ECONOMIC ANNALS, Volume LIX, No.202 / July – September 2014
UDC: 3.33 ISSN: 0013-3264

DOI:10.2298/EKA1402107M

*Srđan Marinković**

NON-PARAMETRIC SIGN TEST AND PAIRED SAMPLES TEST OF EFFECTIVENESS OF OFFICIAL FX INTERVENTION

ABSTRACT: *This article is an event study of the effectiveness of official foreign exchange interventions by the National Bank of Serbia (NBS) in the RSD/EUR market. As the NBS does not have a formally modelled response function we assume that it intervenes as is expected according to its mandate, i.e., to prevent excess daily fluctuations. This paper tests two alternative goals of official intervention, marking as a success an event in which the NBS either breaks/reverses or smooths an ongoing exchange rate movement. According to a pre-defined time window for an intervention-clustering event, a non-parametric sign test supported the view that the NBS has failed to reverse the trend but is fairly effective in smoothing exchange rate return. However, even the smoothing effect is identified as short lasting. A paired samples test leads to similar findings, but because of weak support for the necessary conditions of sampling distribution it remains less conclusive.*

KEY WORDS: *foreign exchange market, sterilized FX interventions, exchange rate dynamics, NBS, event study methodology*

JEL CLASSIFICATION: G15, E58, F31

* Faculty of Economics, University of Niš, Republic of Serbia,
E-mail: srdjan.marinkovic@eknfak.ni.ac.rs

1. INTRODUCTION

Official exchange rate intervention in the foreign exchange market occurs when the authorities buy or sell foreign exchange, normally against their own currency and in order to affect the exchange rate (Sarno and Taylor, 2001, p. 839). Intervention might be unilateral, when one central bank acts on its own, or coordinated, when two or more central banks concert their actions in order to achieve what is considered to be a mutual goal.

According to the impact of foreign exchange (hereafter FX) intervention on money supply, it can be classified either as sterilized or unsterilized. The sterilized type of intervention is the more frequently investigated type in the theory. This is because only this type of intervention allows researchers to isolate the effects of intervention as an independent policy tool. The sterilized intervention is the type of intervention that is immediately or after some short time followed by an official domestic asset transaction with the aim of offsetting the effect of FX intervention operation on money supply. By its very nature, a sterilized intervention's effect on domestic money supply must be ultimately neutral or close to neutral, since an offsetting monetary transaction restores the pre-intervention size of the monetary base. Conversely, an unsterilized intervention is expected to have the same impact on the domestic money supply as other monetary instruments (e.g., open-market operations) might have, the only difference being that foreign rather than domestic assets are bought or sold. From this perspective, "an intervention operation is the analytical equivalent of a trade between the authorities and the public of securities denominated in one currency for those denominated in another" (Henderson and Sampson, 1983, p. 830).

Like many central banks in developed countries, intervention conducted by the National Bank of Serbia (hereafter NBS) is of the sterilized type. The NBS uses repo operations (as well as some other monetary tools) to finely tune domestic money supply. Since over the past decade direct foreign exchange intervention has been by far the most important channel of monetary expansion (the net effect of it was to sell reserve currency) the natural response was reverse repo. Consequently, NBS repo stock exploded.

Many would agree that an intervention-free, pure flexible exchange rate regime is a case from university textbooks (e.g., Calvo and Reinhart, 2002). In the real world it is impossible to imagine a central bank protractedly absent from the exchange market. Central banks often face the challenge of manipulating the exchange rate by intervening directly in the exchange market. The nature of

intervention differs depending on the exchange rate regime. When it pegs its currency, a central bank gives a guarantee that it will exchange an (un)limited amount of foreign currency against the local currency at the pre-agreed parity, as long as it has available international reserves. If exchange rate flexibility is the central bank's choice it will directly purchase and sell the foreign currency only if it considers that necessary. If the necessity comes too often it is a clear sign that the choice of regime was wrong. Sometimes there is notable discrepancy between what central banks say they are doing and what they are seen to do, so that without a closer look at what a monetary authority has done on the foreign exchange market an assessment of the real nature of the exchange regime will stay biased. The basic aim of this paper is to test and validate what effects NBS interventions had from the end of 2003 through 2010.

The paper is structured as follows. We begin Section 1 with a review of the literature on the role of foreign exchange intervention and the effects, economic rationale, and motives behind it. Section 2 explores NBS intervention policy, while Section 3 proceeds with the description of dataset and methodology, as well as discussion of results. Finally, Section 4 concludes.

2. THE ROLE OF FX INTERVENTION – LITERATURE REVIEW

As forcefully summarized in Dominguez (1998, p. 162), foreign exchange operations are a controversial central bank policy tool. Dominguez states, "[i]n one view intervention policy is not only ineffective in influencing the level of the exchange rate, but also dangerous, because it can increase the volatility of the rate. Others argue that intervention operations can influence the level of the exchange rate, and can also 'calm disorderly markets', thereby decreasing volatility. Yet others argue that intervention operations are inconsequential, since they neither affect the level nor the volatility of exchange rates". Although it is not so rare in economics that so much confusion still exists even after much testing, that it is still far from being solved surely indicates the burning nature of the issue.

By their nature, intervention operations are made in order to generate a contemporaneous or at best a short-term effect on exchange rate dynamics. The crucial problem that researchers face in exploring the effectiveness of official foreign exchange intervention is that so far economics has not come up with a theoretical model able to reliably explain the short-term determination of exchange rate.

Relying on the tradition of monetary models of exchange rate determination, researchers first started studying what is today known as the portfolio balance channel. The portfolio balance model of exchange rate determination assumes that investors hold a diversified portfolio with both domestic and foreign assets (bonds). They decide upon the relative stock of domestic vs. foreign assets by solving the problem of optimization of expected returns and the variance in returns. The channel operates by changing the risk premium. In order to generate a shift in investors' relative stock currency composition, which must be the ultimate effect, an intervention has to generate a change in expected relative return, i.e., risk premium. Dominguez and Frankel's (1993a) paper was the first to question the somewhat disappointing results of studies on intervention effects conducted prior to the 1990s. There was almost consensus among researchers and even policymakers that the effects of official intervention in the foreign exchange market were weak and transitory at most. Sarno and Taylor (2001, p. 862) suggest a possible reason why the portfolio balance channel appears to have relatively weak importance in a number of studies: the typical size of the intervention is a very tiny fraction of the total foreign exchange market turnover. Of course, the (preferred) net change in traders' end-of-day stock position, not total market turnover, may come closer to the intervention volume.

More recently scholars have started to investigate another channel of influence (e.g., Dominguez and Frankel, 1993b). It is known as an information or signalling channel. If a signal is communicated to the market with credibility it will generate the desirable effect no matter the amount of intervention. The intervention is then a vector used to convince (other) market participants of the commitment of the monetary authority (intervenient) to support the given exchange rate level, or to communicate private (superior) information about the future course of monetary and fiscal policy as fundamentals of the exchange rate.

There is a bulk of empirical literature investigating which channel dominates the other in general and in any specific case (see Edison, 1993, for a review). Explicitly or implicitly the studies include an assumption about the trading strategy that monetary authorities use to impact the exchange rate. Lean-against-the-wind behaviour assumes confronting the ongoing short-term trend of exchange rate. Most often the trends are interpreted as deviations from what is considered the long-term equilibrium value. This assumes that leaning against the wind is actually choosing the weak side of the market. If, for instance, the NBS is selling a reserve currency in exchange for local currency, it will decrease the value of the reserve currency. According to Kearns and Rigobon (2005), central banks

typically lean against the wind. On some rare occasions central banks can act to enforce an ongoing trend. It is then denoted as 'leaning-with-the-wind' behaviour.

When intervening in the foreign exchange market, a monetary authority not only chooses the weaker side of the market but also acts as a privileged dealer. The authority decides upon intervention after the majority of participants have already made their decisions, i.e., after it sees the order flow. This is exactly what the NBS does, since it intervenes during the second part of the trading day. From the market microstructure literature (e.g., Harris, 2003, p. 508) we know that a trader who sees the asymmetry in order flow can engage in a profitable strategy. Namely, s/he will step in to supply liquidity on the weak side of the market. Since this side is weak, the market-clearing price generally favours it. If prices reverse afterwards, the trader will profit from his/her trade. This is why some researchers tried to assess the effectiveness of official intervention according to the profitability criterion (see for reviews Henderson and Sampson, 1983, or Sarno and Taylor, 2001). Apparently, if the monetary authorities buy low and sell high, they reduce volatility in exchange rates as well as make a profit. However, if the monetary authorities prevent any fluctuation in the exchange rate they make zero profit.

The problem with this approach is its inconclusiveness. If, for example, the authority were to purchase foreign exchange when its price was low and sell it when its price was high, intervention would be profitable, even if the purchases and sales had no meaningful effect on the exchange rate. There are also some technical issues. In order to calculate the profit made from intervening in exchange markets one must choose a sample period and decide how to value the initial and ending stock of reserve assets. Profits from official intervention operations are usually calculated by taking into account the terms on which interventions are accomplished in successive operations with different signs, in addition to any current income that comes from holding a position in different currencies.

Only market microstructure literature can shed some light on the issue of the contemporaneous effects of intervention. Macroeconomic models of exchange rates perform poorly at frequencies higher than one year: the explanatory power of these models is essentially zero. The market microstructure approach is a novel method that focuses on the relationship between order flow, information, and price (Evans and Lyons, 2002a; 2002b). Roughly speaking, there are two generations of market microstructure model: inventory-based models and information-based models (see O'Hara, 2004, for a more general and rather

extensive review, or Lyons, 1995, for the application to foreign exchange markets). The inventory-based approach explains the market-clearing mechanism and the traders' price-setting behaviour that are a consequence of stochastic deviations in order flow. A new order flow is by assumption non-informative, so that traders accommodate their bid and ask for a quote in order to restore an optimal level of inventory. For example, if the distortion of order flow is the result of a central bank selling foreign exchange, traders will manage their positions by lowering both ask and bid exchange rate quotes. By acting in this way they will simultaneously encourage clients to buy and discourage clients from selling. The inventory-based approach requires that initial orders made by the central bank have a substantial size relative to normal order flow, to make quote readjustments necessary for portfolio rebalancing. However, leading world central banks do not regularly practice interventions which are large compared to market turnover, in contrast to NBS intervention, which makes the inventory (portfolio) -based channel an operable way of influencing the local exchange rate.

With the risk that the intervention conveys relevant information about future exchange rate fundamentals, the price-setting behaviour of traders becomes more complicated. It is a matter of crucial importance for trader profitability that s/he correctly extracts information from the new order flow. For example, if a selling intervention brings new information that indicates a lower exchange rate, even if the transaction volume is rather irrelevant, the correct response of any trader would be the same as in the above case of stochastic order flow. Lower bid and ask quotes would ensure inventory optimization. However, if the trade (intervention) is mistakenly taken as informative, the old quotes will still be correct, while the new, revised quotes, will attract informed traders to buy from our trader, no matter if the central bank ceases or continues to intervene. Depending on the elasticity between price and order flow, our trader will sooner or later loose his/her inventory. In order to get back in business s/he must restore the inventory by buying foreign exchange shortly afterwards from other traders at a rate higher that s/he previously sold it. This would decrease its realized spread and profitability. This risk of being wrong in assessing the information content of the trade (as well as the intervention) is known as adverse selection risk. Therefore, in order to be effective, official intervention has to convey a clear and credible signal about the future stance of policies relevant to exchange rate determination. If it does not, the signal, communicated to the market, will generate ambiguity amongst traders. This could explain why sometimes intervention is not followed by a persistent effect at the exchange rate level, but only with an increase in short-term volatility.

The above analysis indicates that there are two channels through which intervention can influence foreign exchange traders' (dealers) behaviour. Some researchers (Lyons, 1995) have found the inventory control channel slightly less important than the information channel in transmitting the order flow impact on dealers' quotation behaviour, i.e., market-clearing exchange rate. Unfortunately, more recent studies (Bjønnes and Rime, 2005) found neither inventory nor information channel statistically significant, what is explained by the changed structure of contemporary FX markets, which now offers better possibilities for controlling inventory risk, and reduces informational asymmetry.

The literature also differs in terms of which intervention goal is primarily studied. According to Beine et al. (2009, p. 780), "the main objective of [foreign exchange] interventions is to influence the exchange rate level, reduce some undesirable trend, smooth exchange rate volatility, or intervene in favour of another central bank". Thus there may be several intervention goals, with most of them not being mutually exclusive. If we try to simplify, there are only two directions of influence which fully correspond to two, more or less alternative, intervention goals; an official authority may attempt to tackle either exchange rate level of volatility. The issue may get a unified framework if we accept that the authority, by taking any level of exchange rate as desirable at the time, actually expresses its concern about long-term exchange rate volatility. Moreover, long gradual swings in the exchange rate might have even more devastating effects on a specific economy than its short-term or daily volatility. Continuous intervention that lasts for long periods of time might reveal this type of concern.

Let us start with the studies that have primarily investigated intervention influence on the exchange rate level. The first study that implemented a case study approach in investigating official intervention effectiveness in this sense was by Dominguez and Frankel (1993b). They were the first to challenge the overly pessimistic view about the effects of intervention on exchange rate that had been almost consensus in earlier papers (see Henderson and Sampson, 1983, or Edison, 1993 for a review). Based on similar methodology, but with some improvement in dataset, later on Dominguez (2003) and Fatum and Hutchison (2003) found the intervention operations effective, especially if they are properly conceived and executed. Moreover, intervention is found more likely to be effective if it is consistent with future monetary policy intentions, i.e., future exchange rate fundamentals (for an emerging market study with the same implications see Égert and Komárek, 2006). The conclusion is completely in line with signalling approach suggestions. Similarly, Kearns and Rigobon (2005) found that the

coordinated interventions of the Bank of Japan and the Reserve Bank of Australia generated a contemporaneous effect on the level of exchange rate.

The above-mentioned papers primarily investigated the influence of intervention on exchange rate level. Following recent changes in authorities' reaction function, a strand of contemporary literature has been concerned with the influence of intervention on exchange rate return volatility. The methodology of these papers is also more sophisticated. For instance, Dominguez (1998) experimented both with GARCH conditional variances and implied volatilities from foreign exchange options to examine the relationship between intervention and exchange rate volatility. She found exchange rate volatility responsive to intervention, while the reverse was not true. The responses were situation-specific. By looking separately at the secret intervention and the publicly announced intervention, she found an opposite influence between the two kinds of intervention. The secret intervention policy did increase volatility, while for the other kind of intervention the opposite was true. In a more recent paper Dominguez (2006) found that G3 intervention did not lead to declines in intraday exchange rate volatility, suggesting that the information conveyed by intervention did not serve to resolve market uncertainty, but rather added to the rational confusion in the market. This effect was found to be short-lived. The author called on the standard market microstructure trader heterogeneity argument, that since the information conveyed by intervention is not common knowledge, either because traders do not receive information simultaneously or because they interpret the information differently, intervention will bring immediate rational confusion. Following new developments in the econometric analysis of financial market time series, Beine et al. (2002) switch from GARCH to a Fractionally Integrated GARCH model that allows for some persistence of volatility shock. Apart from increasing short-term volatility, the intervention operations are found able to even exert an incorrectly signed effect on the level of exchange rates. The findings points out the limited efficacy of official interventions in stabilizing in the short run and emphasize the cost in terms of volatility. Similarly, Beine et al. (2009) have studied the impact of G3 official intervention on daily-realized moments of DEM/USD exchange rate returns and confirmed previous findings of a temporary increase in volatility after a coordinated central bank intervention.

All these studies were primarily concerned with the intervention practice of the leading central banks. Despite their remarkable importance, there are just a few studies of official FX intervention in emerging markets. This is perhaps because other central banks do not regularly publish their data on intervention. This paper is going to be a rare exception, what makes it especially valuable.

3. NBS INTERVENTION POLICY – SOME INSTITUTIONAL DETAILS

Since August 2006 (NBS, 2006) the NBS de facto shifted from exchange rate targeting to a pure-inflation-targeting monetary strategy. The exchange rate was no more the variable of prime concern. According to the agreement signed with the government (NBS, 2008a) and the following new memorandum (NBS, 2008b, p. 4), "NBS is expected to intervene directly on the foreign exchange market in order to 1) prevent excess daily fluctuations [with no transparent numerical threshold], while avoiding cumulating the pressure from either side of the exchange market (buying or selling) in long term sequences, 2) control financial stability risk, and 3) safeguard an adequate level of international reserves".

Although seemingly straightforward, this mandate does not limit the behaviour of the NBS, as strong as it may look at first glance. The first condition means that the NBS is not expected to act against market forces. However, the second condition may be interpreted in a way that allows confronting ongoing exchange rate trends if the exchange rate threatens to somehow endanger financial stability. Finally, the third condition warns of the scarcity of financial resources (international reserves) that can be used for the above purposes.

Let's take a closer look at the first two objectives. The most prominent objective of official FX intervention is smoothing exchange rate return (interpreted as daily return volatility). If the exchange rate moves in small increments (smoothly) but constantly in one direction, i.e., following a trend, it means that the first condition for intervention is not satisfied, so the authority has to refrain from intervention. However, if the trend is there but the daily movements are large enough, it will activate an official response. By confronting such excessive daily oscillations the official authority will at the same time push against the ongoing trend. In the absence of a transparent threshold, it may look as if the NBS arbitrarily breaks the trend. Nevertheless, one could never say that the NBS acts beyond its mandate since the second condition, financial stability, lays the ground for intervention conditioned by the level of exchange rate. It must be a level of exchange rate that can act as an imaginary threshold that triggers FX intervention operations. For a small and open country, which is additionally burdened with a pervasive level of financial euroization, the exchange rate becomes the variable able to endanger financial stability.

4. DATA AND METHODOLOGY

The empirical section of this paper explores the effectiveness of official NBS intervention by employing event study methodology. Why event study methodology? Contrary to the exchange rate, whose time series behaviour is well approximated by a nonlinear model (see Peel and Speight, 1997; Kilian and Taylor, 2003), intervention tends to come in sporadic clusters and can be infrequent or even an extremely rare event (an interesting case is Akinci et al.'s (2006) study of Turkish interventions, which covers only eleven intervention episodes in a period of three years). Researchers (e.g., Dominguez, 1998) that employ time series econometric methodology often neglect actual intervention data by using a dummy variable instead of real intervention data. There are some event studies (Fatum and Hutchison, 2003; Égert and Komárek, 2006; Akinci et al., 2006; Fratzscher, 2008; Gnabo and Teiletche, 2009) that use actual data, but only from around periods of intervention. This is another way to circumvent limitations coming from unusual data-generating processes or the sporadic nature of intervention.

The intervention data are in millions of EUR. The data are sampled daily so they do not tell us whether the NBS clusters its interventions within a trading day or intervenes with a single daily transaction. The central banks of most developed countries often do it in the former way, making clustering of interventions within a working day an important aspect for analysis. Constrained by data frequency, in this paper we will take the case of intervention clustering in which the NBS continuously intervenes on the same side of the market over several days. The available data on NBS intervention tells us only about volume of transaction and the size of the market that the NBS takes. There is no indication of the exchange rate at which the NBS sells or buys foreign currency on any specific intervention occasion. Consequently, having only volume information at hand, it is not possible to examine the impact of joint volume (order flow) and price on the market.

Exchange rate data concerns the official mid-quoted exchange rate RSD/EUR, expressed in units of the local currency for one unit of the reserve currency (e.g., direct quotation). Exchange rate return is calculated as daily logarithmic return and expressed in percentage terms. Logarithmic transformation was a better choice because this way of expressing return satisfies the additivity condition, which is necessary when operating with variable time horizons.

The period for analysis is from December 2003 to December 2010. The nature of exchange-rate-targeting intervention in the period makes this period unsuitable

for implementing the proposed methodology. Over this period the NBS intervened in long-lasting sequences with a few days in between with no intervention. The monetary authority intervened on 519 out of a total of 645 trading days. The NBS was buying the reserve currency on just two days. The reserve currency at all times almost constantly appreciates. Moreover, it was the period with most intense interventions, both in terms of its frequency (number of days in which the NBS was present in the market) and intensity of intervention. In total, the NBS saturated the market with 41.55% of reserve currency supply. In addition, over the period of exchange rate targeting the NBS rarely acknowledged their own intervention operations.

Latter on, the NBS continued to intervene occasionally. Episodes generally continued to involve operations across multiple days, but with long-lasting breaks in between. Thus, from August 2006 to the end of 2010 we identified 39 episodes of intervention clusters. Those operations differ in terms of transparency from the operations conducted over the first period: the NBS started to routinely release information to the press, so that operations no longer caught the market by surprise.

For the sake of this analysis we developed an operable definition of massive intervention. We define large intervention as a trading day in which NBS intervention exceeds one-tenth of the daily turnover recorded in transactions conducted between commercial banks. An intervention is taken to be excessively large if the amount of intervention exceeds half of the turnover recorded the same trading day between commercial banks. NBS interventions are of that massive scale: when it intervenes, the NBS does so on a large scale. This was the case almost without exception during the crisis and post-crisis period. The share of large-scale intervention for the whole period is 75%. More important is the fact that almost half of all interventions (no matter on which side of the market) were excessively large (Marinković and Golubović, 2013).

Empirical studies on the effects of official foreign exchange intervention very often face the problem of endogeneity. This means that it is likely that some other variables apart from the tested variables are influencing the exchange rate. The endogeneity effect is as strong as the sequences are long (Neely, 2005, p. 689). Table (1) lists 39 episodes of intervention cluster. Just two of them lasted for more than 11 days.

Another issue that has to be solved with such methodology is the time window. We decided to operate with pre-event and post-event window lengths of two days. An

issue that is further worth addressing is how sensitive the results are to the chosen time window. In the referent study (Fatum and Hutchison, 2003) several time windows are tested, i.e., 5, 10, and 15 days after the end of intervention. Although a longer-term after-event time window is an indisputably beneficial statistical procedure, in our case it would generate huge data overlapping that would blur statistical inference. Most frequently one intervention cluster comes after another with just a few non-intervention days in between. Some researchers, e.g., Égert and Komárek (2006), responded to this problem by filtering data samples from clusters that could eventually generate overlapping, at the same time allowing for even 60-day-long time windows. However, this procedure significantly decreased the total number of events. Gnabo and Teiletche (2009) consider two consecutive interventions as part of the same event if they are separated by less than five business days without any official intervention (so-called 'tranquillity days'). Since we operate with pre- and post-event window lengths of two days, the pause is treated as part of the intervention event if it lasts no longer than one business day.

Statistical inference of intervention effectiveness depends on pre-defined success criteria. Before starting with a numerical definition of what a successful intervention should be, it is worth addressing the issue in a more general manner. Therefore, more generally, a successful intervention is one that influences either the relative price or the volatility of a currency in the appropriate direction in a meaningful way. In order to make the definition operable several issues must be solved. Firstly, it seems that there are two goals to be achieved: the impact on level and the impact on volatility of exchange rate return. In this paper the empirical work will focus on both the influence of intervention on the level of the exchange rate and on its volatility, albeit the impact on volatility is represented in a less formal way. We take smoothing the trend to empirically represent volatility of the exchange rate. Our forthcoming paper will focus exclusively on the influence of intervention on volatility, which will be defined in a more technical way. The next issue is having a clear idea of what a meaningful influence should be. Unfortunately, because of the lack of an empirically operable model for exchange rate determination, it is difficult to compare actual behaviour to the exchange rate in the absence of intervention. The next issue is the temporal dimension. Is there a case of successful influence if, with no contemporaneous changes, after some days of intervention the exchange rate moves in the desired direction? And how much time lag is acceptable to make the case of causality conclusive?

Table 1. Data on official intervention clusters

Period	Length (days)	INT Volume	Turnover Volume	INT/ Turnover	Prior Return	Post Return
23 Aug 06 – 31 Aug 06	6	–120.4	232.4	51.79	0.546	0.239
6 Sep 06 – 14 Sep 06	7	–14.2	271.4	5.21	–1.081	0.179
22 Sep 06 – 27 Sep 06	4	–2.9	197.0	1.47	0.061	0.061
9 Oct 06 – 13 Oct 06	5	–5.0	182.7	2.73	0.947	0.179
19 Oct 06 – 23 Oct 06	3	–5.0	138.7	3.60	–0.746	0.072
31 Oct 06 – 2 Nov 06	3	4.0	173.3	2.30	–0.527	–0.273
7 Nov 06 – 8 Nov 06	2	41.2	36.0	114.20	–0.050	0.016
21 Nov 06 – 29 Nov 06	7	214.4	196.5	109.12	–0.069	–0.046
14 Dec 06 – 27 Dec 06	9	153.5	241.3	63.62	–0.683	0.040
3 Jan 07 – 17 Jan 07	10	–412.4	365.5	112.87	0.668	0.019
8 May 07 – 9 May 07	2	–75.4	211.9	35.58	1.044	–0.053
4 Jun 07 – 4 Oct 07	87	–88.0	9723.0	0.90	0.036	–0.041
15 Nov 07 – 22 Apr 08	109	–418.0	10183.0	4.10	0.120	–0.018
6 May 08 – 9 May 08	4	–38.0	618.1	6.14	2.405	–0.109
5 Aug 08 – 6 Aug 08	2	6.0	310.5	1.93	–0.738	0.084
3 Oct 08 – 15 Oct 08	6	–163.0	2127.3	7.66	1.244	0.577
27 Oct 08 – 30 Oct 08	3	–106.0	107.6	98.53	0.596	–0.048
5 Nov 08 – 13 Nov 08	5	–82.0	270.6	30.30	0.622	0.086
18 Nov 08 – 4 Dec 08	11	–366.8	615.0	59.64	0.524	–0.177
10 Dec 08 – 12 Dec 08	3	–63.3	63.7	99.38	1.496	0.200
29 Dec 08 – 15 Jan 09	10	–272.0	251.8	108.02	0.705	0.541
20 Jan 09 – 5 Feb 09	8	–286.7	474.7	60.39	2.075	–0.146
19 Feb 09 – 25 Feb 09	3	–76.3	125.9	60.58	0.234	–0.168
5 Jan 10 – 6 Jan 10	2	–37.0	94.3	39.23	0.352	0.114
27 Jan 10 – 3 Feb 10	5	–231.5	203.2	113.92	0.337	0.087
24 Feb 10 – 1 Mar 10	3	–85.0	136.3	62.36	0.174	0.027
4 Mar 10 – 9 Mar 10	3	–65.0	101.8	63.85	0.042	0.036
22 Mar 10 – 25 Mar 10	3	–60.0	135.6	44.24	–0.107	0.045
17 May 10 – 1 Jun 10	8	–349.0	1010.2	34.54	0.721	0.138
7 Jun 10 – 10 Jun 10	3	–183.0	247.0	74.08	0.327	–0.018
17 Jun 10 – 7 Jul 10	11	–288.0	558.6	51.55	0.176	0.007
27 Jul 10 – 3 Aug 10	5	–217.0	344.6	62.97	0.535	–0.029
24 Aug 10 – 27 Aug 10	3	–84.5	144.0	58.68	0.217	–0.012
3 Sep 10 – 8 Sep 10	3	–50.0	104.6	47.80	0.001	–0.148
28 Sep 10 – 6 Oct 10	4	141.7	302.7	46.81	0.062	0.019
28 Oct 10 – 8 Nov 10	7	–248.0	340.5	72.83	0.082	–0.031
12 Nov 10 – 18 Nov 10	4	–70.0	147.5	47.45	–0.089	–0.036
29 Nov 10 – 3 Dec 10	4	–70.0	170.3	41.10	0.105	0.011
13 Dec 10 – 16 Dec 10	4	116.0	525.2	22.08	–0.573	–0.118

Source: Author's calculation

Here we do not study the monetary authority reaction function in a formal way. However, we assume that the NBS reacted as stated in its charter. Some facts tell

us that this assumption is not that strong. In the great majority of cases, i.e., in 35 out of a total of 39, the NBS was acting as expected according to its mandate. In four cases only it was selling the reserve currency when the euro depreciated one day before intervention. Therefore, it can be taken that the NBS reaction was as mandated, but somewhat delayed.

In the rest of the paper we take intervention as successful not only if it diverts the previous trend but also if it moderates or smoothes the pre-intervention trend. Thus, we have two success criteria: the reversal criterion and the smoothing criterion (Fatum and Hutchison, 2003). The reversal criterion for success implies that intervention is seemingly aimed at breaking an ongoing exchange rate movement. According to the direction/reversal criterion, an event is a success if it holds either:

$$(I_i > 0 \wedge \Delta e_{i+} > 0) \vee (I_i < 0 \wedge \Delta e_{i+} < 0) \quad (1)$$

Practically, an official intervention is marked as a success if after buying the foreign currency (positive intervention, $I_i > 0$) an increase occurs in its value against the local currency ($\Delta e_{i+}>0$), or if after selling the foreign currency (negative intervention, $I_i < 0$) a decrease occurs in its value against the local currency ($\Delta e_{i+}<0$). This method of denotation comes from direct quotation of the dinar, i.e., RSD/EUR.

The smoothing criterion is more relaxed than the reversal criterion. With this criterion, success is going to be an intervention that moderates an ongoing trend even when no reversal occurs. This is why all intervention marked as a success according to the previous criterion simultaneously becomes success according to the second criterion. More formally, we have the following condition:

$$(I_i > 0 \wedge \Delta e_{i+} > \Delta e_{i-}) \vee (I_i < 0 \wedge \Delta e_{i+} < \Delta e_{i-}) \quad (2)$$

From the condition above (2) it comes that if the central bank, by buying foreign currency ($I_i > 0$), generates an increase in its value against the local currency bigger than immediately before the intervention, or even generates a decrease lower than immediately before the intervention ($\Delta e_{i+}>\Delta e_{i-}$), the intervention operation will be marked as a success. The opposite holds for selling interventions.

In what follows we will use these definitions in two separate statistical procedures, the non-parametric sign test and the paired samples test, in order to check the effectiveness of the NBS' official FX intervention in the RSD/EUR market.

4.1 Non-parametric sign test

The non-parametric sign test (Wilcoxon, 1945) is a simple statistical procedure which counts the number of cases that belong to a specific class and compares it with the total number of cases. Statistical inference strongly depends on assumed frequency distribution, or how often this feature normally (with no intervention) appears in the total sample.

For this test it is assumed that the statistical variable has binomial probability distribution with the probability for reversal being 0.5 and the probability for smoothing 0.75 (applied in Fatum and Hutchison, 2003, and later on in Fratzscher, 2008). At any given point in time the exchange rate can follow either the previous trend or can reverse, with 0.5 probability that it will join either one or the other class, so that the probability of success is going to be 50% no matter what the intervention. In terms of the smoothing criterion the probability of success is even bigger, since not only the case when, after selling (purchasing) it, the appreciating (depreciating) reserve currency turns into a depreciating (appreciating) currency, but also moderating appreciation (depreciation) is going to be marked as a success. Assuming that any trend, appreciating or depreciating, also has binomial distribution with only two outcomes (to moderate or enforce), the probability of 'smoothing' is 75% no matter what the intervention. Therefore, for intervention to be assessed effective it must exceed the thresholds to a statistically significant extent.

Table 2. Non–parametric sign test results

	Number of events	Number of successes	*p*–value
Total operations			
Sign test of 'reversal'			
EUR purchases when EUR depreciates	6	3	1.000
EUR sales when EUR appreciates	28	13	0.851
Total sales and purchases	34	16	0.864
Sign test of 'smoothing'			
EUR purchases when EUR depreciates	3	3	0.422
EUR sales when EUR appreciates	15	15	0.013*
Total sales and purchases	18	18	0.006**
Small-scale operations			
Sign test of 'reversal'			
EUR purchases when EUR depreciates	2	1	1.000
EUR sales when EUR appreciates	6	3	0.422

Total sales and purchases	8	4	0.316
Sign test of 'smoothing'			
EUR purchases when EUR depreciates	1	1	1.000
EUR sales when EUR appreciates	3	3	1.000
Total sales and purchases	4	4	1.000
Massive operations			
Sign test of 'reversal'			
EUR purchases when EUR depreciates	4	2	1.000
EUR sales when EUR appreciates	22	10	0.832
Total sales and purchases	26	12	0.845
Sign test of 'smoothing'			
EUR purchases when EUR depreciates	2	2	0.563
EUR sales when EUR appreciates	12	12	0.032*
Total sales and purchases	14	14	0.018*

Source: Author's calculation

Note: * Significant at 5% level; ** Significant at 1% level.

The results of the sign tests are straightforward. It is clear that the NBS failed to 'reverse' the pre-intervention trend in more than half the cases. In all cases it managed to 'smooth' the trend. In spite of the small number of observations the sign test is fairly conclusive about the success of FX intervention. We can be 95% confident (*p*-values) that massive intervention generates a 'smoothing' effect. Although it is possible that even small-scale intervention can do the same, the number of interventions of this type is too small to allow for statistically reliable conclusions.

4.2 Paired samples test

This statistical procedure tests whether the paired observations that belong to different but dependent samples differ to a statistically significant extent. It tests the following null hypothesis:

H0: *There is no statistically significant difference in mean value of exchange rate return prior to and after the event.*

against the alternative:

H1: *There is a statistically significant difference in mean value of exchange rate return prior to and after the event.*

For the test all events are considered, so that we have in total 39 events, 7 of which are purchasing interventions, while the others are selling interventions. Not all purchasing (selling) interventions are carried out when the reserve currency depreciates (appreciates), so we tested separately total interventions and those which clearly indicate leaning-against-the-wind behaviour. The essential idea of this test is to compare the movement of the exchange rate prior to and after the event in order to see if they differ in statistically meaningful ways. We first generate two samples of observations. The first sample comprises prior-event average return, while the second contains paired post-event average returns. Then we calculate differences in average return between pairs of observations. The mean of differences (μ_D) is then adjusted for the mean of differences under the null hypothesis (μ_{D_0}), and after that is divided by the standard error term. Standard error is the ratio of standard deviation of differences σ_D and squared root of degrees of freedom $\sqrt{n-1}$. The degree of freedom is the number of pair observations minus one. It gives us *t*-statistics (equation 3), and consequently *p*-values.

$$t = \frac{\mu_D - \mu_{D_0}}{\sigma_D}\sqrt{n-1} = \frac{\mu_D}{\sigma_D}\sqrt{n-1} \tag{3}$$

Table (3) gives the results of the paired samples test. Some basic statistics are also able to gives us an idea of the exchange rate movements around the events. In six events when NBS purchasing intervention came immediately after reserve currency depreciation, the depreciation (on average by –0.44%) failed to turn into an appreciation. The trend decreases significantly (by –0.39) but still continues (–0.049). Everything is the same for the selling interventions. In the majority of cases (28 out of a total of 32) the NBS started selling the reserve currency in response to previous day appreciation, which was on average 0.585%. On average the intervention did not reverse the trend (0.047), albeit it succeeded in slowing down the previous trend significantly (on average by 0.538).

Table 3. Paired samples test results

	Number of Events	Exchange rate return (%)	Standard Error	*t*–stat
EUR purchases	7			
Difference in average return		–0.328	0.131	–2.508 (0.046)*
EUR purchases when depreciates	6			

Prior event average return		–0.440		
Post event average return		–0.049		
Difference in average return		–0.390	0.136	–2.858 (0.035)*
EUR sales	32			
Difference in average return		0.399	0.124	3.216 (0.003)**
EUR sales when appreciates	28			
Prior event average change		0.585		
Post event average change		0.047		
Difference in average return		0.538	0.115	4.673 (0.000)**

Source: Author's calculation

Note: In parenthesis are *p*–values; * Significant at 5% level; ** Significant at 1% level.

The success of 'smoothing' exchange rate movements according to the paired samples test seems fairly strong. When the NBS intervenes in both selling and purchasing the reserve currency it manages to 'smooth' the trend. Seemingly, we can be 99% sure that the NBS was effective when it was fighting appreciation, and 95% sure in the case of depreciation (see *p*-values). The difference between the levels of statistical significance is largely the result of the influence of the number of observations in the samples, so it does not say much about real differences in the effectiveness of interventions between the two sides of the market.

Unfortunately, the matched pairs *t*-test is appropriate if the population distribution is normal, or, alternatively, if each sample is drawn from a normal or near-normal population. Generally, for a sample size of 15 or less observations, the sampling distribution can be taken to be approximately normal if the sample data are symmetric, unimodal, and without outliers. For sample sizes between 16 and 40 it is acceptable to have data slightly skewed, unimodal, and without outliers. In this analysis we have four paired samples. The first two samples gather a small number of cases of EUR purchases, and clearly do not belong to approximately normal distribution. The cases of EUR sales have undergone further analysis in order to test if the samples' distribution satisfies conditions for matched pairs *t*-test. Numerical tests of normality, Jarque-Bera and Kolmogorov-Smirnov (the last one not included), both reject the null hypothesis that each sample has normal distribution (Appendix, Table A).

The results of graphical tests are presented in the Appendix, Table B. In the left column of Table B are histograms, the curves of normal and empirical distribution (Kernel approximation). Normal Q-Q plots are in the right column of the Table. Visual inspection indicates that the empirical distributions are not that different from the normal one, except for the fact that in no case is the distributions unimodal. Moreover, even the population distribution of daily EUR/RSD return for the same period ($N = 2191$) is abnormal (see Appendix, Tables A and B), since it has a much higher peak. These facts seriously limit the statistical inference based on the paired samples test.

5. CONCLUSION

In the period of inflation targeting, official FX intervention was more balanced than before, but, with some rare exceptions, was equally massive. Therefore intervention is expected to have at least some influence on the variable of concern, meaning either exchange rate level or its volatility.

The tests undergone in this event study revealed that the NBS proved itself incapable of breaking or reversing exchange rate trends, even in the short-run. However, it is fairly certain that intervention did influence the trend, by making it smoother.

In this paper we experimented with a two-day time window, and found strong support for the fact that two days after intervention ceases, the NBS manages to generate desirable effects. A possible way to interpret this regularity is by claiming that demand for the reserve currency decreases immediately after the intervention, since the market participants, knowing that NBS pressure will perhaps bring conditions that are more favourable to buying the euro, redirect their trade either forward or backward to intervention periods. However, this method of tactical behaviour needs a strong conviction amongst at least the better-informed market participants about the time when the intervention will start and stop, and consequently how long it will last. Bearing in mind that the NBS does not announce its intervention policy, which is also true for the trigger exchange rates, it is unlikely that market participants can systematically beat the NBS by cracking its response function and consequently foreseeing exchange rate intervention. When carefully monitoring the data we did not find signs of weakening trading activity during the time window, which rejects the assumption that market participants systematically chose to trade in the periods when the NBS intervened.

The fact that we did not experiment with time windows of different time lengths limits the robustness of our findings. However, the very fact that intervention clusters come one after another with just a few days' lag, with the NBS starting to pressurise the same side of the market, is a clear-cut sign that the effect vanishes soon after intervention.

Finally, we would conclude that massive official FX interventions will be effective in terms of their impact on exchange rate dynamics. If someone with specific privilege takes one side of the market and starts to exert strong pressure, it would be surprising if the market were to go that way without being influential.

Acknowledgements: The data on interventions were supplied courtesy of the National Bank of Serbia. We also acknowledge financial support from the Republic of Serbia Ministry of Education, Science and Techological Development (Project No. 179015: Challenges and prospects of structural changes in Serbia: Strategic directions for economic development and harmonization with EU requirements).

REFERENCES

Akinci, Ö., Çulha O. Y., Özlale, U. & Şahinbeyoğlu, G. (2006). The effectiveness of foreign exchange interventions under a floating exchange rate regime for the Turkish economy: a post-crisis period analysis. *Applied Economics*, 38 (12), pp. 1371–88.

Beine, M., Laurent, S. & Palm, C. F. (2009). Central bank FOREX interventions assessed using realized moments. *International Financial Markets, Institutions and Money*, 19 (1), pp. 112–27.

Beine, M., Bénassy-Quéré, A. & Lecourt, C. (2002). Central bank intervention and foreign exchange rates: New evidence from FIGARCH estimations. *Journal of International Money and Finance*, 21 (1), pp. 115–44.

Beine, M., Janssen, G. & Lecourt, C. (2009). Should central bankers talk to the foreign exchange markets? *Journal of International Money and Finance*, 28 (5), pp. 776–803.

Bjønnes, H. G. & Rime, D. (2005). Dealer behavior and trading systems in foreign exchange markets. *Journal of Financial Economics*, 75 (3), pp. 571–605.

Calvo, A. G., & Reinhart, M. C. (2002). Fear of floating. *Quarterly Journal of Economics*, 117 (2), pp. 379–408.

Dominguez, M. K. & Frankel, A. J. (1993a). Does foreign-exchange intervention matter? The portfolio effect. *American Economic Review*, 83 (5),pp. 1356–69.

Dominguez, M. K., Frankel, A. J. (1993b). Foreign exchange intervention: An empirical analysis, In Frankel, J. (Ed.), *On exchange rates*(pp. 327–45). Cambridge, USA: MIT Press.

Dominguez, M. K. (1998). Central bank intervention and exchange rate volatility. *Journal of International Money and Finance*, 17 (1), pp. 161–90.

Dominguez, M. K. (2003). Foreign exchange interventions: Did it work in the 1990s?In Bergsten C. Fred and John Williamson (Eds.), *Dollar overvaluation and the world economy* (pp. 217–45). Special Report 16, Institute for International Economics.

Dominguez, M. K. (2006).When do central bank interventions influence intra-daily and longer-term exchange rate movements? *Journal of International Money and Finance*, 25 (7), pp. 1051–71.

Edison, H. J. (1993). The effectiveness of central-bank intervention: A survey of the literature after 1982. (Special Papers in International Economics, No. 18), Princeton, USA: Princeton University.

Égert, B. & Komárek, L. (2006). Foreign exchange interventions and interest rate policy in the Czech Republic: Hand in glove? *Economic Systems*, 30 (2), pp. 121–40.

Evans, D. M. & Lyons, K. R. (2002a). Order flow and exchange rate dynamics. *Journal of Political Economy*, 110 (1), pp. 170–80.

Evans, D. M. & Lyons, K. R. (2002b). Time-varying liquidity in foreign exchange. *Journal of Monetary Economics*, 49 (5), pp. 1025–51.

Fatum, R. & Hutchison, M. (2003). Is sterilised foreign exchange intervention effective after all? An event study approach. *Economic Journal*, 113 (487), pp. 390–411.

Fratzscher, M. (2008). Oral interventions versus actual interventions in FX markets – an event-study approach. *Economic Journal*, 118 (530), pp. 1079–106.

Gnabo, J-Y., & Teiletche, J. (2009). Foreign-exchange intervention strategies and market expectations: insights from Japan. *Journal of International Financial Markets, Institutions & Money*, 19 (3), pp. 432–46.

Harris, L. (2003). *Trading and exchange: market microstructure for practitioners*. New York, USA:Oxford University Press.

Henderson, D. & Sampson, S. (1983). Intervention in foreign exchange markets: A summary of ten staff studies. *Federal Reserve Bulletin*, 69, pp. 830–6.

Kearns, J. & Rigobon, R. (2005). Identifying the efficacy of central bank interventions: Evidence from Australia and Japan. *Journal of International Economics*, 66 (1), pp. 31–48.

Kilian, L. & Taylor, P. M. (2003). Why is it so difficult to beat the random walk forecast of exchange rates? *Journal of International Economics*, 60 (1), pp. 85–107.

Lyons, K. R. (1995). Test of microstructural hypotheses in the foreign exchange market. *Journal of Financial Economics*, 39 (2/3), pp. 321–51.

Marinković, S. i Golubović, N. (2013). Intervencije Narodne banke Srbije na deviznom tržištu – Stabilizacija deviznog tržišta versus stabilizacija deviznog kursa. In Zoran Aranđelović (Ed.) *Regionalni razvoj i demografski tokovi zemalja Jugoistočne Evrope* (pp 571–84) Niš: Ekonomski fakultet Niš.

NBS (2006). Memorandum Narodne banke Srbije o principima novog okvira monetarne politike: Na putu ka ostvarenju ciljeva niske inflacije. Narodna banka Srbije. Retrieved August 15, 2012 from http://www.nbs.rs/internet/latinica/30/memorandum_novi_okvir_mon_pol_05092006.pdf.

NBS (2008a). Sporazum o ciljanju (targetiranju) inflacije. Narodna banka Srbije. Retrieved August 15, 2012 from http://www.nbs.rs/export/sites/default/internet/latinica/30/memorandum_o_saglasnosti_NBS_i_Vlade.pdf.

NBS (2008b) Memorandum Narodne banke Srbije o ciljanju (targetiranju) inflacije kao monetarnoj strategiji. Narodna banka Srbije. Retrieved August 15, 2012 from http://www.nbs.rs/internet/latinica/30/memorandum_monetarna_strategija_122008.pdf.

Neely, J. C. (2005). An analysis of recent studies of the effect of foreign exchange intervention, *Federal Reserve Bank of Saint-Louis Review*, 87 (6), pp. 685–717.

O'Hara, M. (2004). *Market microstructure theory*. Cambridge, Massachusetts: Blackwell Publishers.

Peel, A. D. & Speight, E. H. A. (1997). Non-linearities in East European black-market exchange rates. *International Journal of Finance & Economics*, 2 (1), pp. 39–57.

Sarno, L. & Taylor, P. M. (2001). Official intervention in the foreign exchange market: Is it effective and, if so, how does it work?. *Journal of Economic Literature*, 39 (3), pp. 839–68.

Wilcoxon, F. (1945). Individual comparisons by ranking methods. *Biometrics Bulletin*, 1 (6), pp. 80–3.

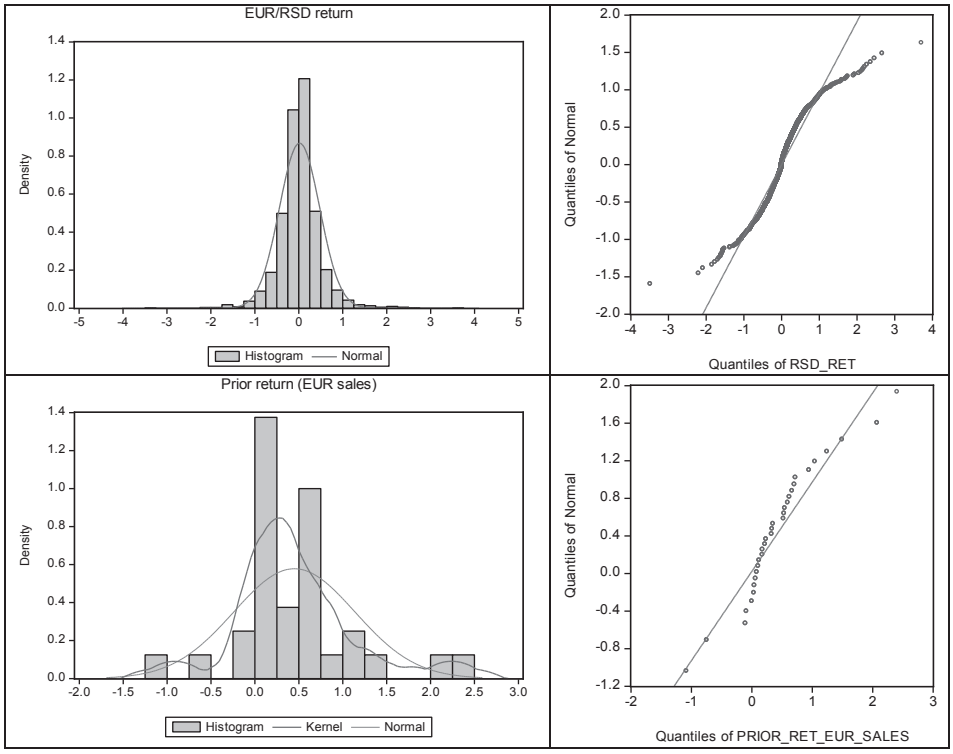
APPENDIX

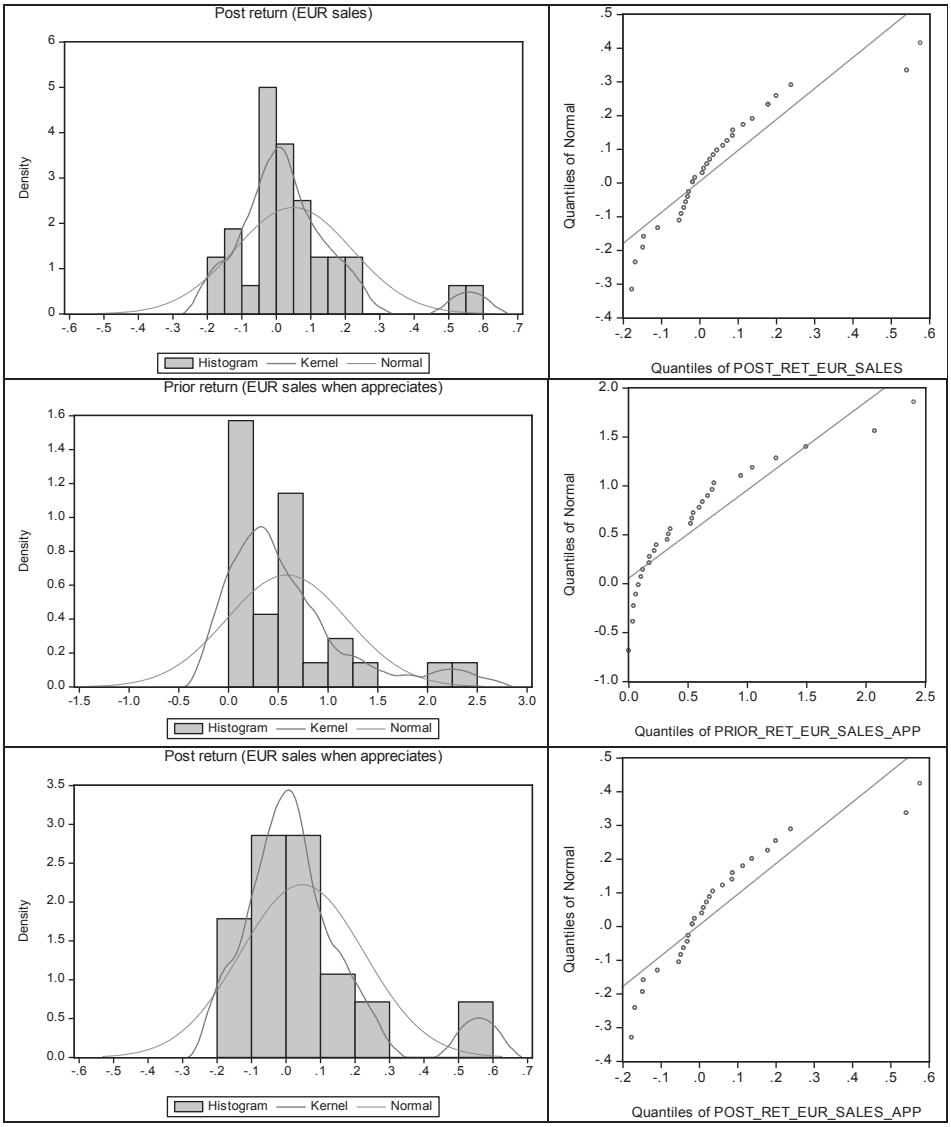
Table A. Paired samples and population distributional parameters

Sample	Skewness	Kurtosis	Jarque-Bera	Probability
Daily exchange rate return	0.4473	10.2465	4866.9920	0.0000
EUR sales				
Prior return	0.7705	4.5955	6.5609	0.0376
Post return	1.5699	5.8896	24.2782	0.0000
EUR sales when appreciates				
Prior return	1.5739	5.0119	16.2831	0.0002
Post return	1.5591	5.5159	18.7299	0.0000

Source: Author's calculation

Table B. Exchange rate return population and samples distribution





Source: Author's calculation

Received: November 22, 2013
Accepted: November 13, 2014