“*There are three major forces driving the world: nonsense, fear and greed”*

Albert Einstein

After the "bursting" of a bubble, usually followed by the "crash", it is possible to ruin or redistribute uneven and non-effectively much of social wealth. Because of this unprivileged resource allotment, according to economists of the Austrian School, caused protracted economic recession. Panic and fear are created, leading to a massive withdrawal of deposits from banks (bank run). Naturally, banks are incompetent to simultaneously encounter the requirements of all depositors. So, the banking system ensures the crisis, which in turn is passed to the actual economy, calling forth a diminution of production, mass layoffs, and plummeting demand. People behold their fortune diminish and limit their costs, hampering economic growth or, worse, sharpening the already existing recession.

*“Fear cancels experience and knowledge without courage does not benefit in anything.”*

Thucydides ~ 460-394 BC ~ Athenian historian

## 2.3 Types of Bubbles

We can distinguish two types of bubbles: rational and irrational bubbles.

<u>Rational bubble:</u> Should investors rationally anticipate an asset’s retailing price to boost, then embracing this in their estimation of the asset's fundamental value would be vindicated. There is a possibility, that the cost of such an asset could raise and persevere even though the ability to grow or develop of each company is implausible to subsidy these prices. Vaguely, this condition illustrates a rational bubble.

<u>Irrational bubble:</u> Should a stock be trading at a very small price compared with its fundamental value, capable investors will exploit this chance in order to make a profit by buying more shares of the stock. The stock’s price will be increased until it will be equal to its fundamental value when there is no further profit that investors can gain. This is a mechanism that also works to ameliorate (reform) stocks that are trading at a higher price than their fundamental values. So, if an asset obstinately is transacted at a price which is above its fundamental value, we would declare that this price displays a bubble and that this asset is overestimated by a volume same with the bubble. From this failure of profiting from

the further value of the asset, we can comprehend that the investors are irrational and that it's why we have an irrational bubble.

## 2.4 Historical examples

1. The Tulip Bubble
2. The Great Crash of the New York Stock Exchange
3. The Dot-com Bubble
4. The US housing Bubble
5. The Bubble of the Athens Exchange in Greece

1. The Tulip Bubble.

Tulips are a fateful flower of economic history. Tulip, until the mid of the 16 century was an unknown flower in Europe and its appearance then caused real mania, especially in Holland, where rare varieties bulbs became famous and gained enormous value. In the Amsterdam stock exchange created a specific area for transaction tulip, which emulates and other Dutch cities. The bulbs were bought and sold like currently shares on the stock exchanges of the world. Indeed, the price of a single tulip bulb reached to be the same as that of a trolley, two horses or thousands of kilos of cheese.

The tulip mania persisted until February 1637, when the market collapsed because of doubts about the continued increment in the price of bulbs. Panic gripped investors, everyone wanted to sell but no one to purchase. “Major marketers came almost begging”, said Charles Mackay, who dealt extensively with the issue. There were many people who saw their features vanish, despite the fact that the Dutch government launched an inquiry into the case, the country's economy entered into recession.

2. The Great Crash of the New York Stock Exchange.

The 1920s was a period of prosperity about the US stock market. It was the period when many households in the US discovered the stock market getting loans which they invested hoping to get rich. In autumn 1929, stock prices had attained unrealistic heights. Despite the fact that there were rumors about the impending fall, many prominent economists assured to the contrary.

Optimism finally evaporated on October 24, when about 13 million shares were sold by panicked investors. The “Black Thursday” was followed by “Black Tuesday”, when the stock market collapsed, even more, causing chaos and accelerating the Great Depression that for almost a decade, hovering over the US.

3. The Dot-com Bubble.

A few bubbles can be compared with that of the 1990s.The internet and new technologies have caused a huge wave of euphoria to the investors who were interested in funding new companies. The composite index, NASDAQ, which includes principally shares in the sector of technology, leaped from 500 units in April 1991 to over 5000 units in March 2000.

This immoderate mania leads people to invest “blind” to anything simply linked to the new industry. When they finally perceive that this is a classic speculative bubble the NASDAQ index will slump in 2002, wiping out trillions of dollars of investors’ portfolios.

4. The US housing bubble.

Many experts believe that the “tech bubble” as has also been characterized, led investors to property, believing that it is a safe area. Real estate prices in the US began to record a significant increase in late 1990 and early 2000. In 2006 they witnessed record prices, as banks lent households, often with loans on which the borrowers pay only the interest or without the banks have full collateral.

That same year began the fall and the bubble will inevitably burst, leading to the crisis of mortgage loans with high risk, where many borrowers were in a difficult position to be unable to satisfy repayment requirements on their loans. The crisis that occurred in the global economy in 2008 is estimated to be due largely to the bursting of the last bubble.

5. The Bubble of the Athens Exchange in Greece.

The history of the Athens Stock Exchange was marked by the crash of 99 which concerned the majority of Greek people. It has been estimated that 100 billion euros changed hands, much of which had lost the so-called retail (small investors). The sharp decline in the stock market followed the rise of earlier years, which peaked at 1999 and was linked with the entry of Greece into the European Union and was the prospect of undertaking the Olympic Games in Athens at 2004. Similar processes followed the stock markets because of optimism on a new economy, id est permanent and a significant increase in productivity thanks to the IT revolution.

Many Greeks in the summer of 1999 occupied with the stock exchange. Even in small villages, there were offices of purchasing and selling of shares and many small companies entranced the Stock Exchange. Active code investors in the stock market reached about 1,5 million when Greek employees are estimated at 4,6 million. With the general index to shatter every record every day, many Greeks believed that they solved the economic problem of their life. The case began on 25 September and continued for several years wiping out the value of shares. Many of the shares that had been introduced in the stock market proved as bubbles, illusory shares in companies without work, with the only purpose to have an attractive picture on the stock exchange.

## 2.5 Calculation of the Bubble measure

The market price in the standard asset price equation for equities is equal to the "fundamentals" (the discounted flow of future dividends) plus an extra bubble term which reflects extrapolative price behavior, where past price increases influence people to buy more of the asset, driving its current price higher. So if we assume that $b_t$ is the speculative bubble, then we can have the following equation with which we are able to calculate the measure of the bubble:

$$b_t = s_t - f_t$$

where $f_t$ is the fundamental value and $s_t$ is the spot exchange rate. Thanks to PPP we can calculate the bubble under the assumption that the relative price differential and nominal exchange rate have a one-to-one relationship, which means that the real exchange rate is stationary.

In the PPP theory the fundamental price ($f_t$), which is measured in units of domestic currency per unit of foreign currency, is equal to the domestic price ($p_t$) minus the foreign price ($p_t^*$).

$$f_t = p_t - p_t^*$$

The cointegrating relation between the log of the nominal exchange rate and the log of the relative prices can be used with a view to testing whether the PPP is valid or not. We are able to calculate the bubble (deviation from the fundamental values) if we take the residuals of this cointegrating relationship.

## 2.6 Is there a way to diagnose a Bubble ex-ante?

It is known that it is very difficult to identify a bubble properly, especially in periods which are characterized by rapid growth in asset, prices, because of the possibility of changing or improving the fundamentals. The fact that we can define the superficial bubbles as an upward acceleration of the price above fundamental value leads as to believe that the precise definition of fundamental value seems to be elusive.

A theoretical model has been proposed by Sornette and his collaborators in order to diagnose bubbles ex-ante. By analyzing the cumulative human behaviors in a new perspective, this model, which is known as the Johansen-Ledoit-Sornette (JLS) model, has the ability to describe the price dynamics during a bubble regime (identification). It is also able to forecast the most plausible crash time after a bubble ex-ante.

In other words, the JSL model introduces a solution in which bubbles are characterized by faster-than-exponential growth of price being an outcome from positive feedbacks in the valuation of assets. Due to these mechanisms of positive feedback, which feedback is able to create an unsustainable regime, the underlying price process is regarded to be intrinsically transient. Many academics, market participants, and policymakers can make a profit by using the Johansen-Ledoit-Sornette Log-Periodic Power Law framework (LPPL) because of its ability to be used as a tool to discern bubbles in real time and make predictions for changes in the current market regime.

**CHAPTER 3**

# Introduction to the FX markets

## Introduction

The foreign exchange market is the global financial market, which includes all the financial centers of the world in which all national currencies are bought and sold. With the term of exchange market, we mainly mean the closed inter-bank circle of the largest commercial banks and investment banks of the world, and all the "over-the-counter" (id est OTC or semi-official) money transactions.

These money transactions can be deposits in different currencies as well as financial highly liquid products such as short-term derivatives in currency between the banks (an estimated 50% of the total trading volume is among the main very large banks), and all other exchange transactions between smaller "players" (smaller banks, institutional investors, multinational corporations, hedge funds and so on).

The exchange market in the last ten years has grown into the largest and most important market in the world with a daily turnover of nearly 3 trillion dollars. This development is rapidly due to technological developments and to ease borrowing (leveraged transactions). In this market both the traded and the price are the money of different currencies.

In this chapter, we will refer the nominal and the real exchange rate (3.1) and then we will refer the risks in the Forex and the Troubleshooting (3.2). Thereafter, we will mention the participants in the foreign exchange market (3.3) and then we will describe the market structure (3.4). Finally, having mentioned the market size and liquidity (3.5), we will close the chapter with the Purchasing Power Parity (3.6).

## 3.1 Exchange rate

The exchange rate is the price at which two national currencies are exchanged in the foreign exchange market. There is the nominal and the real exchange rate.

<u>Nominal exchange rate</u>

The nominal exchange rate is the price at which an exchange of two currencies occurs. For example, in an exchange service or as an exchange of a deposit amount in euro with a dollar amount through bank deposits. Common international conventions are the rates being noted as in the following example: EUR / USD 1.2500. This means that $ 1.25 exchanged for 1.00 Euro. Another common way is the rate noted for example as follows: EUR 0.80 = USD 1.00. This means that $ 1.00 exchanged for 0.80 euros with the first currency to be called "nominal currency" (in this example is the euro), while the second currency is called the "base currency" (in this example the dollar). The nominal currency is, usually, used at the place where the transaction occurs.

<u>Real exchange rate</u>

The real exchange rate is an explanation of the nominal exchange rate divided by the ratio of the price index between the two countries. For example, if the nominal dollar-euro exchange rate is $e = 1.36$ (ie 1.36 dollars exchanged with Euro 1.00) and $P^* / P$ is the ratio of price indices, where $P^*$ is the price index in the euro zone and $P$ is the price index in the US, the real exchange rate is $RER = e \times P^* / P$.

The importance of the real exchange rate is easily understood through the example of Big Mac. If for example a Big Mac in Germany costs 2.50 euro and the US costs $ 3.40, while the nominal exchange rate is $e = 1.36$, then the real exchange rate is equal to the unit: $RER = 1.36 \times 2.50 / 3.40 = 1$, while if the price in Germany is € 3.00 and the US $ 3.40 then the real rate is $RER = 1.36 \times 3.00 / 3.40 = 1.20$. Which means that in the previous example the German-EUR is really appreciated and is more expensive by 20% compared to the dollar.

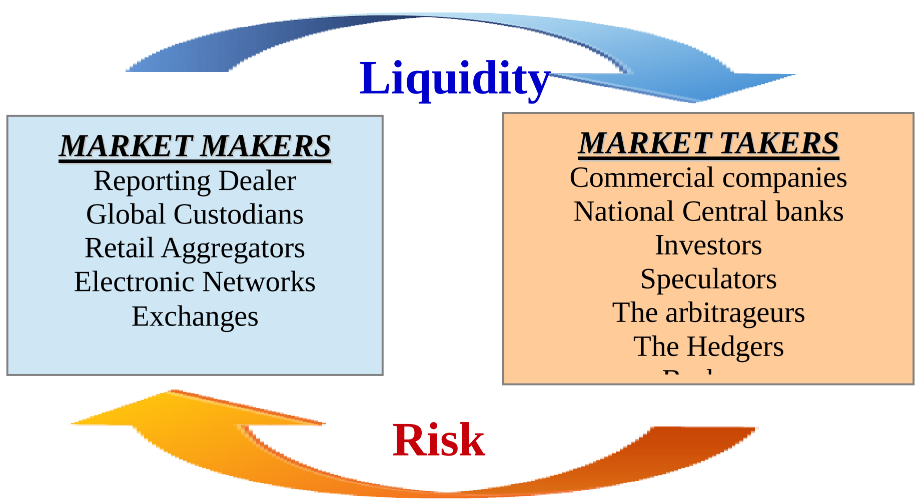
## 3.2 Risks in the Forex market & Troubleshooting

It is an undeniable fact that in the present era, which is characterized by the increase of globalization and heightened currency volatility, variations in exchange rates have an essential influence on operations and profitability of the companies. It is noted that exchange rate volatility affects not only multinationals and large corporations but also small and medium-sized enterprises, even those who only work in their home country. Investors should be familiar with the comprehension and administration of the exchange rate risk, because this risk is very significant for business owners, because of the huge impact it can have on their investments.

The exchange market is highly speculative and unpredictable. The conditions prevailing there, i.e. how expensive or cheap a currency relative to the others can change at any time and moment. The rights and the dual transactions can be used in order to eliminate or reduce the currency risk futures.

## 3.3 Participants in the foreign exchange market

To transactions conducted in the foreign exchange market may be involved commercial companies, national central banks, investors, speculators, arbitrageurs, compensators (hedgers), makers (market makers, dealers), brokers and private individuals.




**Liquidity Takers**

Commercial companies

They take part in the exchange market to pay for goods or services. They trade often small amounts compared to those of other banks and speculators, and their trades have small short-term impact on market prices. Nevertheless, trade flows are an important factor for the long-term direction of the exchange rate of a currency.

National Central banks

The role of these is very important in foreign exchange markets. Their goal is to control the interest rates, money supply, inflation, and frequently have target rates (official or unofficial) for their currencies. They can often use their large stocks of foreign exchange to stabilize the market.

Investors

They rely on their investments in investment management companies which typically manage large accounts on behalf of investors - their customers and employ the foreign exchange market in order to accommodate transactions in foreign securities.

Speculators

They are based on an exchange position (view) with the expectation of a change in the exchange rate in their favor without cover this position.

The arbitrageurs

They are based on differences in currency values to make profit without risk. Arbitrageurs make an arbitrage market (Arbitrage), namely buying a currency at a low price in a market and then selling it in another market at a higher price, thereby earning a profit.

The compensators (hedgers)

They are trying to eliminate or reduce the risk resulting from the change in exchange rates on behalf of their clients.

Brokers

They intermediate between the market makers (dealers) and counterparties - their customers and their profit come from charging their customers for their services. These individuals are a growing segment of this market, both in size and importance. Participants in the foreign exchange market indirectly through brokers or banks.

**Liquidity Makers**

Reporting Dealer (Banks or other financial services)

Their goal is to make money by trading with the customers the time they arrive at the market. This is achieved by providing liquidity to customers which are caused by taking speculative positions on their own account.

Global Custodians

Administrators or custodians are hired by large asset managers in order to track their process dividends, calculate portfolio values, assets and settle trades among other tasks. Real money investors in some cases instead of trading on electronic platforms or with major dealer banks, they interchange with the custodian, pushed to a great extent by administrative efficiency.

Retail Aggregators (like OANDA and FXCM)

In the 2000s, retail traders had access to the market because of the online offering (Electronic Broking Service and major banks) of margin accounts by the retail aggregators. Before offloading retail trades, the retail aggregators bundle them to the interbank market in order to decrease the costs of trading for retail clients.

Electronic Communication Networks and Multi-bank platforms

Electronic trading ameliorated price transparency and efficiency while trading costs are reduced and ask spreaders are aided by the elimination of price distinction in the interbank market. However, until the turn of the millennium, end customers did not start reaping benefits from this form of trading. At this moment, independent not-bank firms made their entry into the market which led to the launch of electronic communication networks which permitted customers to trade electronically with many dealers.

Exchanges

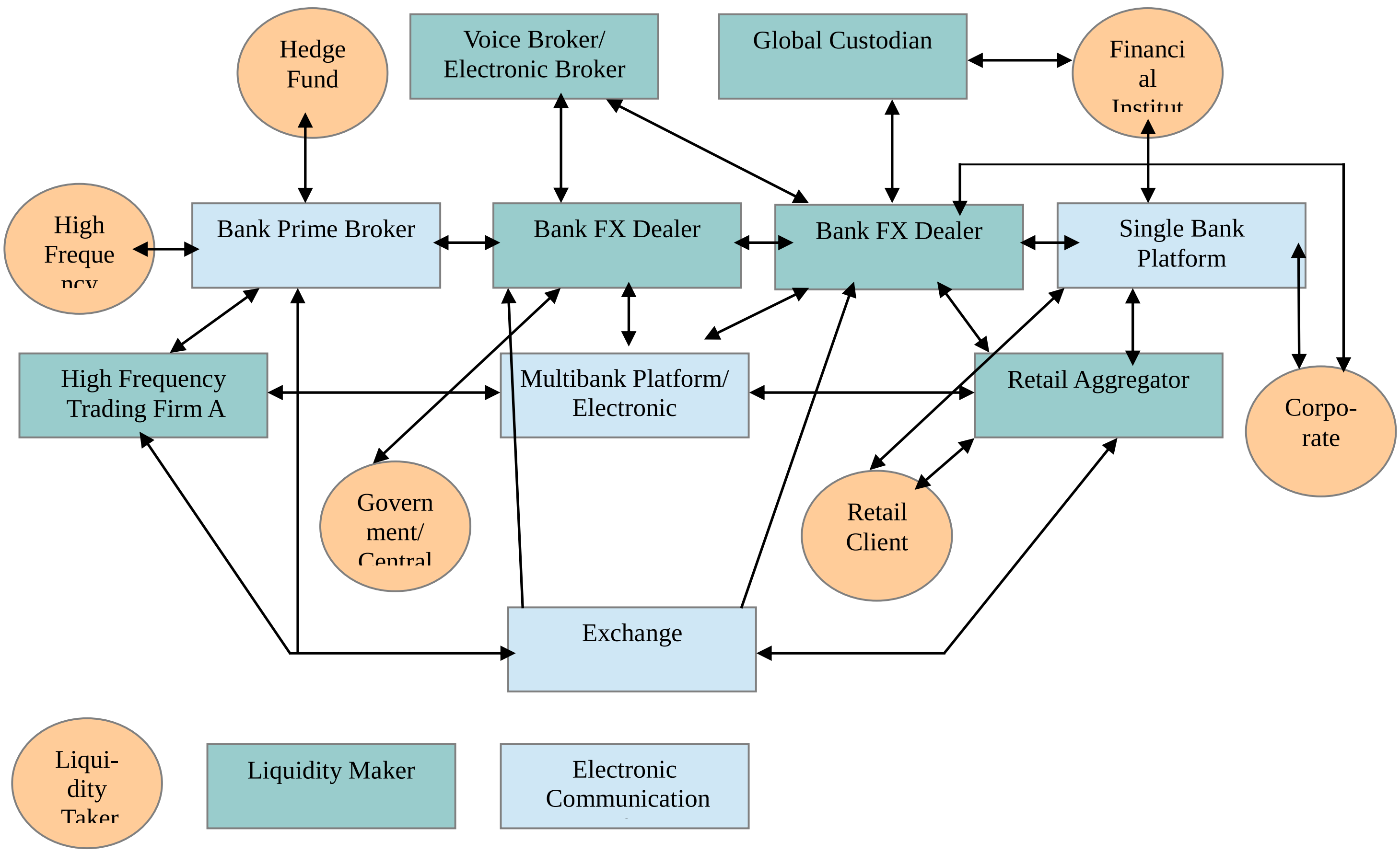
In foreign exchange markets, the Chicago Mercantile Exchange is the only exchange having a major role officially, which exchange holds an actual monopoly on the futures trading of FX.

## 3.4 Market structure

We can design the relationships that bind together all the market participants if we pool together the liquidity makers and liquidity takers. The following figure identifies the market players within today's foreign exchange market and emphasizes the new electronic platforms that have emerged in recent years.

Through prime brokerage relationship, hedge funds, and high-frequency trading firms access the inter-dealers market with the large dealer banks (like Morgan Stanley). They are also able to trade in an indirect way on the CME or ECNs like Currenex. Currency traders may be settled by asset managers and financial institutions with their custodian asset manager e.g. Blackrock or State Street or they go to a dealer bank and then to the interdealer market. Through a single bank platform (like Citi Velocity) can deal high net worth retail clients with corporate access markets, albeit many small retail clients who are trading online might prefer a retail aggregator like OANDA. We can observe that FX dealers are attracted by central banks and pursue to make strong relationships with them in order to make certain that they get market intervention trades directly.

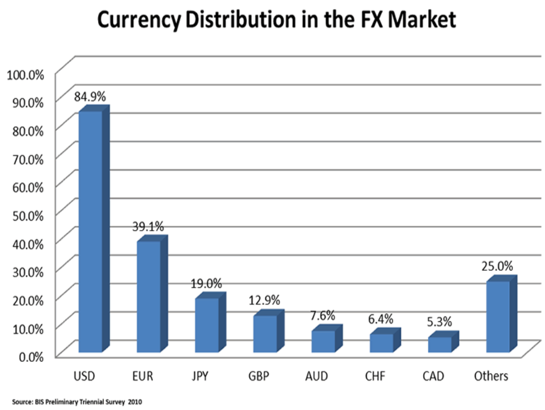
Eventually, at the core of the FX market lies the interdealer market, but electronic communication networks (like Hotspot FX) and multi-bank platforms like Reuters and EBS play an important role expediting electronic trade in this section and open access beyond the major dealer banks. Electronic implementation was estimated, in 2013, above 50% of all trade by volume.

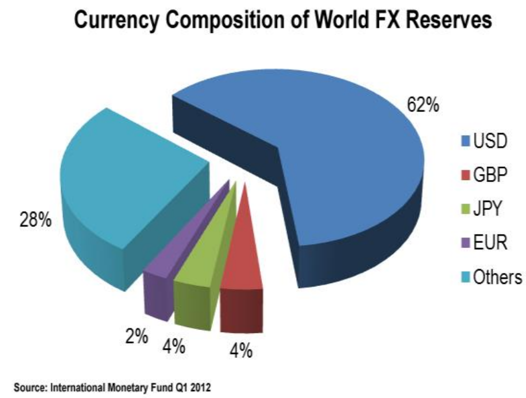



*Graphic adapted from BIS (2011).*

## 3.5 Market Size and Liquidity

Because of the extremely high levels of liquidity, traders from other markets are attracted by the Forex. This seems to be reasonable if someone considers that liquidity is of great importance because of its allowance for traders to get in and out of a position with no difficulty at 24 hours a day 5½ days a week. From this benefit, we can understand that huge trading volumes are allowed to enter and exit the market without the big fluctuations in price that would be possible to happen in less liquid markets. This implies that there is no possibility to get in a position because of the absence of a buyer. This liquidity can diversify from one trading session to another and one currency pair to another as well.




From the first figure we can observe that as the most traded currency, the US dollar makes up 85% of Forex trading volume. Following the euro at nearly 40% which is ahead of the Japanese Yen that takes the third place with almost 20%. The fact that the main volume is concentrated in the US Dollar, Euro and Yen makes the traders pay their attention to just a handful of major pairs. Moreover, the greater liquidity found in the Forex market is conducive for a long time and well-defined trends that reply well to technical analysis and charting methods.

From the second figure, we can also observe that the US dollar includes roughly 62% of the world's official foreign exchange reserves, according to the International Monetary Fund. This may seem reasonable if someone considers that almost every business, investor and central bank own it, they pay attention to the US Dollar.

Given the fact that the United States has the largest economy in the world, the largest and most liquid financial markets in the world, a super stable political system, is the world's sole military superpower and its currency (the US Dollar) is the reserve currency of the world states the statistics of the two figures sensible.

## 3.6 Purchasing Power Parity

Equivalence of purchasing power is a theory of exchange rates based on the law of one price, whereby a unit of any currency should buy the same number of goods in each country. In other words, the price of a product in the domestic market in period t must equal the value of the product in a foreign country in the same period, on the current exchange rate.

If there are no trade restrictions and other transaction costs, the law of one price should apply, otherwise, it will create arbitrage opportunities. However, the law of one price should apply only to goods traded internationally. The absolute equivalence of purchasing power applies the law of one price in a basket of goods that are considered to represent the consumption of an average consumer in a given country and is used to calculate price indices. That is, general price levels determine exchange rates.

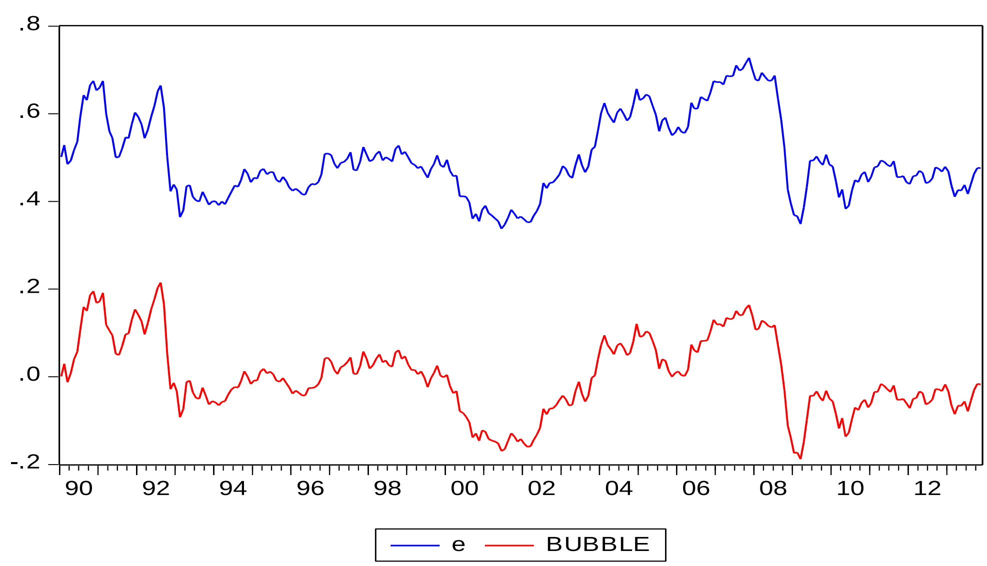
If we assume that $P^d_{i,t}$ is the price of good (i) in the domestic country at time t and $P^f_{i,t}$ the price of the good (i) in the foreign country at the same time, then :

$$P^d_{i,t} = S_t P^f_{i,t} \qquad i= 1,2,....,N \qquad (2.1)$$

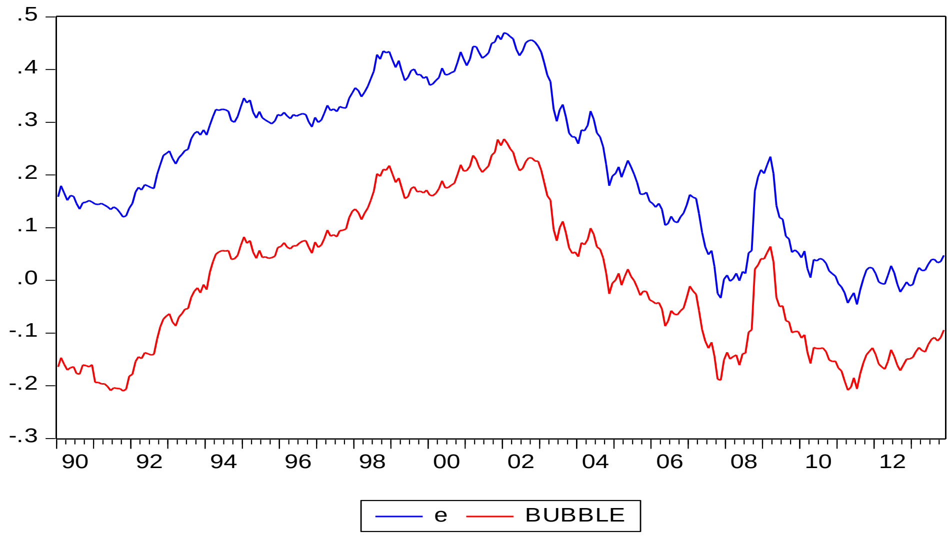
is the *absolute* PPP and $S_t$ is the nominal exchange rate. *Relative* PPP, which says that the exchange rate will change to recompense for the inflation differential between the two countries, is not an as strong condition as the *absolute* PPP. Should the domestic country have a higher rate of inflation, the price of a basket of goods there will increase and therefore its currency will underestimate versus the foreign country. The conditional can be written as

$$(P^f_{i,t+1}S_{t+1})/P^d_{i,t+1} = P^f_{i,t}S_t/P^d_{i,t} \qquad i= 1,2,....,N \qquad (2.2)$$

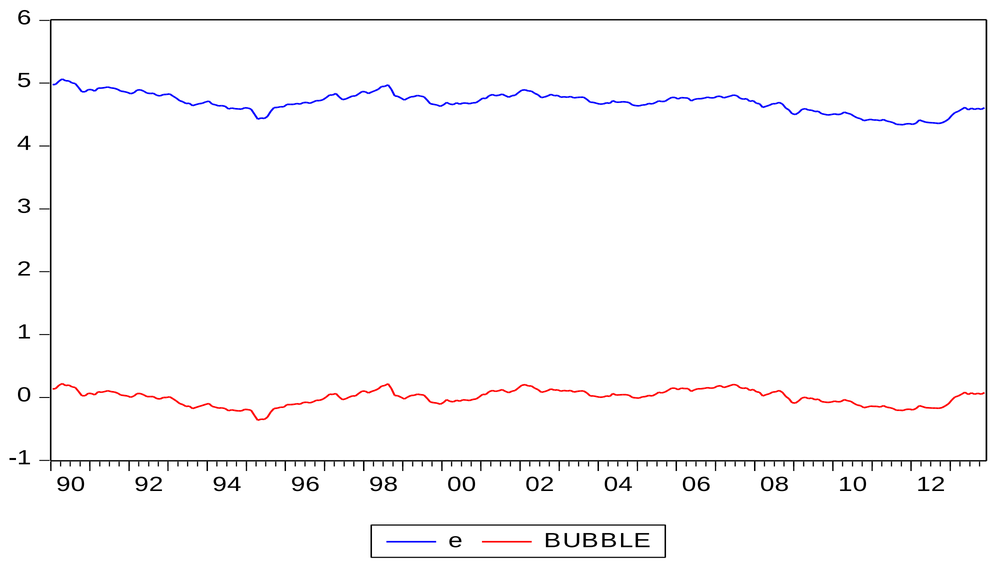
In the following graph, we can observe the progress of the British Pound - United States Dollar Exchange rate (upper line) and the bubble measure (lower line)



<u>In the following graph, we can observe the progress of the Canadian Dollar – United States Dollar Exchange rate (upper line) and the bubble measure (lower line)</u>




<u>In the following graph, we can observe the progress of the Japanese Yen– United States Dollar Exchange rate (upper line) and the bubble measure (lower line).</u>



**CHAPTER 4**

# Model & Estimation Methodology

## 4.1 The Monetary model

The model that is used in this paper follows a standard monetary model and is adopted after taking a look at Evans (1991), Taylor and Peel (1998), Bilson (1979), Hall et al. (1999), Hooker (2000) and Psaradakis et al. (2001). This model includes two countries (domestic and foreign), which countries have the same income elasticity and interest rate semi-elasticity and are characterized by a transactions-type money demand equation. Should we combine the money market equilibrium, we will be led to:

$$m_t - p_t = \alpha_1 y_t - \alpha_2 ( i_t - i_t^*) \tag{1}$$

where $p_t$, $m_t$, and $y_t$ are the natural logs of the relative price level, relative money supply, and relative real income between the two countries (domestic and foreign), respectively. Given that $i_t$ is the interest rate of the domestic county and $i_t^*$ is the interest rate of the foreign country, we can assume that $(i_t - i_t^*)$ is the short-term interest differential and we will symbolize that term in continuation of this work as $i_t$. The variables $\alpha_1$ and $\alpha_2$ are the income elasticity and interest rate semi-elasticity, respectively. We can apply uncovered interest parity (UCIP), so we can have the following equation:

$$i_t = E_t e_{t+1} - e_t \tag{2}$$

where the term $e_t$ is the natural log of the nominal exchange rate at time $t$ and $E_t$ denotes the mathematical expectation condition on information at time $t$. We can conclude from the above mentioned Equation that an eventual non-zero interest rate differential must be offset by an equivalent expected change in the exchange rate. We can be of the opinion that deviations from Purchasing Power Parity (PPP) follow a random walk (RW):

$$e_t - p_t = u_t \tag{3}$$

where $u_t$ is an autoregressive model *AR (1):* $u_t = u_{t-1} + \varepsilon_t$ and $\varepsilon_t$ is white noise which means that its variance is stable = $\sigma_\varepsilon^2$ and has mean equal to zero. We assume that $m_t$ and $y_t$ are exogenous, $\varepsilon_t$ is uncorrelated with $m_t$ and $y_t$ and that it is orthogonal to $m_t$ and $y_t$. The same is valid for $i_t$, for the expected inflation and for cumulated trade balances. So, after substituting *Equations (2, 3)* into *Equation (1)* we can have:

$$e_t = (1-b) f_t + bE_t e_{t+1} + (1-b)u_t \quad \text{and } 0 < b \equiv \alpha_2 / (1+\alpha_2) < 1 \tag{4}$$

where $f_t$ denotes the market fundamental solution and is equal to $m_t + \alpha_1 y_t$. By repeatedly substituting $E_t e_{t+1}$ for $n$ future time periods, from the above *Equation 4*, we can take a first order expectational difference equation:

$$e^f_t = (1-b)\sum_{j=0}^{\infty} b^j E_t f_{t+j} + u_t \tag{5}$$

However, if $(1+\alpha_2)^{-1}$ is greater than a unit, the *Equation (5)* can also have an infinite number of solutions.

$$e^f_t = (1-b)\sum_{j=0}^{\infty} b^j E_t f_{t+j} + B_t = e^f_t + B_t \tag{6}$$

Thus, if $\{B_t\}$ is a non zero term, and it is assumed to be an implicit process of *Equation (6)* and determined by *Equation (7)* as:

$$Et(B_{t+j}) = B_t (1/b)^j, \text{ for } j = 0, 1, 2, \ldots \tag{7}$$

then the solution to *Equation (5)* is not unique and an eventual infinite set of solutions derives from *Equation (7).*

Therefore, the market fundamental can be calculated by *the Equation (5)* and a whole set of bubble solutions is associated with the solution of *Equation (6)* in which the exchange rate bubble is $B_t$. A rational bubble is the extent of the deviation of the exchange rate from the market equilibrium and is captured by the term $B_t$ in *Equation (7).*

## 4.2 Bubbles with periodic process

Evans (1991) embraces the idea of stochastic bubbles with periods of contraction or collapse and describes his idea according to the following representation:

$$B_{t+1} = (1+r)\, B_t u_{t+1} \;\; if \;\;\; B_t \leq \alpha \tag{8.1}$$

and

$$B_{t+1} = [\, \delta + \pi^{-1}\, (1 + r)\, \theta_{t+1}(\, B_t - (1 + r)^{-1}\delta)]\; u_{t+1} \; if \; B_t > \alpha \tag{8.2}$$

where $\delta$, is the mean value of a bubble, and $\alpha$, is a parameter denoting the magnitude of the bubble, and both are real positive parameters such that $0 < \delta < (1+r)\, \alpha$. Furthermore, $(1+r)$ is the discount rate (constant) and $\{u_t\}$ is a sequence of non-negative exogenous identically independent distributed (i.i.d.) random variables with $E_t u_{t+1} = 1$. Moreover, $\theta_{t+1}$ is an exogenous (i.i.d.) Bernoulli process independent of $\{u_t\}$, which takes the value $1$ and $0$ for the probabilities $\pi$ and $(1 - \pi)$ respectively, with $0 \leq \pi \leq 1$. The main idea is that when $B_t$ is positive then $B_s$ will be also positive for every $s > t$. The bubble will be growing at mean rate equal to $(1 + r)$, if $B_t \leq \alpha$ *(Equation 8.1)* and in a different situation *(Equation 8.2)* the bubble acquires a new expansion dynamic at faster mean rate of $(1 + r)$ until the bubble collapses with probability $(1 - \pi)$. Finally, it is important to be stated that once the bubble has collapsed it restarts and expands from the mean value of $\delta$.

## 4.3 Estimation Methodology

Following van Norden (1996), the econometric model that we used in this paper is the two-state regime-switching model, because it is able to identify the existence and the size of a speculative bubble in the foreign exchange markets. More specifically, according to this model, it is assumed that the foreign exchange market in each country can be in two different states, with the first one to be when the bubble appears and begins to grow, known as the “Survival” state (S). Furthermore, the other state is the period in which the bubble collapses and it is known as the ‘Collapse’ state (C). Under the assumption that the foreign exchange market $(R_t)$ can be in two different states (regimes) with different means, slopes and variance and ($\Phi$) is the cumulative density function of the standard normal distribution we will have:

**Models 1, 2**

$$R_{s,t+1} = \beta_{s0} + \beta_{s1} b_t + \varepsilon_{s,t+1}\,, \qquad \text{where } \varepsilon_{s,t+1} \sim N\,(0,\sigma_s^2)$$
$$R_{c,t+1} = \beta_{c0} + \beta_{c1} b_t + \varepsilon_{c,t+1}\,, \qquad \text{where } \varepsilon_{c,t+1} \sim N\,(0,\sigma_c^2)$$

Under the assumption that $\beta_{s0} \neq \beta_{c0}$ and $\beta_{s1} \neq \beta_{c1}$, we will have the seemingly same models with the only difference to be that the probability of Survival is equal to $\Phi\,(\beta q_0)$ for the first model (**Model 1)**,

while this probability is equal to $\Phi\ (\beta q_0 + \beta_{q1} b_t)$ in the second model (**Model 2)**.
where ($q_t$) is the probability of being in the first regime, qt ∈ (0,1) and ( $\Phi$) is the cumulative density function of the standard normal distribution.

By maximizing the following likelihood function, we are able to estimate the above model:

$$\prod_t \left[ q_t\, \varphi\ (R_{t-1} - \beta_{s0} - \beta_{s1} b_t)/\sigma_s)\sigma_s^{-1} + (1 - q_t)\varphi(R_{t-1} - \beta_{c0} - \beta_{c1} b_t)/\sigma_c)\sigma_c^{-1}\ \ \sigma_c^{-1} \right] = A$$

where ($\varphi$) is the normal probability density function

($\sigma_s$) is the standard deviation of $\varepsilon_{s,t+1}$

($\sigma_c$) is the standard deviation of $\varepsilon_{c,t+1}$

the ex-post probability of each regime for this model can be calculated by the following equations:

- $p_t^{x,1} = \{q_t \varphi[(R_{t+1} - \beta_{s0} - \beta_{s1} b_t)/\sigma_s]\sigma_s^{-1}\}/A$
- $p_t^{x,2} = \{(1\text{-}q_t)\varphi[(R_{t+1} - \beta_{c0} - \beta_{c1} b_t)/\sigma_c]\sigma_c^{-1}\}/A$

where the term $\varphi$ is the standard normal probability density function.

Given that $1(i) = 1$ in the “Survival” state and $1(i) = -1$ in the “Collapse” state, the probability of being in regime $i$ at time $t + 1$ can be calculated by $\Phi(1(i)\ (\beta_{q0} + \beta_{q1} b_t))$.

Based on the Early Warning System (EWS), which was proposed by Kaminsky, Lizondo and Reinhart (1998), we will use one indicator of the current account (Exports) and one of the capital account (M2/Reserves), in order to create the second and the third model of this paper, respectively. Any of these indicators is able to act as a signal of changing market expectations about the development of the speculative bubble.

In a more specific way, we can refer that the current account is the equilibrium of trade between a country and its trading partners, reflecting all payments between countries for services, goods, dividends and interest. If there is a deficit in the current account, this means that the country is spending more on foreign trade than it is gaining and that it is borrowing capital from foreign sources to make up this deficit. So, we can easily understand that the country requires more foreign currency than it receives through sales of exports and it provides more of its own currency than foreigners demand its products. Consequently, the country’s foreign exchange rate is reduced by the excess demand for foreign currency until domestic goods and services are cheap enough for foreigners and foreign assets are not cheap enough to generate sales for domestic interests. Finally, it is easily being sketched out that a higher currency makes country's exports more expensive and a lower one makes the exports of the country cheaper.

Due to this lack of credit and business, a severe decline in trade can usually occur before or even more rarely during the crisis. If we look at trade between nations that are both experiencing a financial crisis, we will observe that they both equally may be affected, so the balance of the trade may be debatable. It is also important to be referred that the country which experiences an isolated crisis will show a larger balance of trade problem. According to Kaminsky and Reinhart (2009), prior to a crisis, it was proved that on average, exports decreased significantly during balance-of-payment crises. As far as banking crisis is concerned, we may not see as much of a decrease in exports, which shows that the crisis usually occurs in the financial sector first, though later exports may drop.

Adding the variable of exports in our original model, we will have the following:

**Model 3**

$$R_{s,t+1} = \beta_{s0} + \beta_{s1}b_t + \beta_{s2}x_t + \varepsilon_{s,t+1}\ , \quad \text{where } \varepsilon_{s,t+1} \sim N\,(0,\sigma_s^2)$$
$$R_{c,t+1} = \beta_{c0} + \beta_{c1}b_t + \beta_{c2}x_t + \varepsilon_{c,t+1}\ , \quad \text{where } \varepsilon_{c,t+1} \sim N\,(0,\sigma_c^2)$$

where ($x_t$) is a number of exports in US Dollars

($q_t$) is the probability of being in the 1st regime (Survival) and is equal to $\Phi(\beta q0 + \beta q1bt)$, with qt $\in$ (0,1).

Kaminsky and Reinhart (2009) ascertained that "… a crisis occurs because a country finances its fiscal deficit by printing money to the extent that excessive credit growth leads to the eventual collapse of the fixed exchange rate regime". Given that M2 is determined as M1[1] plus savings deposits, small-denomination time deposits[2] and retail money market mutual fund shares, they observed that during numerous financial crises, the M2/Reserves indicator shot up prior to crisis, tanking almost immediately after, which means that with the bursting of a financial bubble, we see an outflow of the money supply.

1) is defined as the sum of currency held by the public and transaction deposits at depository institutions (which are financial institutions that acquire their funds through deposits from the public, such as savings and loan associations, commercial banks, credit union and savings banks).

2) those issued in amounts of less than $100,000

Bank deposits also decreased in the post-crisis period, while prior to the bursting, much of the money supply was on borrowed assets. From the fact that in 2006, the US total household debt to disposable income ratio was 1.4 higher than the Nordic and Japanese pre-crisis levels, it is easily interpreted that not only the average citizen but also the governments are engaged in excessive borrowing.

Needless to say that some countries can get away with a balance of trade crisis for some years or even decades without turning into a financial crisis. But the danger lies in not being able to control your monetary policy when other countries are controlling your currency and your own debt. In order to allow the government to proceed with funding its fiscal programs, the Fed can lower rates, but it runs the risk of provoking foreign central banks of dumping its currency leading to inflation. In this worst scenario, the government may print money to pay part of the large debt, but increasing the money supply inevitably causes inflation and if the government is not capable of servicing its deficit through domestic means, then it must increase the supply of securities for sale to foreigners, which means lowering their prices. Finally, the foreigners will worry about the large debt and they will be more reluctant to own securities denominated in that currency, because of their belief that the risk of default is huge. For this reason, the country's debt rating is a crucial determinant of its exchange rate.

Adding the variable of M2/Reserves in our original model, we will have the following:

**Model 4**

$$R_{s,t+1} = \beta_{s0} + \beta_{s1}b_t + \beta_{s2}z_t + \varepsilon_{s,t+1}\ , \quad \text{where } \varepsilon_{s,t+1} \sim N(0,\sigma_s^2)$$

$$R_{c,t+1} = \beta_{c0} + \beta_{c1}b_t + \beta_{c2}z_t + \varepsilon_{c,t+1}\ , \quad \text{where } \varepsilon_{c,t+1} \sim N(0,\sigma_c^2)$$

where ($z_t$) is equal to M2/Reserves in US Dollars

($q_t$) is the probability of being in the 1st regime (Survival) and is equal to $\Phi(\beta q0 + \beta q1bt)$, with $qt \in (0,1)$.

**CHAPTER 5**

# Data & Model Selection

## 5.1 Investment Universe

The data used in this paper are collected from the Federal Reserve Economic Data (FRED) database and are monthly observations for the Consumer Price Index (CPI) and exchange rates for three of the G4 currencies: British Pound (GBP), Japanese Yen (JPY), United States Dollar (USD) and the Canadian Dollar (CAD). After taking into consideration that the United States Dollar is dominant in the investment universe and that USD currency pairs are typically the subject of academic research, we take USD as the base currency e.g. GBP/USD.

| Currency | FRED | Currency pair |
|---|---|---|
| **British Pound** | GBP | GBP/USD |
| **Canadian Dollar** | CAD | CAD/USD |
| **Japanese Yen** | JPY | JPY/USD |
| **United States Dollar** | USD | - |

In order to create Models 3, 4 we use the following two extra variables: 1) Exports and 2) M2/Reserves both in US Dollars. The source of these data is the International Monetary Funds (IMF) and especially the International Financial Statistics (IFS) database.

## 5.2 Data Sample

Having observed that the majority of the academic literature on the identification and forecast of financial bubbles in the foreign exchange markets use monthly data for their tests, we have also decided to use monthly data for the listed currency pairs. The period of analysis for the following currency pairs: GBP/USD, CAD/USD and JPY/USD extend from 01 January 1990 to 30 November 2013.

| Data Sampling | |
|---|---|
| **Start-Date** | 01 Jan 1990 |
| **End-Date** | 30 Nov 2013 |
| **Data Points** | 4592 |
| **Interval** | Monthly |

## 5.3 Estimation Results

Now, we estimate the regime-switching models for our three exchange rates taking into account the whole sample. In the following tables, we can see the results of the regressions for GBP/USD, CAD/USD, and JPY/USD currency pairs, respectively.

| UNITED KINGDOM | | | | |
|---|---|---|---|---|
| **Variables** | **M 1** | **M 2** | **M 3** | **M4** |
| $\beta_{s0}$ | 0.535 (0.004) *** | 0.562 (0.018) *** | -0.213 (0.068) *** | -1.361 (0.168) *** |
| $\beta_{s1}$ | 1.123 (0.048) *** | 0.587 (0.137) *** | 0.786 (0.051) *** | 0.994 (0.056) *** |
| $\beta_{s2}$ | - | - | 0.095 (0.008) *** | 0.397 (0.035) *** |
| $\beta_{c0}$ | 0.476 (0.004) *** | 0.477 (0.003) *** | 0.009 (0.055) | 0.866 (0.153) *** |
| $\beta_{c1}$ | 0.779 (0.034) *** | 0.664 (0.040) *** | 0.709 (0.032) *** | 0.620 (0.048) *** |
| $\beta_{c2}$ | - | - | 0.058 (0.007) *** | -0.084 (0.033) *** |
| **log(sigma)$_s$** | -3.771 (0.162) *** | -3.078 (0.110) *** | -3.742 (0.097) *** | -3.345 (0.066) *** |
| **log(sigma)$_c$** | -3.536 (0.110) *** | -3.547 (0.061) *** | -3.790 (0.067) *** | -3.729 (0.124) *** |
| $q_0$ | -0.522 (0.263) ** | -2.453 (0.618) *** | -1.457 (0.323) *** | 0.092 (0.453) |
| $q_1$ | - | 51.913 (12.296) *** | 31.656 (5.539) *** | 33.421 (11.106) *** |
| **Log likelihood** | 526.091 | 537.297 | 600.933 | 577.992 |

where sigma is the standard deviation. The variables $\beta_{s0}$, $\beta_{s1}$, $\beta_{s2}$ and log (sigma)$_s$ represent regime 1, while the variables $\beta_{c0}$, $\beta_{c1}$, $\beta_{c2}$ and log(sigma)$_c$ represent 2 and the numbers in parentheses are the standard errors. ***, ** and * denote rejection of null hypothesis at 1%, 5% and 10% significance level, respectively. The null hypothesis claims that a coefficient is zero and its rejection means that the coefficients are statistically significant.

Given that the critical values are ± 2,58, ±1,96 and ±1,65 for 1%, 5%, and 10%, respectively, all the coefficients are statistically significant at 1% significance level, except for three variables: $q_0$ in Models 1&4 and $\beta_{c0}$ of Model 3.

In order to make the Log-likelihood Ratio-test *(see 5.4)* and decide which model is the best that fits our data, we should focus on the last lines of these tables. It is obvious that the Models with the extra values have higher values, as far as Log likelihood is concerned than the simpler Models 1&2.

| CANADA | | | | |
|---|---|---|---|---|
| **Variables** | **M 1** | **M 2** | **M 3** | **M4** |
| $\beta_{s0}$ | 0.184 (0.002) *** | 0.184 (0.002) *** | 1.424 (0.052) *** | 0.316 (0.126) ** |
| $\beta_{s1}$ | 1.174 (0.015) *** | 1.172 (0.019) *** | 0.516 (0.069) *** | 0.700 (0.011) *** |
| $\beta_{s2}$ | - | - | -0.134 (0.005) *** | -0.008 (0.025) |
| $\beta_{c0}$ | 0.277 (0.001) *** | 0.277 (0.001) *** | 1.484 (0.050) *** | 0.194 (0.081) ** |
| $\beta_{c1}$ | 0.695 (0.009) *** | 0.697 (0.008) *** | 0.936 (0.015) *** | 1.174 (0.021) *** |
| $\beta_{c2}$ | - | - | -0.132 (0.005) *** | -0.002 (0.016) |
| **log(sigma)$_s$** | -3.869 (0.063) *** | -3.863 (0.066) *** | -4.059 (0.113) *** | -4.328 (0.066) *** |
| **log(sigma)$_c$** | -4.344 (0.069) *** | -4.327 (0.065) *** | -3.948 (0.054) *** | -3.863 (0.066) *** |
| $q_0$ | 0.020 (0.140) | -0.062 (0.159) | -3.231 (0.635) *** | 0.056 (0.156) |
| $q_1$ | - | -4.914 (1.357) *** | -27.108 (7.478) *** | 4.896 (1.361) *** |
| **Log likelihood** | 617.551 | 624.700 | 706.594 | 624.760 |

In the case of Canada, all the coefficients are statistical significant either at 1% or 5% significance level except for $q_0$ in Models 1&2&4, $\beta_{s2}$, and $\beta_{c2}$ both in Model 4. Finally, we can see the estimation results in the third exchange rate of our analysis.

| JAPAN | | | | |
|---|---|---|---|---|
| **Variables** | **M 1** | **M 2** | **M 3** | **M4** |
| $\beta_{s0}$ | 4.780 (0.007) *** | 4.602 (0.005) *** | 6.028 (0.192) *** | 3.285 (0.289) *** |
| $\beta_{s1}$ | 0.962 (0.049) *** | 1.274 (0.037) *** | 0.954 (0.030) *** | 0.971 (0.070) *** |
| $\beta_{s2}$ | - | - | -0.147 (0.022) *** | 0.243 (0.053) *** |
| $\beta_{c0}$ | 4.597 (0.005) *** | 4.787 (0.006) *** | 6.588 (0.026) *** | 7.526 (0.270) *** |
| $\beta_{c1}$ | 1.254 (0.036) *** | 1.005 (0.037) *** | 1.178 (0.031) *** | 1.069 (0.026) *** |
| $\beta_{c2}$ | - | - | -0.234 (0.030) *** | -0.500 (0.049) *** |
| **log(sigma)$_s$** | -3.044 (0.110) *** | -3.040 (0.084) *** | -3.329 (0.074) *** | -3.059 (0.074) *** |
| **log(sigma)$_c$** | -3.117 (0.086) *** | -3.150 (0.088) *** | -3.251 (0.074) *** | -3.471 (0.087) *** |
| $q_0$ | 0.025 (0.169) | 0.121 (0.150) | -0.103 (0.132) | 0.148 (0.143) |
| $q_1$ | - | 3.585 (1.147) *** | -3.558 (1.102) *** | 2.751 (1.101) *** |
| **Log likelihood** | 302.894 | 307.982 | 349.890 | 352.385 |

In the case of Japan, all the coefficients are statistically significant at 1% significance level except for

$q_0$ in all Models of our analysis. Now, we have to choose which one of these four Models is the most suitable for our data.

## 5. 4 Selection of the Suitable Model

In order to find which of the models *(see 4.3)* and under which restrictions is more suitable for each case that we examine, we use the Likelihood-Ratio test or its logarithm and by calculating a p-value we can decide whether to reject the model under the null hypothesis in favor of the model under the alternative hypothesis. Both of the models (null and alternative) are separately fitted to the data and the log-likelihood is recorded. Should we use the logarithm of the likelihood ratio, we will have the log-likelihood ratio statistic and its test statistic determined as:

$$D = -2\ln ( L_0 / L_1) = -2\ln(L_0) + 2\ln(L_1)$$

where $L_0$ is the likelihood of the null model (simpler) and $L_1$ is the likelihood for the alternative model. With the freedom degrees to be equal to $df_2$ (free parameters of the alternative model) minus $df_1$ (free parameters of the null model), the probability distribution of this test statistic is about a chi-squared.

We have to estimate the four different models for the three different exchange rates by using the LR-test with a view to selecting the model that fits our data best. For our estimation, we will use, firstly, the LR-test in order to select between the Model 1 and Model 2, because these two Models are the same with a different probability of Collapse. Then, if we choose Model 2 over Model 1, we will compare it with Model 3 and Model 4, separately, because Models 1&2 are restricted versions of the Models 3&4.

Moreover, of significance is the fact that the LR-test cannot be applied to models that are not nested, like Models 3&4. If LR-test shows that both third and fourth Models are suitable for our data, we will accept them both as capable models of fitting our data.

After applying the Log-likelihood Ratio-test, we have the results that are presented in the following three tables. As mentioned before, we examined these currency pairs:

- ✓ British Pound/ US Dollar
- ✓ Canadian Dollar/ US Dollar
- ✓ Japanese Yen/ US Dollar

| LOG LIKELIHOOD RATIO TEST FOR UNITED KINGDOM | | |
|---|---|---|
| | **LR-stat** | **p-value** |
| **M2 vs M1** | 22.412 | 0.000 |
| **M3 vs M1** | 149.684 | 0.000 |
| **M4 vs M1** | 103.802 | 0.000 |
| **M3 vs M2** | 127.272 | 0.000 |
| **M4 vs M2** | 81.390 | 0.000 |

In this table, we can observe that all models are capable of fitting our data, because of the high values of LR-stat and the p-values that are equal to zero. Model 2 is better than Model 1 (LR-stat 22,412), but Model 3 is better than Model 2 because the LR-stat of M3 vs M2 is higher than this of M2 vs M1 and p-value = 0. Model 4 is also better than Model 2 because the LR-stat is high (81,390) and the p-value = 0. We are not able to compare Models 3 and 4 because they are not nested Models (Model 3 is not a restricted version of Model 4). Thus, we conclude that both Models 3 and 4 are optimal.

| LOG LIKELIHOOD RATIO TEST FOR CANADA | | |
|---|---|---|
| | **LR-stat** | **p-value** |
| **M2 vs M1** | 14.298 | 0.000 |
| **M3 vs M1** | 178.086 | 0.000 |
| **M4 vs M1** | 14.418 | 0.000 |
| **M3 vs M2** | 163.788 | 0.000 |
| **M4 vs M2** | 0.120 | 0.942 |

Given that LR-stat for M2 vs M1 is 14,298 and the p-value =0, we choose Model 2 over Model 1. Then we compare Model 2 with Model 3 by looking the LR-stat of M3 vs M2 (163,788) with p-value=0 and we choose Model 3 over Model 2. With p-value = 0,942 Model 4 seem not appropriate for our data. So, after the application of LR-test, we conclude that the most suitable model for our data for Canada is the third model.

If we apply the Log-likelihood Ratio-test for Japan, which results are presented in the following table, we will be led to the same conclusions as in the case of United Kingdom. As we can see, all p-values are either zero or very close to zero and at the same time the values of LR-test are very high, except for the first contrast, which is just high. Given that Model 2 is better than Model 1 and Model 3 is better than Model 2, we conclude that Model 3 is the most suitable for our data. On the other hand, Model 4 is also more capable than Model 2 and this is the reason why we select Models 3&4 for our data in the case of Japan.

| LOG LIKELIHOOD RATIO TEST FOR JAPAN | | |
|---|---|---|
| | **LR-stat** | **p-value** |
| **M2 vs M1** | 10.176 | 0.001 |
| **M3 vs M1** | 93.992 | 0.000 |
| **M4 vs M1** | 98.982 | 0.000 |
| **M3 vs M2** | 83.816 | 0.000 |
| **M4 vs M2** | 88.806 | 0.000 |

Now, it is time for us to use the Regime Classification Measure (RCM) with a view to examining whether the two regimes of our models are classified successfully.

## 5.5 Regime Classification Measure

Introduced by Ang and Bekaert (2002), the Regime Classification Measure is an attempt to evaluate the ability of an RS model to fit the data and its formula for a model with two regimes is the following:

$$RCM = 400 \ x \ \frac{1}{T} \sum_{t=1}^{T} p_t (1 - p_t)$$

where $p_t$ is the smoothed regime probabilities and T is the sample size. Given that the idea behind RCM is that the regime-switching model is good if it is able to classify regimes sharply, we have weak regime inference, if the RS-model cannot successfully separate the regimes. By construction, the RCM bounded between 0 and 100, such that the closer it gets to zero the stronger the evidence in favor of the regime-switching model is. On the other hand, when RCM is 100 we cannot observe any information about the regimes. Now, in our analysis we have the following values for the four models for each country:

| THE REGIME CLASSIFICATION MEASURE (RCM) | | | | |
|---|---|---|---|---|
| | **M1** | **M2** | **M3** | **M4** |
| **United Kingdom** | 38.809 | 10.417 | 8.122 | 36.217 |
| **Canada** | 24.820 | 18.063 | 23.405 | 18.119 |
| **Japan** | 10.753 | 8.437 | 4.855 | 9.211 |

As far as the first currency pair is concerned, our results provided strong support for Model 3 because of the smaller RCM (8,122) among these of the rest models. On the other hand, the best Model for Canada after taking account into the results of RCM is Model 2 (18,063). Because of the fact that the other values of RCM of Canada are counted between 18,063 and 24,820, we can understand that the regime classification is good enough, but not ideal. In the case of Japan, the results are also more supportive for Model 3 with the RCM to be equal to 4,855. Here, it is important to be stated that in the case of Japan, according to RCM, all models are separated in a successful way.

# CHAPTER 6

# Empirical Results & Conclusion

## 6.1 Empirical Results

The main empirical results of our study are now presented. We already know that the most appropriate Models for the British Pound/US Dollar and the Japanese Yen/US Dollar exchange rates are Models 3&4 with time-varying probability. So, the third and fourth Models are good enough to interpret the movements of these exchange rates. In contrast with these currency pairs, only Model 3 with time-varying probability seem appropriate for the Canadian/US Dollar exchange rate. Given that the smoothed regime probabilities indicate in which regime the exchange rate is throughout the period after scrutiny, we are able to observe the movements of the exchange rates. According to Harvey & Siddique (2000) and Chen, Hon & Stein (2001), when the returns have become high in the past, the asymmetry of future performance is more negative, which means that if the returns were high in the past the probability of the bubble to be caused by the explosion situation the next period will be increased.

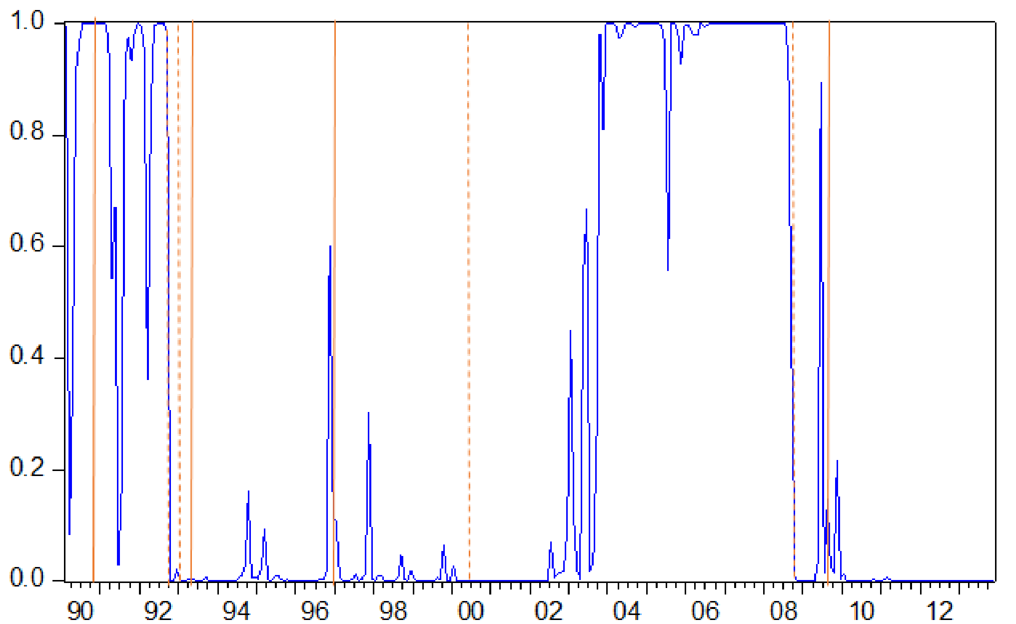
After taking the highest and lowest returns of the examined exchange rates (Return = $\log(e_t)$- $\log(e_{t-1})$), we created the following Figures that show the movements of the exchange rates between the two regimes, in order to examine the predictive ability of the selected models. If a movement is noticed from one state to the other and simultaneously we can observe that the period after this movement a high or low return exists, we can understand that the chosen Model is able to predict and identify a possibility of a collapsing bubble. If the value of the probability is below 0,5 we can understand that the exchange rate is in the first regime, otherwise, it is in the second regime, i.e. in the regime of collapse. The continuous vertical lines highlight the periods with the highest four positive monthly returns in the exchange rate, while the dotted lines show the four highest negative monthly returns.

British Pound/ US Dollar

Applying the Log-likelihood Ratio-test for the British Pound/US Dollar currency, we find that both Models three and four are optimal according to our data. Both exports and M2/Reserves are good enough variables to warn us of a big change in this exchange rate. Now, we find the highest and lowest monthly returns of the examined exchange rate.

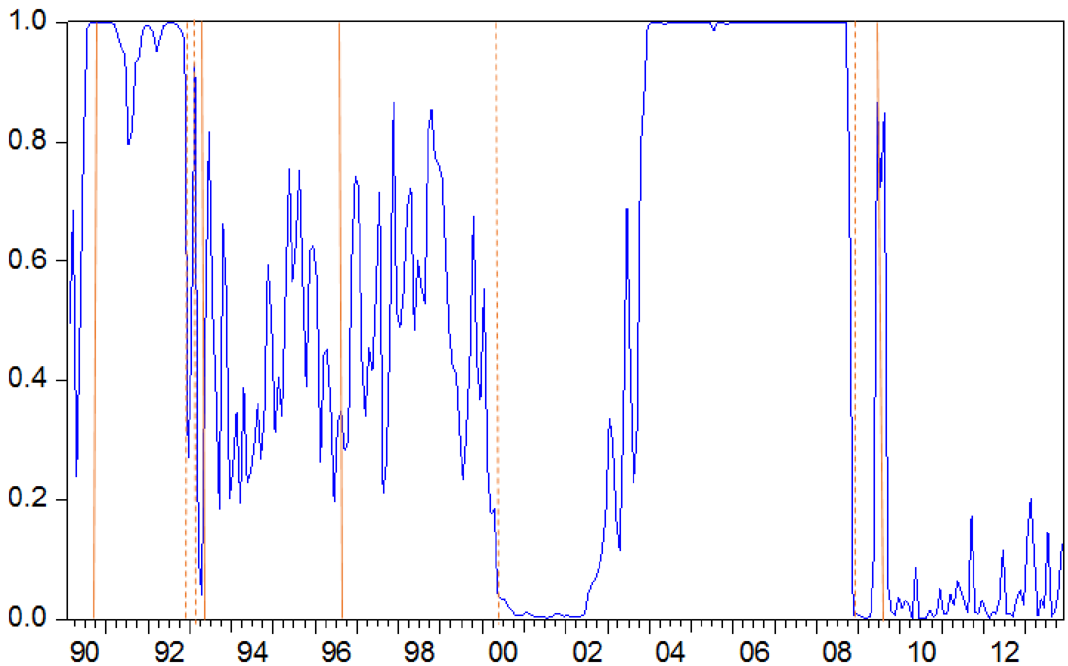
| Date | Highest Returns | Date | Lowest Returns |
|---|---|---|---|
| **2009-06-01** | 0.060 | **1992-10-01** | -0.111 |
| **1993-04-01** | 0.055 | **2008-11-01** | -0.095 |
| **1990-08-01** | 0.049 | **1993-02-01** | -0.063 |
| **1996-11-01** | 0.047 | **2000-05-01** | -0.047 |

The following graph shows the probability of being in the two regimes and also highlights the above-mentioned highest (continuous vertical lines) and lowest (dotted vertical lines) monthly returns. Moreover, it clearly indicates that in most cases, as far as the great increases and decreases in the exchange rate are concerned, the predictive ability of this Model is very strong. Obviously, there is an extreme movement in August 1990 and in June 2009.




Thus, in January 1996 the probability is almost 0, we can see that there is a movement in the second regime at the end of the year following by a return equal to 0.047. Moreover, despite the fact that the extra variable can act as a signal of a financial bubble creation in the most cases of our examined period, in 2000 it is not capable of predicting one of the lowest returns (-0.047). Thanks to Model 3, two of the biggest decreases in this exchange rate could also be forecasted (1992).

A similar picture emerges around 1992 in the following graph that has the extra variable of M2/Reserves in US Dollars. Figure 3 shows that in all cases when a great increase or decrease in the exchange rate occurs, the extra variable can act as a signal of a bubble creation.



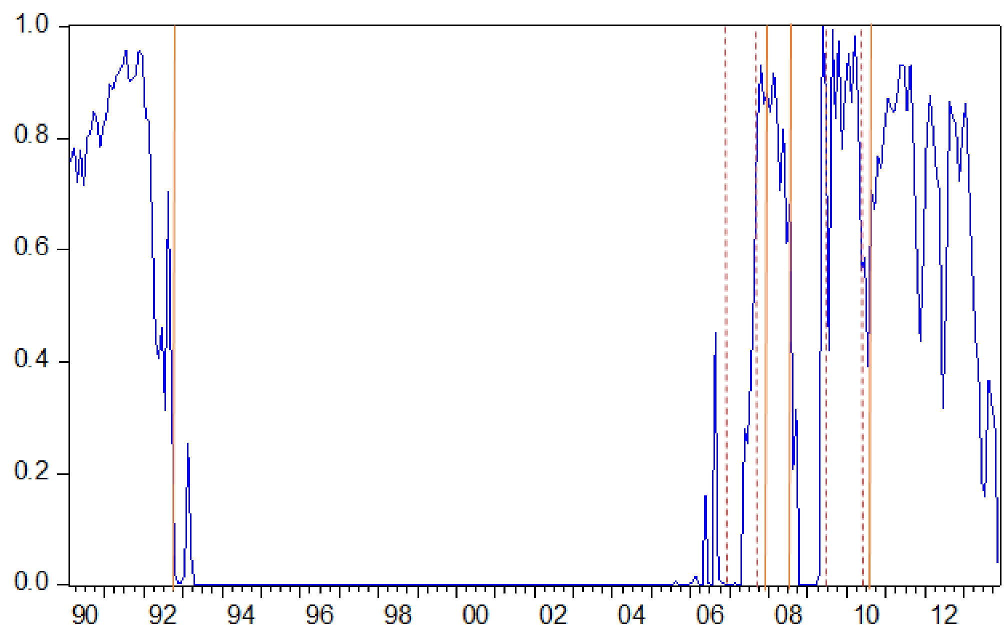

More specifically, in the middle of 1990, we can observe a movement from the first to the second regime, while months later a high return occurred. The same can be noticed in the period between 1992 and 1994, in which 3 variations of exchange rate took place and the probability changes regime three times in almost six months. In 1996, as in the previous figure, we can also predict and prevent a crisis thanks to the Model 4. After several fluctuations in 1995, we can observe that finally, the probability moves in the second regime following by a high monthly return (0.047). More recently, in the period of the global crisis (2009) we have a great increase in the British Pound/US Dollar currency, following a great decrease in 2008, which, as we can see, our model is able to forecast.

<u>Canadian Dollar/ US Dollar</u>

According to the log-likelihood ratio test, in the case of this exchange rate, the most suitable Model for our data is the third one with time-varying probability and an extra variable (exports in US Dollars). Given that exports seem to be capable of giving a signal of a big change in this exchange rate, we will find the highest and lowest monthly returns of the examined exchange rate in order to illustrate the predictive ability of Model 3.

| Date | Highest Returns | Date | Lowest Returns |
|---|---|---|---|
| **2008-08-01** | 0.039 | **2009-05-01** | -0.060 |
| **2007-12-01** | 0.035 | **2007-10-01** | -0.051 |
| **2010-05-01** | 0.034 | **2010-03-01** | -0.033 |
| **1992-09-01** | 0.026 | **2006-05-01** | -0.032 |

Given that most of the movements between the two regimes happen a period before a big change in exchange rate, we can understand that our chosen Model is able to predict the movements of Canadian Dollar/US Dollar currency. To be more specific, we can observe that the examined exchange rate stays from 1990 to 1991 in the second regime, while it starts moving to the first regime and then it goes back to the second in the middle of 1992. This can be interpreted as a signal of a big change, because we can observe that in September 1992 a great increase in the exchange rate was remarked. After 13 years of remaining in the first regime, the examined currency moves to the second regime, collapse, and stays till the end of 2012.



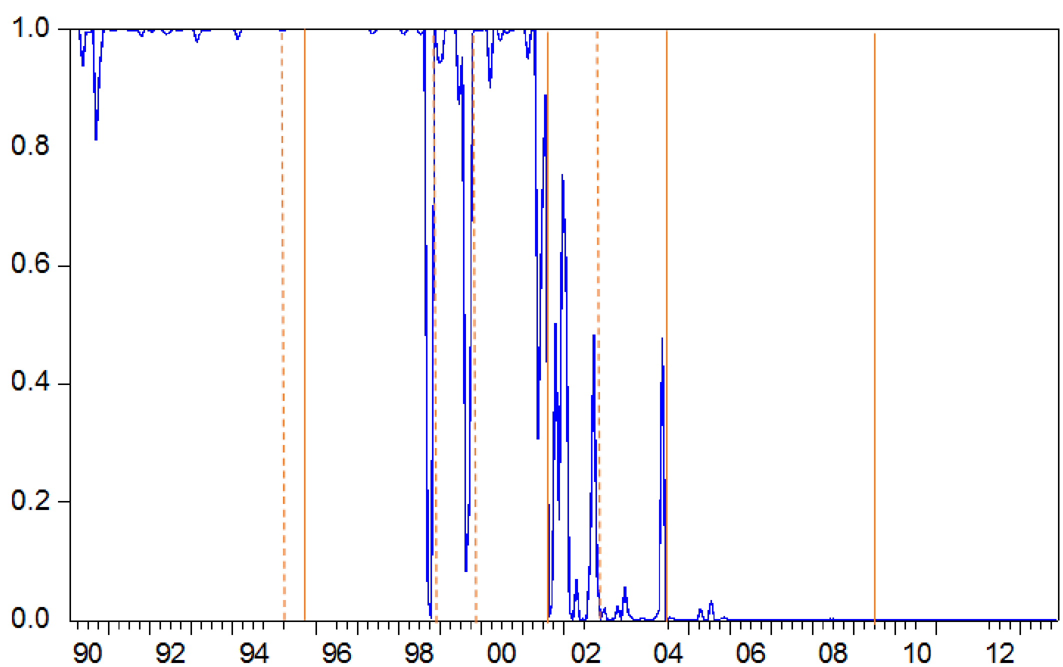

Furthermore, it is important to be noticed that in the period of 2007 and 2008, which is the period of the US housing Bubble, we have 3 great changes in monthly returns and a movement of the exchange rate from the fist to the second regime (collapse) which lasted almost two years. Finally, in the period of the global crisis (2009), we can notice some steep changes in the smoothed probabilities of our Model, while until 2010 we have two and one of the lowest and highest returns, respectively.

Japanese Yen/ US Dollar

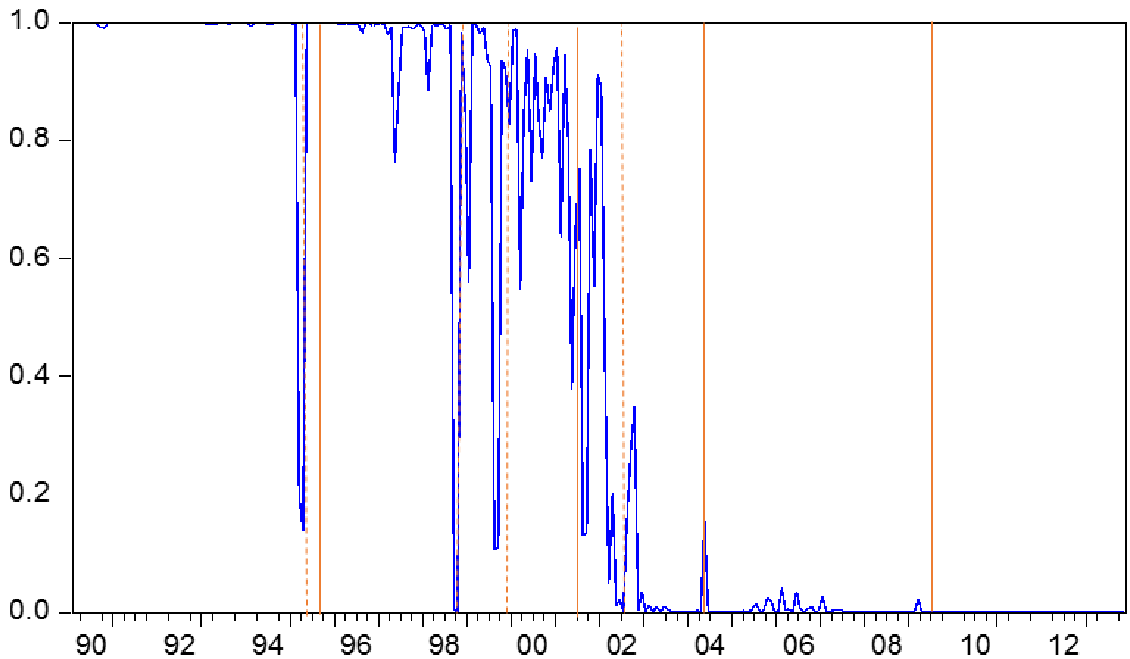
We apply the Log-likelihood Ratio-test for the JPY/USD currency and we conclude that the best models for our data are Model 3 and Model 4. These Models have a time-varying probability of being in the first regime and extra variables, exports, and M2/Reserves, respectively. The four highest and lowest monthly returns are presented in the following table.

| Date | Highest Returns | Date | Lowest Returns |
|---|---|---|---|
| **1995-09-01** | 0.059 | **1998-10-01** | -0.105 |
| **2009-03-01** | 0.052 | **1995-03-01** | -0.082 |
| **2001-03-01** | 0.044 | **1999-09-01** | -0.058 |
| **2004-05-01** | 0.041 | **2002-07-01** | -0.044 |

Firstly, we focus on the highest monthly returns of Japanese Yen/US Dollar exchange rate and then we observe the following graph. It is obvious that our Model is not able to predict all the "extreme" movements of our examined exchange rate. For example, we have great increase and decrease in the year 1995 and no probability movement is spotted this year or a period before. We are able to see that the same applies for the year 2009 too. Despite these failures, we can observe that the probability in the middle of 1998 is 1 and a couple of months later, it moves to the first regime (almost zero) when a huge decrease in the exchange rate occurs.



Furthermore, in the years 1999, 2001 and 2004, our Model seems to be appropriate to forecast a big change, because the probability changes regime some months before an extreme movement of exchange rate happens. Some of the movements that the third model is not capable of predicting, they can be noticed, as we can see, by the fourth Model.




To be more specific, we can see that the probability moves from the second to the first regime in the middle of 1995 following firstly by a decrease and then by an increase in the exchange rate. For the consecutive years until the end of 2013, the graph is almost the same with this of the smoothed probabilities of the third Model. Even though only the high return in 2009 our Model cannot predict, we can conclude that the predictive ability of this Model is good but not good enough as in the cases of the United Kingdom and Canada.

It should be remembered that the probabilities of collapse in all Figures tend to confirm the timings of the bubble episodes. Moreover, the probabilities' variations between the two regimes can reflect the movements of the exchange rate and can act as a signal of a bubble creation.

According to our graphs, the predictive power of our Models is stronger for the British Pound/US Dollar and Canadian Dollar/US Dollar exchange rate than it is for the Japanese Yen/US Dollar currency pair. Increases and decreases in Exports and M2/ Reserves can give us an indication of a future change in the exchange rate.

## 6.2 Summary & Conclusions

In recent years, financial bubbles are well known for their dynamics and consequences that influence in a dramatic way much of the world's population. Consequently, many economists have aimed at understanding, identifying and forecasting bubbles and, in particular, the related, following crashes. However, they cannot come to an agreement on the definition and the causes of bubbles, let alone to correctly identify and predict them in advance.

The motivation of this study stems from the introduction of collapsing bubbles from Evans at 1991, who embraces the idea of stochastic bubbles with periods of contraction or collapse. In this paper, we examine three exchange rate markets for the period from January 1990 to November 2013. The examined currency pairs are the British Pound/US Dollar, the Canadian Dollar/US Dollar, and the Japanese Yen/US Dollar. Our goal is to investigate whether a speculative bubble did occur in these markets, its size, and durance, as well as to inspect if our regime-switching approach has any predictive ability.

First of all, we provide a definition for the bubble in the two regime-switching model and then we described the models that are used in our study. In order to check if our regime-switching approach has any ability to predict negative or positive episodes of extreme market movements before they occur, we used two extra variables in our models. The first one is the exports and the second one the M2/Reserves both in US Dollars. Afterwards, we applied the Log-likelihood Ratio-test with a view to finding out which of the examined models is more suitable in each case. After taking a look at the Regime Classification Measure (RCM), we conclude that the majority of our models are successfully classified.

Given that in all cases Model 3 is capable model to fit our data, we conclude that exports can act as an Early Warning Indicator of a bubble creation. After taking the highest and lowest returns of the examined exchange rates, we created some Figures that show the movements of the exchange rates between the two regimes, in order to examine the predictive ability of the selected models. Our results indicate that in some episodes, which differ in size and duration, there was evidence of a bubble appearance, increase and then collapse. Finally, it is of great importance that in some cases our models managed to capture points of extreme market movements before they occur, so we can assume that our approach has some predictive ability over the examined data.

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