Foreign Exchange Interventions in Emerging Europe: Should We Give a Damn?

The Case of Croatia and Turkey

Balázs Égert[1]

Abstract

This paper studies the impact of daily official foreign exchange interventions on the exchange rates of two EU candidate countries, namely Croatia and Turkey for the periods of 1996 to 2004 and 2001 to 2004, respectively. Drawing on the event study methodology intervention episodes are identified and their impact on the changes in and the volatility of the foreign exchange rates are analysed. Subsequently, a variety of GARCH models is used to study econometrically the effectiveness of foreign exchange interventions. The results indicate that the event study and the econometric estimations are complementary rather than competing approaches: The combination of the two approaches indicate that both the Croatian and the Turkish central banks were in a position to influence the level of the exchange rate during the period studied, which lends support to the view that sterilised intervention may be effective in emerging market economies. The results also reveal that interventions may cause a rise or a fall in foreign exchange volatility, and that the direction of the effect may depend on the type of intervention and on the specific conditions of the individual interventions.

JEL:

Keywords: central bank intervention, foreign exchange intervention, official interventions, foreign exchange market, effectiveness, exchange rate volatility, emerging economies, transition economies

[1] Oesterreichische Nationalbank; MODEM, University of Paris X-Nanterre and William Davidson Institute. E-mail: balazs.egert@oenb.at and begert@u-paris10.fr. Many thanks go to Andreja Pufnik, Danileja Milosevic, Ian Babetskii, Christoph Fischer and Zoltán Walko for help in obtainining some of the data series used in the paper. The paper was written while the author was visiting BOFIT in 2004 and 2005. The opinions expressed in the paper are those of the author and do not necessarily represent the views of the Oesterreichische Nationalbank or the European System of Central Banks (ESCB).

1. Introduction

The question of how, if at all, central bank interventions on the foreign exchange markets may impact on nominal exchange rates has triggered a large body of literature for the last 20 years or so of the post Bretton-Woods period in industrialised OECD economies. Although it is widely acknowledged that unsterilised interventions affect the exchange rate by altering relative money supplies, the empirical evidence is fairly mixed regarding the effectiveness of sterilised interventions, which may work through the portfolio, the signalling and the microstructure (or coordination) channels. In their literature survey, Sarno and Taylor (2001) conclude, however, that what emerges from studies focusing on the 1990s is that interventions tend to impact on the exchange rates, "especially if the intervention is publicly announced and concerted and provided it is consistent with the underlying stance of monetary and fiscal policy"[2].

It is a well documented fact that a large number of emerging market economies have moved recently from fixed exchange regimes towards more flexible exchange regimes. Nevertheless, extensive foreign exchange interventions were undertaken in these countries mainly driven by a fear of floating (Calvo and Reinhard, 2000) or by a dread of depreciation, as suggested by Dutta and Leon (2002). In a recent paper, Canales-Kirjenko (2003) puts forth that foreign exchange interventions may be more effective in emerging market economies as compared to well-established industrialised countries because of the following reasons: (a) central bank interventions are not always fully sterilised, (b) the size of interventions is large relative to market turnover in narrow forex markets, (c) the market organisation and the regulatory framework may be more conducive to interventions, (d) moral suasion may play a bigger role, and (e) because of the larger informational advantage of the central banks vis-à-vis market participants.

However, there is perhaps surprisingly little empirical research conducted to investigate the effectiveness of central bank interventions in emerging market economies. Of the few studies, Domac and Mendoza (2002) and Guiamaraes and Karacadog (2004) studied the cases of Turkey and Mexico. Even more striking is the lack of any published research focusing on countries in Central and Eastern Europe.

In this paper, daily intervention data are used to study the extent to which foreign exchange interventions were effective in Croatia from 1996 to 2004 and in Turkey from 2001 to 2004. In a first step, we apply the event study approach, which is claimed to be superior to econometric analysis if interventions take place only sporadically (Fatum, 2000 and Fatum and Hutchison, 2003), and analyse the influence of official interventions on the mean and the variance of the exchange rates vis-à-vis the German mark prior to 1999 and vis-à-vis the euro after 1999 for Croatia, and vis-à-vis the US dollar for Turkey. In a second step, a variety of GARCH models is employed to get an econometric grip on the data. We also use extensive pair-wise Granger causality tests to establish any causal links running from exchange rate volatility to interventions and the other way around. In addition to this, probit models are estimated to see whether higher short-term exchange rate volatility and exchange rate fluctuations increase the probability of exchange rate interventions. To our knowledge, this is

[2] For limited effectiveness of official interventions, see e.g. Aguilar and Nydahl (2000) for Sweden, Morana and Beltratti (2000) for the USD/DEM, Brandner et al. (2001), Brandner and Grech (2002) for the ERM currencies. Brissimis and Chionis (2004) suggest that interventions by the ECB were not effective for the yen/euro exchange rate. Fatum (2000) finds evidence for effectiveness for the same currency pair. Ramaswamy and Samiei (2000), Fatum and Hutchison (2003) and Brissimis and Chionis (2004) show that sterilised interventions were effective for the yen/USD and yen/euro exchange rates. For mixed evidence for Australia, see e.g. Kim et al (2000), Kearns and Rigobon (2002), Edison et al. (2003) and Rogers and Siklos (2003).

the first paper that applies the event study methodology to Turkey and that analyses daily foreign exchange interventions for Croatia.

The remainder of the study is structured as follows. Section 2 sketches briefly monetary and exchange rate policies and foreign exchange interventions for Croatia and Turkey for the periods 1996 to 2004 and 2001 to 2004, respectively. Section 3 presents the event study approach, describes the data and report the results of the event study. Section 4 contains the estimation results of the different GARCH specifications, the causality tests and the probit analysis. Section 5 finally gives some concluding remarks.

2. Exchange Rate Regimes and Foreign Exchange Interventions

2.1 Croatia

Croatia has been having a managed float exchange rate regime since the introduction of the kuna in April 1994. As shown in Table 1, exchange rate policy has been ever since oriented towards the German mark and subsequently towards the euro even if there was no official currency basket. During the period from January 1996 to November 2004, the exchange rate of the kuna was kept in a fluctuation band of –6.7%/5.2% relative to the period average and the implicit fluctuation band was even narrower during some periods of time as can be seen from Graph 1.

Nominal exchange rate targeting, which is publicly communicated by the Croatian National Bank (see e.g. Croatian National Bank, 2001, 2002 and 2003), has its main goal to achieve price stability. Back in 1994, the managed floating regime and the new kuna were introduced to stem hyperinflation as high as 1518% on average in 1993. Yearly average inflation rapidly went down to 2.0% in 1995 and has been ever since in single-digit territories (1.8% in 2003). The nominal exchange rate target secures price stability through stable imported inflation (and its second round effects), an important factor in a highly euroised country such as Croatia, and, perhaps more importantly, it acts as an anchor for inflation expectations.

Table 1. Exchange rate regimes in Croatia and Turkey, 1990-2004

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Type of exchange rate regime															
Croatia				F	F	F	F	F	F	F	F	F	F	F	F
Turkey	C	C	C	C	C	C	C	C	C	C	B	F	F	F	F
Weight of EMU currencies / euro in the currency basket or in the target currency for managed float															
Croatia				100	100	100	100	100	100	100	100	100	100	100	100
Turkey	60	60	60	60	60	60	60	60	60	43.5	43.5	0	0	0	0

(a) No home currency in circulation

A: peg to a currency or to a basket with fluctuation margins less than or equal to ±2.25%
B: crawling peg with fluctuation margins of less than or equal to ±2.25%
C: float with active management by monetary authorities (implicit crawling peg)
D: crawling peg with fluctuation margins of more than ±2.25%
E: peg to a currency or a basket with fluctuation margins of more than ±2.25%
F: float with intervention
G: free float without intervention

Regime shift

The Croatian National Bank (CNB) regularly intervene on the foreign exchange market to stabilise the kuna against the euro (German mark) in both directions. Excessive exchange rate

movements are actually interpreted by the CNB as an appreciation or a depreciation of the kuna vis-à-vis the euro of about 2% and higher than 2%[3]. It should be noted that part of the exchange rate movements are due to seasonal factors. The kuna tends to depreciate at the beginning and at the end of the year because of a seasonal worsening of the current account, and it appreciates during the summer period because of an increased demand for kunas in the tourist season. If judged excessive, the central bank also acts to encounter seasonal movements in the exchange rate.

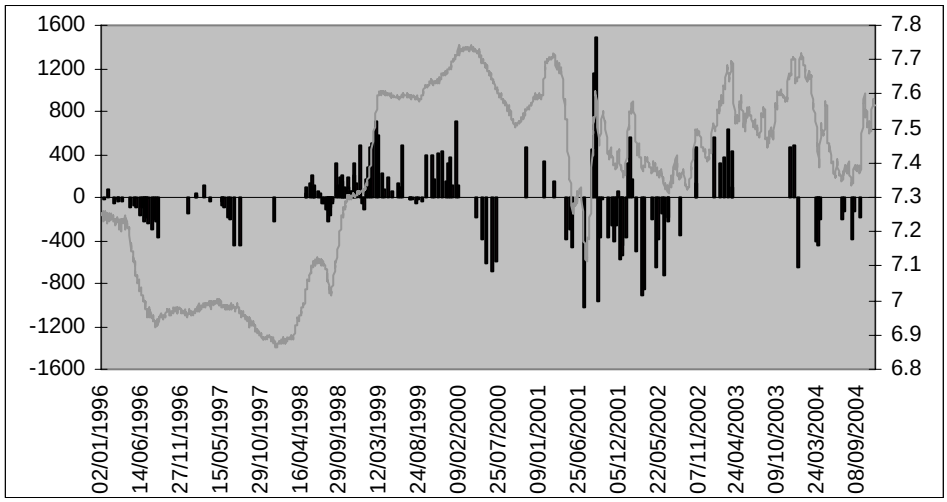
Foreign exchange interventions are achieved through foreign exchange auctions, where the central bank sells or buys domestic currency to and from domestic commercial banks. From 2001 onwards, off-market interventions also took place to prevent appreciation pressures coming from the conversion of privatisation revenues (Croatian Telecom, 2001; INA (Croatian oil company), 2003). The central bank bought or sold foreign currency to and from the Ministry of Finance and the Ministry of Finance held the foreign exchange obtained from issuing eurobonds on its account at the CNB.

Foreign exchange interventions are sterilised by the central bank mainly (a) via reserve requirements for the banks and (b) by issuing foreign currency and kuna central bank bills. The CNB has recently made efforts to move towards more market-based instruments. In this attempt, it unified the kuna and foreign currency requirements in 2000 (e.g. regarding the calculation period and the maintenance period). Since 2001, the reserve requirement rate was decreased several times, and this was compensated by a widening of the calculation base (CNB, 2001, 2002, 2003).

Figure 1 and Table 2 show foreign exchange interventions via auction in the interbank foreign exchange market. The Croatian National Bank intervened on 187 occasions from 1996 to 2004: It sold the domestic currency on 88 occasions and bought it 99 times. The CNB's intervention activity was intensive in 1996, 1998 and 1999 with over 30 yearly interventions. 2001 and 2002 are characterised by roughly 20 interventions a year, whilst 1997 and more recently 2003 and 2004 can be viewed as periods of calm with about 10 interventions a year. Although the number of sales and purchases is fairly balanced for the period as a whole, purchases outweighed sales in 1997, 2001 and 2003 whilst sales occurred much more frequently in 1999, 2002 and 2004. Figure 1b plots two unconditional volatility measures, which indicate increased volatility going in tandem with intervention activity for early-1996, in mid-1998 and on a number of occasions from 2001 to 2004. However, these volatility figures also show periods of interventions that were apparently not associated with changes in unconditional exchange rate volatility.

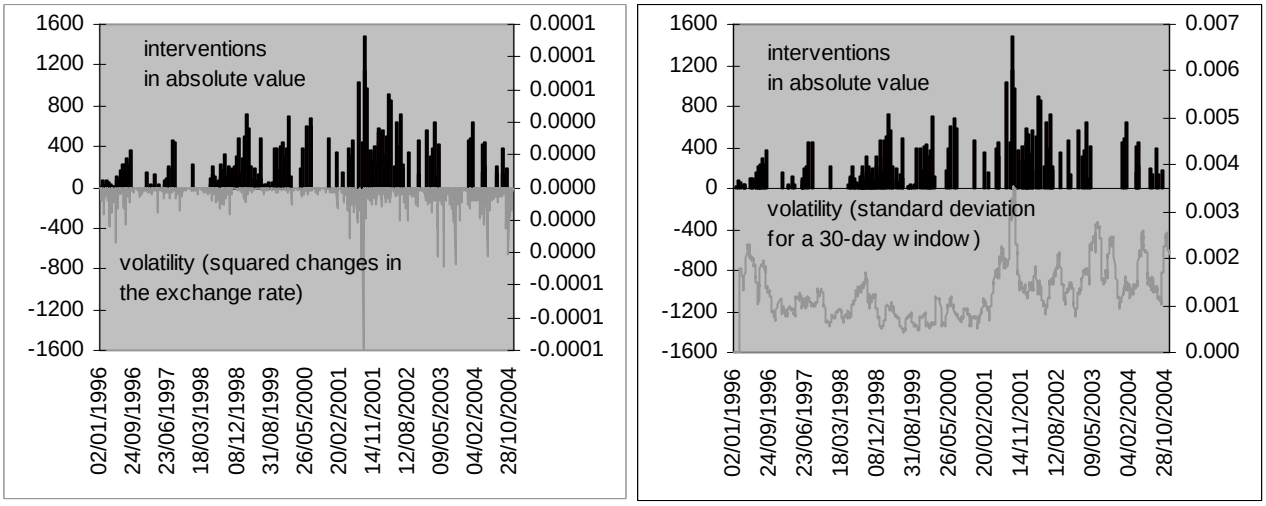
[3] CNB (2001,p. 33): «The kuna/euro value grew by 1.8% in nominal terms in July in comparison with end-June, while it had strengthened by 0.5% in July 2000. In an effort to eases the intense appreciation of the exchange rate of the kuna against the euro, the central bank purchases from banks a total of USD 122.9m ».
CNB (2001,p. 34) : «The last quarter of 2001 was marked by a nominal appreciation of the kuna against the euro of 2.3% (…). In an effort to keep exchange rate movements within satisfactory stability boundaries, the central bank purchased from banks a total of USD 338.5m»
CNB (2003,p 40) : «In this period, the kuna weakened against the euro by a total of 3.4% (…). The kuna depreciation stimulated the sale of foreign exchange at the central bank's auctions in the first quarter of 2003. »

Figure 1a. Interventions and the kuna/euro (German mark) exchange rate, Croatia, 1996-2004



Source: Croatian National Bank

Figure 1b. Interventions and unconditional exchange rate volatility, Croatia, 1996-2004



Note: Interventions are shown in absolute value. Volatility is measured as the mirror image of squared changes in the exchange rate $(\Delta e)^2$ in the figure on the left hand side. In the figure on the right hand side, volatility is computed as standard deviation for a backward looking 30-day window.

Table 2. Summary of interventions activities by the Croatian National Bank, 1996-2004

Summary		Mean	Median	Min	Max	SD	Days of intervention
1996	Total	73	23	1	369	96	39
	Sales	7	2	1	76	18	17
	Purchases	124	98	4	369	100	22
1997	Total	160	105	18	454	155	12
	Sales	57	32	18	120	56	3
	Purchases	195	194	30	454	163	9
1998	Total	109	85	1	475	96	43
	Sales	142	105	31	475	108	24
	Purchases	67	58	1	219	59	19
1999	Total	229	168	4	716	200	30
	Sales	304	299	59	716	182	22
	Purchases	23	22	4	48	16	8
2000	Total	467	533	112	702	225	8
	Sales	429	472	112	702	298	3
	Purchases	490	593	180	684	206	5
2001	Total	500	396	14	1488	378	20
	Sales	606	397	54	1488	580	6
	Purchases	455	396	14	1029	268	14
2002	Total	421	374	137	904	245	17
	Sales	332	326	137	564	183	5
	Purchases	458	386	152	904	265	12
2003	Total	444	458	99	646	171	9
	Sales	418	439	99	635	164	8
	Purchases	646	646	646	646		1
2004	Total	250	199	129	440	126	9
	Sales	--	--	--	--	--	0
	Purchases	250	199	129	440	126	9
1996-2004	Total	232	152	1	1488	245	187
	Sales	231	138	1	1488	256	88
	Purchases	234	163	1	1029	236	99

Source: Author's calculations

2.2 Turkey

Although Turkey's exchange rate stabilisation programme, which rested on a pre-announced crawling peg exchange rate regime, had the merit to having brought down year-on-year inflation from 68.8% in December 1999 to 39% in December 2000, it culminated in a currency crisis in early 2001. As a result, a floating exchange rate regime was introduced on February 22, 2001. This was part of a new monetary policy, which can be best described as an implicit inflation targeting. Under this regime, the central bank pursues an inflation target at a given horizon in the future. The central bank's main instruments are short-term interest rates. The base money and net international reserves are used as "indicative criteria", which can be perhaps deemed as intermediary targets. Net domestic assets, measuring domestic credit expansion, is considered as an indicator for monetary policy. This monetary policy framework was underpinned with the amendment of the Central Bank Act on May 5, 2001, aimed at securing the operational independence of the central bank.

The role of foreign exchange interventions is understood to be limited in such a framework. The Central Bank of the Republic of Turkey (CBRT) has been stressing in its official publications that foreign exchange interventions should take place as rarely as possible and in a transparent manner (CBRT, 2001, p. 109 and CBRT, 2004, paragraph 34). In addition to this, it is also emphasised that foreign exchange interventions do not intend to target any precise level of the long-run equilibrium exchange rate but aims to dampen excessive volatility instead and is used for building international reserves.[4] When considering exchange

[4] CTB (2001, p. 109) : « The Central Bank conducted regular FX sales auxtions after March 29 in order to smooth excessive short-run exchange rate fluctuations without affecting the long-run equilibrium level of exchange rates… »
CTB (2002, p. 71) : « …the Central Bank announced that it would intervene in the foreign exchange rate market in a strictly limited fashion to prevent excessive volatility without targeting a certain trend level. »

rate volatility, the central bank not only looks at past and present volatilities but also considers expected changes in volatility occurring in the future (CBRT, 2004, paragraph 26).

However, reading between the lines may reveal that the central bank may give a lower weight to decrease excessive exchange rate volatility and it may ponder to alter the trend of the exchange rate. According to CBRT (2002, p. 74), "foreign exchange auctions were temporarily suspended as of July due to the volatilities of exchange rates", which somehow contradicts to the declared intention to counteract excessive volatility. It is also mentioned several times that the central bank considers excessive volatility in both directions. Given that volatility is an absolute measure, this may indicate that the CBRT also looks at changes in the exchange rate.[5]

The central bank carries out several operations to sterilise foreign exchange interventions by means of (1) Turkish lira deposit operations in the interbank money market and (2) reverse repo transactions at the Istanbul Stock Exchange. It also ensures that short-term money market interest rates remain in line with the inflation target.

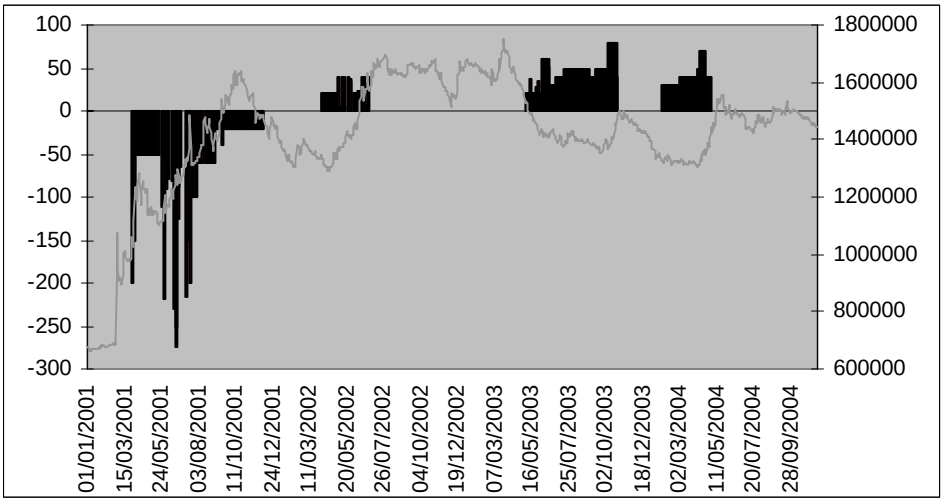
The interventions by the central bank were mostly carried out based on either discretionary or pre-announced auctions. However, the central bank also did some discretionary interventions. The amount of these discretionary interventions are not reported by the central bank.[6] Table 3 and Figure 2a provide an overview of the interventions via discretionary and pre-announced auctions, from which it can be seen that the central bank intervened massively on four occasions. First, it purchased Turkish lira 124 times in 2001 in the aftermath of the crisis. The remaining three intervention episodes are all lira selling operations, which contain 33 (2002), 117 (2003) and 62 (2004) separate interventions. As reported in divers central bank publications, these operations resulted in a substantial increase in international reserves, which is consistent with the monetary policy framework (international reserves are an intermediary target). Figure 2b displays unconditional volatilities, and they show that exchange rate volatility deceased as a result of the first block of interventions in 2001, whilst it increased after the second and fourth intervention episodes in 2002 and 2004. The graphs suggests that volatility was slightly higher prior to than after the intervention episode in 2003.

CTB (2004, paragraph 34) : « The Bank has not performed any foreign exchange buying or selling operations intended at determining the level or direction of the exchange rates. The Bank's foreign exchange buying or selling operations aimed at controlling excessive volatilities. »

[5] CTB(2003, p.97) : « (…) it would directly intervene in the event of excessive volatility that might occur in both directions ».
CTB (2002, p. 96) : « (…) the Central Bank did not target any exchange rate level and that it would respond symmetrically to both upward and downward volatility. »

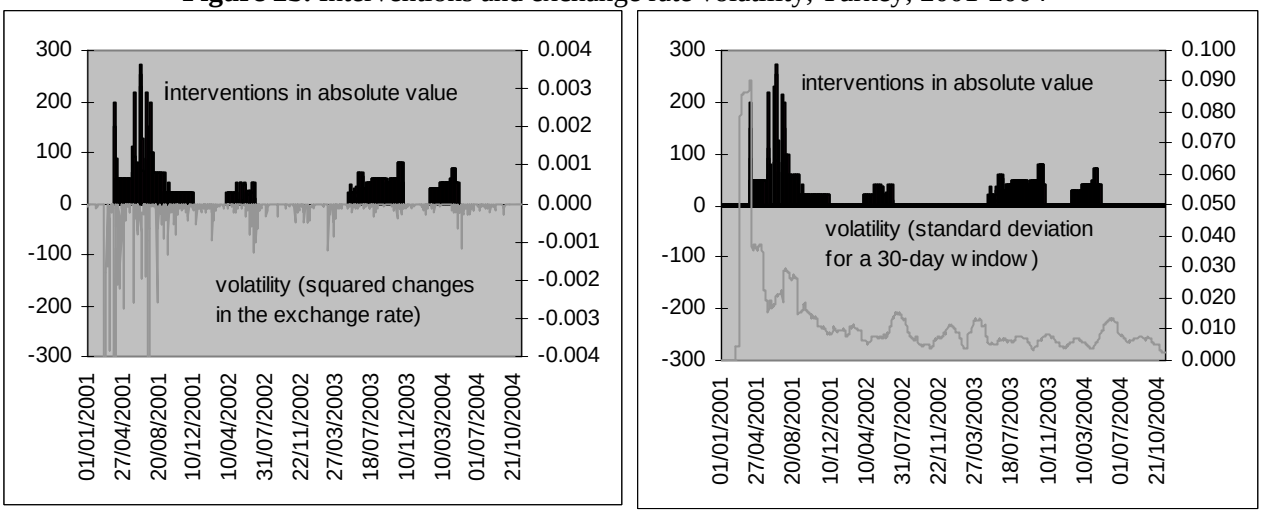
[6] Guimaraes and Karacadag (2004) provide a useful overview regarding the types of central bank interventions from February 2002 to November 2003.

Figure 2a. Interventions and the Turkish lira/dollar exchange rate, Turkey, 2001-2004



Source: Central Bank of the Republic of Turkey

Figure 2b. Interventions and exchange rate volatility, Turkey, 2001-2004



Note: Interventions are shown in absolute value. Volatility is measured as the mirror image of squared changes in the exchange rate $(\Delta e)^2$ in the figure on the left hand side. In the figure on the right hand side, volatility is computed as standard deviation for a backward looking 30-day window.

Table 3. Summary of interventions activities by the Central Bank of the Republic of Turkey 2001-2004

Summary		Mean	Median	Min	Max	SD	Days of intervention
2001	Total	53	50	20	274	51	124
	Sales	--	--	--	--	--	0
	Purchases	53	50	20	274	51	124
2002	Total	24	20	4	40	10	33
	Sales	24	20	4	40	10	33
	Purchases	--	--	--	--	--	0
2003	Total	43	50	2	80	18	117
	Sales	43	50	2	80	18	117
	Purchases	--	--	--	--	--	0
2004	Total	40	40	30	70	11	62
	Sales	40	40	30	70	11	62
	Purchases	--	--	--	--	--	0
2001-2004	Total	44	40	2	274	34	336
	Sales	39	40	2	80	16	212
	Purchases	53	50	20	274	51	124

Source: Author's calculations

3. The Effectiveness of Interventions: An Event Study Approach

3.1 Methodological Issues

If foreign exchange interventions occur rarely or only after a large number of days without intervention, standard time series econometric techniques are likely to find that official interventions does not have an effect on exchange rates, which are highly volatile in the short run (Fatum (2000), and Fatum and Hutchinson (2003)). A big advantage of the event study approach over time series techniques is that it only looks at periods when interventions take place, and is thus able to filter out longer periods during which no interventions happen and which may cause econometric studies to find no relation between foreign exchange interventions and exchange rate behaviour.

When applying the event study approach, three issues have to be tackled:

(a) how single interventions in one direction can form a single intervention episode or event,

(b) under what circumstances an intervention episode can be viewed as effective/successful.

(c) how long a time horizon should be analysed before and after the intervention event (definition of pre- and post-event windows)

Regarding the definition of an intervention event, the question is of how many days may separate two single intervention acts going in the same direction (both purchases or both sales) can be considered as two distinct intervention events. If too few, say one or two, days, are taken as the boundary between two intervention events, overlaps between the pre- and post-event may occur, which makes it difficult to interpret the effect of a given intervention event on the exchange rate in the pre- and post event windows because of the simultaneous impact of the overlapping intervention events. Furthermore, setting the distance too short may lead to the overestimation of the intervention episodes. By contrast, if too large a distance is set between single interventions to form a common intervention episode, the risk then is to underestimate the number of true intervention episodes (Fatum, 2000).

Five alternative definitions of the intervention event are considered in this study. We consider intervention events which comprise single interventions in one direction between which up to 2, 5, 10, 20 and 30 consecutive days can pass without intervention activity. The intervention event ends if more than 2, 5, 10, 20 or 30 days go by without intervention or if an intervention in the other direction takes place.[7]

Turning now to measuring the effectiveness of an intervention event, a central bank intervention can be thought of as being effective, if purchases (sales) of the domestic currency result in an appreciation (deprecation). Nevertheless, the definition of success crucially hinges on the direction of the exchange rate prior to the intervention event. In this sense, the following three classes of effective interventions can be distinguished.

- Leaning against the wind: the central bank intervention may intend to reverse the trend of the exchange rate. Such an intervention is deemed a success if the exchange rate depreciate (appreciate) in the pre-event window, and following the purchases (sales) of domestic currency, it appreciates (depreciates) in the post-event window:

Buying the domestic currency: $(I_t < 0,\ \Delta e_{t-} > 0 \text{ and } \Delta e_{t+} < 0)$

Selling the domestic currency: $(I_t > 0,\ \Delta e_{t-} < 0 \text{ and } \Delta e_{t+} > 0)$

[7] Fatum (2000) and Fatum and Hutchison (2003) use up to 15 days and Edison et al. (2003) use up to 10 days with no intervention between two neighbouring interventions within an event.

where $I_t < 0$ ($I_t > 0$) stands for purchases (sales) of the domestic currency, Δe_{t-} is the change in the exchange rate in the pre-event window, and Δe_{t+} is the change in the exchange rate in the post-event window.

- Smoothing exchange rate movements: the central bank may want to slow down the appreciation or the depreciation of the domestic currency. Such an operation is viewed successful in the event that buying (selling) the domestic currency causes the exchange rate to depreciate less (appreciate more) in the post-event window than in the pre-event window.

Domestic currency purchases: $(I_t < 0,\ \Delta e_{t-} > 0,\ \Delta e_{t+} > 0 \text{ and } \Delta e_{t+} < \Delta e_{t-})$

Domestic currency sales: $(I_t < 0,\ \Delta e_{t-} < 0,\ \Delta e_{t+} < 0 \text{ and } \Delta e_{t+} > \Delta e_{t-})$

Leaning with the wind: Such a strategy involves the accentuation of an ongoing trend in the exchange rate market. In such a case, purchases (sales) of the domestic currency should cause the exchange rate to appreciate more (depreciate more) after the intervention episode than before the intervention episode.

Buying the domestic currency: $(I_t < 0,\ \Delta e_{t-} < 0,\ \Delta e_{t+} < 0 \text{ and } \Delta e_{t+} < \Delta e_{t-})$

Selling the domestic currency: $(I_t > 0,\ \Delta e_{t-} > 0,\ \Delta e_{t+} > 0 \text{ and } \Delta e_{t+} > \Delta e_{t-})$

As to the size of the pre- and post-event windows. We look at six different lengths: 2, 5, 10, 20, 30, 40, 60. The pre- and post-event windows are constructed in a symmetric way implying that a 2-day (5-day etc.) pre-event window is compared to a 2-day (5-day etc.) post-event window.[8] In addition, effectiveness is also analysed for the event window itself. The pre-event window is set to 2 , 5, 10, 20, 30 days if the event window size is equal or lower than 2 days (higher than 2 (5, 10, 20,) but equal or lower than 5 (10, 20, 30)).

Finally, not only changes in the exchange rate but also changes in the volatility of the exchange rate can be analysed. For this purpose, volatility measured as standard deviation over the (symmetric) pre- and post-event windows are compared.

3.2 Data Source and a First Look

Daily intervention data are obtained from the national central banks. The sample period spans from January 1996 to November 2004 for Croatia and from January 2001 to June 2004 for Turkey. For Turkey, the sub-period of January 2002 to June 2004 is also studied. The interventions are expressed in the domestic currencies for Croatia because the sample period comprises the switch from the German mark to the euro. Expressing interventions in the same currency units ensures full comparability. Interventions by the Central Bank of the Republic of Turkey are expressed in terms of the US dollar. In accordance with common practice in the literature, purchases (sales) of the foreign currency are positive (negative) values. Thus, purchases (sales) of the domestic currencies are denoted with negative (positive) figures. Exchange rate series against the German mark and the euro are used for Croatia (provided by the respective central bank, and against the US dollar for Turkey (obtained from Datastream, code: TKUSDSP). Exchange rates are defined as units of the domestic currency per one unit of the foreign currency. This implies that a decrease (increase) in the exchange rate is an appreciation (depreciation). The exchange rate returns series are obtained as first differences of the level series taken in natural logs. Only data for trading days are considered for the study implying the exclusion of week-ends and public holidays. Summary statistics for the exchange rate return series are reported in Table 4. All series are highly leptokurtic and the

[8] Fatum (2000) employs 2, 5, 10, and 15-day window sizes, whilst Edison et al. (2003) looks at 2-day and 21-day windows. Edison and others term the 2-day window the short-term and the 21-day window the long-term.

series for Turkey for the whole period is asymmetric. The Jarque-Bera tests systematically reject the null hypothesis of normality. The return series are stationary in first difference as the Augmented Dickey-Fuller (ADF), the Phillips-Perron (PP) and the Elliott-Rothenberg-Stock (ERS) point optimal unit root tests reject the null hypothesis of a unit root and the Kwiatowski-Phillips-Schmidt-Shin (KPSS) cannot reject the null of stationarity for Croatia and for Turkey for the sub-period. The KPSS test indicate that the series are non-stationary for Turkey for the whole period. Nonetheless, the results of the three previous tests are taken as evidence enough for difference stationarity for this series as well.

Table 4. Summary statistics for the exchange rate returns series

	Mean	Median	Max	Min	SD	Skewness	Kurtosis	Jarque-Bera	ADF	PP	KPSS	ERS
Croatia: 1996-2004												
Croatia	1.93E-05	1.73E-05	0.010	-0.007	0.001	0.08	6.21	963 (0.000)	(2) -17.035***	(26) –57.144***	(25) 0.082	(2) 0.115***
Turkey: 2001-2004												
Turkey	0.001	-0.001	0.335	-0.126	0.018	7.62	141.96	675030 (0.000)	(1) -24.532***	(10) –25.019***	(7) 0.664**	(1) 0.042***
Turkey: 2002-2004												
Sub-smpl	2.30E-06	-0.001	0.035	-0.022	0.008	0.69	4.85	128 (0.000)	(0) -22.454***	(8) -22.588***	(9) 0.148	(0) 0.198***

Notes: ADF, PP; KPPS and ERS are the Augmented Dickey-Fuller, the Phillips-Perron, the Kwiatowski-Phillips-Schmidt-Shin and the Elliott-Rothenberg-Stock point optimal unit root tests, respectively, for the case including only a constant. In parentheses is the lag length chosen using the Shwartz information criterion for the ADF and ERS tests, and the Newey West kernel estimator for the PP and KPSS tests. *, ** and *** denote the rejection of the null hypothesis at the 10%, 5% and 1% levels. For the ADF, PP and ERS tests, the null hypothesis is the presence of a unit root, whereas for the KPSS tests, the null hypothesis is stationarity.

3.3 Results

Croatia

Table 5 below documents that in Croatia, the identification of intervention episodes is fairly sensitive to the maximum days of no intervention elapsed between to interventions. Using maximum two days yields a total of 148 intervention episodes, and this number drops to 71 when 10 days are employed. When the criterion is set at 20 or 30 days, the number of identified episodes drops further to 49 and 46, respectively.

Table 5. The number of the identified intervention episodes

		Maximum days of intervention inactivity between two consecutive interventionss				
		2 days	5 days	10 days	20 days	30 days
Croatia	1996:01 to 2004:10	148	95	71	49	46
Turkey	2001:01 to 2004:06	10	5	4	4	4

Summary statistics are provided for each filter in Tables 6 to 8. Despite the difference regarding the number of identified intervention episodes, a number of common features can be observed for the intervention episodes based on different filters. First, Table 6 documents the high number of episodes, 12 or 13, for which the effectiveness of interventions can be addressed only for the pre-event window and the event window itself, but not for the post-event window because the next intervention episode starts the next day or one day later after the episodes considered. This is because the central bank changed the direction of the intervention, and after buying (selling) the domestic currency against the euro (German mark)on one day, it started selling (buying) the kruna the next day or so. In addition to this, for another bunch of episodes, the impact of the episode on changes in the exchange rate can be assessed only at the shorter horizons because of the short distance separating the episodes. The shorter the maximum days of no interventions used for the episode selection, the lower the number of non-overlapping longer pre- and post-event windows. Using maximum 2 days, 46% of the episodes can be assessed for the pre- and post-event window size of 5 days, and the share of assessable episodes for 10, 20 and 30-day post-event window drops to 20%, 7% and 3%, respectively. For the post-event window of 60 days, all the episodes have an overlap with other episodes. Although the share of episodes with no overlap increases with the rise in

the maximum days of no intervention, it is still fairly low. For maximum 30 days, for the 10-day post-event window, 35% of the episodes can be analysed without overlaps occurring, and the share goes down to 11% for the 60-day post-event window. Hence, the effectiveness of central bank interventions can be studied only partially for Croatia using the study event approach.

An episode is qualified as a success if the episode can be viewed as leaning against the window (AGAINST), smoothing exchange rate movements (SMOOTH), or leaning with the wind (WITH) in accordance with the criteria explained in the previous section. Table 6 also reports successful and unsuccessful episodes as a share of non-overlapping episodes. The share of successful episodes ranges from 8% to 60%. However, the share is rather stable at about 30% for different post-window sizes and event sizes.

Table 7 contains the relative shares of the three types of successful intervention (leaning with and against the wind and smoothing), which indicate that the Croatian National Bank carried out all three strategies but with different weights. Leaning with the wind can be most often observed within the event window, and effective intervention periods are mostly either leaning against the wind or leaning with the wind operations when comparing the pre- and post-event periods. An increase in the share of leaning against the wind operations can be observed for higher pre- and post-event windows and this especially with a rise in the maximum days of no intervention.

Table 6. Non-overlapping episodes, and the share of successful episodes, Croatia

EVENT SIZE		PRE- AND POST-EVENT WINDOW															
		WINDOW		**2**		**5**		**10**		**20**		**30**		**40**		**60**	
2 DAYS	SUCCESS	42	(28%)	45	(33%)	20	(29%)	6	(20%)	4	(36%)	2	(50%)	1	(33%)		
	FAILURE	106	(72%)	91	(67%)	48	(71%)	24	(80%)	7	(64%)	2	(50%)	2	(67%)		
	ASSESSABLE	148	(100%)	136	(92%)	68	(46%)	30	(20%)	11	(7%)	4	(3%)	3	(2%)	0	(0%)
	TOTAL	148		148		148		148		148		148		148		148	
5 DAYS	SUCCESS	27	(28%)	24	(29%)	20	(27%)	6	(17%)	4	(33%)	2	(40%)	1	(25%)	1	(50%)
	FAILURE	68	(72%)	59	(71%)	55	(73%)	30	(83%)	8	(67%)	3	(60%)	3	(75%)	1	(50%)
	ASSESSABLE	95	(100%)	83	(87%)	75	(79%)	36	(38%)	12	(13%)	5	(5%)	4	(4%)	2	(2%)
	TOTAL	95		95		95		95		95		95		95		95	
10 DAYS	SUCCESS	26	(37%)	13	(22%)	9	(18%)	3	(8%)	4	(27%)	1	(25%)	1	(25%)	0	(0%)
	FAILURE	45	(63%)	45	(78%)	41	(82%)	34	(92%)	11	(73%)	3	(75%)	3	(75%)	1	(100%)
	ASSESSABLE	71	(100%)	58	(82%)	50	(70%)	37	(52%)	15	(21%)	4	(6%)	4	(6%)	1	(1%)
	TOTAL	71		71		71		71		71		71		71		71	
20 DAYS	SUCCESS	21	(43%)	7	(19%)	7	(23%)	4	(21%)	6	(38%)	4	(44%)	2	(33%)	0	(0%)
	FAILURE	28	(57%)	30	(81%)	23	(77%)	15	(79%)	10	(63%)	5	(56%)	4	(67%)	1	(100%)
	ASSESSABLE	49	(100%)	37	(76%)	30	(61%)	19	(39%)	16	(33%)	9	(18%)	6	(12%)	1	(2%)
	TOTAL	49		49		49		49		49		49		49		49	
30 DAYS	SUCCESS	27	(59%)	6	(18%)	7	(26%)	3	(19%)	5	(38%)	4	(36%)	2	(29%)	3	(60%)
	FAILURE	19	(41%)	27	(82%)	20	(74%)	13	(81%)	8	(62%)	7	(64%)	5	(71%)	2	(40%)
	ASSESSABLE	46	(100%)	33	(72%)	27	(59%)	16	(35%)	13	(28%)	11	(24%)	7	(15%)	5	(11%)
	TOTAL	46		46		46		46		46		46		46		46	

Table 7. The distribution of successful episodes, Croatia

EVENT SIZE		PRE- AND POST-EVENT WINDOW															
		WINDOW		**2**		**5**		**10**		**20**		**30**		**40**		**60**	
2 DAYS	WITH	26	(62%)	25	(56%)	10	(50%)	4	(67%)	3	(75%)	1	(50%)	1	(100%)	0	
	AGAINST	8	(19%)	18	(40%)	6	(30%)	0	(0%)	1	(25%)	1	(50%)	0	(0%)	0	
	SMOOTH	8	(19%)	2	(4%)	4	(20%)	2	(33%)	0	(0%)	0	(0%)	0	(0%)	0	
5 DAYS	WITH	13	(48%)	14	(58%)	11	(55%)	4	(67%)	3	(75%)	1	(50%)	1	(100%)	0	(0%)
	AGAINST	5	(19%)	7	(29%)	6	(30%)	0	(0%)	1	(25%)	1	(50%)	0	(0%)	1	(100%)
	SMOOTH	9	(33%)	3	(13%)	3	(15%)	2	(33%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)
10 DAYS	WITH	15	(58%)	9	(69%)	4	(44%)	2	(67%)	3	(75%)	1	(100%)	1	(100%)	0	
	AGAINST	6	(23%)	3	(23%)	2	(22%)	0	(0%)	1	(25%)	0	(0%)	0	(0%)	0	
	SMOOTH	5	(19%)	1	(8%)	3	(33%)	1	(33%)	0	(0%)	0	(0%)	0	(0%)	0	
20 DAYS	WITH	14	(67%)	5	(71%)	3	(43%)	4	(100%)	4	(67%)	2	(50%)	2	(100%)	0	
	AGAINST	5	(24%)	1	(14%)	4	(57%)	0	(0%)	2	(33%)	2	(50%)	0	(0%)	0	
	SMOOTH	2	(10%)	1	(14%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	

30 DAYS	WITH	21	(78%)	4	(67%)	3	(43%)	3	(100%)	3	(60%)	2	(50%)	2	(100%)	1	(33%)
	AGAINST	4	(15%)	1	(17%)	4	(57%)	0	(0%)	2	(40%)	2	(50%)	0	(0%)	2	(67%)
	SMOOTH	2	(7%)	1	(17%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)

Regarding unconditional exchange rate volatility measured by means of standard deviation, it is fair to say according to results reported in Table 9 that interventions are associated with both increases and decreases in volatility broadly to the same extent. The share of intervention episodes that can be associated with higher exchange rate volatility after the episode than before it, is slightly higher, and, on average is close to 60%.[9]

As the overall pattern emerging for episodes using different event window and pre-and post-event window sizes, is fairly comparable, in-detail results are shown only for episodes obtained on the basis of maximum 30 days of no intervention in order to save ink and paper (Tables 9 and 10).[10] In yellow are marked the pre- and post event windows without any overlap with previous or forthcoming intervention episodes. A point to draw attention to is that there are episodes which exhibit success only for a precise post-event window, and for the remaining window sizes, no success could be identified. The episodes No. 1,17,18 and 28 are the ones for which effectiveness is stable for the range of window sizes (without overlaps). Regarding exchange rate volatility, there are episodes for which whether or not volatility increases or decreases hinges largely upon the size of the pre- and post-event window. However, in a number of episodes, interventions systematically rise volatility such (episodes No. 1, 18, 27, 28, 31, 32, 33, 43 and 45) or dampen volatility (episodes No. 2, 8, 17, 26, 29, 37, 40, 41

Table 8. Intervention episodes and unconditional exchange rate volatility, Croatia

EVENT SIZE	**PRE- AND POST-EVENT WINDOW**																	
	WINDOW	**2**		**5**		**10**		**20**		**30**		**40**		**60**				
2 DAYS	148																	
HIGH	13	(54%)	74	(54%)	41	(60%)	18	(60%)	5	(45%)	1	(25%)	1	(33%)	0			
LOW	11	(46%)	62	(46%)	27	(40%)	12	(40%)	6	(55%)	3	(75%)	2	(67%)	0			
5 DAYS	95																	
HIGH	22	(54%)	44	(53%)	42	(56%)	22	(61%)	6	(50%)	2	(40%)	2	(50%)	2	(100%)		
LOW	19	(46%)	39	(47%)	33	(44%)	14	(39%)	6	(50%)	3	(60%)	2	(50%)	0	(0%)		
10 DAYS	71																	
HIGH	18	(47%)	32	(55%)	31	(62%)	24	(65%)	8	(53%)	2	(50%)	2	(50%)	1	(100%)		
LOW	20	(53%)	26	(45%)	19	(38%)	13	(35%)	7	(47%)	2	(50%)	2	(50%)	0	(0%)		
20 DAYS	49																	
HIGH	23	(68%)	21	(57%)	18	(60%)	14	(74%)	11	(69%)	5	(56%)	4	(67%)	1	(100%)		
LOW	11	(32%)	16	(43%)	12	(40%)	5	(26%)	5	(31%)	4	(44%)	2	(33%)	0	(0%)		
30 DAYS	46																	
HIGH	22	(67%)	18	(55%)	15	(56%)	10	(63%)	9	(69%)	7	(64%)	5	(71%)	4	(80%)		
LOW	11	(33%)	15	(45%)	12	(44%)	6	(38%)	4	(31%)	4	(36%)	2	(29%)	1	(20%)		

[9] It should be noted that for single-day episodes, volatility cannot be computed and this implies that exchange rate volatility cannot be studied for the episode window.

[10] Results for the episodes determined on the basis of maximum 2, 5, 10 and 20 days of no interventions are available from the author upon request.

Table 9. The effectiveness of intervention episodes based on maximum 30 days of no intervention, Croatia

No.	Start	End	Initial intervention	Total intervention	Days of Interventions	Total days	Next episode (days away)	Type of intervention	window	2	5	10	20	30	40	60
1	10/01/1996	11/01/1996	-22.634	-30.52	2	2	7	PURCHASE	SMOOTH	AGAINST	AGAINST					
2	23/01/1996	01/02/1996	2.94	80.92	3	8	10	SALE	AGAINST	SMOOTH						
3	16/02/1996	16/02/1996	-60.8463	-60.85	1	1	7	PURCHASE			WITH	WITH	WITH	WITH		
4	28/02/1996	06/03/1996	1.072	16.04	5	6	1	SALE	WITH				AGAINST	SMOOTH		
5	08/03/1996	11/03/1996	-46.3407	-58.47	2	2	2	PURCHASE		WITH	WITH	AGAINST	WITH	AGAINST	WITH	
6	14/03/1996	14/03/1996	0.732	0.73	1	1	1	SALE			AGAINST	WITH	AGAINST	SMOOTH		
7	18/03/1996	19/03/1996	-3.6499	-36.47	2	2	2	PURCHASE						WITH	WITH	
8	22/03/1996	18/04/1996	4.745	9.13	4	19	5	SALE								
9	26/04/1996	05/07/1996	-98.4615	-1058.93	9	49	0	PURCHASE	WITH	WITH	WITH		WITH	WITH	WITH	
10	08/07/1996	05/07/1996	0.71	-80.34	2	2	4	SALE	SMOOTH	SMOOTH	SMOOTH	SMOOTH	SMOOTH	SMOOTH	SMOOTH	SMOOTH
11	12/07/1996	25/07/1996	-234.051228	-526.03	2	10	0	PURCHASE	WITH							
12	26/07/1996	30/07/1996	2.118	8.83	3	3	2	SALE			AGAINST		AGAINST	AGAINST	AGAINST	AGAINST
13	02/08/1996	21/08/1996	-201.47995	-797.88	3	12	85	PURCHASE		WITH						
14	20/12/1996	20/12/1996	-155.659254	-155.66	1	1	25	PURCHASE								
15	31/01/1997	28/02/1997	17.7	170.13	3	21	18	SALE	WITH		AGAINST			WITH	WITH	
16	27/03/1997	27/03/1997	-30.1045	-30.10	1	1	32	PURCHASE	WITH					AGAINST	AGAINST	AGAINST
17	15/05/1997	01/08/1997	-69.9584	-1496.73	7	55	95	PURCHASE	AGAINST	WITH	AGAINST	WITH	AGAINST	AGAINST	AGAINST	AGAINST
18	18/12/1997	18/12/1997	-223.842512	-223.84	1	1	94	PURCHASE	WITH		WITH	WITH	WITH	WITH		
19	08/05/1998	08/07/1998	37.97344	682.91	8	43	4	SALE								
20	15/07/1998	26/08/1998	-48.54579	-1088.76	15	30	8	PURCHASE	WITH							
21	08/09/1998	18/12/1998	314.425875	2723.20	16	74	1	SALE	WITH					WITH	AGAINST	AGAINST
22	22/12/1998	31/12/1998	-1.491193	-185.35	4	7	7	PURCHASE	AGAINST							
23	14/01/1999	31/05/1999	161.960475	3481.78	12	97	1	SALE	WITH							
24	02/06/1999	02/06/1999	-4.371242	-4.37	1	1	3	PURCHASE		WITH						
25	08/06/1999	08/06/1999	480.64659	480.65	1	1	21	SALE			WITH		AGAINST	SMOOTH	AGAINST	AGAINST
26	08/07/1999	02/09/1999	-27.376553	-182.22	7	40	7	PURCHASE								
27	14/09/1999	27/01/2000	390.920157	3541.80	11	93	55	SALE	WITH		WITH					
28	17/04/2000	07/07/2000	-180.039169	-2448.78	5	56	88	PURCHASE	WITH		AGAINST	WITH	WITH	WITH	WITH	AGAINST
29	13/11/2000	13/11/2000	472.113949	472.11	1	1	51	SALE					WITH		WITH	AGAINST
30	29/01/2001	06/03/2001	343.19413	490.48	2	27	37	SALE	WITH							
31	30/04/2001	23/05/2001	-383.0089	-1142.85	3	17	34	PURCHASE	WITH	WITH						
32	13/07/2001	13/07/2001	-1028.981	-1028.98	1	1	20	PURCHASE		WITH						
33	13/08/2001	31/08/2001	451.145	3091.23	3	14	5	SALE	WITH							
34	10/09/2001	21/11/2001	-970.158	-2644.98	7	52	8	PURCHASE	WITH				AGAINST	AGAINST	SMOOTH	SMOOTH
35	04/12/2001	04/12/2001	54.385	54.39	1	1	2	SALE						WITH	AGAINST	AGAINST
36	07/12/2001	19/12/2001	-575.72	-1556.09	3	9	7	PURCHASE	WITH			SMOOTH				
37	03/01/2002	03/01/2002	-373.634	-373.63	1	1	9	PURCHASE								
38	17/01/2002	31/01/2002	325.5	1060.41	3	11	11	SALE	WITH							
39	18/02/2002	28/06/2002	-499.895	-4774.56	10	91	32	PURCHASE	WITH					SMOOTH	SMOOTH	AGAINST
40	16/08/2002	16/08/2002	-347.0169	-347.02	1	1	47	PURCHASE	AGAINST				AGAINST	AGAINST		
41	24/10/2002	29/10/2002	460.635	597.70	2	4	46	SALE								
42	09/01/2003	28/03/2003	560.992	2401.44	6	57	163	SALE	WITH							
43	21/11/2003	11/12/2003	458.4	944.27	2	15	8	SALE	WITH							
44	24/12/2003	24/12/2003	-646.425	-646.43	1	1	51	PURCHASE						SMOOTH	SMOOTH	AGAINST
45	11/03/2004	30/03/2004	-415.075	-1215.10	4	14	64	PURCHASE	WITH							
46	05/07/2004	17/09/2004	-199.3	-1037.25	5	54	41	PURCHASE								WITH

Table 10. Unconditional exchange rate volatility for intervention episodes based on maximum 30 days of no intervention, Croatia

No.	Start	End	Initial intervention	Total intervention	Days of interventions	Total days	Next episode (days away)	Type of intervention	window	2	5	10	20	30	40	60
1	10/01/1996	11/01/1996	-22.634	-30.52	2	2	7	PURCHASE	HIGH	HIGH	HIGH					
2	23/01/1996	01/02/1996	2.94	80.92	3	8	10	SALE	LOW	LOW	LOW	LOW				
3	16/02/1996	16/02/1996	-60.8463	-60.85	1	1	7	PURCHASE		HIGH	LOW	LOW	LOW	HIGH		
4	28/02/1996	06/03/1996	1.072	16.04	5	6	1	SALE	HIGH	LOW	HIGH	HIGH	HIGH	HIGH	HIGH	
5	08/03/1996	11/03/1996	-46.3407	-58.47	2	2	2	PURCHASE	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	
6	14/03/1996	14/03/1996	0.732	0.73	1	1	1	SALE		LOW	HIGH	HIGH	HIGH	HIGH	HIGH	
7	18/03/1996	19/03/1996	-3.6499	-36.47	2	2	2	PURCHASE	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	
8	22/03/1996	18/04/1996	4.745	9.13	4	19	5	SALE	LOW	LOW	LOW	LOW	LOW	LOW	LOW	
9	26/04/1996	05/07/1996	-98.4615	-1058.93	9	49	0	PURCHASE	HIGH	HIGH	HIGH	HIGH	HIGH	LOW	LOW	LOW
10	08/07/1996	05/07/1996	0.71	-80.34	2	2	4	SALE	HIGH	HIGH	LOW	HIGH	HIGH	HIGH	HIGH	LOW
11	12/07/1996	25/07/1996	-234.051228	-526.03	2	10	0	PURCHASE	HIGH	LOW	LOW	LOW	LOW	LOW	LOW	LOW
12	26/07/1996	30/07/1996	2.118	8.83	3	3	2	SALE	HIGH	HIGH	HIGH	LOW	LOW	LOW	LOW	LOW
13	02/08/1996	21/08/1996	-201.47995	-797.88	3	12	85	PURCHASE	LOW	HIGH	HIGH	HIGH	LOW	LOW	LOW	LOW
14	20/12/1996	20/12/1996	-155.659254	-155.66	1	1	25	PURCHASE		HIGH	LOW	HIGH	LOW	LOW	LOW	LOW
15	31/01/1997	28/02/1997	17.7	170.13	3	21	18	SALE	HIGH	HIGH	LOW	LOW	HIGH	HIGH	HIGH	HIGH
16	27/03/1997	27/03/1997	-30.1045	-30.10	1	1	32	PURCHASE		LOW	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
17	15/05/1997	01/08/1997	-69.9584	-1496.73	7	55	95	PURCHASE	LOW	LOW	LOW	LOW	HIGH	LOW	HIGH	HIGH
18	18/12/1997	18/12/1997	-223.842512	-223.84	1	1	94	PURCHASE		LOW	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
19	08/05/1998	08/07/1998	37.97344	682.91	8	43	4	SALE	HIGH	LOW	LOW	HIGH	HIGH	HIGH	HIGH	HIGH
20	15/07/1998	26/08/1998	-48.54579	-1088.76	15	30	8	PURCHASE	HIGH	HIGH	HIGH	HIGH	LOW	LOW	LOW	HIGH
21	08/09/1998	18/12/1998	314.425875	2723.20	16	74	1	SALE	LOW	HIGH	LOW	LOW	LOW	LOW	LOW	LOW
22	22/12/1998	31/12/1998	-1.491193	-185.35	4	7	7	PURCHASE	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	LOW
23	14/01/1999	31/05/1999	161.960475	3481.78	12	97	1	SALE	HIGH	LOW	LOW	LOW	LOW	HIGH	HIGH	LOW
24	02/06/1999	02/06/1999	-4.371242	-4.37	1	1	3	PURCHASE		LOW	LOW	LOW	HIGH	HIGH	HIGH	HIGH
25	08/06/1999	08/06/1999	480.64659	480.65	1	1	21	SALE		LOW	LOW	HIGH	HIGH	HIGH	HIGH	HIGH
26	08/07/1999	02/09/1999	-27.376553	-182.22	7	40	7	PURCHASE	LOW	LOW	LOW	LOW	LOW	HIGH	HIGH	HIGH
27	14/09/1999	27/01/2000	390.920157	3541.80	11	93	55	SALE	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
28	17/04/2000	07/07/2000	-180.039169	-2448.78	5	56	88	PURCHASE	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	LOW
29	13/11/2000	13/11/2000	472.113949	472.11	1	1	51	SALE		LOW	LOW	LOW	LOW	LOW	LOW	HIGH
30	29/01/2001	06/03/2001	343.19413	490.48	2	27	37	SALE	LOW	HIGH	HIGH	LOW	HIGH	HIGH	HIGH	HIGH
31	30/04/2001	23/05/2001	-383.0089	-1142.85	3	17	34	PURCHASE	LOW	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
32	13/07/2001	13/07/2001	-1028.981	-1028.98	1	1	20	PURCHASE		HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
33	13/08/2001	31/08/2001	451.145	3091.23	3	14	5	SALE	HIGH	HIGH	HIGH	HIGH	LOW	LOW	LOW	LOW
34	10/09/2001	21/11/2001	-970.158	-2644.98	7	52	8	PURCHASE	HIGH	HIGH	LOW	LOW	LOW	LOW	LOW	LOW
35	04/12/2001	04/12/2001	54.385	54.39	1	1	2	SALE		HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
36	07/12/2001	19/12/2001	-575.72	-1556.09	3	9	7	PURCHASE	LOW	LOW	LOW	LOW	HIGH	LOW	HIGH	HIGH
37	03/01/2002	03/01/2002	-373.634	-373.63	1	1	9	PURCHASE		LOW	LOW	LOW	HIGH	HIGH	HIGH	HIGH
38	17/01/2002	31/01/2002	325.5	1060.41	3	11	11	SALE	HIGH	LOW	HIGH	HIGH	HIGH	LOW	HIGH	LOW
39	18/02/2002	28/06/2002	-499.895	-4774.56	10	91	32	PURCHASE	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
40	16/08/2002	16/08/2002	-347.0169	-347.02	1	1	47	PURCHASE		HIGH	LOW	LOW	LOW	LOW	LOW	LOW
41	24/10/2002	29/10/2002	460.635	597.70	2	4	46	SALE	HIGH	LOW	HIGH	LOW	LOW	LOW	LOW	LOW
42	09/01/2003	28/03/2003	560.992	2401.44	6	57	163	SALE	HIGH	LOW	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
43	21/11/2003	11/12/2003	458.4	944.27	2	15	8	SALE	HIGH	HIGH	LOW	HIGH	HIGH	HIGH	HIGH	LOW
44	24/12/2003	24/12/2003	-646.425	-646.43	1	1	51	PURCHASE		LOW	LOW	LOW	LOW	LOW	LOW	HIGH
45	11/03/2004	30/03/2004	-415.075	-1215.10	4	14	64	PURCHASE	LOW	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
46	05/07/2004	17/09/2004	-199.3	-1037.25	5	54	41	PURCHASE	LOW	LOW	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH

Turkey

As shown in Table 5, the number of intervention episodes in Turkey varies between 10 (maximum 2 days of no intervention) and 4 (maximum 10, 20 and 30 days of no intervention). The number of intervention episodes appears very robust to the use of the 10-day, 20-day and 30-day filters as four episodes are established in all three cases. The four episodes correspond to the four blocks of intervention activities depicted in Figure 2a. During the period from 2001 to 2004, one intervention episode took place in each year. In the first intervention episode in 2001, the central bank bought the Turkish lira, whilst in the three remaining intervention events, it sold the domestic currency against the dollar. Table 12 hereafter reports the results. In yellow are marked the pre- and post event windows without any overlap with previous or forthcoming intervention episodes. Given that 59 days elapsed without interventions after the third intervention episode, the pre- and post window size of 60 days cannot be assessed for the third and last episodes.

All four intervention episodes turn out to be very effective, and this for most pre- and post-event windows. The intervention episodes can be viewed mainly as leaning against the wind operations. Looking at the intervention windows[11] indicate that the first and third intervention episodes started as exchange rate smoothing, which subsequently managed to reverse the trend of the exchange rate against the US dollar. The third episode did so only at the 2, 5 and 10-day horizons beyond which it turned out to be exchange rate smoothing.

Finally, Table 13 reports the change in the standard deviation-based exchange rate volatility between the pre- and post-event window. The first intervention episode is the only episode during and after which exchange rate volatility decreased systematically as compared to the period preceding it. During the second and last episodes, exchange rate volatility were higher both in the event window and after the intervention episode. For the third episode, volatility first declined during interventions were taking place, but then increase up to 20 days following it. For the post-event windows of 30, 40 and 60 days, it is found to be lower than in the corresponding pre-event windows.

Table 11. Volatility ummary of the results for exchange rate, Croatia

No.	Type	Beginning	End	Initial Intervention	Total intervention	Days of Interventions	Total days of the episode	Next episode (days away)
1	BUY	29/03/2001	30/11/2001	-200	-6553	124	173	77
2	SELL	01/04/2002	26/06/2002	20	795	33	62	209
3	SELL	06/05/2003	22/10/2003	20	4989	117	121	59
4	SELL	23/01/2004	26/04/2004	30	2480	62	63	143

Table 12. Volatility ummary of the results for exchange rate, Croatia

No.	Type	window	**2**	**5**	**10**	**20**	**30**	**40**	**60**
1	PURCHASE	SMOOTH	WIND	WIND	WIND	WITH	WIND	WIND	
2	SALE	WIND		WITH	WIND	WIND	WIND		WIND
3	SALE	SMOOTH	WIND	WIND	WIND	SMOOTH	SMOOTH	SMOOTH	
4	SALE	WIND	WIND	WIND	WIND	WIND	WIND	WIND	WIND

Table 13. Volatility ummary of the results for exchange rate, Croatia

	window	**2**	**5**	**10**	**20**	**30**	**40**	**60**
1	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
2	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
3	LOW	HIGH	HIGH	HIGH	HIGH	LOW	LOW	LOW
4	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH

[11] This is a worthwhile undertaking because of the large size of the event windows, namely 173, 62, 121 and 63 days, respectively.

4. Econometric Investigations
4.1. Econometric Issues
4.1.1 Interventions, Exchange Rates and Volatility

The effectiveness of foreign exchange interventions is investigated using a GARCH framework, which is admittedly well-suited for such an investigation because they analyse simultaneously the mean and the conditional variance of the exchange rate series. In our economic specification, the avenue adopted here is in line with the approach proposed by Dominguez (1998) for a GARCH(1,1) framework. That is, in the mean equation, the log-difference of the exchange rate returns (Δe_t) are regressed on the intervention series (I_t), the interest differential (Δi_t) between overnight money market rates in the home economy and the foreign benchmark (Germany and the euro area for the Czech Republic, and the US for Turkey), and dummy variables capturing day of the week effects. The conditional variance equation includes the absolute value of interventions, the interest differential and the day-of-the-week dummies:

$$\Delta e_t = \phi_1 + \phi_2 \cdot I_t + \phi_3 \cdot \Delta i_t + \sum_{i=1}^{4} \phi_{3+i} \cdot D_i + \varepsilon_t \qquad (1)$$

$$\varepsilon_t \left| \Omega_{t-1} \sim N(0, \sigma^2) \right. \qquad (2)$$

$$\sigma_t^2 = \psi_1 + \psi_2 \cdot \left| I_t \right| + \psi_3 \cdot \Delta i_t + \psi \cdot D_i + \alpha \cdot \varepsilon_{t-1}^2 + \beta \cdot \sigma_{t-1}^2 \qquad (3)$$

where I_t takes negative (positive) values for purchases (sales) of the domestic currency. D_1, D_2, D_3 and D_4 are dummy variables that take the value of 1 on Monday, Tuesday, Wednesday and Thursday, respectively. ε_{t-1}^2 and σ_{t-1}^2 are the ARCH and GARCH terms.

Domac and Mendoza (2002) and Giumaraes and Karacadag (2004) show that estimation results are sensitive to whether a single intervention variable containing both sales and purchases as in (1) is used or whether sales and purchases are considered separately. The use of absolute values of interventions in the conditional variance equation studies whether higher intervention volumes lead to higher or lower exchange rate volatility. However, it may be also legitimate to think that sales and purchases may impact on exchange rate volatility in a different way. Therefore, equations (1) and (3) are modified correspondingly:

$$\Delta e_t = \phi_1 + \phi_{21} \cdot I_t^{sales} + \phi_{22} \cdot I_t^{purchases} + \phi_3 \cdot \Delta i_t + \sum_{i=1}^{4} \phi_{3+i} \cdot D_i + \varepsilon_t \qquad (4)$$

$$\sigma_t^2 = \psi_1 + \psi_{21} \cdot I_t^{sales} + \psi_{22} I_t^{purchases} + \psi_3 \cdot \Delta i_t + \psi \cdot D_i + \alpha \cdot \varepsilon_{t-1}^2 + \beta \cdot \sigma_{t-1}^2 \qquad (5)$$

Kearns and Rigobon (2002) and Guimaraes and Karacadag (2004) point out that the coefficient estimates on contemporaneous interventions may be biased because of the possible endogeneity of exchange rates and interventions. To correct for this bias, equations (1), (3), (4) and (5) are re-specified with the inclusion of two-day lagged interventions.

The equations presented thus far rest on a GARCH(1,1) model. In order to check for robustness to model specification and to look at possible asymmetries in the conditional variance equation, a number of alternative GARCH models are also used for the econometric investigation, and these are (a) the GARCH in mean (GARCH-M), (b) the exponential GARCH (EGARCH), (c) the threshold GARCH (TGARCH), (d) the component GARCH (CGARCH) and (e) the asymmetric component GARCH (ACGARCH). Let us now review the major characteristics of the different models.

Starting with the GARCH in Mean, the only difference compared to the standard GARCH model is the inclusion of the conditional variance in the mean equation. The economic interpretation of this, shown on the example of (1), is that exchange rate returns may depend on exchange rate volatility:

$$\Delta e_t = \phi_1 + \phi_2 \cdot I_t + \phi_3 \cdot \Delta i_t + \sum_{i=1}^{4} \phi_{3+i} \cdot D_i + \lambda \cdot \sigma_t^2 + \varepsilon_t \qquad (6)$$

The TGARCH and EGARCH models modify the conditional variance equation in a way to account for asymmetries in the conditional variance. In addition to the standard ARCH and GARCH terms, the TGARCH model also includes a dummy term, S_{t-1}, that takes the value of 1, if $\varepsilon_{t-1} < 0$ (negative shock) and is 0 if $\varepsilon_{t-1} > 0$ (positive shock).

$$\sigma_t^2 = \psi_1 + \psi_2 \cdot I_t + \psi_3 \cdot \Delta i_t + \psi \cdot D_i + \alpha \cdot \varepsilon_{t-1}^2 + \beta \cdot \sigma_{t-1}^2 + \lambda \cdot \varepsilon_{t-1}^2 \cdot S_{t-1} \qquad (7)$$

The impact of negative shocks on the conditional variance is higher than that of positive shocks if $\alpha + \lambda > \beta$ and is lower if $\alpha + \lambda < \beta$ provided $\lambda \neq 0$. The EGARCH is based on the log-transformed conditional variance, which causes the asymmetric effect to be exponential instead of being quadratic as in the TGARCH model:

$$log(\sigma_t^2) = \psi_1 + \psi_2 \cdot I_t + \psi_3 \cdot \Delta i_t + \psi \cdot D_i + \beta \cdot log(\sigma_{t-1}^2) + \alpha \cdot \left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| + \lambda \cdot \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \qquad (8)$$

The presence of asymmetry is ensured by $\lambda \neq 0$. The CGARCH model distinguishes between short- and long-term conditional volatility. Contrary to constant conditional volatility in a standard GARCH model, long-term volatility (q_t) is allowed to vary over time, to which the short-term volatility or the transitory component of the long-term volatility ($\sigma_t^2 - q_t$)) mean-reverts. Such a model makes it possible to model separately the effect of interventions on exchange rate volatility in the short-run and in the long-run. The short-term conditional variance model can be written as:

$$\sigma_t^2 - q_t = q_t + \psi_2 \cdot I_t + \psi_3 \cdot \Delta i_t + \psi \cdot D_i + \alpha \cdot (\varepsilon_{t-1}^2 - q_t) + \beta \cdot (\sigma_{t-1}^2 - q_t) \qquad (9)$$

The time-varying long-term volatility converges to χ with ρ as shown in (10):

$$q_t = \chi + \psi_2 \cdot I_t + \psi_3 \cdot \Delta i_t + \psi \cdot D_i + \rho \cdot (q_{t-1} - \chi) + \delta \cdot (\varepsilon_{t-1}^2 - \sigma_{t-1}^2) \qquad (10)$$

The combination of the TGARCH model with the short-term volatility equation of the CGARCH models yields the asymmetric component GARCH model, where the short-term conditional variance looks like this:

$$\sigma_t^2 - q_t = q_t + \psi_2 \cdot I_t + \psi_3 \cdot \Delta i_t + \psi \cdot D_i + \alpha \cdot (\varepsilon_{t-1}^2 - q_t) + \beta \cdot (\sigma_{t-1}^2 - q_t) + \lambda \cdot \varepsilon_{t-1}^2 \cdot S_{t-1} \qquad (11)$$

4.1.2 The Causal Direction Between Interventions and Forex Volatility

Although the GARCH framework provides help in identifying any relationship between official interventions on the one hand, and between changes in and the volatility of the exchange rate, on the other hand, it does not indicate the direction of causality, i.e. whether past exchange volatility initiates interventions or past interventions leads to higher volatility or whether interventions are exogenous. An interesting question to address is the causal relation between interventions and exchange rate volatility. Central banks may intervene in order to lower volatility on disorderly exchange markets. This may be especially the case during periods of market turmoil. However, during periods of relative calm, central banks may want to intervene to increase exchange rate volatility. This is because higher market

uncertainty may discourage market participants to take large open positions (Edison et al., 2003).

When investigating the relationship between interventions and forex volatility, one may use either volatility measures based on the implied volatility of option prices (Bonser-Neal and Tanner (1996), Dauchy (2001), Beine et al. (2002) for the three big currency pairs and Rogers and Siklos (2003) for Canada and Australia) or volatility derived using econometric techniques, such as the GARCH framework (Dominguez, 1998, Edison et al, 2003, and Guimaraes and Karacadag, 2004). We follow the second avenue mainly because of the lack of data on currency options in the countries under study, and the conditional volatility obtained from the different GARCH models is employed.

The issue of causality between interventions and exchange rate volatility can be addressed using pair-wise Granger causality tests. According to the concept of Granger causality, only lagged values of the interventions, I, (volatility) but also past values of volatility, VOL, (interventions) can impact on interventions (volatility) as shown below:

$$\begin{aligned} |I_t| &= \omega_0 + \sum_{i=1}^{k} \omega_i |I_{t-i}| + \sum_{i=1}^{k} \theta_i VOL_{t-i} + \varepsilon_t \\ VOL_t &= \omega_0 + \sum_{i=1}^{k} \omega_i VOL_{t-i} + \sum_{i=1}^{k} \theta_i |I_{t-i}| + \varepsilon_t \end{aligned} \tag{12a}$$

where k is the lag length. Conventional F-tests can be carried out to verify if the joint null hypothesis of $H_0 : \theta_1 = \theta_2 = ... = \theta_k = 0$ can be rejected, i.e. whether or not lagged values of volatility (interventions) are significant in statistical terms. If the null hypothesis is rejected, volatility (intervention) is said to Granger-cause interventions (volatility).

Similarly to the GARCH models, besides a single intervention variable incorporating both sales and purchases of the domestic currency in absolute values ($|I|$), sales and purchases are also looked at separately:

$$\begin{aligned} |I_t^{sales}| &= \omega_0 + \sum_{i=1}^{k} \omega_i |I_t^{sales}| + \sum_{i=1}^{k} \theta_i VOL_{t-i} + \varepsilon_t \\ VOL_t &= \omega_0 + \sum_{i=1}^{k} \omega_i VOL_{t-i} + \sum_{i=1}^{k} \theta_i |I_t^{sales}| + \varepsilon_t \end{aligned} \tag{12b}$$

$$\begin{aligned} |I_t^{purchases}| &= \omega_0 + \sum_{i=1}^{k} \omega_i |I_t^{purchases}| + \sum_{i=1}^{k} \theta_i VOL_{t-i} + \varepsilon_t \\ VOL_t &= \omega_0 + \sum_{i=1}^{k} \omega_i VOL_{t-i} + \sum_{i=1}^{k} \theta_i |I_t^{purchases}| + \varepsilon_t \end{aligned} \tag{12c}$$

Given that both the intervention and the volatility series are found to be difference stationary in levels, the Granger causality tests are carried out for variables in levels.

4.1.3 Central Bank Reaction Function – A Probit Analysis

An alternative way to study the relation between interventions and the exchange rate is to estimate the reaction function of the central bank. Dominguez (1998) and more recently, Guimaraes and Karacadag (2004) used probit models in an attempt to pin down the factors, which increase the probability of central bank intervention on the foreign exchange market. Two variables are commonly included in the estimated probit model: the deviation of the exchange rate from its past average ($e_t - \sum_{i=1}^{k} e_{t-i} / k$) and the deviation of exchange rate

volatility from its past average ($\sigma_t^2 - \sum_{i=1}^{k} \sigma_{t-i}^2 / k$), which leads us to estimate the following probit model:

$$\xi_2 \, Pr(D_t^I = 1) = \Theta(\xi_1 + \xi_2(e_{t-1} - 1 - \sum_{i=2}^{k+1} e_{t-i} / k) + \xi_3(\sigma_{t-1}^2 - \sum_{i=2}^{k+1} \sigma_{t-i}^2 / k) \quad (13)$$

where D_t^I is a dummy variable that takes the value of 1 in the presence of intervention (either purchases or sales), and is 0 otherwise. $Pr(.)$ is the probability that intervention takes place conditioned on the explanatory variables. $\Theta(.)$ is the cumulative distribution function of the standard normal distribution. Sales and purchases of the domestic currency are analysed separately using the dummy variables D_t^{sales} and $D_t^{purchases}$ as dependent variable, which take the value of 1 if sales and purchases by the central bank occur in the foreign exchange market and are zero otherwise. Guimaraes and Karacadag (2004) note that the results may be sensitive to the lag length k based on which the average exchange rate and volatility are computed. For this reason, alternative lag lengths of 10, 20, 30 and 40 are applied to (13).

4.2. Estimation Results

The estimations are carried out using the same dataset as for the event study approach. For the interest rates, overnight money market rates are used. The data for Croatia and Germany are obtained from the Croatian National Bank and the Bundesbank, whilst the data for Turkey and the US are drawn from Bloomberg.

4.2.1 Croatia

The summary of the estimation results of the different GARCH models displayed in Table 14 suggest that interventions and exchange rate returns are strongly correlated in Croatia. The relationship between the aggregated intervention variable and exchange rate returns is positive and statistically significant and it appears to be very robust to different GARCH model specifications. The results are quasi identical when interventions are used with a lag of two days. These results indicate that sales of the Croatian kuna are associated with a depreciation, whilst purchases go in tandem with an appreciation, just as we have expected. The separate inclusion of sales and purchases confirm these results as they are always significant and have a positive sign.[12] Nevertheless, when using sales and purchases with a two-day lag, only interventions reflecting kuna purchases remain significant. But they do so for all GARCH specifications and with comparable coefficient estimates both in terms of sign and size.

Coming now to conditional variance equation, the results indicate a less robust relationship between interventions and exchange rate volatility. When using the absolute size of interventions, there is a significant negative relationship (the higher the interventions, the lower the volatility) for the TGARCH and GARCH-in-Mean models, whereas the relationship becomes positive for the EGARCH and ACGARCH models. The use of lagged interventions makes the relationship insignificant in the TGARCH and GARCH-in-Mean models. The separate use of kuna sales and purchases indicate a positive relationship between purchases and volatility (EGARCH, TGARCH), and a negative relationship between sales and volatility (GARCH-in-Mean). Overall, there is weak evidence that interventions and exchange rate volatility are strongly correlated in Croatia. However, kuna purchases tend to increase volatility whilst kuna sales may decrease forex volatility.[13]

[12] Kuna purchases (sales) are denoted by negative (positive) figures. Hence, a positive relation between kuna purchases (sales) and changes in the exchange rate means that a decrease (increase) in kuna purchases (sales) causes the exchange rate appreciate (depreciate).

[13] The interest differential variable enters the mean equation significantly only when using the ACGARCH model and the aggregate intervention variable. In this case, an increase in the interest differential turns out to

Table 14. GARCH estimation results for Croatia, 1996-2004

	GARCH		GARCH-in-Mean		EGARCH		TGARCH		CGARCH		ACGARCH	
MEAN EQUATION												
I_t	**1.12E-06**	(0.000)	**1.11E-06**	(0.000)	**1.24E-06**	(0.000)	**1.26E-06**	(0.000)	**1.72E-06**	(0.000)	**2.31E-06**	(0.000)
Δi_t	3.11E-06	(0.561)	1.82E-06	(0.716)	2.27E-06	(0.604)	-6.64E-06	(0.467)	-9.25E-06	(0.014)	**-5.73E-06**	(0.005)
VARIANCE EQUATION												
$\lvert I_t \rvert$	-3.65E-10	(0.256)	**-3.47E-10**	(0.077)	**0.976**	(0.000)	**-2.26E-09**	(0.012)	1.43E-09	(0.675)	**0.001**	(0.000)
Δi_t	-9.61E-10	(0.736)	-1.19E-09	(0.145)	**-2.93E-04**	(0.042)	-1.86E-08	(0.277)	**8.05E-08**	(0.000)	1.72E-08	(0.235)
SHORT-TERM VARIANCE EQUATION												
$\lvert I_t \rvert$									-2.42E-09	(0.470)	0.016	(0.737)
Δi_t									**-1.86E-07**	(0.000)	**-0.001**	(0.000)
MEAN EQUATION												
I_{t-2}	**6.66E-07**	(0.007)	**6.68E-07**	(0.019)	**7.24E-07**	(0.003)	**6.81E-07**	(0.006)	**1.24E-06**	(0.000)	**9.83E-07**	(0.041)
Δi_t	3.37E-06	(0.522)	1.82E-06	(0.714)	3.52E-06	(0.497)	3.04E-06	(0.579)	**-9.57E-06**	(0.050)	**-7.45E-06**	(0.048)
VARIANCE EQUATION												
$\lvert I_{t-2} \rvert$	-1.45E-10	(0.679)	-1.27E-10	(0.536)	**0.976**	(0.000)	-1.35E-10	(0.693)	1.59E-09	(0.576)	**0.002**	(0.000)
Δi_t	-9.80E-10	(0.734)	-1.21E-09	(0.213)	**-2.41E-04**	(0.087)	-9.36E-10	(0.737)	**5.27E-08**	(0.000)	**4.96E-08**	(0.000)
SHORT-TERM VARIANCE EQUATION												
$\lvert I_{t-2} \rvert$									-8.16E-10	(0.794)	0.016	(0.756)
Δi_t									**-1.30E-07**	(0.000)	**-0.002**	(0.000)
MEAN EQUATION												
$I_t^{purchase}$	**1.40E-06**	(0.000)	**1.29E-06**	(0.001)	**1.31E-06**	(0.000)	**1.34E-06**	(0.000)	**1.08E-06**	(0.000)		
I_t^{sale}	**8.56E-07**	(0.014)	**1.78E-06**	(0.000)	**1.12E-06**	(0.001)	**1.87E-06**	(0.000)	**2.26E-06**	(0.000)		
Δi_t	3.11E-06	(0.557)	-5.41E-06	(0.276)	2.90E-06	(0.575)	-5.68E-06	(0.511)	-8.11E-06	(0.257)		
VARIANCE EQUATION												
$\lvert I_t^{purchase} \rvert$	-7.45E-11	(0.907)	**1.48E-09**	(0.000)	**0.975**	(0.000)	**0.600**	(0.000)	-1.24E-09	(0.809)		
$\lvert I_t^{sale} \rvert$	-5.14E-10	(0.170)	**-2.25E-09**	(0.000)	1.24E-05	(0.955)	**2.57E-09**	(0.001)	-2.10E-09	(0.528)		
Δi_t	-6.84E-10	(0.803)	**-1.99E-08**	(0.000)	**-6.05E-04**	(0.003)	**-2.71E-09**	(0.008)	**4.40E-08**	(0.000)		
SHORT-TERM VARIANCE EQUATION												
$\lvert I_t^{purchase} \rvert$									3.07E-09	(0.550)		
$\lvert I_t^{sale} \rvert$									1.22E-09	(0.718)		
Δi_t									**-1.10E-07**	(0.000)		
MEAN EQUATION												
$I_{t-2}^{purchase}$	**1.29E-06**	(0.001)	**1.52E-06**	(0.001)	**1.31E-06**	(0.000)	**1.29E-06**	(0.001)	**1.90E-06**	(0.000)		
I_{t-2}^{sale}	1.97E-07	(0.470)	2.09E-07	(0.416)	2.01E-07	(0.471)	1.84E-07	(0.503)	5.56E-07	(0.194)		
Δi_t	3.41E-06	(0.519)	-5.51E-06	(0.279)	3.37E-06	(0.515)	2.74E-06	(0.607)	**-1.00E-05**	(0.001)		
VARIANCE EQUATION												
$\lvert I_{t-2}^{purchase} \rvert$	-5.56E-10	(0.461)	1.65E-10	(0.816)	**0.975**	(0.000)	**0.840**	(0.000)	-3.75E-09	(0.318)		
$\lvert I_{t-2}^{sale} \rvert$	-4.98E-10	(0.183)	**-1.42E-09**	(0.000)	-5.93E-05	(0.776)	-6.58E-10	(0.392)	4.12E-10	(0.918)		
Δi_t	-7.56E-10	(0.792)	**-1.08E-08**	(0.000)	**-5.66E-04**	(0.006)	-5.37E-10	(0.149)	**8.39E-08**	(0.000)		
SHORT-TERM VARIANCE EQUATION												
$\lvert I_{t-2}^{purchase} \rvert$									9.69E-10	(0.843)		
$\lvert I_{t-2}^{sale} \rvert$									-9.41E-10	(0.821)		
Δi_t									**-1.92E-07**	(0.000)		

lead to an appreciation of the kuna. In the conditional variance equation, it has always the negative sign but is not always significant. More interesting are the results obtained using the component and asymmetric component GARCH models, which distinguish between volatility in the short run and in the long run. For most specifications (The ACGARCH model did not converge when sales and purchases were included separately.), an increase in the interest differential is associated with a decrease in exchange rate volatility in the short run, but this relationship reverses in the long run. It deserves mention that the dummy variables are found significant both in the mean and the variance equations indicating strong day-of-the-week effects on the Croatian foreign exchange market.

Based on the volatility estimated by the different GARCH models, Table 15 reports the results of the pair-wise Granger causality tests up to 30 lags[14] between interventions (aggregated and disaggregated into sales and purchases) and exchange rate volatility. Results for overall interventions very much are in line with results obtained for kuna sales, while results are rather different for kuna purchases. Starting with kuna sales, the results indicate a bi-directional causal relationship between kuna sales and forex volatility for all lag lengths except for k=1 where only volatility (Granger) causes interventions and not the other way around. Hence, excess volatility incites the central bank to intervene, and, in turn, central bank intervention dampens forex volatility. In contrast with this finding stand the results obtained for kuna purchases where the causal relation runs from forex volatility towards interventions, and this only for k=1,2,3,10,15,20,30. However, it should be mentioned that results based on volatility derived from the CGARCH model indicate that interventions also (Granger) cause volatility at all time horizon.

The results of the probit estimations (Table 16) clearly brings an additional piece of evidence that the central bank cares more about the level of the exchange rate than about exchange rate volatility. Focusing on the equations treating kuna sales and purchases[15], an increase in the deviation of the exchange rate from its past trend increases the probability of intervention, whilst the coefficients are in most cases insignificant for excess volatility. Regarding kuna purchases, a rise in excess exchange rate deviation results in a lower probability for the central bank to intervene. At the same time, an increase in excess volatility also decreases the central bank's willingness to intervene. Note that these results are very robust for the use of different estimated volatilities and for the time period to which the deviation of the exchange rate and its volatility are compared.

Table 15. Pair-wise Granger causality tests for Croatia, 1996-2004

	1	2	3	4	5	10	15	20	30
INTERVENTIONS ALL									
GARCH=> inter	19.928***	13.139***	9.056***	7.513***	6.245***	8.706***	7.717***	6.673***	4.992***
inter=> GARCH	0.112	0.069	1.315	0.83	0.698	1.863	1.814***	1.562	2.021**
GARCHM=> inter	5.989***	5.689***	3.893***	3.138**	5.096***	4.407***	4.342***	3.901***	2.998***
inter=> GARCHM	1.078	18.609***	12.095***	9.904***	8.757***	10.08***	6.682***	4.754***	4.336***
EGARCH=> inter	11.766***	6.671***	5.029***	3.798***	12.475***	11.604***	9.67***	8.441***	6.096***
inter=> EGARCH	0.056	32.035***	21.163***	15.862***	12.664***	6.672***	4.959***	3.675***	3.359***
TGARCH=> inter	22.043***	14.93***	10.295***	8.819***	7.5***	10.625***	9.268***	7.954***	5.85***
inter=> TGARCH	0.08	0.03	1.591	1.102	0.916	1.984*	1.868***	1.606	2.198***
CGARCH=> inter	7.348***	8.575***	6.572***	5.097***	3.418***	5.32***	5.347***	4.213***	3.227***
inter=> CGARCH	0.609	47.57***	35.915***	26.325***	20.532***	10.887***	7.995***	6.724***	5.113***
SALES									
GARCH=> inter	15.481***	9.95***	7.234***	6.675***	5.496***	15.168***	10.103***	8.04***	5.84***
inter=> GARCH	0.056	4.11***	6.681***	5.018***	3.992***	3.848***	3.133***	2.604**	2.266***
GARCHM=> inter	4.524***	5.27***	3.774***	3.5***	5.276***	6.982***	5.789***	5.341***	3.907***
inter=> GARCHM	2.855**	33.473***	22.262***	18.651***	15.314***	17.222***	10.92***	8.265***	6.159***
EGARCH=> inter	11.691***	6.279***	5.206***	4.291***	12.306***	17.946***	12.578***	9.94***	7.042***
inter=> EGARCH	0.048	78.137***	52.628***	39.149***	30.91***	16.001***	10.566***	7.751***	5.692***
TGARCH=> inter	21.121***	13.639***	9.934***	9.017***	7.431***	18.638***	12.498***	9.961***	7.119***
inter=> TGARCH	0.158	4.85***	8.618***	6.538***	5.195***	4.111***	3.311***	2.679**	2.28***
CGARCH=> inter	2.952**	3.898***	2.647***	2.96**	2.396**	6.839***	4.866***	3.835***	3.102***
inter=> CGARCH	0.283	9.398***	6.328***	5.245***	4.339***	4.057***	3.102***	2.484**	2.051**
PURCHASES									
GARCH=> inter	5.493***	3.342***	2.352**	1.678	1.414	2.04*	4.675***	4.046***	3.143***
inter=> GARCH	0.478	4.262***	2.697***	1.933	1.609	0.925	0.882	0.996	2.414***
GARCHM=> inter	2.206*	1.269	0.895	0.659	1.041	0.944	3.893***	3.077***	2.453***
inter=> GARCHM	0.046	0.16	0.226	0.404	0.521	0.579	0.475	0.537	1.824**
EGARCH=> inter	2.497*	1.278	0.81	0.585	2.492**	2.077*	7.83***	6.665***	4.818***
inter=> EGARCH	0.012	0.4	0.307	0.679	0.621	0.388	0.365	0.618	2.59***
TGARCH=> inter	4.236***	2.751**	2.13**	1.549	1.527	2.288**	5.275***	4.581***	3.505***
inter=> TGARCH	0.602	5.003***	3.254***	2.368*	1.931*	1.172	1.029	1.102	2.83***

[14] The tests were carried out up to 60 lags, but given that the results for lags higher than 30 are very similar to the results based on k=20 and k=30, they are not reported here, but are available from the author upon request.
[15] The equations containing aggregate interventions yield unanimously no significant results.

CGARCH=> inter	5.058***	4.406***	4.514***	3.461**	0.715	0.541	3.741***	2.723**	2.021**
inter=> CGARCH	0.31	175.106***	122.591***	91.59***	72.555***	38.955***	25.757***	19.945***	14.548***

Table 16. Probit estimation results for Croatia, 1996-2004

	INTERVENTIONS ALL			SALES			PURCHASES		
MA	**C**	**c**	**g**	**c**	**c**	**g**	**c**	**c**	**G**
GARCH									
10	-1.402***	-8.314	9702.776	-1.896***	87.603***	-29934.489	-1.818***	-103.065***	-76240.14**
20	-1.415***	-0.735	15073.314	-1.925***	64.074***	-38598.587	-1.84***	-69.307***	-61759.679**
30	-1.423***	1.544	17765.458	-1.966***	55.914***	-44613.867**	-1.814***	-49.681***	-44613.274
40	-1.424***	2.114	16043.577	-1.983***	49.247***	-26463.631	-1.797***	-38.888***	-39041.597
GARCH-in-Mean									
10	-1.402***	-8.113	-29001.33	-1.894***	84.831***	-33057.359	-1.818***	-102.535***	-99512.167**
20	-1.416***	0.295	-35459.193	-1.916***	59.701***	-33225.958	-1.841***	-68.449***	-111497.747**
30	-1.423***	2.467	-27629.935	-1.95***	50.659***	-21604.432	-1.818***	-49.421***	-103669.059**
40	-1.424***	2.709	-22972.345	-1.973***	46.429***	-730.451	-1.802***	-38.959***	-102783.526**
EGARCH									
10	-1.402***	-8.369	11458.901	-1.895***	86.799***	-31717.288	-1.816***	-101.511***	-81479.901*
20	-1.415***	-0.425	10561.271	-1.916***	60.065***	-18953.49	-1.843***	-68.936***	-91450.525**
30	-1.423***	1.854	14716.603	-1.951***	51.247***	-16199.033	-1.821***	-50.206***	-80235.231**
40	-1.424***	2.363	12809.163	-1.974***	46.611***	-3090.839	-1.805***	-39.669***	-77915.307**
TGARCH									
10	-1.402***	-8.303	5298.365	-1.899***	89.978***	-39126.615	-1.817***	-100.793***	-69193.918*
20	-1.415***	-0.728	11022.234	-1.928***	65.681***	-43066.164*	-1.841***	-68.435***	-60543.836**
30	-1.423***	1.494	14555.128	-1.967***	56.552***	-43414.694**	-1.816***	-49.592***	-49070.566*
40	-1.424***	2.064	13563.037	-1.983***	49.441***	-24874.157	-1.799***	-38.876***	-44561.487
CGARCH									
10	-1.403***	-6.932	79117.039	-1.89***	81.815***	82936.132	-1.806***	-99.066***	-67907.242
20	-1.417***	0.245	98387.925	-1.912***	57.538***	47944.55	-1.825***	-65.675***	-7403.566
30	-1.425***	2.493	98024.692	-1.948***	49.687***	32492.261	-1.804***	-46.959***	32917.686
40	-1.427***	2.918	104804.201*	-1.973***	46.197***	56808.914	-1.79***	-37.003***	51021.427

4.2.2 Turkey

For Turkey, the estimations were conducted for two periods: (a) for the entire period running from 2001 to 2004 and (b) for the period from 2002 to 2004. The reason for investigating this sub-period is that, as already noted earlier, there are two clearly distinguished sub-periods. In 2001, the Central Bank of the Republic of Turkey undertook exclusively lira purchases on the foreign exchange market. During the period from 2002 to 2004, it only sold the Turkish currency against the US dollar. We decided not to use the period 2001 separately because of the relative small number of observations available for this period.

Estimation results for the whole period are presented in Table 17a below, which shows that there is ambiguity regarding the sign on the aggregated intervention variable across different GARCH models in the mean equation: the sign is negative for the GARCH, GARCH-in-Mean, TGARCH and ACGARCH models, and it is positive for the EGARCH. Using the lagged intervention variable, the GARCH model now provides us with the right positive sign, and as the CGARCH (insignificant previously). Coefficient estimates for the GARCH-in-Mean and TGARCH turn out to be statistically insignificant and the negative sign remains unchanged for the ACGARCH. Using instantaneous interventions disaggregated into lira sales and purchases, no relationship between lira purchases and exchange rate returns could be established. For lira sales, most of the coefficient estimates are significant and bear the correct positive sign although there is one negatively signed (GARCH-in-Mean) and one insignificant estimate (GARCH). Nevertheless, results based on lagged interventions to account for the simultaneity bias are much more encouraging as all coefficient estimates for lira sales turn out to be significant at least at the 5% level and have the expected positive sign. Note also that lira purchases remain insignificant. The robustness of this finding is investigated re-running the equations for the period 2002 to 2004 (Table 17b). The estimations, now including only lira sales as no lira purchases occurred during this period, very much confirm the previous results. Lira sales with a lag of two days are found to be significant and positively correlated with foreign exchange returns for all GARCH models but the ACGARCH model. In sum, when considering sales and purchases separately with a lag of two days, interventions and the exchange rate are linked positively to each other, and this finding is very robust for the use of different GARCH models. This is in line with the results reported in Domac and Mendoza (2002) but stand in contrast with what is found by Guimaraes and Karacadag (2004).

For the variance equation, little empirical support is provided by the estimations that interventions and exchange rate volatility are correlated in a rather robust way for the period as whole (2001-2004) because the sign of the estimated coefficient is found either negative or positive depending on the specific GARCH model, the inclusion of lagged and disaggregated interventions. For the sub-period 2002 to 2004, the relationship appears to be more robust because lira sales are found to be associated systematically to higher exchange rate volatility with four out of six GARCH models finding the estimated coefficient to be statistically significant at conventional significance levels.[16]

[16] The effect of the overnight interest differential on the exchange rate and its volatility is found to be not very robust. Although the relationship between interest rates and the exchange rate, if significant, is consistently positive in the mean equation for the period 2001-2004, it becomes largely insignificant for the sub-period 2002 to 2004. For the conditional variance equation, an increase in the interest differential causes an increase in exchange rate volatility when aggregated interventions for the whole period are used. However, the opposite effect is detected for the same period if lira sales and purchases are used separately. For the sub-period 2002-2004, if the estimated coefficient turns out to be not insignificant (for two cases), it has a positive sign. Note also that there is some evidence for day-of-the-week effects for both the mean and the variance equation.

Table 17a. GARCH estimation results for Turkey, 2001-2004

	GARCH		GARCH-in-Mean		EGARCH		TGARCH		CGARCH		ACGARCH	
MEAN EQUATION												
I_t	**-2.73E-05**	(0.000)	**-2.68E-05**	(0.001)	**3.73E-05**	(0.004)	**-2.88E-05**	(0.000)	9.37E-06	(0.531)	**-3.55E-05**	(0.000)
Δi_t	6.59E-05	(0.240)	1.44E-05	(0.781)	**1.01E-04**	(0.000)	5.71E-05	(0.203)	**6.04E-05**	(0.053)	**1.15E-04**	(0.000)
VARIANCE EQUATION												
$\lvert I_t \rvert$	**-1.37E-06**	(0.062)	**-9.58E-07**	(0.000)	**0.644**	(0.000)	**-1.26E-06**	(0.027)	**5.29E-07**	(0.000)	0.012	(0.418)
Δi_t	9.54E-08	(0.934)	6.38E-07	(0.329)	6.84E-04	(0.819)	1.52E-07	(0.914)	**5.38E-07**	(0.000)	2.59E-07	(0.927)
SHORT-RUN VARIANCE EQUATION												
$\lvert I_t \rvert$									-5.15E-07	(0.515)	0.054	(0.810)
Δi_t									**1.98E-06**	(0.000)	-0.012	(0.418)
MEAN EQUATION												
I_{t-2}	**3.17E-05**	(0.059)	1.33E-06	(0.944)	**5.06E-05**	(0.000)	2.42E-05	(0.183)	**3.42E-05**	(0.019)	**-6.12E-05**	(0.000)
Δi_t	**9.04E-05**	(0.003)	3.48E-05	(0.348)	**1.03E-04**	(0.000)	**8.34E-05**	(0.019)	**8.85E-05**	(0.002)	**1.29E-04**	(0.000)
VARIANCE EQUATION												
$\lvert I_{t-2} \rvert$	1.44E-08	(0.195)	**-2.52E-07**	(0.000)	**0.622**	(0.000)	**3.79E-08**	(0.008)	**9.85E-08**	(0.000)	0.011	(0.578)
Δi_t	**9.58E-07**	(0.000)	**3.57E-07**	(0.000)	0.002	(0.313)	**8.93E-07**	(0.000)	**1.77E-06**	(0.000)	3.87E-07	(0.960)
SHORT-RUN VARIANCE EQUATION												
$\lvert I_{t-2} \rvert$									**4.57E-07**	(0.000)	0.084	(0.788)
Δi_t									-1.87E-09	(0.837)	-0.011	(0.578)
MEAN EQUATION												
$I_t^{purchase}$	-1.6E-05	(0.632)	-1.9E-05	(0.588)	-1.3E-05	(0.627)	5.2E-06	(0.888)	-1.5E-05	(0.666)		
I_t^{sale}	-3.7E-05	(0.292)	**-4.9E-05**	(0.096)	**5.0E-05**	(0.000)	**3.9E-05**	(0.057)	**4.6E-05**	(0.000)		
VARIANCE EQUATION												
Δi_t	7.9E-05	(0.119)	2.3E-05	(0.604)	**9.1E-05**	(0.000)	**7.6E-05**	(0.047)	**8.7E-05**	(0.002)		
$\lvert I_t^{purchase} \rvert$	2.2E-07	(0.792)	-6.9E-07	(0.417)	**0.649**	(0.000)	**0.411**	(0.000)	-4.7E-06	(0.275)		
$\lvert I_t^{sale} \rvert$	**-3.1E-06**	(0.000)	**-2.9E-06**	(0.000)	-1.4E-04	(0.969)	**-2.3E-06**	(0.000)	**8.0E-07**	(0.000)		
Δi_t	**-1.6E-06**	(0.000)	**-3.2E-06**	(0.000)	-5.3E-04	(0.880)	**-4.5E-07**	(0.000)	**5.7E-07**	(0.000)		
SHORT-RUN VARIANCE EQUATION												
$\lvert I_t^{purchase} \rvert$									3.7E-06	(0.409)		
$\lvert I_t^{sale} \rvert$									**-1.2E-06**	(0.038)		
Δi_t									**1.4E-06**	(0.012)		
MEAN EQUATION												
$I_{t-2}^{purchase}$	-3.65E-05	(0.454)	-2.56E-05	(0.491)	-6.47E-06	(0.814)	-1.52E-05	(0.643)	-1.41E-05	(0.685)		
I_{t-2}^{sale}	**7.11E-05**	(0.001)	**4.58E-05**	(0.014)	**6.21E-05**	(0.000)	**5.12E-05**	(0.002)	**4.87E-05**	(0.000)		
Δi_t	3.27E-05	(0.514)	**7.02E-05**	(0.014)	**9.08E-05**	(0.000)	**7.98E-05**	(0.003)	**8.05E-05**	(0.001)		
VARIANCE EQUATION												
$\lvert I_{t-2}^{purchase} \rvert$	7.79E-07	(0.471)	**-2.20E-06**	(0.071)	**0.644**	(0.000)	0.327	(0.202)	**-1.67E-06**	(0.072)		
$\lvert I_{t-2}^{sale} \rvert$	**-3.41E-06**	(0.000)	**-3.05E-07**	(0.001)	-0.003	(0.246)	-2.22E-06	(0.120)	**1.13E-07**	(0.000)		
Δi_t	-3.20E-07	(0.688)	**-3.41E-07**	(0.000)	3.89E-04	(0.901)	-6.86E-08	(0.237)	**1.20E-06**	(0.000)		
SHORT-RUN VARIANCE EQUATION												
$\lvert I_{t-2}^{purchase} \rvert$									-4.00E-07	(0.838)		
$\lvert I_{t-2}^{sale} \rvert$									3.24E-08	(0.640)		
Δi_t									**-1.62E-06**	(0.000)		

Table 17b. GARCH estimation results for Turkey, 2002-2004

	GARCH		GARCH-in-Mean		EGARCH		TGARCH		CGARCH		ACGARCH	
MEAN EQUATION												
I_t^{sale}	**3.27E-05**	(0.010)	**2.73E-05**	(0.023)	2.19E-05	(0.125)	**3.29E-05**	(0.011)	**3.68E-05**	(0.014)	**6.76E-05**	(0.073)
Δi_t	9.24E-06	(0.689)	-1.95E-05	(0.192)	-1.36E-05	(0.631)	2.85E-06	(0.910)	4.74E-06	(0.874)	7.79E-06	(0.850)
VARIANCE EQUATION												
I_t^{sale}	**9.87E-08**	(0.006)	7.90E-08	(0.393)	**0.840**	(0.000)	**1.18E-07**	(0.001)	2.59E-07	(0.924)	**0.011**	(0.094)
Δi_t	**4.51E-07**	(0.000)	3.79E-07	(0.285)	2.68E-04	(0.852)	**4.71E-07**	(0.000)	3.68E-07	(0.884)	4.96E-08	(0.976)
SHORT-RUN VARIANCE EQUATION												
I_t^{sale}									-3.62E-07	(0.910)	0.016	(0.910)
Δi_t									5.36E-07	(0.911)	**-0.011**	(0.094)
MEAN EQUATION												
I_{t-2}^{sale}	**5.08E-05**	(0.000)	**4.38E-05**	(0.001)	**3.90E-05**	(0.004)	**5.15E-05**	(0.000)	**4.99E-05**	(0.001)	2.94E-05	(0.782)
Δi_t	2.94E-05	(0.248)	7.03E-06	(0.831)	6.11E-06	(0.830)	2.86E-05	(0.260)	2.18E-05	(0.439)	5.94E-06	(0.847)
VARIANCE EQUATION												
I_{t-2}^{sale}	**1.28E-07**	(0.002)	9.86E-08	(0.400)	**0.838**	(0.000)	**1.23E-07**	(0.002)	6.24E-07	(0.864)	**0.012**	(0.090)
Δi_t	**4.85E-07**	(0.000)	3.86E-07	(0.231)	4.37E-04	(0.768)	**4.39E-07**	(0.000)	4.11E-07	(0.869)	9.76E-08	(0.952)
SHORT-RUN VARIANCE EQUATION												
I_{t-2}^{sale}									-8.36E-07	(0.823)	0.016	(0.907)
Δi_t									6.76E-07	(0.890)	**-0.012**	(0.090)

Regarding the causal link between interventions and exchange rate volatility, pair-wise Granger causality tests are applied to the estimated volatilites and the interventions, similarly to the case of Croatia. As shown in Table 18, exchange rate volatility is found to (Granger) cause interventions at the horizons of 20 and 30 days. Note, however, that the interpretation of these results is tricky given that viewing through the glass of GARCH estimations, it is not clear whether forex volatility and lira purchases are correlated negatively or positively. For the sub-period 2002 to 2004, a positive relation could be established. Looking at Table 18 indicates, however, the lack of any robust causal relationship. Only using volatility estimated on the basis of the EGARCH model reveals causality up to five days running from volatility to intervention. At the same time, CGARCH-based estimations indicate a causal relation from interventions to volatility.

Finally, the estimation of the central bank reaction function shows for lira purchases (Table 19), the higher the departure of the exchange rate from its recent trend, the higher the probability that the central bank intervenes. For excess volatility, significance of the estimations rests largely upon the time horizon over which average volatility is computed. For lira sales, the study of the period 2002 to 2004 indicate, somewhat surprisingly, that the probability of intervention decreases with the increase in the gap between the spot exchange rate and its 30-day and 40-day average. Excess volatility does not seem to be significant for either of the model specifications. This confirms the earlier weak non-causality finding.

Table 18. Pair-wise Granger causality tests for Turkey

	1	2	3	4	5	10	15	20	30
INTERVENTIONS ALL									
GARCH=> inter	2.755**	1.094	0.501	0.352	0.24	0.133	0.111	3.555***	4.049***
inter=> GARCH	0.632	1.578	1.193	0.897	0.742	0.548	0.371	0.337	0.252
GARCHM=> inter	0.223	0.267	0.607	0.46	0.397	0.216	0.12	4.207***	3.784***
inter=> GARCHM	2.704**	1.466	1.085	0.873	0.74	0.653	0.426	0.332	0.273
EGARCH=> inter	0.233	0.118	0.071	0.052	0.032	0.024	0.008	4.975***	4.105***
inter=> EGARCH	0.189	0.138	0.117	0.09	0.077	0.058	0.045	0.035	0.026
TGARCH=> inter	0.226	0.213	0.32	0.252	0.236	0.133	0.086	4.679***	3.87***
inter=> TGARCH	1.783	0.95	0.644	0.5	0.446	0.444	0.304	0.266	0.205
CGARCH=> inter	0.165	0.155	0.311	0.25	0.237	0.147	0.074	3.938***	3.879***
inter=> CGARCH	2.113*	1.136	0.768	0.642	0.61	0.517	0.355	0.265	0.218
PURCHASES									
GARCH=> inter	0.084	0.115	0.068	0.158	0.095	0.112	0.148	5.812***	6.342***
inter=> GARCH	0.709	0.507	0.534	0.499	0.394	0.247	0.168	0.181	0.128
GARCHM=> inter	0.409	0.045	0.395	0.324	0.166	0.18	0.104	6.556***	6.071***
inter=> GARCHM	6.824***	4.043***	2.76***	2.165*	1.684	0.954	0.626	0.468	0.322
EGARCH=> inter	0.056	0.03	0.019	0.013	0.008	0.005	0.001	6.834***	6.536***
inter=> EGARCH	0.007	0.011	0.014	0.01	0.009	0.011	0.009	0.008	0.006
TGARCH=> inter	0.265	0.049	0.165	0.176	0.082	0.11	0.087	7.062***	6.175***
inter=> TGARCH	5.125***	2.858**	1.971**	1.54	1.213	0.686	0.464	0.382	0.241
CGARCH=> inter	0.788	0.133	0.201	0.196	0.079	0.154	0.08	6.426***	6.287***
inter=> CGARCH	5.599***	3.202***	2.22**	1.814	1.434	0.781	0.531	0.38	0.255
SALES									
GARCH=> inter	2.017	0.463	0.153	0.086	0.061	0.028	0.031	0.021	0.023
inter=> GARCH	6.566***	4.282***	3.259***	2.423**	1.852*	0.863	0.574	0.393	0.239
GARCHM=> inter	0.361	0.304	0.213	0.152	0.11	0.153	0.11	0.107	0.109
inter=> GARCHM	1.166	0.716	0.598	0.481	0.377	0.229	0.167	0.13	0.083
EGARCH=> inter	0.059	0.022	0.012	0.009	0.007	0.006	0.005	0.005	0.005
inter=> EGARCH	0.34	0.185	0.127	0.097	0.079	0.041	0.029	0.022	0.015
TGARCH=> inter	0.267	0.196	0.114	0.081	0.06	0.079	0.06	0.058	0.059
inter=> TGARCH	1.179	0.609	0.508	0.392	0.311	0.168	0.124	0.097	0.06
CGARCH=> inter	0.303	0.263	0.163	0.121	0.088	0.118	0.086	0.078	0.077
inter=> CGARCH	1.077	0.578	0.51	0.406	0.337	0.197	0.142	0.104	0.068
SALES – SUB-PERIOD 2002-2004									
GARCH=> inter	1.149	0.983	0.924	1.273	1.233	1.379	1.104	0.865	0.653
inter=> GARCH	0.181	0.381	0.396	0.297	0.736	1.004	0.783	1.158	1.09
GARCHM=> inter	1.385	1.17	1.039	1.427	1.319	1.348	1.082	0.837	0.631
inter=> GARCHM	0.155	0.715	0.492	0.372	0.723	1.036	0.788	1.096	1.068
EGARCH=> inter	2.469*	1.834	1.786*	2.088*	1.906*	1.24	0.921	0.709	0.546
inter=> EGARCH	1.297	1.365	0.611	0.498	0.409	1.316	1.044	1.234	1.411
TGARCH=> inter	0.982	0.916	0.887	1.333	1.235	1.394	1.152	0.913	0.694
inter=> TGARCH	0.104	0.364	0.325	0.237	0.722	0.831	0.634	1.005	0.989
CGARCH=> inter	0.238	0.318	0.119	1.514	2.076**	1.299	1.136	1.098	0.769
inter=> CGARCH	3.437**	3.379***	6.08***	4.897***	7.195***	5.736***	4.362***	3.881***	2.927***

Table 19. Probit estimation results for Turkey

FULL PERIOD: 2001-2004

	INTERVENTIONS ALL			SALES			PURCHASES		
MA	**C**	**c**	**g**	**c**	**c**	**g**	**c**	**C**	**G**
GARCH									
10	-0.23***	1.084	-57.166	-0.629***	-4.826***	13.881	-1.07***	5.407***	-106.595**
20	-0.217***	0.058	-164.102**	-0.612***	-6.336***	-130.774	-1.1***	5.107***	-170.069***
30	-0.231***	-1.685*	-913.019***	-0.626***	-8.428***	-797.373***	-1.155***	5.189***	-389.731**
40	-0.26***	-1.636*	-1557.615***	-0.649***	-9.307***	-1235.475***	-1.234***	5.831***	-633.335***
GARCH-in-Mean									
10	-0.227***	0.565	-1.691	-0.628***	-5.246***	78.445**	-1.067***	5.163***	-71.721
20	-0.21***	-0.135	-23.302	-0.605***	-6.375***	102.939***	-1.095***	5.005***	-111.149**
30	-0.201***	0.065	-118.81*	-0.587***	-7.308***	112.476***	-1.149***	5.575***	-202.837**
40	-0.202***	0.495	-197.252	-0.575***	-7.965***	307.224*	-1.224***	6.396***	-294.785
EGARCH									
10	-0.227***	0.6	-0.082	-0.629***	-4.981***	0.756*	-1.065***	4.771***	-0.687
20	-0.209***	-0.219	-0.111	-0.606***	-6.211***	0.943***	-1.089***	4.636***	-0.814
30	-0.199***	-0.023	-0.903*	-0.589***	-7.194***	0.91***	-1.139***	5.363***	-1.275***
40	-0.203***	-0.294	-9.28	-0.573***	-7.863***	80.695	-1.224***	8.211***	10.278
TGARCH									
10	-0.227***	0.584	-2.483	-0.628***	-5.236***	56.709**	-1.067***	5.133***	-51.67
20	-0.21***	-0.16	-13.674	-0.605***	-6.367***	73.746***	-1.094***	4.941***	-75.938**
30	-0.201***	0.04	-85.135	-0.588***	-7.308***	81.695***	-1.148***	5.511***	-152.152**
40	-0.202***	0.48	-145.038	-0.573***	-7.941***	338.57**	-1.221***	6.372***	-210.267
CGARCH									
10	-0.227***	0.519	1.879	-0.627***	-5.401***	79.539**	-1.068***	5.215***	-65.38
20	-0.21***	-0.119	-22.605	-0.605***	-6.479***	103.18***	-1.097***	5.073***	-107.309***
30	-0.202***	0.064	-117.214*	-0.588***	-7.4***	116.337***	-1.151***	5.55***	-213.093**
40	-0.205***	0.433	-220.627*	-0.573***	-8.12***	461.286***	-1.229***	6.255***	-361.591**

SUBPERIOD: 2002-2004

GARCH									
10				-0.358***	3.496	-4047.289***			
20				-0.4***	-0.678	-5518.565***			
30				-0.462***	-2.921	-6777.189***			
40				-0.517***	-3.802**	-7535.599***			
GARCH-in-Mean									
10				-0.342***	1.523	-44.505			
20				-0.345***	-2.767	-3.56			
30				-0.356***	-5.147***	8.39			
40				-0.371***	-6.395***	-2.666			
EGARCH									
10				-0.342***	1.521	-9.793			
20				-0.345***	-2.811	26.437			
30				-0.356***	-5.192***	37.285			
40				-0.371***	-6.411***	16.258			
TGARCH									
10				-0.342***	1.504	-6.323			
20				-0.345***	-2.786	52.959			
30				-0.356***	-5.164***	77.737			
40				-0.371***	-6.41***	67.093			
CGARCH									
10				-0.342***	1.41	175.671			
20				-0.345***	-2.873	306.811			
30				-0.356***	-5.251***	378.099			
40				-0.37***	-6.499***	404.528			

5. Conclusions

This paper analysed the impact of foreign exchange interventions in two EU candidate countries, namely in Croatia and Turkey by applying the event study methodology to the data and by analysing a variety of the class of GARCH models. The results indicate that the event study and the econometric estimations are complementary rather than competing approaches.

The event study approach can be used to analyse only a fraction of foreign exchange interventions by the Croatian National Bank because of its regular interventions leaving little time to elapse between two interventions (episodes). For the non-overlapping intervention episodes, it is found that perhaps 1/3 of them was effective in changing changes in the exchange rate. The successful episodes were half leaning against the wind operation and half leaning with the wind operations. The analysis of the episodes' impact on volatility shows a colourful picture. Some intervention episodes systematically increased volatility, whilst another part of interventions dampened volatility. A third part of interventions affected volatility differently at different time horizons. The inability of the event study approach to evaluate a high number of intervention episodes makes the use of econometric estimations necessary. The estimation results reveal a very robust relationship between kuna purchases and exchange rate returns, whilst kuna sales appear to have no impact on the exchange rate when using them with a lag of two days. The relationship between kuna purchases conditional volatility is found to be positive, while sales appear to decrease volatility. All in all, the Croatian National Bank was relatively successful in influencing the level of the exchange rate (when buying kunas) and dampening volatility (when selling kunas). These findings are broadly in line with the officially announced policy of the Croatian central bank.

For Turkey, the event study approach revealed that the Central Bank of the Republic of Turkey intervened periodically, but massively on the foreign exchange market. The identified four intervention episodes are all found to have been very effective. The Central Bank of Turkey always acted as leaning against the wind, and the interventions had a significant impact on changes in the exchange rate against the dollar to a horizon up to 60 days. Regarding unconditional exchange rate volatility, the first intervention episode occurred in 2001 in the aftermath of the currency crisis clearly dampened volatility, whilst the episodes in 2002 and 2004 turn out to have led to higher volatility with comparison to the pre-event volatility. The third intervention episode taking place in 2003 first increased volatility but then resulted in lower volatility at the horizons of 30 to 60 days. When accounting properly for simultaneity and using lira purchases and sales separately, the results of the GARCH estimations revealed that lira sales are positively correlated with changes in the exchange rate, which lends further support to the leaning against the wind hypothesis. In contrast to this finding is the result that lira purchases had no effect on exchange rate returns. The analysis of the conditional variance indicated that lira purchases tended to increase volatility whereas lira sales had no significant effect on volatility. However, the lack of econometric evidence for lira purchases to affect exchange rate returns and volatility may be due to the fact that lira purchases took place in one cluster in 2001. Hence, for this period, results of the event study should be preferred.

Combining the results of the event study and the econometric estimations suggest that both lira purchases and lira sales were successful in changing the trend of exchange rate movements (leaning against the wind). In addition, exchange rate volatility decreased following lira purchases by the central bank in 2001, whereas volatility rose when the central bank proceeded with lira sales. These findings are in contrast with official policy statements of the Central Bank of the Republic of Turkey, according to which foreign exchange interventions aim to dampen volatility but not to alter the level of the long-run exchange rate.

Overall, the results of this study gives further evidence in favour of the fact that emerging market economies are in a good position to carry out sterilised foreign exchange interventions effectively (Canales-Kriljenko, 2003).

References

Aguilar, Javiera and Stefan Nydahl (2000): Central bank intervention and exchange rates: The case of Sweden, Journal of International Financial Markets, Institutions and Money, 10, 303-322.

Beine, Michel, Agnès Bénassy-Quéré, Estelle Dauchy and Ronald MacDonald (2002): The Impoact of Central Bank Intervention on Exchange Rate Forecast Heterogeneity, CEPII Working Paper No 4.

Bonser-Neal, C. and G. Tanner (1996): Central bank intervention and the volatility of foreign exchange rates: evidence from the option markets, Journal of International Money and Finance, 15, 853-877.

Brandner, P. and H. Grech (2002): Why did central banks intervene in the EMS? The post 1993 experience, Oesterreichische Nationalbank Working Paper No. 77.

Brandner, P., Grech H and H. Stix (2001): The effectiveness of central bank intervention in the EMS: The post 1993 experience, Oesterreichische Nationalbank Working Paper No. 55.

Brissimis, Sophocles N. and Dionysios P. Chionis (2004): Foreign exchange market intervention: implications of publicly announced and secret intervention for the euro exchange rate and its volatility, Journal of Policy Modeling, 26, 661-673.

Calvo, G.A. and C.M. Reinhart (2000): Fear of floating, NBER Working Paper No. 7993.

Canales-Kriljenko, Jorge Iván (2003): Foreign exchange intervention in developing and transition economies: Results of a survey, IMF Working Paper No. 95.

Canales-Kriljenko, Jorge-Iván, Roberto Guimaraes and Cem Karacadag (2003): Official intervention in the foreign exchange market: Elements of best practice, IMF Working Paper No 152.

Central Bank of Turkey (2001, 2002, 2003): Annual Report

Central Bank of Turkey (2004): General framework of monetary and exchange rate policy in 2004, Press Release No. 2.

Croatian National Bank (2001, 2002, 2003): Annual Report.

Dauchy, Estelle (2001): The Effect of Official Speeches and Central Bank Intervention Rumours on Foreign Exchange Market Forecasts, TEAM Working Paper, University of Paris I.

Domac, Ilker and Alfonso Mendoza (2002): Is there room for forex interventions under inflation targeting framework? Evidence from Mexico and Turkey, Central Bank of the Republic of Turkey Discussion Paper No. 58.

Dominguez, Kathryn M. (1998): Central bank intervention and exchange rate volatility, Journal of International Money and Finance, 17, 161-190.

Dutta, Jayasri and Leon Hyginus (2002): Dread of depreciation: Measuring real exchange rate interventions, IMF Working Paper No. 63.

Edison, Hali, Paul Cashin and Hong Liang (2003): Foreign exchange intervention and the Australian dollar: Has it mattered? IMF Working Paper No 99.

Fatum, Rasmus (2000): On the effectiveness of sterilised Foreign Exchange Intervention, ECB Working Paper No. 10.

Fatum, Rasmus and Michael M. Hutchison (2003): Effectiveness of official daily foreign exchange market intervention operations in Japan, NBER Working Paper No. 9648.

Guimaraes, Roberto and Cem Karacadag (2004): The empirics of foreign exchange intervention in emerging market countries: The case of Mexico and Turkey, IMF Working Paper 123.

Kearns, Jonathan and Roberto Rigobon (2002): Identifying the efficacy of central bank interventions: The Australian case, NBER Working Paper No. 9062.

Kim, Suk-Joong, Tro Kortian and Jeffrey Sheen (2000): Central bank intervention and exchange rate volatility – Australian evidence, Journal of International Financial Markets, Institutions and Money, 10, 381-405.

Morana, Claudia and Andrea Beltratti (2000): Central bank interventions and exchange rates: an analysis with high frequency data, , Journal of International Financial Markets, Institutions and Money, 10, 349-362.

Ramaswamy, Ramana and Hossein Samiei (2000): The yen-dollar rate: Have interventions mattered? IMF Working Paper No. 95.

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

Sarno, Lucio and Mark P. Taylor (2001): Official intervention in the foreign exchange market: Is it effective, and, if so, how does it work? CEPR Discussion Paper No. 2690.