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Exchange Rate Dynamics and the Relationship between the Random Walk Hypothesis and Official Interventions

Eduardo José Araújo Lima[*]
Benjamin Miranda Tabak[**]

Abstract

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This paper examines the empirical evidence that official interventions are associated with periods of high predictability in exchange rate markets. We employ a block bootstrap methodology to build critical values for the Variance Ratio statistics and test for predictability within moving windows of fixed length sizes for major developed countries currencies. Empirical results suggest that interventions are indeed associated to periods of increase in predictability and that time varying risk premium may, at least partially, explain such results.

Keywords: joint variance ratio test; predictability; block bootstrap; multiple comparison test; fixed-length moving subsample window.
JEL Classification: G38; F31; F37.

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1. Introduction

The economic study of the exchange rates can be considered one of the most active and challenging research areas since mid-70s (Taylor, 1995). Different interest themes, related to the study of the behavior of exchange rates, are studied by the literature, including the study of official interventions in the exchange rate market. Additionally, the economic study of the exchange rates has important implications not only for economic models, but also for policymakers, financial markets agents, for risk modeling, for balance of payments and for the economy, as a whole, of every country. While researchers try to understand the behavior of the exchange rates and markets, investors try to identify inefficiencies in this market that may result in abnormal returns. At the same time, government agents and regulators seek to reduce, or even eliminate, possible inefficiencies and risks to assure economic stability.

Since it is not possible to examine all the issues related to this theme, the scope of the present paper will be limited to the analysis of the impact of official interventions operations on the efficiency of exchange rate markets. Although, this issue has been object of a vast literature (see Sarno and Taylor (2001)), it continues to be of great interest to policymakers in the conduction of exchange rate and monetary policies.

Applying a new methodology to nominal exchange rates data and information of Central Bank interventions in exchange rate markets we will reexamine the results found in Yilmaz (2003). The key point is to test if the official interventions coordinated by different Central Banks, rather than unilateral intervention by a single monetary authority, have effect over the behavior of exchange rates.

The contribution to the literature will be the presentation of results and stylized facts related to the effect of official interventions over the nominal exchange rate, using a new methodology for the variance ratio test (VR), where the intervals of acceptance of the null hypothesis will be constructed using the block bootstrap methods, together with the use of moving windows with fixed size to evaluate the result of the interventions dynamically.

The paper will be divided in six sections, beyond this introduction. In the second section, official intervention will be defined and the channels through which this

operation can affect the exchange rate dynamics will be discussed. Section 3 brings a brief report about official interventions. Section 4 describes the methodology and the relation between predictability and empirical regularity of exchange rates. Section 5 presents empirical results for the relation between official intervention operations and predictability in exchange rate markets. Finally, section 6 concludes the paper.

2. Official Interventions and their effects over exchange rate markets

During the last decades, the effects of official interventions in the exchange rate markets over the volatility and the level of the rates were object of study of several researchers. Examples of the diversity of empirical articles and the theory about this issue can be found in surveys of Edison (1993) and Sarno and Taylor (2001).

One of the research areas analyzes the association between the probable inefficiency of exchange rate markets and intervention operations. Some authors[1] argue that the official intervention in the exchange rate markets would be responsible for the apparent inefficiency present in these markets. The economic intuition is that when government authorities make interventions, they alleviate the changes and, in a certain way, interfere in the adjustment of exchange rates to economic fundamentals, leaning against the wind. Therefore, one should expect that opportunities were created in these situations.

Assuming the hypothesis of changes in the dynamics of exchange rates in moments of official interventions, the empirical regularity of the behavior of these rates can be analyzed using the random walk hypothesis (RWH) test. It is supposed, consequently, that when an intervention in an allegedly efficient market (market where the exchange rate follows a random walk) is made, the government generates a shock that deviates this exchange rate from its equilibrium trajectory, distancing it from a random walk behavior. Therefore, a relationship between interventions and the distancing of the rates from a trajectory purely random may be established. On the other hand, the intervention operations would be related to moments of higher predictability in exchange rate markets.

[1] For examples, see Sweeney (1986) and Kritzman (1989).

As in several other hypothesis of economic interest, the consensus about the issue of predictability in exchange rate markets is complicated. In the 80's, there was a consensus that the series of nominal exchange rates followed a random walk process. This can be verified in the works of Meese and Singleton (1982), Baillie and Bollerslev (1989) and Hsieh (1988), among others. More recently, what can be observed is that the conclusions are not consensus, depending on the periods, the series, the frequency, and the research methods, and also on the applied methodology. However, there is a greater tendency in supporting the results that lead to the rejection of the RWH in the long run. Several authors with the use of different tools approach the issue of the predictability in the exchange rate markets, where we can give greater attention to the rules of technical analysis and the VR test.

Many studies gave base to the belief that strategies generated by technical analysis would be capable of making profits in the exchange rate markets[2]. However, the reasons of this relationship were not sufficiently elucidated. According to Neely (2002), the literature points three basic hypothesis that try to give this answer: (1) the return of rules of technical analysis would only compensate investors for the assumed risks (Kho (1996)); (2) the apparent success of the technical analysis can be explained by the problem of data-snooping (Sullivan et al. (1999)); and (3) official interventions in the exchange rate markets generate inefficiencies that may be explored by the rules of technical analysis in the generation of profit.

The economic intuition associated to this last hypothesis is based on the idea that in the absence of official interventions, it is presumed that the rates will freely float according to the economic scenario seeking to reach what would be the equilibrium in the exchange rate market. However, periodical interventions aiming to reduce the volatility of the exchange rate market[3], may imply deviations from the equilibrium trajectory, generating possible inefficiencies, or higher predictability in the exchange rate market.

Citing just a few recent works, this possible relationship between predictability and official interventions in the exchange rate market was explored in the works of

2 See, among others, Corrado and Taylor (1986), Sweeney (1986), Levich and Thomas (1993) and Szakmary and Mathur (1997).

Szakmary and Mathur (1997), LeBaron (1999), Martin (2001), Neely (2002) and Sapp (2004), who used technical analysis in the investigation of the predictability. Yilmaz (2003) also explored the subject, working with a different and innovative line, since he applied the VR test in order to evaluate predictability by testing the RWH.

The results presented in Szakmary and Mathur (1997) showed that the interventions of Central Banks are strongly associated to the profitability of returns of technical analysis rules.

LeBaron (1999) examined the official interventions as a possible explanation to the existence of predictability in exchange rate markets. Using data of official interventions performed by the Federal Reserve Bank (FED), LeBaron (1999) evaluates the predictability issue by the profitability of technical rules, comparing the results of periods with and without interventions. His conclusions indicate that the removal of periods where there were official interventions causes the reduction of the predictability. However, the author indicates that it is not possible to establish a causality relation between interventions and profitability of technical rules, because both are moved by common factors, having, then, a serious problem of simultaneity.

Martin (2001), with a different approach, finds significant correlations between out-of-sample returns and the level of international reserves (a proxy used to measure the effects of interventions) in data of several developing countries. This way, he states that he found evidence that the profitability of rules based in technical analysis is related to the interventions. However, when he calculates the performance of these rules adjusted to the risk, he verifies that they are not superior to simple passive strategies of buy and sell.

Aiming to investigate this same hypothesis, that the interventions generate profits from rules of technical analysis, Neely (2002) analyzed the time pattern of technical analysis' returns and official interventions for daily and intraday data for Australia, Germany, Switzerland and United States. The results, with high frequency data, showed that abnormal returns precede interventions in the markets of Germany, Switzerland and United States. In the Australian case, the interventions precede high

3 Several studies conclude that the primary goal of the official interventions is indeed to reduce the volatility of the exchange market (Taylor (1982)).

returns of technical rules. However, there is no plausible reason to assume the hypothesis that the interventions would be the responsible for these returns. On the contrary, the interventions respond to trends already explored by the technical rules. According to Neely (2002), the signs and the returns in moments next to interventions, and the direction of the negotiations are inconsistent with the hypothesis of interventions that generate opportunities of profit for the technical analysis rules.

Sapp (2004), when analyzing the characteristics of the exchange rate market in periods close to official interventions, shows that the interferences are related to the movements of many economic factors, specially the uncertainty of the market. Despite the fact that there are evidences of a probable entail among certain monetary policy measures, the impact of this relationship is not consistent. The most important connection is the increase of the originated returns by these rules of technical analysis in periods next to the interventions, mainly the announced and coordinated interventions. Sapp (2004) evaluates, also, the existence of the relationship between the concentration of the profit of the rules and the increase in the market uncertainty about the interventions with a probable risk premium. Although he has not studied in detail this relation, Sapp (2004) was not capable of rejecting the possible presence of a risk premium related to the interventions, being consistent with the works of McCurdy and Morgan (1992) and Kho (1996), in the direction of strengthening the existence of a risk premium that varies with time in future exchange rate markets.

Another part of the literature, also related to the issue of predictability in the exchange rate markets, apply the VR test to time series of exchange rate. Although they have not examined the possible connection with official interventions, Liu and He (1991) and Fong et al. (1997) deal with the predictability issue in the exchange rate market, preceding the works of Yilmaz (2003).

Liu and He (1991) examined the RWH for weekly data of nominal exchange rates, for the period from august 1974 to march 1989, with the application of the VR test to data from the exchange rate of five currencies of industrialized countries (Canadian dollar (CAD), French franc (FRF), German marc (DEM), Japanese yen (JPY) and Pound sterling (GBP)), and rejected the RWH for the DEM, the JPY and the GBP, while, for the CAD and the FRF vis-à-vis the North-American dollar (US$), it was not

possible to reject the mentioned hypothesis. It means that, in opposite to great part of the literature, the RWH is rejected for the majority of the tested series[4].

Given the construction of the VR test robust to heteroscedasticity, rejections of the RWH would be due to the presence of autocorrelation. Facing this fact and aware that the existence of autocorrelation does not necessarily imply the market inefficiency, Liu and He (1991) report that, in the exchange rates case, there would be other possible explanations to the presence of autocorrelation, including the hypothesis of overshooting (Dornbusch (1976)) or undershooting (Frenkel and Rodriguez (1982)), risk aversion and official interventions in the exchange rate market.

In the specific case of their results, Liu and He (1991) attribute the rejection of the RWH to the phenomenon of undershooting, in face of the presence of positive autocorrelation in almost all the studied series, with the exception of the FRF data.

Aware of the problem with the procedures used by Liu and He (1991), focused only in individual statistics, without taking into consideration the joint implications of the test, Fong et al. (1997) applied multiple versions of the VR test to the same data set (August 1974 to March 1989) used by Liu and He (1991), aiming to reexamine the results. To verify the joint implications of the VR test, Fong et al. (1997) used the results of Hochberg (1974) - multiple comparison test (MCT) for multiple comparisons, and the results of Richardson and Smith (1991) - RS Wald to test the serial correlation in the presence of overlapping observations.

The results of Fong et al. (1997) indicate that, when the joint nature of the test is taken into consideration, the evidences against the RWH become weaker. For the complete period, Fong et al. (1997) applied the MCT of Hochberg (1974), who rejected the RWH for the DEM, JPY and GBP, just like Liu and He (1991). Applied to the same two subperiods studied by Liu and He (1991), the RS Wald test rejects the RWH for three currencies (CAD, DEM e GBP) in the first subperiod and cannot reject the RWH for any currency in the second subperiod. It means that, Fong et al. (1997) conclude that martingale model seems to work very well for exchange rates in the most recent period from October 1979 to March 1989.

[4] See also Belaire-Franch and Opong (2005) that employ the VR developed by Wright (2000), Lee *et al.* (2001) and Pan *et al.* (1997).

More recently, Yilmaz (2003) used the same couple of tests applied by Fong et al. (1997), the MCT proposed by Chow and Denning (1993) and the RS Wald, to test the RWH over series of daily changes of exchange rates of the US dollar vis-à-vis currency of seven industrialized countries, DEM, JPY, GBP, FRF, CAD, Switzerland franc (CHF) and Italian lira (ITL), for the daily period from January 1, 1974 to December 2, 2001, and established a relation, even if indirect, of the RWH with official interventions.

Yilmaz (2003) concludes that the behavior of the daily exchange rates is not uniform during all the analyzed period, that is, the bilateral rates of US$ in relation to the seven currencies analyzed do not follow a random walk during all the period of the research. More specifically, the exchange rates tend to deviate from a martingale behavior during periods where coordinated official interventions occur. Besides the period of interventions of the 70's, are cited the periods where the Reagan's administration interventions occurred (June and August of 1982), the Plaza Accord (September 1985), the Louvre Accord (February 1987), and the period immediately after the Gulf war (February and March 1991). The inclusion of data related to these episodes in the sample windows leads the test statistics to the region of rejection. Finally, the answers of the exchange rates to similar shocks (coordinated interventions and decisions of let the Exchange Rate Mechanism (ERM)[5] of the European Monetary System (EMS) do not necessarily occur in the same intensity for different rates. For example, in terms of the effects of coordinated interventions after the Plaza Accord, the rates can be divided in two different groups. While the DEM, FRF and CHF are different from the martingale model temporarily after the Plaza Accord, the difference of the JPY, GBP and CAD is stronger and lasting. Similarly, while the outflow of EMS in October 1992 takes the GBP to get distanced of the martingale properties for a longer period, in the ITL rate there is only a temporary and weaker shunt.

The work of Yilmaz (20003) establishes the relationship between the RWH and official interventions in the exchange rate market. The author affirms that when the VR statistics is used, for example, it is not correct to assume that the process that rules the

[5] The ERM is a system of rules to the maintenance of the exchange rates of the members of the European Community (EC), now the European Union (EU), that adhered to the system, in a fixed pattern, however adjustable. The ERM members define the value of their currencies in terms of the European Currency

behavior of a time series is the same during all the researched period. One of the alternatives, according to him, is to assume, a priori, that there are structural breaks in the data. A second alternative, followed by Yilmaz (2003), is to use moving windows of fixed size[6], previously determined, so that the test can be applied to several subseries of equal size, instead of being applied only once in the studied period, given that, when a graphic with the statistics of the test is constructed, it can be easily visualized the periods where the studied series suffered modifications in their dynamics.

Another contribution in relation to the previous works can be found in the new connection, although indirect, of the VR test to facts about official interventions in the exchange rate markets[7]. However, Yilmaz (2003) alerts that his article is not an attempt of developing a theory that shows how the martingale property can be rejected after Central Bank's interventions, given that this can be done using models that establish the connection between monetary policy actions and violations of the martingale property, at the same time that warns that, since the connection between Central Bank's interventions and the martingale behavior is not directly tested, the official interventions cannot be interpreted as the unique cause of the violation of the martingale property.

However, the author employs the Chow and Denning (1993) and the RS Wald, which have low power for finite sample time series. These procedures can generate serious distortions in inferences, due to low power when testing the RWH against near unit root alternatives. An interesting way to circumvent such deficiencies would be to employ bootstrap procedures to derive bootstrapped critical values, which could be used for inference purposes.

This way, trying to reexamine the conclusions of the work of Yilmaz (2003), a bootstrap methodology will be used. Before we define this methodology, the registers of official interventions present in the literature will be discussed.

Unit (ECU) and agree to maintain the market value of their currencies inside a band around this fixed rate.

[6] Tabak (2003) also used the procedure of fixed windows when he worked with the VR test, in what was entitled rolling variance ratio test.

[7] Liu and He (1991) had mentioned that one of the possible explanations to the presence of autocorrelations in exchange rate series could be the existence of official interventions in the exchange markets. The official interventions would have an effect over the increments of the exchange rates, which would present positive or negative correlation, depending on the objective of the political intervention.

3. Brief Report about official interventions

In the beginning of the 70's, with the collapse of the exchange system, there was a trend towards the adoption of a system of free floating exchange rates, without interventions. However, the experience of the 70's with this kind of system and the high volatility of exchange rates led to a change in the then prevailing view. Economists and policymakers started to criticize the government because it did not interfere in the exchange rate market. Due to the speed and facility that capital moved among the developed countries, the consensus moved to the side that did not believe in the effectiveness of the interventions, since their impact occurs only in a very short run. Followed by the strong and persistent overvaluation of the US dollar (US$) during the early and mid 80's and after the Plaza Accord, in September 1985, the consensus changes again, arguing that occasional intervention might be useful. After the decline of the US$, during the end of the 80's and after the Louvre Accord, in February 1987, there was an agreement so that the industrialized countries carried through coordinated interventions, aiming to stabilize the US currency.

After the Plaza and Louvre Accords, over the period from 1987 to 1995, the official interventions in the main exchange rate markets started to be more regular (see Dominguez, 2003 and Schwartz, 2000). Additionally, these interventions, together with coordinated macroeconomic policy, had important role in the ERM, with the adoption of target zones among the European exchange rates.

According to Dominguez (1998), after the Bretton Woods break in 1973, the politics of interventions were defined discretionally for each country. In 1977, the International Monetary Fund (IMF), when published some principles of politics of intervention, demonstrated implicitly that interferences could influence the exchange rates and explicitly that the countries could use it as way to diminish the volatility of the rates.

Schwartz (2000) argues that the FED made interventions in 1973 due to the worries generated by the depreciation of the dollar, by an increase in inflation, increase in the oil prices and the Watergate scandal. Until September 1974, there were seldom interventions by the US government, with exception of may 1974, where there are registers of coordinated interventions by the authorities of Germany, Switzerland and

the United States, aiming to decrease the volatility of the rates of the DEM and CHF, and also decrease the depreciation of the US$. From September/1977 to December/1979, the Bank of Japan (BOJ) started to be part of the coordinated interventions. Even with these actions, the US$ continued on a depreciation trajectory. In the end of 1978, the USA started an anti-inflation program and spent around US$ 30 billions in order to finance the interventions, in cooperation with Germany, Japan and Switzerland.

Around June 1979, the year of the second petroleum crisis, the dollar had recovered 10% of its lowest 1978 value, starting, however, a new depreciation. In October 1979, the American government announced measures of monetary control and started to interfere daily in the two points of the exchange rate market until, practically, February 1981 (Schwartz (2000)). After actively interfering in the exchange rate markets during the 70's, the United States abandoned the interventionist policy during the period from 1981 to 1984. During this period where there was persistent appreciation of the US$, the FED interfered in rare occasions. On the other side, the BOJ and the Bundesbank kept a more consistent presence in the exchange rate market. When the FED was absent from the market, the BOJ and the Bundesbank heavily interfered (Dominguez (1998)).

In the beginning of 1985, due to the huge commercial deficit of the USA, and after the period of strong appreciation of the US dollar facing the DEM, approximately 40%, the FED, jointly with the Bundesbank and the BOJ, decided to interfere in the exchange rate market. This agreement was closed on a meet of the group of the five (G5)[8] in the Hotel Plaza in New York, in September 22nd of 1985, where the meet was known as the Plaza Accord. According to Schwartz (2000), the American government did not carry through any intervention in 1986.

During the period that followed after the Plaza Accord, in September 1985, the US dollar depreciated substantially relative to the currencies of the major economies. Particularly, the JPY was appreciated from 240 to 150 yens per dollar. The authorities

[8] On March 25th of 1973, George Schultz, at that time the American Treasury Secretary, invited the Finance Ministers of France, United Kingdom and Germany for an informal discussion in Washington. They discussed about the monetary international disorder created by the American decision of abandoning the gold standard. They decided to continue their discussions and invited the Japanese

of the main economies recognized at the time that a substantial change in the value of their currencies could represent a strong threat to the expectations of growth and agreed to coordinate macroeconomic politics aiming to establish their exchange rates around the current levels at that time, determining a sort of target zone to the rates. On October 22nd of 1987, this agreement was made during a meeting of the G5 in the Louvre Palace (Louvre Accord).

Despite the fact that the details of this agreement were not published, the literature suggests that target-zones were adopted as a way of keeping the stability of the exchange rates (Funabashi, 1989). Considering that neither the central rates nor the bands for the exchange rates were announced, these target-zones were not official. It could be argued, following Krugman (1991), that implementation of unofficial, unannounced targets is far from optimal.

According to Funabashi (1989), the central rates adopted after the Louvre Accord were supposedly 153.50 yens and 1,825 marcs per dollar, with a 5% band. In the case of the JPY, on April 7th of 1987, the central rate was modified to 146 yens per dollar, in order to reflect the new market conditions.

In the period from 1987 to 1995, the Bundesbank, the FED and the BOJ seldom intervened. According to Dominguez (2003), in these nine years, the FED, frequently followed by the Bundesbank and the BOJ, intervened only in 273 days in the markets of the DEM or the JPY vis-à-vis the US dollar.

According to Schwartz (2000), on October 1989 there is evidence of coordinated intervention during three weeks, aiming to weaken the US$. In the years of 1990 to 1993, there were only buys and sells of DEM and JPY by the FED. In the end of 1994 and beginning of 1995 (until may), due to the decrease of the dollar relatively to the DEM and the JPY, there was an organized effort of intervention by 13 Central Banks, and also the FED. This effort is also registered in the graphics presented by Sapp (2004). On July and August 1995, the north-American authorities, along with Japan, sold yens. After August 1995, the authorities seemed to accept the value stipulated by the market for their exchange rates, with the exception of Japan that, together with the

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Finance Minister to join them. In the next months, there were new meetings, now with five, with the inclusion of Japan. The press created the expressions “Group of Five” or “G5”.

USA, performed interventions buying yens on July 1998 and, isolated, selling on January 1999.

The relative calmness of the exchange rate market in the 90's, when compared to the 80's, explains the low frequency of interventions after 1987. One of the exceptions was the ERM crisis, initiated, in a certain way, on June 2nd of 1992, when Denmark rejected the Maastricht[9] Treaty. It is important to highlight that intervention in floating exchange rate regimes such as the USD, DM and JPY is very different from interventions in fixed exchange regimes such as the ERM. This rejection, added to the worries of a new rejection by France, led the investors and practitioners of the market to revaluate their expectations in relation to the monetary union and questioned the central rates of the ERM. The financial, economical and political tensions culminated with the withdrawal of the ITL and the GBP from the ERM, in the mid-September of 1992. On November 1992, the Spanish peseta and the Portuguese escudo suffered strong depreciation, followed by the depreciation of the Irish pound, on February 1st of 1993. During this crisis, the main European Central Banks interfered in the exchange rate markets aiming to defend their exchange rates (Booth et al. (2000)).

After the introduction of the Euro as the official currency of the Eurozone on January 1999, and its immediate and persistent depreciation relatively to the US$, several coordinated interventions were made by the main European industrialized countries in order to support the value of the Euro in relation to the US$. Sarno and Taylor (2001) relate that these interventions reached its apex after the annual meetings of the IMF and the World Bank, on 09/22/2000.

According to Yilmaz (2003), the financial crisis in Mexico, Asia and Russia did not affect the exchange rate market of the G3, which explains the absence of official interventions during these periods.

[9] The European Union Treaty, also known as the Maastricht Treaty because it was signed in this Dutch city, built the basis of the process of European integration, because it modified and completed the previous Treaties, overcoming the initial goal of the European community (the common market), giving it a trend for political unity.

4. Methodology

Starting from the hypothesis that the behavior of the Central Banks of the main economies, relatively to the use or not of interventions on the exchange rate market, suffered modifications throughout the years, Yilmaz (2003) foresaw that the possibility of changes in the politics of interventions might result in changes in the behavior of exchange rates time series.

Believing in the hypothesis that the coordinated official interventions can generate changes in the exchange rates dynamics and, independently of the great discussion about the belief in the effectiveness of these politics of interventions[10], the empirical regularity of the behavior of the exchange rates can be analyzed using the RWH. Aiming to reexamine the conclusions of the work of Yilmaz (2003), we will use an alternative methodology, which employs a block bootstrap to build critical values for a multivariate version of the VR statistic.

In order to test the RWH, we will adopt the VR test, robust with heterogeneity, in its multiple version with the use of the Wald statistics, just like Cecchetti and Lam (1994). Intending to avoid problems with inferences for small samples, instead of using the statistics of the test developed by Lo and MacKinlay (1988), we will employ the Moving Block Bootstrap method with the rule of Hall et al. (1995) for the selection of the optimal size of the block – MBBH[11], in the construction of the empirical disturbances of the Wald statistics. These distributions will be derived based on 1,000 bootstrap samples, following the suggestion of Efron (1979) and Efron and Tibshirani (1986). For ends of comparison with the results of Yilmaz (2003), the test statistics will be calculated for maximum horizon of sixteen days[12].

To obtain samples of equal sizes in all resampled series, maintaining the ideal identity $n = bl$, we will use b blocks of l size and one block of $n - n'$ size to complete the resampled size, if it is necessary[13].

[10] See Schwartz (2000), as an example.
[11] See the appendix for more details on methodology
[12] See also Whang and Kim (2003) who have developed a subsampling approach to test the RWH using the VR statistic.
[13] See Buhlman and Kunsch (1999), Davison and Hall (1993) and Davison and Hinkley (2003).

We have conducted several Monte Carlo simulations to test whether this bootstrap approach has higher power than the traditional Chow and Denning (1993) test. Simulation results suggest that this is indeed the case. Table 1 presents results for the power of the test for a block bootstrap (MBBH), standard bootstrap (STD) and Chow and Denning (1993) statistic (MCT).

Table 1 – Power of the test of a Multiple Version of the VR test, with an ARIMA(1,1,1) as an alternative

N	*Maximum q*	MBBH	STD	MCT
64	4	0.039	0.071	0.030
	8	0.043	0.072	0.035
	16	0.045	0.069	0.038
	32	0.051	0.075	0.045
256	4	0.119	0.216	0.100
	8	0.216	0.315	0.157
	16	0.365	0.435	0.183
	32	0.466	0.504	0.183
	64	0.498	0.509	0.183
	128	0.535	0.540	0.184
1024	4	0.385	0.788	0.649
	8	0.723	0.952	0.913
	16	0.874	0.996	0.989
	32	0.930	1.000	0.997
	64	0.951	1.000	0.999
	128	0.952	0.999	0.999
	256	0.945	0.986	0.999
	512	0.972	0.985	0.999

The power of the test was estimated with an ARIMA (1,1,1) model, given by $p_t = y_t + z_t$, where $y_t = 0{,}85 y_{t-1} + \varepsilon_t$, with $\varepsilon_t \sim iid(0,1)$, and $z_t = z_{t-1} + \tau_t$, with $\tau_t \sim iid(0,1/2)$. N and q represent the number of observations and the investment horizon employed in the estimation of the VR statistic, respectively. In each case a separated simulation experiment was conducted, based on 2,000 replications. Furthermore, we use 1,000 bootstrap samples to assess the performance of the bootstrap method. The results of the MBBH (block bootstrap with optimal block size calculated using Hall's *et al.* (1995) rule), STD (standard bootstrap) and MCT (Chow and Denning (1993) Multiple Variance Ratio) are presented in different columns. The maximum *q* of 64, means that the joint VR test was done for investment horizons from 2 to 64.

The results in Table 1 suggest that for small samples the bootstrap approach has higher power than the MCT. We also compare how the power of the test changes for different parameters of the autoregressive coefficient used in the simulations. In Table 1 we employ a value of 0.85. We increase the parameter up to 0.98 (close to unity). An important finding is that the power of the test of Chow and Denning (1993) statistic decreases exponentially with increases in autoregressive parameter, which shows that its

power decreases substantially on the boundary. In the simulations the power of the test of the bootstrapped statistic decreases but at a much lower pace, which suggests that these bootstrap procedures are quite useful for inference. These results are robust to the use of different alternatives such as a heteroscedastic autoregressive process. We also compare the size of these statistics and simulation results suggest that, for small samples, the MBBH performs better.

Given that the process that rules the behavior of a time series is not constant, and aiming to control the sensitivity of the results of the researched period, the test will be made using the same procedure adopted in Tabak (2003) and Yilmaz (2003) relatively to the division of the sample in many subsamples of equal size and previously fixed (moving subsample windows). Each one of these subsamples will be formed by 1.000 observations. To reduce the time of computational process, between one subsample and other, a jump of 5 observations will be applied. This way, the first subsample will be formed by the observations 1 to 1,000, the second will be formed by the observations 6 to 1,005, and so forth.

Finally, since possible rejections of the RWH may be related to the fact that the risk premium varies over the time[14], we will examine the aspect of the official interventions and which official interventions may be related to the periods of better predictability as a result of the increase of the volatility in the exchange rates in that periods, which would lead investors, because of this higher risk, to demand a higher premium or, in other way, higher returns. Beyond calculating the volatility over the exchange rates returns, measured by the standard deviation, following the same procedure of moving windows with 1.000 observations adopted in the calculus of the VR test, we will analyze the possible relation between the p-value of the Wald statistics and the volatility of the increments of the exchange rates using the Spearman correlation (see Conover (1999)).

[14] About the variability over the time of the conditional variances of exchange rates, see Hsieh (1984), Frenkel (1988) and Sapp (2004), among others.

5. Empirical Results

For the DEM/US$ rate, the MBBH test rejects the RWH for the periods between mid and end of the 70' and from the beginning of 1981 to April 1987, which includes the periods of the Plaza and Louvre Accords. Although Figure 1 indicates a decrease in the value, the statistics of the test does not enter in the zone of rejection in the Gulf war period (February/March 1991 and mid-1992) and in the period of the ERM crisis (October 1991 to September 1992).

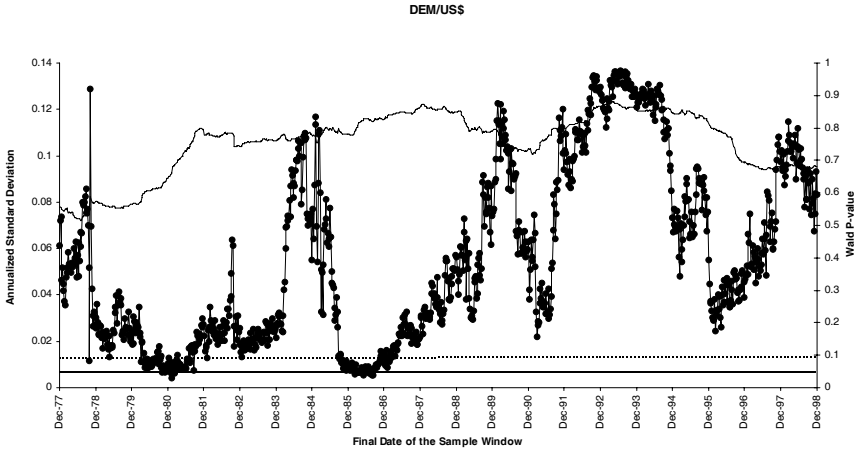

Figure 1 – Wald Statistic p-value and annualized standard deviation for the DEM/US$

Except the period of the 70's, the behavior of the FRF/US$ rate until the end of the 80's is similar to the DEM rate. The null hypothesis is rejected for the windows that include either the period of the Reagan administration (mid-82), or the end of 85 (September/October), period of the Plaza Accord. Observing Figure 3, it can be noticed the influence of the Gulf war and the period of the ERM crisis, when the test statistics decreases, getting close to the rejection region when data of mid-1992 are included.

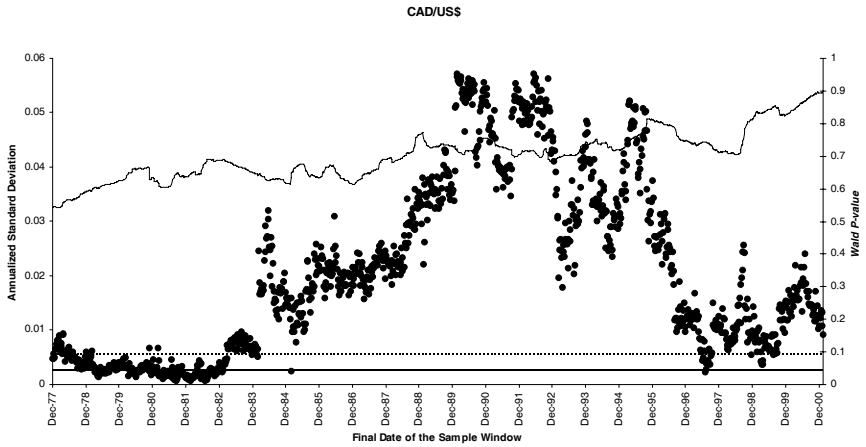

Figure 2 – Wald Statistic p-value and annualized standard deviation for the CAD/US$

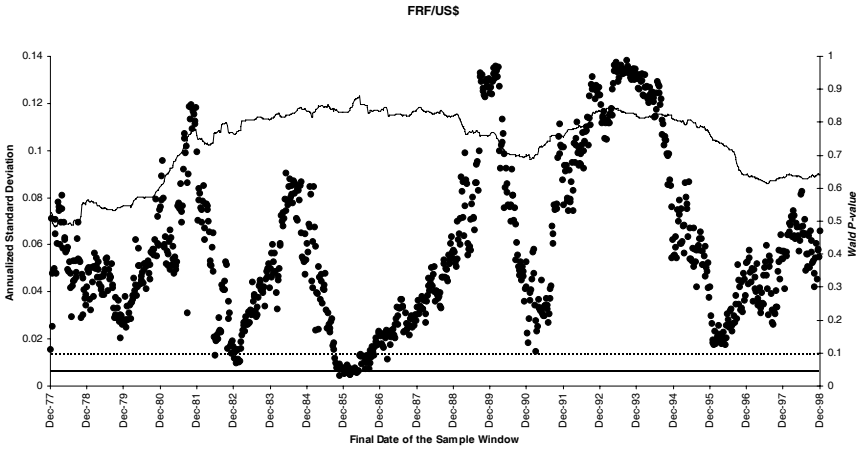

Figure 3 – Wald Statistic p-value and annualized standard deviation for the FRF/US$

The results of the test for the exchange rate of the CHF, relatively to the US dollar, also follow a similar pattern of the DEM/US$ rate. The MBBH test rejects the null hypothesis for the beginning of the 70's and for the period of the Plaza Accord. There is an approximation of the rejection region for the periods of the Gulf war and for the period of the ERM crisis. It was not confirmed in our data the mention made by Ylmaz (2003) to the outlier observations for December 30th and 31st of 1982 in the CHF/US$ rate, possibly because the series have been corrected. When the outliers are removed, Yilmaz (2003) also observes that the results for the CHF are similar to the ones for DEM and FRF for the periods before and after the Plaza Accord.

The behavior of the ITL/US$ exchange rate is also similar to the other rates. The null hypothesis is rejected for the windows with data from the 70's (starting in 1976),

occurring the same in the period of the Plaza Accord (windows from 1981 to 1986). The test statistics gets very closer from the rejection region, at the 10% significance level, when data next from the Gulf war are included, in 1991, and from the ERM crisis, in September 1992. The null hypothesis is again rejected, at the 10% significance level, in the windows with data from the end of 1993 until the begin of 1997, which includes the return of the ITL to the ERM and a few interventions combined between the FED, Bundesbank and the BOJ.

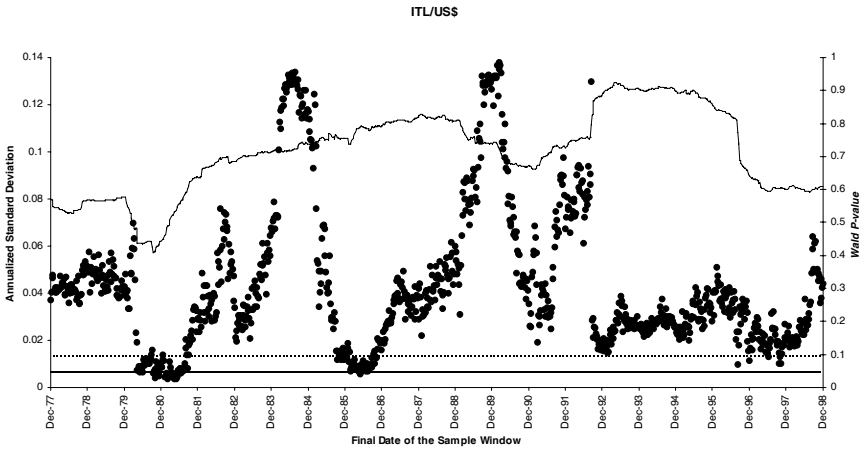

Figure 4 – Wald Statistic p-value and annualized standard deviation for the ITL/US$

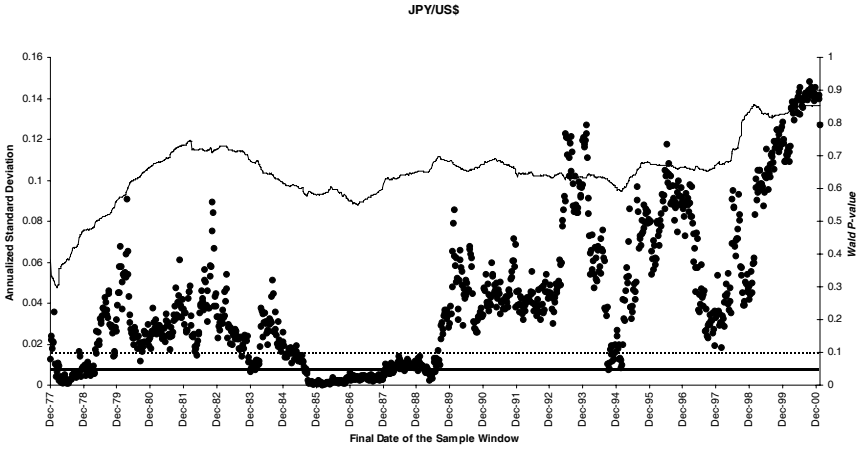

Figure 5 – Wald Statistic p-value and annualized standard deviation for the JPY/US$

To the CAD/US$ exchange rate, the MBBH test rejects the null hypothesis from mid-70's until the beginning of 1983, differently from the results of Ylmaz (2003), since the used statistics cannot reject the null hypothesis of martingale for the windows that include observations from the beginning of the 80's. The statistics only returns to

the rejection region with the inclusion of data from the period that starts in mid-1993 and ends in the beginning of 1999. Yilmaz (2003) explains this behavior by the probable influence of the low interest rate politics adopted in Canada in the end of the 90's, which led to a fast decrease of the CAD/US$ exchange rate.

The periods of increase in the predictability of the US$/GBP rate are more restricted. The RWH is rejected only in one window of the period from 1977 to 1981, and with the inclusion of data from the period of the ERM crisis, in September. In the windows with data from 91, even though with no data of 92, there is no rejection of the null hypothesis. This way, it can be said that the interventions made in the period of the war had no impact over the predictability of the US$/GBP rate.

For the JPY/US$ rate, the moments of higher predictability are the windows with data from the 70's (1974 to 1979), some points that include data from 1982, many windows with data from 1985 (period of the Plaza Accord), and also samples with observations from the end of 1994 until the begin of 1995, which corresponds to the period of the greatest recession of the Japanese economy, where Sapp (2004) and Schwartz (2000) register FED interventions, jointly with the BOJ, in the yens market.

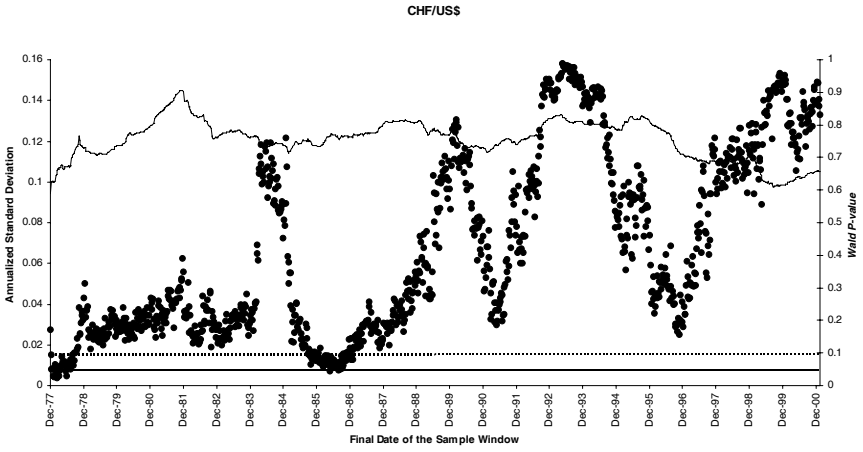

Figure 6 – Wald Statistic p-value and annualized standard deviation for the CHF/US$

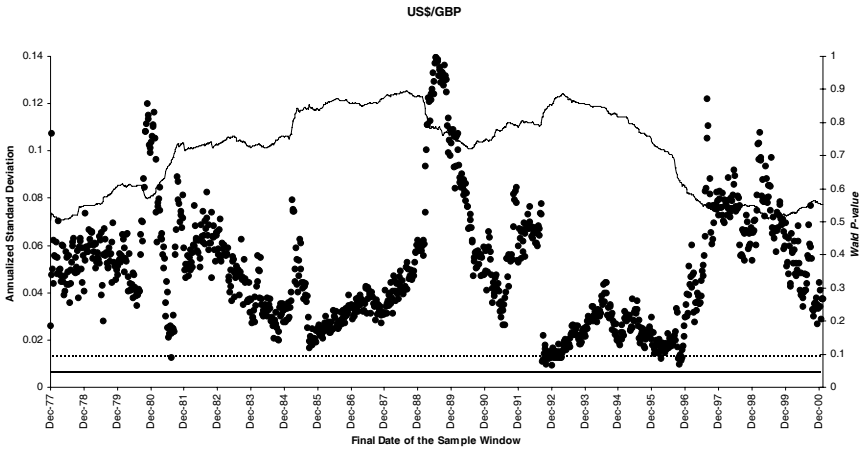

Figure 7 – Wald Statistic p-value and annualized standard deviation for the US$/GBP

In a general way, what is observed is that the results found with the test that is used here (variance ratio with bootstrap MBBH) are very similar to the effects found by Yilmaz (2003). It can be noticed that, despite the use of a test of higher power, results are quite similar. In fact, the results are not identical, however, have certain similarity, mainly in the periods where there were heavier coordinated interventions. Inasmuch, the evidences of relations between the coordinated intervention periods and the increase in the predictability, reported by Liu and He (1991) and observed by Yilmaz (2003), are confirmed.

With respect to the existence of probable relation between the risk premium, that varies over time, and the increase in the predictability, the full lines traced in Figures 1 to 7, together with the data of Table 2, where are shown the measures of the Spearman correlation, indicate that there is a relationship between volatility and predictability. Furthermore, our results indicate that the increases in the predictability observed in the periods close to official coordinated interventions cannot be explained solely by the time variation of the risk premium.

Table 2 – Spearman Correlation between the *p*-value of the Wald Statistics and the Volatility of the Exchange Rate Increments

Currency	Correlation
DEM	0,02461
CAD	0,00637
FRF	0,08396 *
ITL	0,01709
JPY	0,07276 *
CHF	0,10223 *
GBP	0,00456

The table presents the correlation of Spearman orders between the p-value of the Wald statistics and the annualized standard deviation of the exchange rates returns, calculated in moving windows of 1.000 observations. The asterisk stands for the existence of correlation between the variables, with 5% significance.

6. Conclusions

When testing the martingale properties using the Variance ratios of variances in daily series of exchange rates of seven of the main world economies, it is concluded that, during the periods of coordinated official interventions, the behavior of these exchange rates shunts, moving away from a random walk. It is confirmed the relation between periods of official interventions and moments of increase in the predictability, mentioned by Liu and He (1991) and observed by Yilmaz (2003).

In a general way, what is observed is that, although it is used a test with higher power (variance ratio with MBBH bootstrap), the result of the test is similar to the ones of Yilmaz (2003). Additionally, our results indicate that the increase in predictability observed close to moments of coordinated official interventions cannot be explained solely by the time variation of the risk premium.

These results do not imply that every increase in the predictability occurred in the period studied can be explained by intervention politics. Even controlling for the variability of the risk premium, there are several other factors that escape of the control of the researcher. Hansen and Hodrick (1980), for example, indicate the implied necessity of specification of the level of information that the agents have about the stochastic properties of government actions, such as monetary policy and capital control. Thus, our results should not be construed as evidence supporting more active

involvement by major central banks in the currency markets, and certainly do not apply to unilateral intervention by emerging market central banks.

Further research could exploit the emergence of nonlinearities in exchange rates in periods of intervention and analyze whether such intervention may cause nonlinear dynamics in these series[15].

[15] Hinich and Serletis (2007) show that the Canadian exchange rate shows nonlinear dynamics in specific time periods. See also Hsieh (1989).

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Appendix

In order to test the RWH, we use the variance ratio statistic (VR). Lo and MacKinlay (1988) suggest the use of VR to test this hypothesis. Under the RWH null the variance of first differences of a time series increases linearly, such that the variance of the kth differences is simply k times the variance of the first difference. Thus, they propose the test

$$VR(k) = \frac{\sigma_k^2}{k\sigma^2} \tag{1}$$

where σ_k^2 is an estimator of the variance of the *k*th difference of stock price and σ^2 is an estimator of the variance of the first difference of stock price.

Lo and MacKinlay (1989) show that the VR can be rewritten as a weighted sum of the autocorrelation coefficients

$$VR(k) \overset{a}{=} 1 + 2\sum_{i=1}^{k-1}\left(1 - \frac{1}{k}\right)\hat{\rho}(i) \tag{2}$$

where the $\hat{\rho}$ are the autocorrelation coefficient estimators.

If we allow for heteroscedasticity under the RWH null, the limiting distribution of $M_r(k) \equiv VR(k) - 1$ is given by

$$T^{1/2} M_r(k) \overset{a}{\sim} N(0, V(K)) \tag{3}$$

with $V(K) \equiv \sum_{i=1}^{k-1}\left(\frac{2(k-i)}{k}\right)^2 \hat{\delta}(i)$ and $\hat{\delta}(j) \equiv \frac{\sum_{t=i+1}^{T} r_t^2 r_{t-i}^2}{\sum_{t=1}^{T} r_t^2}$

where $\hat{\delta}(j)$ is the heteroscedasticity-consistent estimator of the asymptotic variance of the autocorrelation of r_t.

However, two major drawbacks are present in most of the tests performed in the literature. In the first place they do not control for the joint test size. Furthermore, the accuracy of asymptotic approximations in small samples is low and thus customized percentiles using bootstrap techniques should be used.

To provide a joint test that takes into account the correlations between VR statistics at various horizons, we consider the Wald test in a similar manner to that of Goetzmann (1993) and Cecchetti and Lam (1994) as follows:

$$W(q) = \{VR(k) - E[VR(k)]\}' \Sigma^{-1} \{VR(k) - E[VR(k)]\} \sim \chi^2_k \qquad (4)$$

where E is the expectation operator, VR is a column vector of a sequence of VR statistics, $EVR(k)$ is the expected value of the $VR(k)$ statistic and Ω is a measure of the covariance matrix of $VR(k)$.

This joint variance-ratio $W(q)$ statistic follows a χ^2 distribution with q degrees of freedom. However, the simulation results presented in Cecchetti and Lam (1994) indicate that the empirical distributions of VR statistics have a large degree of positive skewness, suggesting that inference based on the χ^2 distribution will be misleading. Accordingly, we calculated the Wald statistic for each bootstrapped VR estimator vector and also used the bootstrapped distribution of Wald statistics for hypothesis testing, as in Lee et al. (2001).

In order to proceed with our testing strategy, we need to construct confidence intervals for the joint variance ratio test. We employ the moving block bootstrap (MBB) method with optimal block size defined as suggested by Hall et al. (1995) - MBBH. Let $l = l_n \in N$, with $1 \le l \le n$, denote the lenght of the blocks and let $B_{i,l} = \{X_i, X_{i+1}, ..., X_{i+l-1}\}$ be the block of l consecutive observations starting at X_i. It´s clear that $l = 1$ corresponds to the standard bootstrap of Efron (1979). Assume for simplicity that $n = bl$, the MBB resamples $b = n/l$ blocks randomly with replacement from the set of $n - l + 1$ overlapping blocks $\{B_{1,l}, ..., B_{n-l+1,l}\}$. Thus, let $I_1, ..., I_b$ be iid random variables uniformly distributed on $\{1, ..., n-l+1\}$, i.e., with conditional probability $P(I_1 = i) = (n-l+1)^{-1}$, $1 \le i \le n-l+1$, thus rearranging b MBB blocks $B(I_1, l), ..., B(I_b, l)$ in a sequence, we obtain a bootstrap sample or a pseudo-time series $X_1^{MBB}, ..., X_{bl}^{MBB}$.

Additionally, when block bootstrap methods were used, the selection of the optimal size of the block was treated using the rule of Hall et al. (1995). It is shown that optimal block size depends significantly on context, being equal to $n^{1/3}$, $n^{1/4}$ e $n^{1/5}$ in the

cases of variance or bias estimation, estimation of a one-sided distribution function, and estimation of a two-sided distribution function, respectively.

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