NÁRODNÁ BANKA SLOVENSKA
EUROSYSTÉM

On the Effectiveness of Central Bank Intervention in the Foreign Exchange Market: The Case of Slovakia, 1999-2007

Biswajit Banerjee, Juraj Zeman,
Ľudovít Ódor, William O. Riiska Jr

Working
paper

4/2017

www.nbs.sk
Imricha Karvaša 1
813 25 Bratislava

research@nbs.sk

July 2017

ISSN 1337-5830

On the Effectiveness of Central Bank Intervention in the Foreign Exchange Market: The Case of Slovakia, 1999-2007

NBS Working Paper

Biswajit Banerjee#, Juraj Zeman†, Ľudovít Ódor‡, William O. Riiska Jr.§[1]

Abstract

Based on intra-day high-frequency data, this paper investigates the effect of sterilized interventions on the Slovak koruna/euro exchange rate for different time windows during a period that coincides with Slovakia's preparation for EU accession and euro adoption. Results confirm a significant relationship between intervention and exchange rate change. The maximum effect of intervention is reflected in the exchange rate change within a couple of hours and the effect over longer time windows weakens only gradually. The initial impact of sales interventions is stronger than that of purchase interventions.

JEL code: E44, E58, F31, G15
Key words: Foreign exchange market intervention, koruna/euro exchange rate, monetary policy framework, ERM II participation, Slovakia

Downloadable at http://www.nbs.sk/en/publications-issued-by-the-nbs/working-papers

[1] # Bank of Slovenia, Ljubljana, Slovenia.

† National Bank of Slovakia, Bratislava, Slovak Republic

‡ EU Independent Fiscal Institution, Bratislava, Slovak Republic

§ Hutchin Hill Capital, New York, USA

INTRODUCTION

Central bank intervention in the foreign exchange markets is widely used as a policy tool for achieving a variety of macroeconomic objectives such as controlling inflation, preserving competitiveness and safeguarding financial stability (Moreno, 2005). In this regard, the pertinent question is to what extent intervention is effective in influencing the exchange rate. Surveys of central banks find overwhelming support for the view that interventions are effective (Mihaljek, 2004; Neely, 2000 and 2008). However, answering this question has not been easy for researchers despite the considerable empirical investigation into the effect of central bank intervention in the foreign exchange markets.[2] The difficulty has to do mainly with the endogeneity of changes in the exchange rate and intervention, since the central bank reacts to the same exchange rate that it is seeking to impact.

Most researchers have typically attempted to address this simultaneous equations problem by focusing on the effect of lagged interventions on the exchange rate or by assuming that the contemporaneous intervention decision is independent of current developments in the exchange rate. Neither of these procedures is strictly tenable, because like any other big player in financial markets that acts strategically in response to current as well as past developments in the price of the asset in which it is interested, central banks do care about contemporaneous movements in the exchange rate. As a consequence, in using such procedures to solve the simultaneous equations problem, much of the previous literature find very small or insignificant coefficients on the intervention variable, and occasionally the coefficients even take the wrong sign.[3]

Some researchers have sought to overcome the endogeneity bias by using a two-stage instrumental variable approach (e.g. Adler and Tovar, 2011; Kearns and Rigobon, 2005; Tapia et al., 2004). Menkhoff (2010 and 2013) and Neely (2005 and 2008) argue that the simultaneous equations problem also can be avoided by using high-frequency foreign exchange pricing data and high-frequency central bank intervention data to study the effectiveness of intervention. Specifically, the endogeneity bias is absent if the time interval over which the change in the exchange rate is observed is smaller than the time duration that a central bank takes to react to market developments and intervene. Limiting the time window for observing exchange rate change ensures that there is insufficient time for the change in the exchange rate resulting from the central bank's intervention to loop-back and influence the central bank's initial decision to intervene. Studies based on intra-day high-

[2] For a review of the literature, see Cavusoglu (2010), Dominguez and Frankel (1993), Edison (1993), Menkhoff (2010 and 2013), Neely (2005) and Sarno and Taylor (2001). Notable country-specific studies include Adler and Tovar (2011) for a select group of 15 countries; Beattie and Fillion (1999), Fatum (2008) and Fatum and King (2005) for Canada; Chang and Taylor (1998), Fatum and Hutchison (2006), Hoshikawa (2008), Ito (2002), Kim (2007) and Rasmus and Hutchison (2006) for Japan; Disyatat and Galati (2005), Égert and Komárek (2006), Gersl (2006) and Gersl and Holub (2006) for the Czech Republic; Fischer and Zurlinden (1999) and Payne and Vitale (2003) for Switzerland; Fuentes et al. (2014) for four Latin American countries, Lahura and Vega (2013) for Peru and Tapia et al. (2004) for Chile; Guimaraes and Karacadag (2004) for Mexico and Turkey; Kearns and Rigobon (2005) for Australia and Japan; Kim et al. (2000) for Australia; Kohlscheen and Andrade (2014) for Brazil; Rogers and Siklos (2003) for Australia and Canada.

[3] Examples of studies that obtained coefficients with the wrong sign include Kaminsky and Lewis (1996) and Kim et al. (2000).

frequency data typically find that intervention is effective in moving the exchange rate in the desired direction but that the effect dissipates relatively quickly.[4]

This paper contributes to the empirical literature on foreign exchange intervention in several ways. It is the first comprehensive analysis of intra-day high-frequency intervention data for Slovakia. Based on such data, the paper examines if sterilized interventions by the National Bank of Slovakia (NBS) in the foreign exchange market during 1999−2007 had an effect on the level of the Slovak koruna's exchange rate vis-à-vis the euro. The paper also sheds light on the dynamics of the impact of intervention by estimating equations for different intra-day time windows and comparing the coefficients on the intervention variable across different intra-day time windows. Furthermore, the paper adds to the limited number of studies that have examined the potential asymmetric effects of central bank interventions in the foreign exchange market by looking at the impact of purchases and sales of foreign exchange separately.

The main findings of the paper are that intervention has a significant impact on the exchange rate and that the effect deteriorates over longer time windows gradually. Also, the initial impact of sales interventions is stronger than that of purchase interventions, but the situation reverses after the 60-minute time window. Although of interest, the paper does not seek to differentiate between the different channels through which intervention operated in Slovakia.[5] Instead, it focuses only on measuring the overall impact of intervention on the exchange rate, in line with many recent studies on emerging markets (see Cavusoglu, 2010).

The period of the inquiry coincides with Slovakia's preparation for European Union (EU) accession and euro adoption. Slovakia was invited for negotiations on EU accession in December 1999. EU accession negotiations ended in December 2002, and Slovakia joined the EU in May 2004. Slovakia entered the Exchange Rate Mechanism II in November 2005 and eventually adopted the euro in January 2009. Faced with multiple objectives of controlling inflation, keeping the exchange rate competitive and meeting the exchange rate stability criterion, the NBS closely monitored exchange rate developments during the entire sample period and periodically intervened in the foreign exchange market to prevent excessive exchange rate volatility or/and to lean against the wind of exchange rate developments. Thus, the findings of the paper have important implications for future Eurozone entrants with a managed floating exchange rate regime.

---

[4] See, for example, Fuentes et al. (2014) for Chile, Columbia, Mexico and Peru; Payne and Vitale (2003) for Switzerland; and Tapia et al. (2004) for Chile. In a similar vein, Kohlscheen and Andrade (2014) found that in Brazil about 90 percent of the impact of foreign exchange market intervention through derivatives occurs in the first half-hour. Lahura and Vega (2013) found that in Peru sales interventions have a strong effect on cumulative returns through minute 15 following the intervention but purchase interventions do not have significant effects.

[5] The literature distinguishes between three different channels through which intervention in the foreign exchange market alters the exchange rate: the portfolio channel, the signaling channel, and the coordination channel (see Fuentes et al., 2014 and Neely, 2008). However, there is no consensus on the relative strengths of these different channels. In Slovakia, since the central bank relied on multiple instruments of policy and sterilized interventions were not the only monetary policy instrument, it would be difficult to disentangle the influence of the different channels.

The rest of the paper is organized as follows. The next section presents the features of foreign exchange market intervention in Slovakia during the 1999–2007. The section after that describes the data and methodology. The subsequent section presents the results of the econometric analysis, and the final section concludes.

FEATURES OF FOREIGN EXCHANGE MARKET INTERVENTION IN SLOVAKIA, 1999–2007

Following the switch in October 1998 from a fixed exchange rate regime to a managed floating under an implicit inflation targeting regime, the intervention objective of the National Bank of Slovakia (NBS) was to mitigate "excessive volatility in the exchange rate of the Slovak koruna".[6] However, as foreign exchange market conditions changed fundamentally from mid-2002 onward and monetary policy began to be challenged by trend appreciation because of strong capital inflows spurred by an improvement in the political and economic landscape, the NBS amended the wording of its intervention policy to indicate that it may intervene in the foreign exchange market "in the event of excessive volatility in the exchange rate of the Slovak koruna, and/or when the exchange rate development was inconsistent with macro-economic fundamentals".[7] Operationally, intervention still remained geared toward dampening depreciation or appreciation deemed to be excessive. Prior to ERM II entry in November 2005, the NBS did not have any explicit commitment to a range for the exchange rate. However, following ERM II entry, the NBS faced the explicit constraint of keeping the exchange rate within a ± 15 percent band and meeting the Maastricht criterion on exchange rate stability.[8]

Interventions in the foreign exchange market were fully discretionary and were decided by the NBS Board, which typically reviewed the appropriateness of the level of the exchange rate in weekly meetings. In the event of sharp movements in the exchange rate considered to be excessive trends in the rate, intervention decisions were made at extraordinary meetings of the NBS Board. A decision to start an intervention did not specify any particular exchange rate target or intervention volume. There were "periodic" communications between foreign exchange dealers and the top management of NBS, and on this basis the management decided when intervention was sufficient.[9]

---

[6] See the Annual Report of the National Bank of Slovakia for the years 1999 to 2002. http://www.nbs.sk/_img/Documents/_Publikacie/AnnualReport/ARNBS00.pdf

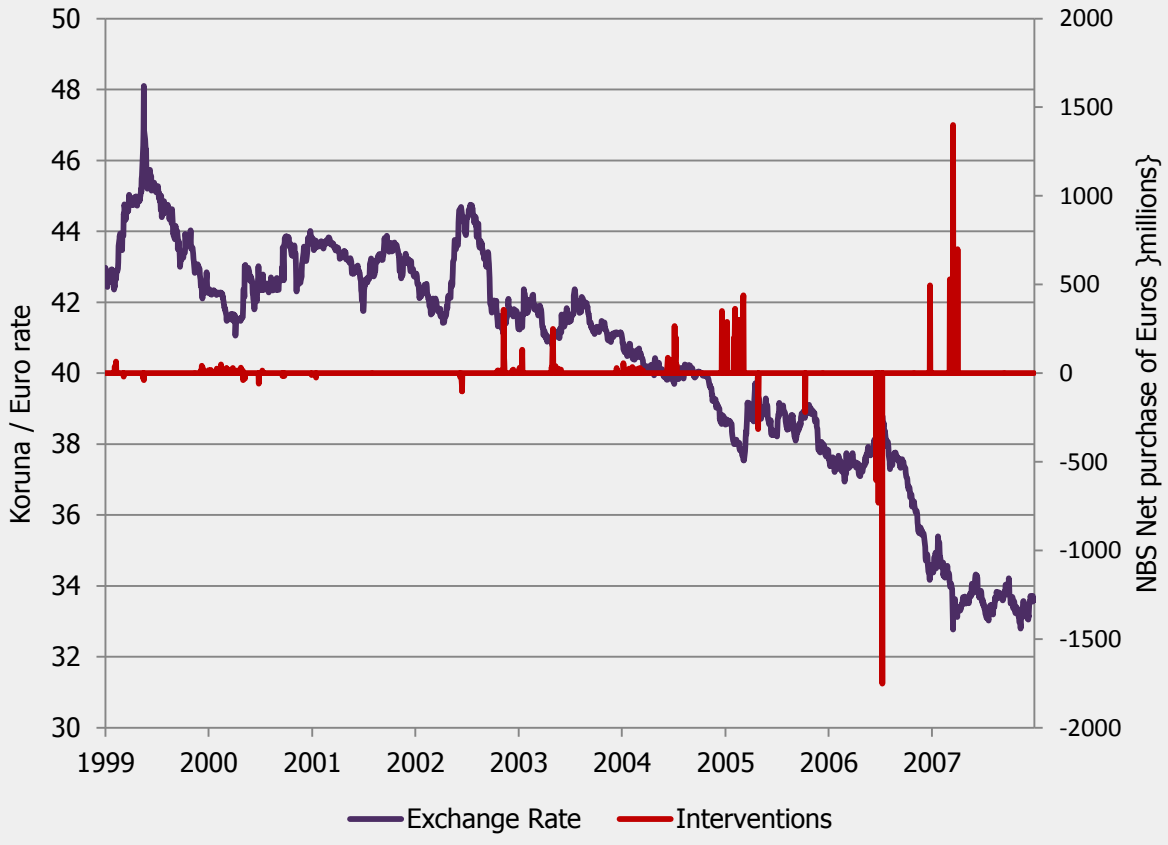
[7] See the Annual Report of the National Bank of Slovakia for the years 2003 onward.

[8] Although a ±15 per cent exchange rate band around the central parity seemingly provided some flexibility, it was not clear in advance how the European Commission (EC) and European Central Bank (ECB) would interpret exchange rate stability. This issue was frequently discussed by the NBS staff with the EC and ECB staff. On this basis, the NBS staff considered it likely that real exchange rate appreciation generated by structural factors would be taken into account in the assessment of exchange rate stability. It was also believed by the NBS staff and the market that there was an informal lower limit of 2.25 percent on the depreciation side of the ERM II band.

[9] This was communicated to the authors by a NBS Board member who was in charge of foreign exchange operations.

Figure 1 shows the daily evolution of the foreign exchange rate of the Slovak koruna vis-à-vis the euro and interventions by the NBS during January 1999 to April 2007.[10] The monthly distribution of the number of intervention trades by the NBS and the total volume of intervention during the reference period is shown in Table 1. After abandoning the fixed exchange rate regime in 1998, the NBS intervened on the foreign exchange market in 38 months on 123 days through 1,155 intervention trades. Interventions took two forms: interventions in the foreign exchange market and direct trades (normally secret) with commercial banks. The total volume of interventions amounted to EUR 14.113 billion, of which direct trade with commercial banks accounted for EUR 1.888 billion (i.e., 13.4%). The interventions were mostly to dampen the pace of koruna appreciation (100 days). EUR 10.054 billion (i.e., 71.2%) of the total intervention volume were purchases of euro to counter appreciation of the koruna and EUR 4.059 billion (i.e., 28.8%) were sales of euro to counter depreciation of the koruna. All the interventions were sterilized.

Figure 1. Daily SKK/EUR Exchange Rate and Daily NBS Intervention Volume



Source: NBS.

Until mid-2002, owing mainly to political uncertainties, Slovakia experienced periodic depreciation drifts in the foreign exchange market, which the NBS resisted through verbal interventions and direct sales interventions in the foreign exchange market. The NBS also

[10] The daily exchange rate in Figure 1 is represented by the end of day rate.

engaged in significant sales interventions in June-July 2006 when the koruna depreciated sharply and the exchange rate dropped below the central parity under ERM II in the wake of uncertainties around the parliamentary elections and unclear communications from the new government after the elections regarding whether it would stick to the objective of Eurozone entry in 2009. Market conditions calmed only after the Prime Minister and Finance Minister declared their support for the original target Eurozone date.

During the rest of the reference period, the Slovak koruna exhibited an appreciating trend. The NBS accommodated a moderate appreciation of the koruna as some of the appreciation was deemed to reflect productivity-driven equilibrium real appreciation and as it would also help restrain inflation. But, it also sought to dampen the appreciation through purchase interventions on numerous occasions. Still, with the appreciation intensifying significantly from 2006Q4 and with the koruna approaching the upper edge of the ERM II ±15 percent band, the central parity was revalued in mid-March 2007. There was no direct intervention subsequently despite a renewed tendency toward appreciation from late January 2008. Instead, the central parity was revalued for the second time in late-May 2008 just prior to the adoption of the final conversion rate in July 2008.[11]

DATA AND METHODOLOGY

DATA

The study utilizes two datasets: one for the NBS intervention transactions and another for the spot price of the Slovak koruna vis-à-vis the euro in the foreign exchange market. The first dataset comprises the interventions of the NBS in the foreign exchange market from January 1999 to April 2007. This dataset is proprietary. For each intervention, the dataset records the time-stamp down to the minute, the type of intervention transaction (i.e., intervention trade or direct trade), whether it was a purchase or a sale of euros for the Slovak koruna, the volume of the intervention in millions of euros, and the exchange rate at which the NBS executed the intervention trade.

The second dataset is composed of spot market, bid and ask quotations from the Reuters dealing system and these are time-stamped down to the second. The foreign exchange prices and quotations taken from the Reuters dealing system were binding for the submitting parties and are therefore representative of the prevailing exchange rate at a given time. The binding SK/EUR quotations and traded prices from the Reuters dealing system are equal to either the price of a trade if a trade was executed at that time, or an average of the bid/ask spread if a quotation was put through at that time.[12] Quotations are not evenly spaced,

[11] At the time of ERM II entry in November 2005, the central parity was set at the then-prevailing market rate of Sk 38.4550 per euro. In March 2007, the central parity was revalued by 8.5 percent to Sk 35.4424. The central parity was revalued for the second time in May 2008 to Sk 30.1260 per euro, a rate which was higher than the prevailing market rate and corresponded to the top edge of the ±15 per cent exchange rate band under the previous central parity. The revised parity was subsequently adopted as the final conversion rate in July. Thus, the final conversion rate was some 22 percent more appreciated than the central parity set at time of ERM II entry.

[12] The average of the bid/ask spread depends on the nature of the quote submitted. Not all quotes were submitted with both a bid and ask. If only one of these values was available, we took this value

meaning the amount of time between each quotation varies. However, quotations are highly granular between the hours of 8:00:00 and 17:00:00 as 634,672 of the 698,679 quotations (i.e., 91%) and 1,074 of the 1,099 intervention trades (i.e., 98%) occurred during this time interval.

METHODOLOGY

We estimate the impact of NBS intervention during fixed time intervals on the change in the exchange rate over these intervals. Each day is divided into intervals based on the length of the period of observation. For instance, if the period of observation is 10 minutes, then the day is divided into 144 intervals, with the first interval encompassing all interventions and FX prices occurring from 00:00:00 to 00:09:59, and the second 10 minute interval encompassing all interventions and FX prices from 00:10:00 to 00:19:59, and so on.

We examine the effect of intervention on time intervals of different width. Specifically, the time interval width starts from 1 minute, 5 minutes and is then widened by 10 minutes from 10 minutes to 8 hours (i.e., 10 minutes, 20 minutes, 30 minutes and, so on).[13] The total intervention during each time interval is summed to a signed volume (positive for purchases of euros and negative for sales of euros). A sense of the dynamics of the impact of intervention can be obtained by comparing the coefficients on the intervention variable across different intra-day time windows. The width of the time intervals in our analysis conforms to those used in earlier studies that have analyzed foreign exchange market intervention using intra-day data (see, for example, Fuentes et al., 2014; Kohlscheen and Andrade, 2014; Lahura and Vega, 2013; Payne and Vitale, 2003; and Tapia and Tokman, 2004).[14]

In our benchmark specification, the percentage change in the exchange rate during the interval in which the intervention occurred is regressed only on the signed total volume of intervention during the interval.[15] Thus,

---

as the average, whereas if both were available, the average was calculated as the uniformly weighted average of the bid and ask.

[13] For certain time windows, it is impossible to divide the day evenly. For instance, for the time window of 2 hours and 50 minutes the day cannot be divided evenly as 1,440 (the number of minutes in a day) divided by 170 (the number of minutes in a 2 hour and 50 minute time interval) is 8.4706. In these instances, the day was segmented in the normal way, except for the last time window which was composed of the remaining minutes in the day. Thus, for the 2 hour and 50 minute time interval, the day is broken up beginning at 00:00:00 into eight 170 minute time intervals and one 80 minute time interval. This is not an unreasonable assumption because of the 1,099 intervention trades, only two intervention trades occurred after 16:00:00.

[14] In earlier studies, the exchange rate variations have been measured over time intervals of varying lengths: 5 minutes (Fuentes et al., 2014 for Peru and Mexico; and Lahura and Vega, 2013 for Peru), 10 minutes (Tapia and Tokman, 2004 for Chile), 15 minutes (Kohlscheen and Andrade, 2014 for Brazil; and Payne and Vitale, 2003 for Switzerland), and 20 minutes (Fuentes et al., 2014 for Chile; and Tapia and Tokman, 2004 for Chile). In the study by Kohlscheen and Andrade (2014) the time window goes up to 90 minutes after the event. Fuentes et al. (2014) also report descriptive statistics of the transactions data for the 5-minute, 20-minutes, 1-hour, 6-hours and 24-hours time intervals.

[15] Adler and Tovar (2011) and Tapia and Tokman (2004) also have a baseline specification in which the intervention volume is the only explanatory variable.

$$XRGR_t = \alpha + \beta_1 INTVOL_t + \varepsilon_t, \quad (1)$$

where $XRGR_t$ is the percentage change in the exchange rate during the time interval (measured as the last price in the interval minus the first price in the interval period divided by the first price in the interval) and $INTVOL_t$ is the signed total volume of NBS intervention occurring within the same time interval.

The coefficient of interest is β_1. Given that each intervention is recorded in millions of euros and that the exchange rate is measured as the number of koruna per 1 euro, the expectation is that this coefficient should be positive. This would imply that purchase (sale) of euros for the koruna by the NBS would depreciate (appreciate) the koruna relative to the euro.

We also estimate an expanded specification in which a measure of global risk appetite and the difference between domestic and international short-term interest rates are included as controls. Thus,

$$XRGR_t = \alpha + \beta_1 INTVOL_t + \beta_2 IRDIF + \beta_3 VIX + \varepsilon_t, \quad (2)$$

where IRDIF is the difference between the average Slovak money market rate and the 1-week European inter-bank offer rate (EURIBOR) and the VIX index, which measures expected short-term turbulence of the S&P 500 implied by stock options, is a proxy for global risk appetite. The inclusion of interest rate differential seeks to control for exchange rate changes that arise as a result of relative monetary policy developments and opportunities for arbitrage (Adler and Tovar, 2011; Cavusoglu, 2010; Watanabe and Harada, 2006; Tapia and Tokman, 2004). Changes in global risk appetite generally affect international capital flows that are likely to drive changes in the nominal exchange rate (Adler and Tovar, 2011). However, as the data on the interest rate differential and the VIX index in this paper are at the daily frequency level and not at a high intra-day frequency, these variables also serve as controls for daily fixed effects.

In alternative specifications we also test, one at a time, whether verbal official interventions have a significant effect on exchange rates, whether the effect of interventions depends on how far the exchange rate is from the ERM II band limits, and whether interventions lose their effectiveness if they become too frequent (by including a variable that counts the amount of time elapsed since the last intervention). However, unlike some studies (e.g., Disyatat and Galati, 2005; Fuentes et al., 2014; Kohlscheen and Andrade, 2014), we do not include macroeconomic or policy news on the intervention day as a control variable because of lack of data.

Studies have noted that the effectiveness of intervention operations may vary over time (Tapia and Tokman, 2004 and Watanabe and Harada, 2006). It is therefore important to determine whether the effectiveness of intervention in Slovakia varied with the changing monetary policy framework of the NBS. Hence, we re-estimate regression equation (2) for all time windows separately for two sub-periods, namely January 1999–December 2004 and January 2005–April 2007, and conduct the Chow test to determine if there is a structural break at the beginning of 2005. The dividing line corresponds to a modification in Slovakia's monetary framework. During January 1999–December 2004, Slovakia maintained an "implicit" inflation targeting policy framework. Thereafter, Slovakia maintained an "explicit"

inflation targeting policy framework under conditions of ERM II until November 27, 2005 and was a participant in the ERM II from November 28, 2005 onward until euro adoption.[16]

Following Domaç and Mendoza (2004) and Lahura and Vega (2013), we examine if intervention by the NBS had asymmetric effects on the exchange rate. Few papers have tackled asymmetric effects of central bank interventions in emerging economies. Lahura and Vega (2013) argue that if the central bank has an asymmetric loss function regarding the behaviour of the exchange rate, it would likely result in an asymmetric reaction function in the face of depreciation or appreciation events. Also, asymmetric effects may turn up if purchases and sales interventions have different transmission channels. In the case of Slovakia, the dangers of sharp exchange rate depreciations were markedly different from those of exchange rate appreciations. Besides the implications of exchange rate depreciation for a pickup in inflationary pressure, there was also a concern regarding the interpretation of the exchange rate stability criterion under ERM II. As noted earlier in footnote 7, it was believed by the NBS staff and the market that there was an informal lower limit of 2.25 percent on the depreciation side of the ERM II band instead of the formal 15 percent. Thus, we estimate separate regressions for purchase interventions and sales interventions in order to test an asymmetric reaction to depreciation and appreciation events.

Following Tapia and Tokman (2004) and as justified by Neely (2008), we estimate all the regression equations by the Ordinary Least Squares (OLS) method and ascertain the significance levels on the basis of Newey-West standard errors.[17] When high-frequency pricing and intervention data are available, OLS is a suitable tool for empirical analysis. The endogeneity problem is circumvented as our finely time-stamped dataset allows the dependent variable, the percent change in the exchange rate, to fall within the central bank's decision window. As Neely (2008, p. 13) argues:

> "The response time for intervention is important because the recent spate of high-frequency intervention studies depend on reaction time for their justification. That is, an important potential advantage of high-frequency studies is that they can avoid simultaneity between intervention and exchange rate returns at a frequency higher than the decision loop of the authority. If an authority takes 10 min to react to exchange rate developments but exchange rate returns are available at a 5 min frequency, then there is no contemporaneous effect of exchange rates on intervention and a simple regression of returns on intervention can produce consistent estimates of the pseudo-structural impact of intervention."

In our view, the regression coefficients of equations based on time intervals of 10 minutes or less for exchange rate change should not be subject to endogeneity bias. Unless on "special alert," a central bank's decision loop is most likely no shorter than 10 minutes. As noted

[16] This is the official classification of the monetary framework. See the various issues of the Annual Report of the National Bank of Slovakia.
http://www.nbs.sk/_img/Documents/_Publikacie/AnnualReport/ARNBS00.pdf

[17] Post-regression diagnostic tests revealed that residuals of a majority of time windows passed the tests for omitted variable, serial correlation and multicollinearity but did not pass the test of heteroscedasticity. The Newey-West standard errors are robust to both heteroscedasticity and serial correlation, and are often termed heteroscedasticity- and autocorrelation-consistent (HAC) standard errors.

earlier, Slovakia's intervention strategy did not follow a high-frequency response pattern. Nevertheless, given the theoretical possibility of endogeneity bias increasing with the widening of the time interval for exchange rate change, we estimate regression equations for progressively wider time intervals up to 8 hours to see what happens to the coefficient on intervention as the time interval is widened.

Since exchange rates, like most financial variables, have a heteroscedastic pattern, many researchers (e.g., Kohlscheen and Andrade, 2014) have estimated the impact of foreign exchange market intervention using a Generalized Autoregressive Conditional Heteroscedasticity (GARCH) framework to avoid any bias in the t-statistics that may arise from ignoring volatility clustering. Hence, to check the robustness of the findings based on the OLS methodology, we re-estimate the effects of interventions using a first order GARCH model. It is notable in this context that in their study on intervention in the foreign exchange market in Brazil using intra-day data, Kohlscheen and Andrade (2014) checked the robustness of their findings based on the GARCH methodology by re-estimating the model using OLS.

EMPIRICAL RESULTS

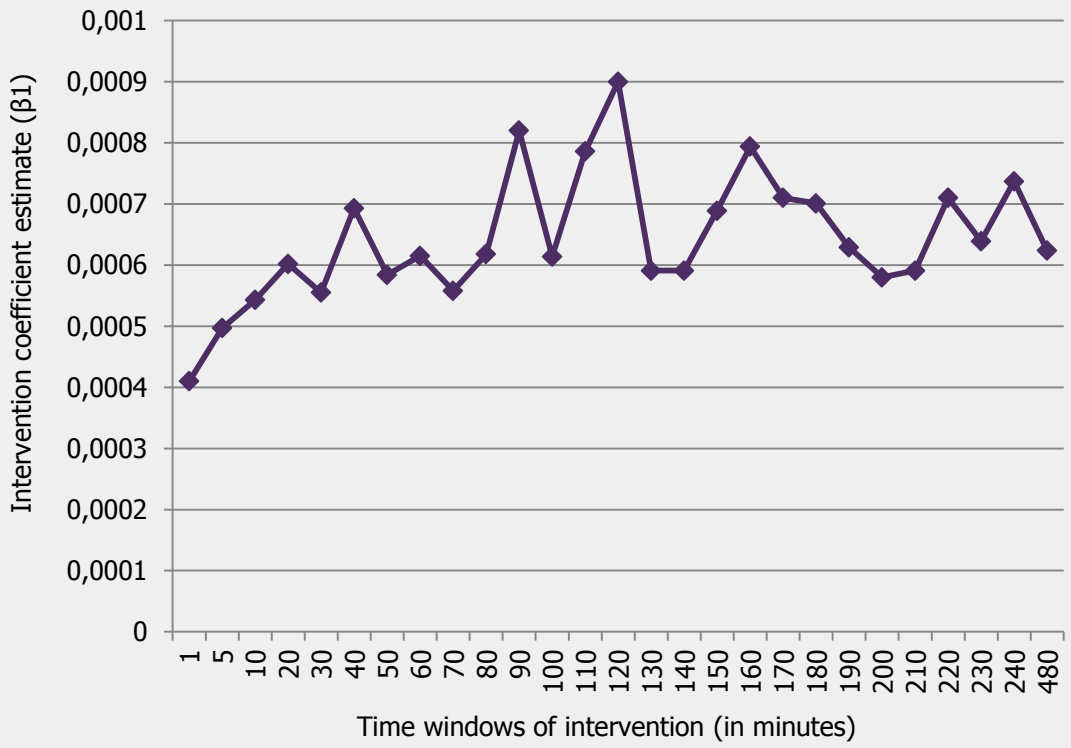
ENTIRE SAMPLE PERIOD, 1999–2007

The regression results for the entire sample period, shown in Table 2, confirm a statistically significant relationship between intervention volumes and exchange rate changes. For all time windows, the coefficient on the signed NBS intervention volume, β_1, is positive and statistically significant at the 5 percent level or better.

The coefficients for the various time windows are plotted in Figure 2 to show the variation in the impact. The effect is lowest for interventions during a 1-minute time interval and highest for interventions during a 2-hour time interval. A 100 million euro purchase (sale) by the NBS during a 10-minute time interval depreciates (appreciates) the koruna during this time interval by 0.054 percentage points or 5.4 basis points. For a similar volume of intervention during a 2-hour interval, the effect rises to 0.09 percentage points or 9 basis points. Although the effect of intervention on the exchange rate change falls as the time windows are widened beyond 2-hours, the effect during these wider time windows is higher than during time windows shorter than 1 hour 20 minutes. Still, the effect of interventions varies within a narrow range—between 5.4 and 6 basis points for nine out of the 24 time windows, and between 6 and 7 basis points for another ten time windows.[18]

[18] It is possible that interventions could have an effect on the exchange rate during a specific time window that is not captured by looking at the difference in the exchange rate at the beginning and the end of the time window. Perhaps, this could explain the variations in the coefficients for different time windows shown in Figure 2.

Figure 2. Estimate of the impact of intervention on exchange rate change for various time windows



Source: Authors' calculations.

The size of the impact of intervention on the exchange rate change in Slovakia is much smaller than those obtained by Payne and Vitale (2003) for Switzerland (30 basis points for a $50 million intervention during a 15-minute time interval) and by Gersl (2006) and Gersl and Holub (2006) for the Czech Republic (approximately 20 basis points over the course of the day for an intervention of 100 million euros). One reason for the smaller size of the impact of intervention for Slovakia may be that the markets believed that the real equilibrium exchange rate was appreciating, so that the impact would be smaller than in a situation in which the underlying real rate was not appreciating. Another reason could be that the design of the Maastricht criteria gives much more room for nominal exchange rate appreciation than depreciation. In addition, a very strict interpretation of the Maastricht criterion on sustainability of price stability likely led to expectations of future appreciation being an almost safe bet.

The results of baseline specification (Equation 1) are robust to expanding the specification to include interest rate differential with abroad and the VIX index as controls (Equation 2). As Table 3 shows, the coefficients on the intervention variable, β_1, retain their magnitude and statistical significance across the different time windows. Interestingly, Adler and Tovar (2011) also found that the introduction of controls had little impact on the intervention coefficient. The results of the expanded specification show the coefficient on the interest rate differential variable has the expected negative sign but is not statistically significant except

for the 1-minute and 5-minute time windows where the coefficient has an unexpected positive sign and is statistically significant. The coefficient on the VIX index is positive and statistically significant for most time windows, indicating that an increase (decrease) in the expected volatility of the S&P 500 implied by stock options was associated with depreciation (appreciation) of the Slovak koruna during the sample period.

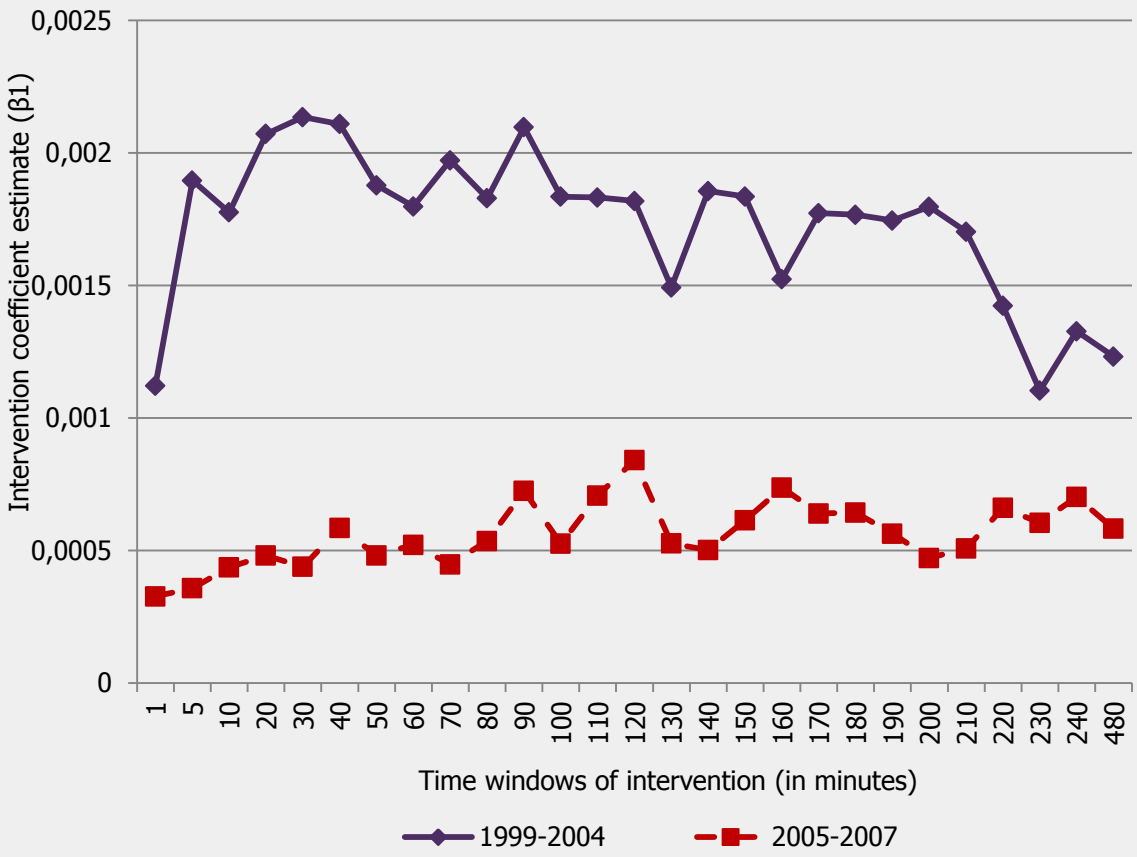
None of the other controls that were added to the baseline specification one at a time—namely, dummy for verbal intervention, distance of the exchange rate from the ERM II band limits, and the amount of time elapsed since the last intervention—was statistically significant.[19]

SUB-SAMPLE ANALYSIS

Regression results for the two subsamples, January 1999–December 2004 and January 2005–April 2007, are presented in Figure 3. The standard Chow test for the equality of coefficients for the two subsamples allows the rejection of the null hypothesis at the 99 percent confidence level.[20] The coefficient on the volume of intervention is positive and statistically significant for all time windows. However, some important differences are discernible between the two subsamples on the impact of intervention on exchange rate change.

[19] The results are not reported in tables but are available from the corresponding author.
[20] For example, the computed F-ratios are 5.30 (p=0.0050) for the 1-minute window; 9.84 (p=0.0001) for the 5-minute window; and 9.33 (p=0.0001) for the 10-minute window.

Figure 3. Estimates of the impact of intervention on exchange rate change for different subsamples



Source: Authors' calculations.

First, the effect of intervention on exchange rate change across all time windows is stronger during 1999–2004 than during 2005–2007. Whereas in the earlier period the impact of intervention of 100 million euros during a given time interval over the course of a 8 hour time span varies between 11 basis points and 21 basis points, in the later period the impact ranges between 3.3 basis points and 8.4 basis points. The main reason for the smaller impact of intervention during 2005–2007 is that during this period the NBS was leaning against a strong trend appreciation of the koruna. As noted above, a very strict interpretation of the Maastricht criterion on sustainability of price stability likely led to expectations of future appreciation being almost a safe bet during the ERM II period. Whereas during 1999–2004 there was no trend movement in the exchange rate and the NBS was seeking to moderate the fluctuations. Another reason for higher sensitivity of coefficients during 1999-2004 might be lower liquidity on the Koruna/Euro exchange market in this period relative to the later period of 2005-2007.

Second, the impact of intervention peaks at shorter time widow and deteriorates more quickly during 1999–2004 compared to the 2005–2007 period. Specifically, during the first period the impact of intervention is strongest for the 30 minute time window and decays by one third of the peak level by the 4 hour time window. In contrast, during the second period

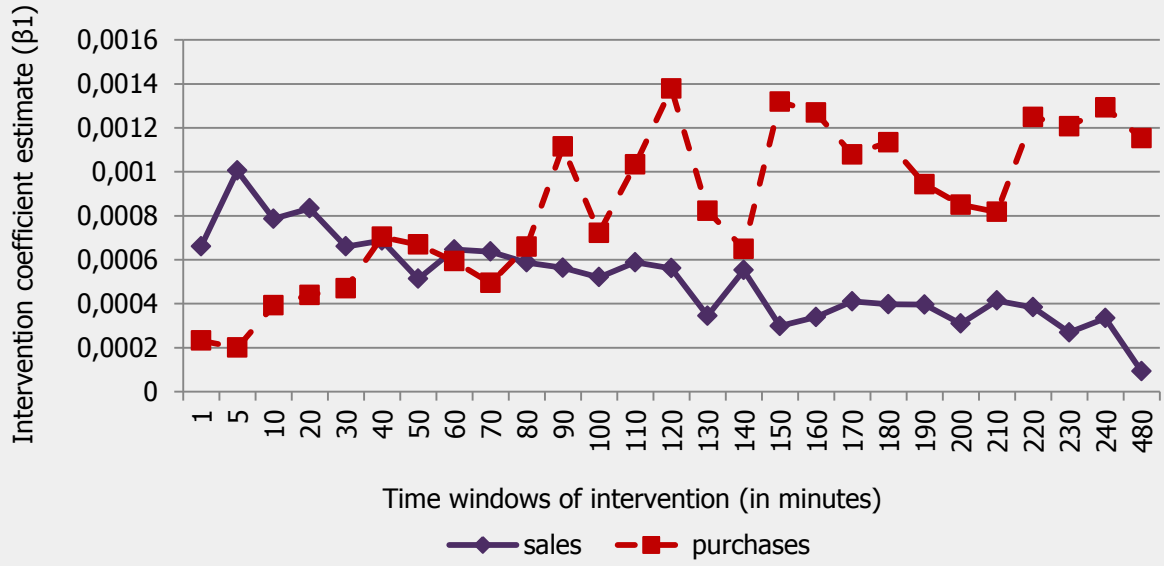
the effect of intervention peaks during the 2 hour time window. There is a slight deterioration in the effect as the length of the time window increases beyond this, but the magnitude of the impact of intervention during the wider time windows is greater than during time windows narrower than 2 hours.

Third, the results reported in Table 3 on the effect of intervention for the sample period as a whole are driven by the outcomes during 2005–2007. The intervention coefficients, β_1, during 2005–2007 are quite close in magnitude to the coefficients for the entire sample period.

ASYMMETRIC EFFECTS OF PURCHASE AND SALE OPERATIONS

The impact of both sales and purchase interventions on the exchange rate is statistically significant across all time windows, but the impact is not symmetric (Tables 6 and 7, and Figure 4). The initial impact of sales interventions is stronger than that of purchase interventions, but the situation reverses after the 70-minute time window. The impact of sale interventions is the highest during a 5-minute time window, when a 100 million euro sale by the NBS appreciates the koruna by 10 basis points. The impact gradually decreases as the time window widens. Euro purchases exhibit the opposite pattern. Their impact is smaller for short time windows but gradually increases as the time window span widens. A 100 million euro purchase by the NBS depreciates the koruna by as much as 14 basis points during a 2-hours interval and this impact remains elevated for another 13 time windows.

Figure 4. Impact of sale and purchase interventions in the foreign exchange market



Source: Authors' calculations.

Our findings for shorter time windows are broadly consistent with the findings of Lahura and Vega (2013) for Peru. They found that sales interventions had a strong effect on cumulative

returns through minute 15 following the intervention while purchase interventions did not have significant effects. Lahura and Vega (2013) argue that the asymmetry likely came into play in Peru because agents perceived intervention purchases and sales differently and attributed different degrees of credibility and motivations to the two types of interventions. In the case of Slovakia, it is likely that the results are capturing the market's greater credibility to the significant sales interventions by the NBS in June-July 2006 when the koruna depreciated sharply and the exchange rate dropped below the central parity under ERM II. Since the informal lower limit on the depreciation side of the ERM II band was considered to be 2.25 percent, it was feared that breaching this threshold would lead to a re-setting of clock for ERM II participation and delay euro adoption.

ROBUSTNESS CHECK: GARCH ESTIMATION

Because OLS regression residuals do not pass test of heteroscedasticity, we re-estimate Equation (2) using the GARCH framework. The size and significance of the estimated intervention coefficients using the GARCH framework shown in Table 8 are virtually identical (except for two time windows where the estimation method does not converge) to the OLS estimates presented earlier in Table 3. Interestingly, in their study on Brazil, Kohlscheen and Andrade (2014) also found that the pattern of the OLS results resembled that obtained with the GARCH (1, 1) specification very closely.

CONCLUSIONS

This paper investigates the effects of sterilized intervention in the spot Slovak koruna/euro exchange rate market for different intra-day time windows. Regression results confirm a significant relationship between intervention and exchange rate change for all time windows and throughout the sample period. The maximum effect of intervention is reflected in the exchange rate change within a couple of hours. The effect falls for longer time windows only gradually. The introduction of controls in the regression equation had little impact on the intervention coefficient.

Slovakia's decision to participate in ERM II and adopt the euro had a demonstrable impact on the effectiveness of NBS' interventions. The effect of intervention weakened, albeit still significant, during the period just prior to and during ERM II participation (2005–2007), when there were sustained capital inflows and the NBS was leaning against the wind of a strong trend appreciation of the koruna. While the NBS was successful in its interventions, counteracting sustained capital inflows through intervention in order to remain within the ±15 percent band around a central parity was going to be clearly unmanageable in the context of the chosen Maastricht criteria interpretation and with the given intervention strategy.[21] The financial markets as well as the NBS, European Commission and European

[21] We are grateful to one of the anonymous referees for pointing out that the story would be completely different under a unilateral commitment (like in the Czech Republic) to intervene with no volume limits against appreciation at some exchange rate level.

accepted that real equilibrium exchange rate of the koruna was appreciating during the ERM II period and this prompted the revaluation of the koruna twice within ERM II.

The size of the effect of intervention by the NBS was considerably smaller than the effect observed in studies on intervention in some small open economies such as the Czech Republic and Switzerland. This difference is likely explained, inter alia, by differences in institutional environment (in particular, ERM II participation for Slovakia) and the underlying trend in the real equilibrium exchange rate which has an influence on the pace and persistence of capital inflows.

REFERENCES

Adler, G and Tovar CE. 2011: Foreign exchange intervention: A shield against appreciation winds? IMF Working Paper WP/11/165, International Monetary Fund: Washington DC.

Beattie, N and Fillion, JF. 1999: An intraday analysis of the effectiveness of foreign exchange intervention. Bank of Canada Working Paper 99-4, February.

Cavusoglu, N. 2010: Exchange rates and the effectiveness of actual and oral official interventions: A survey on findings, issues and policy implications. *Global Economy Journal* 10 (4): 1–40.

Chang, Y and Taylor, SJ. 1998: Intraday effects of foreign exchange intervention by the Bank of Japan. *Journal of International Money and Finance* 17 (1): 191-210.

Daude, C, Yeyati, EL and Nagengast, A. 2014: On the effectiveness of exchange rate interventions in emerging markets. Center for International Development at Harvard University Working Paper No. 288, September.

Disyatat, P and Galati, G. 2005. The effectiveness of foreign exchange intervention in emerging market countries: evidence from the Czech koruna. BIS Working Papers No 172.

Domaç, I and Mendoza, A. 2004: Is There Room for Foreign Exchange Interventions under an Inflation Targeting Framework? Evidence from Mexico and Turkey. World Bank Policy Research Working Paper No. 3288.

Dominguez, KM and Frankel, JA. 1993: *Does Foreign Exchange Intervention Work?* Washington, DC: Institute of International Economics.

Edison, HJ. 1993: *The Effectiveness of Central-Bank Intervention: A Survey of the Literature After 1982.* Special Papers in International Economics No.18, Princeton University, Princeton, New Jersey.

Égert, B and Komárek, L. 2006: Foreign exchange interventions and interest rate policy in the Czech Republic: Hand in Glove? *Economic Systems* 30 (2): 121–140.

Fatum, R. 2008: Daily effects of foreign exchange intervention: Evidence from official Bank of Canada data. *Journal of International Money and Finance* 27 (3): 438–454.

Fatum, R and King, MR. 2005: The effectiveness of official foreign exchange intervention in a small open economy: The case of the Canadian dollar. Bank of Canada Working Paper 2005–21, July.

Fatum, R and Hutchison, M. 2006: Effectiveness of official daily foreign exchange market intervention operations in Japan. *Journal of International Money and Finance* 25 (2): 199–219.

Fischer, AM and Zurlinden, M. 1999: Exchange rate effects of central bank interventions: An analysis of transaction prices. *The Economic Journal* 109: 662–676.

Fuentes, M, Pincheira P, Julio, JM, Rincón, H, García-Verdú, S, Zerecero, M, Vega, M, Lahura, E and Moreno, R. 2014: The effects of intraday foreign exchange market operations in Latin America: results for Chile, Colombia, Mexico and Peru. BIS Working Paper No. 462, September.

Gersl, A. 2006: Testing the effectiveness of the Czech National Bank's foreign-exchange interventions. *Czech Journal of Economics and Finance* 56 (9−10): 398–415.

Gersl, A. and Holub, T. 2006: Foreign exchange interventions under inflation targeting: The Czech experience*. Contemporary Economic Policy* 24 (4): 475–491.

Guimaraes, RF and Karacadag, C. 2004: The Empirics of foreign exchange intervention in emerging market countries: The Cases of Mexico and Turkey. IMF Working Paper WP/04/123.

Hoshikawa, T. 2008: The effect of intervention frequency on the foreign exchange market: The Japanese experience. *Journal of International Money and Finance* 27 (4), 547–559.

Ito, T. 2002: Is foreign exchange intervention effective? The Japanese experience in the 1990s. NBER Working Paper No. 8914, April.

Kaminsky, GL and Lewis, KK. 1996: Does foreign exchange intervention signal future monetary policy? *Journal of Monetary Economics* 37 (2): 258–312.

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

Kim, SJ. 2007: Intraday evidence of efficacy of 1991-2004 yen interventions by the Bank of Japan. *Journal of International Financial Markets, Institutions and Money* 17 (4): 341–60.

Kim, SJ, Kortian, T and Sheen, J. 2000: Central bank intervention and exchange rate volatility - Australian evidence. *Journal of International Financial Markets, Institutions and Money* 10 (3−4): 381–405.

Kohlscheen, E and Andrade, SC. 2014: Official FX interventions through derivatives. *Journal of International Money and Finance* 47 (C): 202–216.

Lahura, E and Vega, M. 2013: Asymmetric effects of FOREX intervention using intraday data: evidence from Peru. BIS Working Papers, no. 430. September.

Menkhoff, L. 2010: High-frequency analysis of foreign exchange interventions: What do we learn? *Journal of Economic Surveys* 24 (1): 85–112.

Menkhoff, L. 2013: Foreign exchange intervention in emerging markets: A survey of empirical studies. *The World Economy* 36 (9): 1187–1208.

Mihaljek, D. 2004: Survey of central banks' views on effects of intervention. In: Foreign exchange market intervention in emerging markets: motives, techniques and implications. BIS Papers No. 24. Bank for International Settlements.

Moreno, R. 2005: Motives for intervention. In: Foreign exchange market intervention in emerging markets: motives, techniques and implications. BIS Papers No 24. Bank for International Settlements.

Národná Banka Slovenska. *Annual Report* (various issues).
http://www.nbs.sk/en/publications-issued-by-the-nbs/annual-report

Neely, CJ. 2000: The Practice of Central Bank Intervention: Looking Under the Hood. *Central Banking* 11 (2): 24–37.

Neely, CJ. 2005: An analysis of recent studies of the effect of foreign exchange intervention. *Federal Reserve Bank of St. Louis Review* 87 (6): 685–717.

Neely, CJ. 2008: Central bank authorities' beliefs about foreign exchange intervention. *Journal of International Money and Finance* 27 (1): 1–25.

Payne, R and Vitale, P. 2003: A transaction level study of the effects of central bank intervention on exchange rates. *Journal of International Economics* 61 (2): 331–352.

Rasmus, F and Hutchison, M. (2006) Effectiveness of official daily foreign exchange market intervention operations in Japan. *Journal of International Money and Finance* 25 (2): 199–219.

Rogers, J.M. and Siklos, P.L. (2003). Foreign exchange market intervention in two small open economies: the Canadian and Australian experience. *Journal of International Money and Finance* 22 (3): 393–416.

Sarno, L and Taylor, MP. 2001: Official intervention in the foreign exchange market: Is it effective and, if so, how does it work? *Journal of Economic Literature* 39 (3): 839–868.

Tapia, M and Tokman, A. 2004: Effects of Foreign Exchange Intervention under Public Information: The Chilean Case. Central Bank of Chile Working Paper No. 255.

Tapia, M, Tokman, A, Landerretche, O and Rigobon, R. 2004: Effects of Foreign Exchange

Intervention under Public Information: The Chilean Case. *Economia* 4 (2): 215–25.

Watanabe, T and Harada, K. 2006: Effects of the Bank of Japan's intervention on yen/dollar exchange rate volatility. *Journal of the Japanese and International Economies* 20: 99–111.

APPENDIX

Table 1. Monthly distribution of number and volume of interventions by the National Bank of Slovakia (NBS) in the foreign exchange market

Month and year	Number of NBS intervention trades	Total volume of NBS intervention (millions of euros per month) positive number means purchase of euros; negative number means sale
Jan-99	3	103
Feb-99	7	20
May-99	46	90
Dec-99	38	114
Jan-00	45	63
Feb-00	86	188
Mar-00	10	165
Apr-00	7	106
May-00	18	-85
Jun-00	1	-60
Jul-00	1	15
Sep-00	3	-45
Jan-01	24	-44
Jun-02	60	-205
Oct-02	3	45
Nov-02	155	562
Dec-02	3	50
Jan-03	9	200
Apr-03	1	35
May-03	53	373
Jun-03	1	20
Dec-03	1	30
Jan-04	3	82
Feb-04	6	110
Mar-04	4	85
Jun-04	5	237
Jul-04	77	616
Dec-04	47	600
Jan-05	25	290
Feb-05	106	1890
Mar-05	58	840
Apr-05	10	-315
Oct-05	5	-220
Jun-06	75	-1335
Jul-06	36	-1750
Dec-06	41	495
Mar-07	67	1930
Apr-07	15	700

Source: Compiled from data provided by the National Bank of Slovakia.

Table 2. Regression results on the impact of interventions by the NBS on exchange rate change within various time windows for the benchmark specification for the full sample period January 1999–April 2007
(Dependent variable: percentage change in the exchange rate during the time interval)

Time window	INTVOL		Constant		# obs.	R^2	F
	Coefficient	Newey-West SE	Coefficient	Newey-West SE			
1 min	0.000410***	(0.000105)	0.000556**	(0.000224)	260 780	0.0000	15.26
5 min	0.000497***	(0.000171)	0.000944***	(0.000281)	130 846	0.0002	8.46
10 min	0.000543***	(0.000172)	0.001477***	(0.000443)	87 261	0.0003	10.30
20 min	0.000602***	(0.000165)	0.002056***	(0.000669)	54 711	0.0007	13.26
30 min	0.000555***	(0.000172)	0.002749***	(0.000867)	40 543	0.0007	10.43
40 min	0.000693***	(0.000150)	0.001973**	(0.000943)	32 429	0.0016	21.34
50 min	0.000584***	(0.000153)	0.003149**	(0.001204)	27 231	0.0011	14.56
1 hr	0.000615***	(0.000167)	0.003617***	(0.001344)	23 528	0.0014	13.59
1 hr 10 min	0.000558***	(0.000173)	0.004072**	(0.001780)	20 718	0.0010	10.46
1 hr 20 min	0.000618***	(0.000150)	0.004848***	(0.001702)	18 606	0.0017	17.04
1 hr 30 min	0.000820***	(0.000228)	0.004574**	(0.001977)	17 022	0.0027	12.94
1 hr 40 min	0.000614***	(0.000168)	0.005083**	(0.002205)	15 664	0.0015	13.30
1 hr 50 min	0.000786***	(0.000205)	0.001948	(0.002253)	14 467	0.0028	14.70
2 hr	0.000900***	(0.000284)	0.005831**	(0.002365)	13 552	0.0042	10.02
2 hr 10 min	0.000591***	(0.000190)	0.005909**	(0.002585)	12 805	0.0015	9.67
2 hr 20 min	0.000591***	(0.000179)	0.008261***	(0.002954)	12 169	0.0015	10.87
2 hr 30 min	0.000689**	(0.000290)	0.005588*	(0.002878)	11 419	0.0025	5.64
2 hr 40 min	0.000794***	(0.000297)	0.007670***	(0.002893)	10 882	0.0031	7.17
2 hr 50 min	0.000710***	(0.000247)	0.008074***	(0.003098)	10 270	0.0029	8.25
3 hr	0.000701***	(0.000246)	0.004883	(0.003349)	9 963	0.0030	8.11
3hr 10 min	0.000629***	(0.000209)	0.009013***	(0.003491)	9 627	0.0024	9.05
3 hr 20 min	0.000580***	(0.000209)	0.009185***	(0.003447)	9 409	0.0016	7.73
3 hr 30 min	0.000591***	(0.000227)	0.007385**	(0.003627)	9 081	0.0020	6.78
3 hr 40 min	0.000710***	(0.000255)	0.002290	(0.003717)	8 865	0.0031	7.75
3 hr 50 min	0.000639**	(0.000289)	0.009459**	(0.003928)	8 728	0.0023	4.88
4 hr	0.000737**	(0.000305)	0.011291***	(0.003849)	8 367	0.0036	5.84
8 hr	0.000624*	(0.000322)	0.010865*	(0.005760)	5 493	0.0031	3.76

*** significant at the 1 percent level; ** at the 5 percent level; * at the 10 percent level

Table 3. Regression results on the impact of interventions by the NBS on exchange rate change for the extended specification with control for full sample period January 1999–April 2007
(Dependent variable: percentage change in the exchange rate during the time interval)

Time window	INTVOL		IRDIFF		VIX		Constant		# obs.	R^2	F
	Coefficient	Newey-West SE	Coefficient	Newey-West SE	Coefficient	Newey-West SE	Coefficient	Newey-West SE			
1 m	0.000410***	0.000105	0.000661***	0.000256	0.000221***	0.000065	-0.001929***	0.000705	260 780	0.0001	9.048
5 m	0.000499***	0.000171	0.000702**	0.000285	0.000278***	0.000066	-0.002483***	0.000659	130 846	0.0004	9.445
10 m	0.000545***	0.000172	0.000494	0.000424	0.000296***	0.000085	-0.002808***	0.000864	87 261	0.0005	9.970
20 m	0.000605***	0.000165	0.000103	0.000517	0.000288***	0.000103	-0.003125***	0.001179	54 711	0.0008	10.040
30 m	0.000558***	0.000172	-0.000008	0.000678	0.000467***	0.000140	-0.006175***	0.001678	40 543	0.0010	10.290
40 m	0.000696***	0.000151	0.000116	0.000828	0.000431**	0.000169	-0.005953***	0.001864	32 429	0.0019	12.570
50 m	0.000588***	0.000155	-0.000103	0.001017	0.000587***	0.000215	-0.008356***	0.002618	27 231	0.0015	10.640
1 hr	0.000619***	0.000168	-0.000317	0.001285	0.000525**	0.000238	-0.007280***	0.002652	23 528	0.0018	9.273
1 hr 10 m	0.000561***	0.000173	0.001118	0.001526	0.000847***	0.000287	-0.009206***	0.003375	20 718	0.0013	8.748
1 hr 20 m	0.000622***	0.000151	-0.000900	0.001589	0.000599**	0.000295	-0.009010***	0.003282	18 606	0.0022	10.920
1 hr 30 m	0.000824***	0.000231	-0.001101	0.001808	0.000641*	0.000337	-0.010652***	0.003849	17 022	0.0032	9.524
1 hr 40 m	0.000619***	0.000170	-0.000825	0.001940	0.000768**	0.000371	-0.011823***	0.004239	15 664	0.0020	9.525
1 hr 50 m	0.000788***	0.000206	0.001343	0.001855	0.000774**	0.000391	-0.009313**	0.004563	14 467	0.0031	6.807
2 hr	0.000905***	0.000288	-0.001996	0.002233	0.000525	0.000407	-0.009588**	0.004613	13 552	0.0048	6.906
2 hr 10 m	0.000595***	0.000193	0.000094	0.002410	0.000927**	0.000447	-0.011642**	0.005092	12 805	0.0020	7.018
2 hr 20 m	0.000596***	0.000181	-0.000623	0.002504	0.000941**	0.000469	-0.011434**	0.005370	12 169	0.0020	7.795
2 hr 30 m	0.000694**	0.000294	0.000748	0.002306	0.001363***	0.000492	-0.018600***	0.006116	11 419	0.0032	6.398
2 hr 40 m	0.000800***	0.000301	-0.002708	0.002695	0.000579	0.000504	-0.010612*	0.005737	10 882	0.0037	5.728
2 hr 50 m	0.000715***	0.000251	-0.001180	0.002921	0.000991*	0.000540	-0.014130**	0.006056	10 270	0.0036	6.644
3 hr	0.000706***	0.000250	-0.002234	0.003101	0.000770	0.000572	-0.015923**	0.006552	9 963	0.0036	6.210
3 hr 10 m	0.000634***	0.000213	-0.003670	0.003184	0.000285	0.000585	-0.006468	0.006885	9 627	0.0029	5.202
3 hr 20 m	0.000588***	0.000213	-0.002916	0.003159	0.000923	0.000583	-0.016422**	0.006580	9 409	0.0026	7.281
3 hr 30 m	0.000596***	0.000230	-0.000926	0.003355	0.001185*	0.000618	-0.017900***	0.006852	9 081	0.0027	6.220
3 hr 40 m	0.000712***	0.000257	0.001439	0.002983	0.001028*	0.000610	-0.013703*	0.007234	8 865	0.0034	4.180
3 hr 50 m	0.000645**	0.000295	-0.002954	0.003481	0.000835	0.000657	-0.014678**	0.007612	8 728	0.0030	5.209
4 hr	0.000743**	0.000310	-0.003972	0.003497	0.000547	0.000650	-0.009821	0.007436	8 367	0.0043	4.750
8 hr	0.000630*	0.000326	-0.001608	0.004452	0.001498	0.000900	-0.022623*	0.011731	5 493	0.0039	3.851

*** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.

Table 4. Regression results on the impact of interventions by the NBS on exchange rate change for subsample period January 1999–December 2004
(Dependent variable: percentage change in the exchange rate during the time interval)

Time window	INTVOL		IRDIFF		VIX		Constant		# obs.	R^2	F
	Coefficient	Newey-West SE	Coefficient	Newey-West SE	Coefficient	Newey-West SE	Coefficient	Newey-West SE			
1 m	0.001122***	0.000351	0.001513***	0.000561	0.000209***	0.000074	0.001836	0.002067	126 655	0.0002	7.163
5 m	0.001896***	0.000533	0.001736***	0.000568	0.000241***	0.000067	0.002585	0.001748	72 012	0.0006	9.104
10 m	0.001776***	0.000620	0.001663**	0.000794	0.000227**	0.000087	0.003599	0.002785	51 398	0.0004	5.251
20 m	0.002072***	0.000572	0.000880	0.000819	0.000207*	0.000112	0.001932	0.003257	34 049	0.0007	5.421
30 m	0.002135***	0.000488	0.000086	0.001109	0.000433***	0.000150	-0.005074	0.004228	25 777	0.0009	9.141
40 m	0.002109***	0.000526	0.000412	0.001237	0.000349**	0.000176	-0.002877	0.004094	20 847	0.0012	6.773
50 m	0.001878***	0.000427	0.000050	0.001596	0.000496**	0.000239	-0.005587	0.006638	17 576	0.0010	7.801
1 hr	0.001798***	0.000424	-0.000020	0.002043	0.000391	0.000244	-0.002931	0.006448	15 276	0.0011	6.896
1 hr 10m	0.001972***	0.000416	0.002272	0.002448	0.000671**	0.000316	-0.000361	0.009812	13 482	0.0011	8.600
1 hr 20m	0.001829***	0.000397	-0.001055	0.002500	0.000443	0.000307	-0.005913	0.008125	12 098	0.0011	8.131
1 hr 30m	0.002097***	0.000387	-0.001116	0.002758	0.000511	0.000364	-0.007701	0.009875	11 134	0.0015	10.590
1 hr 40m	0.001835***	0.000478	-0.001216	0.002989	0.000627	0.000401	-0.010154	0.010990	10 230	0.0011	6.072
1 hr 50m	0.001832***	0.000408	0.002298	0.002567	0.000566	0.000430	-0.000597	0.010312	9 459	0.0013	7.113
2 hr	0.001819***	0.000395	-0.002030	0.003484	0.000294	0.000424	-0.004241	0.011467	8 930	0.0013	7.490
2 hr 10m	0.001493***	0.000390	0.000532	0.003696	0.000750	0.000481	-0.005785	0.013023	8 422	0.0009	5.583
2 hr 20m	0.001856***	0.000424	0.000967	0.004146	0.000623	0.000502	0.002512	0.015814	7 975	0.0011	6.660
2 hr 30m	0.001836***	0.000373	0.000891	0.003614	0.001171**	0.000544	-0.013655	0.015368	7 543	0.0015	9.306
2 hr 40m	0.001524***	0.000395	-0.002348	0.004218	0.000214	0.000529	-0.000320	0.014276	7 136	0.0010	5.125
2 hr 50m	0.001773***	0.000468	-0.001169	0.004584	0.000675	0.000560	-0.006573	0.015028	6 794	0.0014	5.353
3 hr	0.001767***	0.000440	-0.003444	0.004758	0.000583	0.000614	-0.016448	0.016730	6 596	0.0013	5.978
3 hr 10m	0.001745***	0.000409	-0.003918	0.004837	-0.000012	0.000633	-0.000495	0.017462	6 499	0.0012	6.328
3 hr 20m	0.001797***	0.000414	-0.002716	0.005105	0.000587	0.000606	-0.007729	0.016940	6 251	0.0015	6.841
3 hr 30m	0.001703***	0.000418	-0.000813	0.005351	0.000894	0.000644	-0.010621	0.017741	6 004	0.0014	6.225
3 hr 40m	0.001423***	0.000342	0.002779	0.004008	0.000679	0.000676	-0.000037	0.016546	5 967	0.0010	5.965
3 hr 50m	0.001103***	0.000373	-0.003057	0.005184	0.000490	0.000711	-0.006637	0.019072	5 854	0.0006	3.325
4 hr	0.001327***	0.000411	-0.003286	0.005359	0.000091	0.000687	0.003970	0.018529	5 531	0.0008	3.616
8 hr	0.001232***	0.000349	-0.001572	0.006839	0.001010	0.001004	-0.010757	0.030366	3 720	0.0010	4.358

*** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.

Table 5. Regression results on the impact of interventions by the NBS on exchange rate change for subsample period January 2005–April 2007
(Dependent variable: percentage change in the exchange rate during the time interval)

Time window	INTVOL		IRDIFF		VIX		Constant		# obs.	R^2	F
	Coefficient	Newey-West SE	Coefficient	Newey-West SE	Coefficient	Newey-West SE	Coefficient	Newey-West SE			
1 m	0.000327***	0.000109	0.000295**	0.000132	0.000026	0.000041	-0.000045	0.000531	134 125	0.0004	4.957
5 m	0.000358**	0.000167	0.000230	0.000254	0.000105	0.000076	-0.001206	0.001002	58 834	0.0015	2.506
10 m	0.000437***	0.000164	0.000526	0.000430	0.000149	0.000126	-0.001797	0.001667	35 863	0.0036	3.482
20 m	0.000481***	0.000156	0.001124	0.000792	0.000441**	0.000217	-0.005161*	0.002871	20 662	0.0068	5.799
30 m	0.000439***	0.000154	0.001382	0.001085	0.000692**	0.000297	-0.008284**	0.003915	14 766	0.0073	5.644
40 m	0.000586***	0.000129	0.002671*	0.001487	0.000855**	0.000354	-0.010102**	0.004753	11 582	0.0132	11.32
50 m	0.000482***	0.000127	0.004062**	0.001810	0.000968**	0.000418	-0.010778*	0.005627	9 655	0.0114	9.270
1 hr	0.000522***	0.000155	0.003735*	0.002165	0.001423***	0.000532	-0.016577**	0.007018	8 252	0.0118	8.194
1 hr 10 m	0.000448***	0.000160	0.006066**	0.002440	0.001308**	0.000546	-0.013151*	0.007230	7 236	0.0116	7.923
1 hr 20 m	0.000536***	0.000135	0.006381**	0.002650	0.001644***	0.000588	-0.017693**	0.007687	6 508	0.0186	11.380
1 hr 30 m	0.000725***	0.000216	0.005321*	0.002894	0.001423**	0.000698	-0.016640*	0.008886	5 888	0.0299	6.170
1 hr 40 m	0.000526***	0.000152	0.006092**	0.002937	0.002033***	0.000741	-0.023340**	0.009977	5 434	0.0188	8.983
1 hr 50 m	0.000708***	0.000190	0.006231*	0.003373	0.001955**	0.000789	-0.022360**	0.010470	5 008	0.0277	8.181
2 hr	0.000841***	0.000283	0.006084*	0.003674	0.002492***	0.000911	-0.029751**	0.011946	4 622	0.0443	6.447
2 hr 10 m	0.000527***	0.000186	0.004879	0.003896	0.002309***	0.000869	-0.026849**	0.011409	4 383	0.0188	6.135
2 hr 20 m	0.000502***	0.000161	0.008227**	0.003794	0.002359**	0.000908	-0.025645**	0.011930	4 194	0.0218	8.368
2 hr 30 m	0.000614**	0.000277	0.007420*	0.003988	0.003029***	0.001074	-0.035960**	0.014260	3 876	0.0300	5.478
2 hr 40 m	0.000737***	0.000309	0.009645**	0.004451	0.003009***	0.001029	-0.034407***	0.013388	3 746	0.0364	6.241
2 hr 50 m	0.000640***	0.000239	0.011345**	0.004657	0.003343***	0.001169	-0.036455**	0.014858	3 476	0.0319	7.208
3 hr	0.000643***	0.000238	0.009716*	0.005101	0.002724**	0.001230	-0.032295**	0.015607	3 367	0.0358	5.500
3hr 10 m	0.000564***	0.000197	0.008770	0.005488	0.003050**	0.001228	-0.033944**	0.016101	3 128	0.0298	6.034
3 hr 20 m	0.000472**	0.000197	0.009945**	0.004901	0.003505***	0.001271	-0.041677**	0.017290	3 158	0.0182	6.348
3 hr 30 m	0.000508**	0.000220	0.010726**	0.005015	0.003370***	0.001262	-0.038732**	0.016742	3 077	0.0247	5.858
3 hr 40 m	0.000661***	0.000252	0.008863*	0.005050	0.003621***	0.001327	-0.043783**	0.017649	2 898	0.0423	6.068
3 hr 50 m	0.000605**	0.000299	0.011383**	0.005277	0.003353**	0.001372	-0.037813**	0.017894	2 874	0.0352	4.981
4 hr	0.000702**	0.000315	0.010084*	0.005268	0.003812***	0.001400	-0.043578**	0.018184	2 836	0.0469	5.481
8 hr	0.000583*	0.000339	0.016795*	0.008227	0.006120**	0.002358	-0.070198**	0.030171	1 773	0.0423	4.596

*** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.

Table 6. Regression results on the impact of sales interventions by the NBS on exchange rate change for full sample period January 1999–April 2007
(Dependent variable: percentage change in the exchange rate during the time interval)

Time window	INTVOL		IRDIFF		VIX		Constant		# obs.	R^2	F
	Coefficient	Newey-West SE	Coefficient	Newey-West SE	Coefficient	Newey-West SE	Coefficient	Newey-West SE			
1 m	0.000661***	0.000205	0.000676***	0.000258	0.000222***	0.000065	-0.001917***	0.000706	260 069	0.0001	7.360
5 m	0.001005***	0.000293	0.000746***	0.000287	0.000281***	0.000066	-0.002471***	0.000660	130 386	0.0005	10.530
10 m	0.000786***	0.000287	0.000541	0.000429	0.000302***	0.000085	-0.002862***	0.000863	86 905	0.0004	9.203
20 m	0.000833***	0.000271	0.000137	0.000527	0.000291***	0.000104	-0.003149***	0.001177	54 427	0.0007	8.863
30 m	0.000660**	0.000326	0.000015	0.000695	0.000474***	0.000141	-0.006283***	0.001676	40 290	0.0008	8.549
40 m	0.000687***	0.000222	0.000054	0.000852	0.000426**	0.000171	-0.006052***	0.001864	32 203	0.0011	9.214
50 m	0.000513**	0.000223	-0.000128	0.001050	0.000584**	0.000218	-0.008484***	0.002623	27 022	0.0009	7.999
1 hr	0.000646***	0.000252	-0.000407	0.001332	0.000519**	0.000243	-0.007382***	0.002651	23 330	0.0012	7.354
1 hr 10 m	0.000637***	0.000217	0.001115	0.001601	0.000852***	0.000295	-0.009330***	0.003384	20 526	0.0010	8.456
1 hr 20 m	0.000587***	0.000184	-0.000894	0.001664	0.000609**	0.000303	-0.009258***	0.003287	18 422	0.0014	8.964
1 hr 30 m	0.000563***	0.000199	-0.001182	0.001892	0.000636*	0.000347	-0.010884***	0.003853	16 848	0.0012	8.356
1 hr 40 m	0.000520***	0.000212	-0.000886	0.002025	0.000764**	0.000379	-0.012039***	0.004252	15 501	0.0011	7.530
1 hr 50 m	0.000588***	0.000177	0.001423	0.001950	0.000799**	0.000402	-0.009661**	0.004577	14 299	0.0011	5.917
2 hr	0.000561***	0.000198	-0.002446	0.002346	0.000480	0.000418	-0.009888**	0.004605	13 391	0.0016	6.869
2 hr 10 m	0.000345	0.000240	0.000121	0.002531	0.000943**	0.000460	-0.012099**	0.005106	12 652	0.0007	4.942
2 hr 20 m	0.000552***	0.000205	-0.000666	0.002649	0.000941*	0.000484	-0.011428**	0.005393	12 016	0.0012	6.823
2 hr 30 m	0.000298**	0.000131	0.000349	0.002407	0.001330**	0.000502	-0.019267***	0.006122	11 273	0.0011	6.684
2 hr 40 m	0.000339*	0.000230	-0.002814	0.002847	0.000566	0.000521	-0.010949*	0.005725	10 732	0.0010	4.444
2 hr 50 m	0.000410*	0.000221	-0.001337	0.003100	0.000969*	0.000559	-0.014399**	0.006054	10 124	0.0013	5.509
3 hr	0.000397**	0.000159	-0.002681	0.003272	0.000722	0.000591	-0.016194**	0.006570	9 823	0.0013	6.009
3hr 10 m	0.000396***	0.000117	-0.004114	0.003380	0.000225	0.000606	-0.006551	0.006919	9 488	0.0011	6.210
3 hr 20 m	0.000309*	0.000199	-0.003120	0.003367	0.000912	0.000605	-0.016882**	0.006610	9 271	0.0012	5.928
3 hr 30 m	0.000414**	0.000209	-0.001061	0.003624	0.001199*	0.000646	-0.018400***	0.006884	8 938	0.0013	5.705
3 hr 40 m	0.000383**	0.000150	0.001527	0.003163	0.001093*	0.000632	-0.015084**	0.007256	8 728	0.0009	4.255
3 hr 50 m	0.000269	0.000163	-0.003606	0.003678	0.000799	0.000679	-0.015819**	0.007626	8 599	0.0011	5.117
4 hr	0.000334**	0.000159	-0.004375	0.003707	0.000496	0.000672	-0.010119	0.007424	8 232	0.0013	4.571
8 hr	0.000092	0.000147	-0.002314	0.004724	0.001437	0.000929	-0.023387**	0.011737	5 382	0.0009	3.090

*** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.

Table 7. Regression results on the impact of purchase interventions by the NBS on exchange rate change for full sample period January 1999–April 2007
(Dependent variable: percentage change in the exchange rate during the time interval)

Time window	INTVOL		IRDIFF		VIX		Constant		# obs.	R^2	F
	Coefficient	Newey-West SE	Coefficient	Newey-West SE	Coefficient	Newey-West SE	Coefficient	Newey-West SE			
1 m	0.000232***	0.000091	0.000670***	0.000256	0.000226***	0.000065	-0.001959***	0.000704	260 569	0.0001	6.330
5 m	0.000200	0.000164	0.000716**	0.000284	0.000286***	0.000066	-0.002501***	0.000657	130 735	0.0002	7.565
10 m	0.000392*	0.000207	0.000500	0.000424	0.000301***	0.000085	-0.002800***	0.000863	87 177	0.0003	8.076
20 m	0.000439**	0.000203	0.000102	0.000517	0.000295***	0.000103	-0.003120***	0.001179	54 649	0.0004	7.448
30 m	0.000469**	0.000189	-0.000004	0.000677	0.000476***	0.000140	-0.006186***	0.001678	40 494	0.0006	9.128
40 m	0.000704***	0.000203	0.000113	0.000828	0.000440***	0.000169	-0.006032***	0.001864	32 385	0.0012	9.762
50 m	0.000669***	0.000155	-0.000112	0.001017	0.000607***	0.000215	-0.008628***	0.002618	27 192	0.0011	12.460
1 hr	0.000593**	0.000229	-0.000312	0.001285	0.000543**	0.000238	-0.007457***	0.002656	23 491	0.0011	7.228
1 hr 10 m	0.000494*	0.000271	0.001146	0.001527	0.000859***	0.000287	-0.009211***	0.003382	20 683	0.0008	6.508
1 hr 20 m	0.000659***	0.000232	-0.000890	0.001591	0.000608**	0.000295	-0.009069***	0.003279	18 574	0.0014	8.074
1 hr 30 m	0.001114***	0.000277	-0.001182	0.001808	0.000667**	0.000338	-0.011421***	0.003845	16 991	0.0029	11.250
1 hr 40 m	0.000722***	0.000220	-0.000841	0.001941	0.000778**	0.000370	-0.011994***	0.004237	15 634	0.0015	8.866
1 hr 50 m	0.001033***	0.000285	0.001282	0.001856	0.000804**	0.000392	-0.010080**	0.004566	14 437	0.0024	6.602
2 hr	0.001379***	0.000267	-0.002160	0.002233	0.000551	0.000407	-0.010764**	0.004585	13 524	0.0047	13.220
2 hr 10 m	0.000822***	0.000157	0.000074	0.002412	0.000945**	0.000447	-0.012159**	0.005080	12 776	0.0020	13.190
2 hr 20 m	0.000649**	0.000294	-0.000563	0.002506	0.000968**	0.000469	-0.011697**	0.005379	12 141	0.0013	5.969
2 hr 30 m	0.001319***	0.000240	0.000549	0.002304	0.001383***	0.000492	-0.020020***	0.006089	11 392	0.0042	15.050
2 hr 40 m	0.001269***	0.000233	-0.002886	0.002696	0.000604	0.000504	-0.011937**	0.005700	10 856	0.0045	13.680
2 hr 50 m	0.001079***	0.000192	-0.001263	0.002923	0.001022*	0.000540	-0.015224**	0.006025	10 241	0.0038	14.760
3 hr	0.001134***	0.000250	-0.002384	0.003102	0.000806	0.000572	-0.017295***	0.006529	9 937	0.0038	10.930
3hr 10 m	0.000943***	0.000332	-0.003779	0.003187	0.000301	0.000585	-0.007216	0.006890	9 602	0.0028	5.020
3 hr 20 m	0.000850***	0.000241	-0.003046	0.003162	0.000938	0.000583	-0.017184***	0.006571	9 384	0.0027	9.103
3 hr 30 m	0.000817**	0.000326	-0.001018	0.003358	0.001207**	0.000618	-0.018661***	0.006863	9 055	0.0024	6.200
3 hr 40 m	0.001249***	0.000185	0.001290	0.002979	0.001028*	0.000609	-0.014768**	0.007175	8 841	0.0039	17.020
3 hr 50 m	0.001206***	0.000232	-0.003101	0.003482	0.000827	0.000656	-0.015746**	0.007544	8 703	0.0039	12.920
4 hr	0.001293***	0.000252	-0.004146	0.003500	0.000569	0.000650	-0.011416	0.007383	8 342	0.0054	11.960
8 hr	0.001152***	0.000198	-0.001893	0.004455	0.001517	0.000899	-0.024928**	0.011629	5 471	0.0060	14.210

*** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.

Table 8. GARCH estimates of the impact of interventions by the NBS on exchange rate change for full sample period January 1999–April 2007

Time window	INTVOL		IRDIFF		VIX		Constant		# obs.	Chi^2
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error		
1 m	0.000384	0.000250	0.000653***	0.000157	0.000351***	0.000023	-0.003813***	0.000543	260 780	376.9
5 m	0.000500***	0.000056	0.000659***	0.000192	0.000284***	0.000054	-0.002604**	0.001217	130 846	111.1
10 m	0.000540***	0.000055	0.000628**	0.000308	0.000322***	0.000102	-0.003095	0.002214	87 261	105.8
20 m	0.000602***	0.000057	0.000066	0.000596	0.000274	0.000177	-0.002978	0.003658	54 711	115.4
30 m	0.000529***	0.000060	0.000334	0.000876	0.000499**	0.000218	-0.006061	0.004391	40 543	82.24
40 m	0.000696***	0.000059	0.000160	0.000720	0.000405*	0.000216	-0.005645	0.004512	32 429	142.3
50 m	0.000584***	0.000060	0.000172	0.000985	0.000507**	0.000242	-0.006737	0.005149	27 231	99.47
1 hr	0.000604***	0.000060	0.000170	0.001031	0.000502*	0.000302	-0.006567	0.006187	23 528	102.1
1 hr 10 m	0.000550***	0.000077	0.001266	0.001426	0.000766*	0.000438	-0.007345	0.008946	20 718	53.81
1 hr 20 m	0.000625***	0.000077	-0.000966	0.001308	0.000541	0.000422	-0.008478	0.008288	18 606	68.93
1 hr 30 m	0.000824***	0.000064	-0.000546	0.001759	0.000658	0.000501	-0.010157	0.010407	17 022	169.6
1 hr 40 m	0.000619***	0.000100	-0.000312	0.002040	0.000749	0.000571	-0.010990	0.011767	15 664	39.89
1 hr 50 m	0.000787***	0.000082	0.001373	0.001971	0.000835	0.000542	-0.010019	0.010883	14 467	95.71
2 hr	0.000905***	0.000050	-0.001987	0.001859	0.000529	0.000582	-0.009692	0.011245	13 552	331.1
2 hr 10 m	0.000641***	0.000102	0.000390	0.002036	0.001191**	0.000584	-0.014616	0.011434	12 805	44.76
2 hr 20 m	0.000594***	0.000103	-0.000039	0.002770	0.000955	0.000797	-0.010968	0.016470	12 169	34.65
2 hr 30 m	0.000693***	0.000060	0.000603	0.002380	0.001434**	0.000659	-0.018959	0.012661	11 419	140.8
2 hr 40 m	flat log likelihood encountered, cannot find uphill direction									
2 hr 50 m	0.000718***	0.000063	0.000142	0.002516	0.001119	0.000741	-0.014379	0.015421	10 270	132.5
3 hr	0.000703***	0.000069	-0.001417	0.002634	0.000722	0.000798	-0.012631	0.015170	9 963	104.3
3hr 10 m	0.000653***	0.000080	-0.003393	0.002908	0.000310	0.000862	-0.005745	0.016504	9 627	68.65
3 hr 20 m	0.000590***	0.000102	-0.001877	0.003060	0.000949	0.000873	-0.015667	0.018013	9 409	35.03
3 hr 30 m	0.000616***	0.000087	0.000069	0.002839	0.001458*	0.000779	-0.018298	0.014807	9 081	54.94
3 hr 40 m	0.000702***	0.000074	0.000920	0.003251	0.001032	0.000859	-0.013912	0.017331	8 865	90.78
3 hr 50 m	0.000641***	0.000071	-0.002654	0.003228	0.000929	0.000944	-0.014781	0.018796	8 728	83.71
4 hr	flat log likelihood encountered, cannot find uphill direction									
8 hr	0.000630***	0.000067	-0.002276	0.004940	0.001467	0.001383	-0.021946	0.026503	5 493	91.22

*** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.