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Maurizio Michael Habib

Financial contagion, interest rates and the role of the exchange rate as shock absorber in Central and Eastern Europe

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Contents

Maurizio Michael Habib*

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Abstract

This paper studies the impact of external factors on daily exchange rates and short-term interest rates in the Czech Republic, Hungary and Poland during the period August 1997 – May 2001. I find that neither exchange rates nor interest rates are influenced by short-term German interest rates. Nevertheless, I show that shocks to emerging-market risk premia had a significant impact on exchange rates in all three Central and Eastern European countries and on interest rates in the Czech Republic. In addition, studying the second moment of the variables, I demonstrate that Czech and Polish exchange rates were affected by 'volatility contagion' coming from emerging markets. I find also some partial support for the 'volatility contagion' hypothesis on Czech interest rates. These findings shed some doubts on the alleged theoretical ability of a floating exchange rate – such as in the Czech Republic – to absorb external shocks and insulate a country's domestic monetary policy completely. However, the spill-over effect on Czech interest rates might be explained by the 'managed' nature of the exchange rate regime, thereby re-establishing some credibility of the theory.

Key words: exchange rates, short-term interest rates, volatility, Czech Republic, Hungary, Poland

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Maurizio Michael Habib

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Tiivistelmä

Tutkimuksessa selvitetään ulkoisten tekijöiden vaikutusta valuuttakurssien ja lyhyiden korkojen päivämuutoksiin Puolassa, Tšekin tasavallassa ja Unkarissa. Tutkimus kattaa aikavälin elokuusta 1997 toukokuuhun 2001. Saksan lyhyiden korkojen muutokset eivät vaikuta näiden kandidaattimaiden valuuttakursseihin tai korkoihin. Kehittyvien talouksien korkoihin liittyvä riskipreemio on vaikuttanut selvästi kaikkien kolmen maan valuuttakursseihin ja Tšekin korkoihin. Lisääntynyt volatiliteetti kehittyvien talouksien markkinoilla on vaikuttanut Puolan ja Tšekin valuuttakurssien volatiliteettiin sekä Tšekin korkoihin. Näin ollen saattaa olla, että edes kelluva valuuttakurssi ei pysty suojelemaan näitä talouksia ulkoisilta shokeilta.

Asiasanat: valuuttakurssit, lyhyet korot, volatiliteetti, Puola, Tšekin tasavalta, Unkari

1 Introduction

The choice of an exchange rate system is one of the main open issues in international macroeconomics. The exchange rate regime is often the cornerstone of macroeconomic stabilisation programmes in emerging markets. In small open economies, an exchange rate target may be an effective nominal anchor to domestic prices and wages. In practice, the quest for an external anchor may turn out to be a difficult task, as shown by the collapse of several traditional fixed or crawling peg arrangements during the nineties. These currency crises provoked a new stream of theoretical and policy arguments on exchange arrangements. Once more, the merits and drawbacks of fixed exchange regimes have been compared with those of floating exchange rates. In particular, economists have focused on the ability of a given exchange rate regime to face periodic and potentially contagious financial crises, which seem to be an inevitable collateral inconvenience of greatly integrated financial markets. This paper contributes to the current debate providing empirical evidence on the behaviour of exchange rates and interest rates in three Central and Eastern European countries (CEECs) – the Czech Republic, Hungary and Poland – during the period 1997-2001. The paper analyses the reaction of interest rates and exchange rates to external shocks and examines the volatility of these two variables, testing for a possible "volatility contagion" caused by German interest volatility or emerging market instability. The objective of the research is to investigate whether the degree of exchange rate flexibility did matter in CEECs, checking if a managed floating exchange rate – as in the Czech Republic – has been able to insulate the domestic monetary policy by absorbing external shocks and/or volatility contagion. At the same time, I verify if relatively more rigid exchange rate systems – as in Hungary and Poland – have been associated with spillovers of these shocks and/or volatility contagion on short-term interest rates.

2 Foreign shocks, volatility contagion and the role of the exchange rate as shock absorber

According to economic textbooks, one of the main benefits of flexible exchange rates for a small open economy is the ability to run an independent monetary policy and insulate it from external shocks. This assumption can be illustrated by a simple analysis of the uncovered interest parity equality, which is shown in equation (1):

$$i_t = i_t^* + E_t e_{t+1} - e_t + \pi_t \qquad (1)$$

where i_t is the domestic interest rate with maturity $t+1$; i_t^* is the foreign interest rates with the same maturity; e_t is the natural logarithm of the spot exchange rate (E is the usual expectation operator) at time t; and π_t is the country risk premium. This equality shows that every shock to i^* or π can be absorbed by changes in domestic interest rates, i, and changes in the expected rate of depreciation, $E_t\, e_{t+1} - e_t$. In the case of fixed exchange rates, the expected rate of depreciation of the domestic currency is equal to zero, so that external shocks should proportionally affect domestic interest rates. Under floating exchange rates, instead, policy-makers enjoy a degree of freedom and can set domestic interest rates, letting the exchange rate adjust in order to satisfy the parity. In this case, external shocks produce complex exchange rate dynamics. For instance, a positive shock to $i*$ or π may cause an immediate devaluation of the exchange rate which overshoots its long-run equilibrium and then tends to appreciate (or reduce its rate of depreciation) as in the Dornbusch (1976) model. Hence, under fixed exchange rates, the burden of adjustment to external shocks should fall on domestic interest rates, while a more flexible exchange rate could theoretically absorb external shocks and insulate domestic rates.

Observing equation (1), it is possible to distinguish between shocks to foreign interest rates, i^*, and shocks to the perception of emerging markets' riskiness affecting the country risk premium, π. The country risk premium depends on a set of domestic macroeconomic variables such as expected growth, the current account deficit, or the burden of foreign debt. Nevertheless, the international investors' assessment of these domestic macroeconomic variables in a particular emerging market may be affected by the riskiness of the whole pool of emerging markets, especially during a period of financial turmoil. Hence, shocks to emerging-market risk premia can enter in the uncovered interest parity through this channel. Finally, note that equality (1) holds when the capital account is fully open. If capital controls are in place, an additional term representing the tax equivalence of the capital restrictions should be added in the right-hand side of the formula. Capital controls create a wedge between the return on the domestic investment (i) and the corresponding expected return on a foreign security $(i^* + E_t\, e_{t+1} - e_t)$, leaving room for independent monetary policies even if the exchange rate is rigidly fixed. In other terms, equation (1) outlines the problem of the impossible trinity, i.e. the inability to have, at the same time, full financial integration, monetary independence and exchange rate stability.

Empirical investigations on the reaction of domestic interest rates to external factors under different exchange rate arrangements do not offer strong support for the theory. Frankel et al. (2000) analyse the relationship between domestic and foreign interest rates in a large sample of industrial and developing countries, looking for empirical regularities under different exchange rate arrangements over the past three decades. They find evidence of transmission of international interest rate disturbances into domestic rates during the nineties, regardless of exchange regime and income level. Edwards (2000) compares the behaviour of interest rates in three Latin American countries – Chile, Argentina and Mexico – in the second half of the nineties. He shows that the response of interest rates in these three countries to shocks to the emerging markets' degree of risk is similar, although they have different exchange rate regimes and different degrees of capital mobility. Finally, Borensztein et al. (2001) consider the effects of both shocks to international interest rates and shocks to emerging market risk premia on domestic interest rates and exchange rates in a selected sample of industrial and emerging countries. Their results are mixed. The comparison of interest rate reaction to external shocks between Hong Kong (currency board) and Singapore (floating rate) confirms the conventional view on monetary independence under floating exchange rates. Nevertheless, the comparison between Argentina (currency board) and Mexico (floating rate) does not support the same conclusion, since the reaction of interest rates to shocks to risk premia is significant in both countries, confirming the result of Edwards (2000).

Comparative analyses including Central and Eastern European Countries (CEECs) reach similar results and do not find a clear pattern for interest rate response to external factors according to different exchange rate systems. Using various econometric techniques, Scheicher (2000) shows that short-term interest rates in the Czech Republic, Hungary and Poland are segmented at a regional and at a global level and do not interact with the benchmark rate in Germany during the period 1997-98. However, he neither checks for differences in the behaviour of exchange rates nor tests for emerging-market contagion. Instead, Darvas and Szapary (1999) provide a descriptive analysis of the impact of recent global financial crises on exchange rates and interest rates in a sample of emerging economies, which includes our three CEECs. Once again, they find it impossible to differentiate interest rate responses to external shocks according to the exchange rate regime. However, an econometric study on the trade-off between interest rate and exchange rate responses to external shocks in the CEECs is still missing. From the empirical point of view, the sequence of financial crises that hit emerging markets since the Asian crisis in 1997 represents an ideal set of external shocks that may modify the equilibrium in equation (1). For this reason, I include external shocks coming from other emerging markets, testing for their effects on exchange rates and interest rates in the Czech Republic, Hungary and Poland.

Nevertheless, this paper does not limit its scope to the study of the impact of external shocks on the *level* of interest rates and exchange rates in the CEECs, but also explores the impact of external factors on their *volatility*. I test whether foreign interest rates or financial crises affecting emerging market risk premia transmitted a series of shocks to the CEECs' country risk premia. If this is the case, then the volatility of external factors – such as foreign interest rates or emerging financial markets – should be in some way correlated with the volatility of exchange rates and/or interest rates in the CEECs. Since I am not investigating the channels through which these shocks are transmitted – trade links, financial links, or simply re-assessment of the country risk under new global economic conditions – this correlation, or external influence, will be generally defined as 'volatility contagion' or 'volatility spillover'.

While the empirical literature has investigated the 'volatility contagion' hypothesis in stock markets, much less attention has been devoted to the propagation of interest rate and exchange rate volatility across different countries[1]. To date, only Edwards (1998) and Edwards and Susmel (2000) have extended this line of research to nominal interest rates. Edwards (1998) compares the behaviour of short-term interest rate volatility in Argentina and Chile between January 1992 and June 1998. Identifying *a priori* Mexico as the source of financial shocks in Latin America, he selects a group of indexes of Mexican volatility to be used in the estimation of the conditional variance of interest rates in Argentina and Chile and finds a very different effect of Mexico's volatility spillovers in these two countries. Whereas interest rate volatility in Argentina – which had a currency board during that period - was systematically affected by Mexican financial turbulence, interest rate volatility in Chile – which had a crawling band regime and capital controls – was spared from 'volatility contagion'[2]. Edwards and Susmel (2000) attempted a different econometric treatment of interest rate volatility contagion in five emerging market economies during the nineties, relying on univariate and bivariate switching volatility models. Within the univariate analysis, they identify breakpoints in the conditional variance of interest rates and find that "high volatility states roughly coincide" across countries (*ibid.* p. 10). Nevertheless, the results of the bivariate analysis, matching countries in pairs, are mixed. The authors find that the correlation coefficients are not significant and are not state-dependent, finding neither contagion, nor interdependence. In some cases, they can reject the hypothesis that volatility states are independent across countries; however, they conclude that the results are not strongly supportive of the contagion hypothesis for interest rates.

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1 The literature on the volatility and integration of stock markets is remarkably large. See, for instance, King and Wadhwani (1990); Hamao, Masulis and Ng (1990); King, Sentana and Wadhwani (1994); Longin and Solnik (1995); Bekaert and Harvey (1997); Ramchand and Susmel (1998). Rockinger and Urga (2001) have recently extended the analysis to stock markets in transition economies.

2 Edwards (1998) investigates to what extent this result could depend on the presence of capital controls in Chile. He finds that the imposition of restrictions on capital movements increased short-term control over domestic interest rates by the authorities, but the effect is much more ambiguous over the long run. Note that the result concerning Chilean interest rate reaction to external factors differs from Edwards (2000), which included the turbulent period 1998-1999 in the analysis.

The contrasting results obtained by Edwards (1998) and Edwards and Susmel (2000) raise a methodological issue. It seems that the research of the statistical dependence of interest rates across countries addresses the wrong problem, applying an interpretation of contagion defined as a significant increase in cross-market linkages, which is typical of bond and stock market studies[3]. Notably, short-term interest rates are segmented at the global level – as the results of Scheicher (2000) as well as Edwards and Susmel (2000) confirm – while bond and, above all, stock markets are internationally integrated. Short-term interest rates primarily reflect the impact of domestic idiosyncratic shocks – such as macroeconomic announcements - and the intervention of monetary authorities, which can inject or absorb liquidity in the money market through open-market operations. These domestic factors will interfere with external factors, making it difficult or impossible to find a significant interest rate correlation across countries, or statistically significant synchronisation of high volatility states. This does not mean that external factors cannot occasionally affect domestic interest rates and that volatility cannot spill over across countries. In other terms, financial contagion can be compared to the spread of a “flu”: you can catch it or not, maybe one or two week later than your friends, and it can last a few days or longer according to your immune defences. Evidently, this does not imply that all your friends will have the flu exactly at the same time over the same period. Hence the interpretation of contagion that has been adopted for this paper is a general one, defining contagion simply as the spread of market disturbances across countries. In particular, I concentrate on “volatility contagion” following the fruitful approach of Edwards (1998). I first check if the volatility of domestic interest rates and exchange rates shared a common pattern with the volatility of foreign interest rates and emerging markets. Then I will specify a GARCH model to describe the behaviour of domestic interest rates and exchange rates, testing if some indicators of foreign interest rate and emerging-market volatility can help in explaining their conditional variance.

After having tested if the volatility of external factors spilled over onto the volatility of exchange rates and interest rates, it will be possible to check for the presence of a volatility trade-off between the latter. Turning our attention back to the uncovered interest parity, equation (1) implies a volatility trade-off between the exchange rate and the interest rate. If the exchange rate is fixed, then shocks make interest rates volatile. If the exchange rate floats freely, then it should absorb the shocks and become more volatile. This volatility trade-off can be considered a special case of the more general “volatility transfer” hypothesis of fixed exchange rates. This hypothesis can be backdated to Friedman (1953) and Frankel and Mussa (1980), who suggest that exchange rate instability is a symptom of underlying macroeconomic instability, implying that any attempt to stabilise the exchange rate should only transfer the underlying volatility somewhere else in the economic system. The volatility transfer hypothesis can be easily illustrated within a flex-price monetary model of the exchange rate. Flood and Rose (1995) present an exchange rate model that includes a money-market equilibrium:

(2) $$m_t - p_t = \beta y_t - \alpha i_t + \varepsilon_t$$

and a purchasing-power-parity (PPP) condition:

(3) $$p_t = e_t + p_t^* + v_t$$

3 See Dornbusch et al. (2000) for a general discussion and a survey on contagion.

where m_t is the domestic money supply at time t, p is the price level, y is the real income, i is the nominal interest rate, e is the domestic price of foreign exchange, ε and v denote well-behaved shocks to money demand and to PPP respectively, and an asterisk indicates a foreign variable. All of the variables are expressed in logarithms apart from interest rates. Assuming a similar money-market equilibrium condition for the foreign country, one can subtract it from equation (2), and then substitute the result in the PPP equation. Solving for the exchange rate and interest rate differential, the result is:

$$e_t - \alpha(i - i^*)_t = (m - m^*)_t - \beta(y - y^*)_t - (\varepsilon - \varepsilon^*)_t - v_t \tag{4}$$

where domestic and foreign elasticities, α and β, are assumed to be equal. Equation (4) shows how a fixed exchange rate may give rise to a volatility trade-off with interest rates. In the short-run, the money supply, prices and real income are fixed, while exchange rates and interest rates may react to shocks to money demand (ε) or to PPP (v). If the exchange rate is fixed, then shocks make interest rates volatile; if the exchange rate fluctuates freely, then it can absorb these shocks without interest rate movements. In the longer run, the volatility trade-off may be extended to money and output fluctuations. Allowing for price rigidities, a sticky-price monetary model of the exchange rate produces similar results.

Nevertheless, the empirical evidence of Flood and Rose (1995 and 1999) proves that the variability of macroeconomic variables such as interest rates, money and output does not change across exchange rate regimes. As regards the trade-off between the exchange rate and interest rates, Artis and Taylor (1994) have demonstrated that the increased exchange rate stability for members of the European Exchange Rate Mechanism during 1979-1992 was not achieved at the expense of greater interest rate volatility. Actually, Bodart and Reding (1999) have shown that ERM members, by credibly fixing the exchange rate during the period 1989-1992, reduced bond market volatility with respect to the following turbulent period 1992-1994, when exchange rate and bond market volatility significantly increased. Finally, Hausmann et al. (1999) note that, during the turbulent period 1997-1998, Latin American countries with flexible exchange rates used interest rates very aggressively to defend their exchange rates and had larger movements in the domestic interest rates compared to Argentina and Panama, which had no exchange rate flexibility. Since the authors did not control for the degree of exchange rate volatility under floating rates, this piece of evidence could, at the same time, be used against the trade-off volatility hypothesis – interest rates did not react in Argentina and Panama – and supporting the same hypothesis – countries with floating rates had to accept greater interest rate volatility in order to limit exchange rate volatility. Overall, empirical evidence is not strongly supportive of the conventional view on volatility trade-off. This paper offers an original contribution to the debate, extending the empirical evidence to CEECs and identifying a priori the source of external turbulence – international interest rate volatility or emerging market volatility – which should give rise to the trade-off. Moreover, the above-mentioned studies used weekly or monthly data, while I use daily data, which should better describe the volatility of financial variables, such as interest rates and exchange rates, and capture the short-term nature of the trade-off.

3 Methodology and data

In this paper two lines of investigation have been explored in order to study the impact of external factors on interest rates and exchange rates in the three main financial markets in Central and Eastern Europe (CEE): the Czech Republic, Hungary and Poland.

First, following Edwards (2000) and Borensztein et al. (2001), I study the effect of external shocks, specifying for each country a Vector Auto Regression (VAR) model which includes: the domestic short-term interest rate; the natural logarithm of the exchange rate against the German mark; German interest rates; and a variable which represents the risk premium attached to emerging markets - the spread on an emerging-market bond index (see below). The VAR model captures the dynamic among the variables and presents the additional advantage of treating all of the variables as endogenous. Once the model has been specified, the inspection of impulse response functions will shed some light on the reaction of domestic variables to external shocks.

Second, I study the impact of the volatility of external factors on CEE financial markets, testing the hypothesis of "volatility contagion", i.e. I verify if German interest rate volatility or emerging-market volatility spilled over onto the volatility of short-term interest rates and exchange rates in the Czech Republic, Hungary and Poland. In a preliminary analysis, I examine whether the volatility of domestic variables shared a common pattern with the volatility of the external factors. Then, I specify a set of General Auto Regressive Conditional Heteroskedasticity (GARCH) models to describe the behaviour of first differences of interest rates and of exchange rate logarithms[4]. Finally, I formally test whether some indicators of volatility of German interest rates and returns on an emerging-market bond index can help in explaining the conditional variance of domestic variables, using an augmented GARCH as presented in Edwards (1998). The data set includes daily 3-month interbank interest rates in the Czech Republic (CZ3M), Hungary (HN3M)[5], Poland (PL3M) and Germany (GE3M) - where the latter represents the international benchmark rate - and daily spot exchange rates against the German mark for the Czech koruna (CZK), the Hungarian forint (HNF) and the Polish zloty (PLZ). All exchange rates are defined as the domestic currency spot price of the German mark. After the 1st of January 1999, exchange rates against the mark are recovered from spot exchange rates against the euro. Finally, the data comprehend the value and the corresponding spread of the J.P. Morgan EMBI+ bond index. This is a composite emerging-market bond index, which tracks total returns for traded external debt instruments in the emerging markets. The advantage of using this index is represented by the fact that neither Czech bonds nor Hungarian bonds are included, so that the impact of external factors is gauged by a variable – spreads or returns on the EMBI+ – that is not directly affected by the recipient countries. Polish bonds are instead included in the index, but their relative weight was less than five per cent in 1995. Considering that during the observation period none of the three CEECs was the source of a particular shock in the emerging markets, endogeneity problems should not represent an obstacle to the analysis. Data cover the period 1 August 1997 - 1 May 2001 for a total of 978 daily observations and were downloaded from Datastream, apart from the EMBI+ spread, which starts in 1998 and was downloaded from Bloomberg[6]. The choice of the sample period depends on the availability of data and on the possibility of contrasting three alternati-

[4] I use first differences to overcome the problem of regressions with non-stationary variables.

[5] The series of Hungarian interest rates has been corrected for various errors.

[6] Exactly, the data set begins on 1 July 1997, but observations in the first month were used to calculate some indicators of German interest rate and emerging-market volatility and then were excluded from calculations.

ve exchange rate regimes. Table 1 summarises the exchange rate arrangements adopted in the Czech Republic, Hungary and Poland since 1995. The 1997 koruna crisis roughly identifies the lower limit of the sample. At the end of May 1997 the Czech koruna was floated, after a successful speculative attack had forced Czech authorities to abandon the fixed peg regime, which was the centrepiece of Czech macroeconomic strategy since 1991, before the break-up from the Slovak Republic. Economic and econometric considerations suggested that the data coverage be up to May 2001, when Hungarian authorities widened the floating band of the forint from +/-2.25 percent to +/-15 percent, switching from a relatively rigid crawling peg to a more flexible crawling band[7]. Regressions for Poland terminate in mid-March 2000, in order to consider only the period when the crawling band regime was in place[8]. Consequently, the data cover the Asian crisis with its peak in October 1997, the Russian crisis spanning from August to September 1998, and the Brazilian crisis in January 1999. Within this sample, it will be possible to compare the behaviour of interest rates and exchange rates under a managed floating exchange rate system: the Czech Republic; a relatively flexible crawling band regime: Poland; and a more rigid crawling peg: Hungary. Capital flows were not fully liberalised during the sample period. Table 2 provides information on capital account liberalisation in these three countries. As of the end of 1997, the three CEECs had a similar degree of restriction on credit operations, but the Czech Republic had fewer controls on portfolio flows. According to the IMF Annual Report on Exchange Arrangements and Exchange Restrictions (1999), all of the three countries had controls on money market instruments at the end of January 1999.

[7] In fact, the volatility of the forint significantly increased after this structural change.

[8] Since the zloty was already floating in a comfortably large band before the change of regime on 12 April 2000, the announcement of the decision to float the currency provoked an increase in its volatility well before the institutional change took place. Polish regressions end in mid-March in order to exclude this turbulent period from the sample.

Table 1. Exchange rate regimes in the Czech Republic, Hungary and Poland, 1995- 2001

Date	Regime	Band	Monthly Devaluation	Basket
Czech Republic				
Since January 1993	Fixed	+/- 0.5%	NO	DM 65%, USD 35%
February 1996	Fixed	+/- 7.5%	NO	-
27 May 1997	Managed floating	NO	NO	NO
Hungary				
Since 16 March 1995	Crawling Peg	+/- 2.25%	1.9%	USD 30%, ECU 70%
29 June 1995	-	-	1.3%	-
02 January 1996	-	-	1.2%	-
01 January 1997	-	-	-	USD 30%, DM 70%
01 April 1997	-	-	1.1%	-
15 August 1997	-	-	1.0%	-
01 January 1998	-	-	0.9%	-
15 June 1998	-	-	0.8%	-
01 October 1998	-	-	0.7%	-
01 January 1999	-	-	0.6%	USD 30%, EUR 70%
01 July 1999	-	-	0.5%	-
01 October 1999	-	-	0.4%	-
01 January 2000	-	-	-	EUR 100%
01 April 2000	-	-	0.3%	-
01 April 2001	-	-	0.2%	-
04 May 2001	Crawling Band	+/- 15%	0.2%	-
Poland				
Since May 1995	Crawling Band	+/- 7%	1.2%	USD 45%, DM 35%, GBP 10%, FRF 5%, CHF 5%
December 1995	(6% revaluation)	-	-	-
January 1996	-	-	1.0%	-
26 February 1998	-	+/- 10%	0.8%	-
17 July 1998	-	-	0.65%	-
10 September 1998	-	-	0.5%	-
28 October 1998	-	+/- 12.5%	-	-
01 January 1999	-	-	-	EUR 55%, USD 45%
25 March 1999	-	+/- 15%	0.3%	-
12 April 2000	Free floating	NO	NO	NO

Source: National central banks.

Table 2. Exchange rate regime, monetary policy and capital controls in the CEEC-3

	Czech Republic	**Hungary**	**Poland**
Exchange rate regime [1]	Managed float with no pre-announced path for exchange rate	Fixed peg within a +/- 15% band	Independent float
Monetary policy framework [1]	Inflation targeting	Exchange rate anchor (Euro) and inflation targeting	Inflation targeting
Capital account liberalisation index [2]	*As of 31 December 1997*	*As of 31 December 1997*	*As of 31 December 1997*
- Controls on credit operations	62.5	75.0	75.0
- Controls on portfolio flows	70.0	33.3	35.0
- Overall index of liberalisation	73.7	59.5	55.3
Controls on [3]	*As of 31 January 1999*	*As of 31 January 1999*	*As of 31 January 1999*
- Capital market securities	YES	YES	YES
- Money market instruments	YES	YES	YES
- Collective investment securities	YES	YES	YES
- Derivatives and other instruments	NO	YES	YES
- Commercial credits	NO	NO	YES
- Financial credits	NO	YES	YES
- Guarantees and financial backup facilities	NO	YES	YES
- Direct investments	YES	YES	YES
- Liquidation of direct investments	NO	NO	NO
- Real estate transactions	YES	YES	YES
- Personal capital movements	NO	YES	YES
Controls on credit operations and portfolio flows. Major changes since 1998 [4]	1998. The Securities Commission Act entered into force, removing most restrictions on controls imposed by the previous Securities Law. 1999. Controls on foreign securities operations and in derivatives were eliminated. 2000. Prior authorisation for issuing debt securities abroad was eliminated.	1998. Issue of shares and bonds with maturity of more than one year, denominated in foreign exchange and issued by OECD-based enterprises, was liberalised. 2000. Credits and loans in foreign currency with a maturity of more than one year granted by residents to non-residents, were liberalised. 2001 Full convertibility of the forint introduced. Non-residents allowed to access short-term securities and currency derivatives.	1999 New foreign exchange law entered into force. The law differentiates between bank and non-bank entities. Banks can conduct some short-term capital transactions freely. Controls on financial derivatives listed on the Warsaw Stock Exchange were lifted. As of 2001, there were still restrictions on short-term capital movements.

1 According to the IMF classification of exchange rate regimes, see IMF International Financial Statistics, November 2001.
2 Temprano-Arroyo and Feldman (1999). The index ranges from 0 to 100, where 100 = full liberalisation.
3 IMF Annual Report on Exchange Arrangements and Exchange Restrictions (1999).
4 IMF Annual Report on Exchange Arrangements and Exchange Restrictions (1999) and European Commission November 2000 and November 2001 Regular Reports on progress towards accession.

4 The impact of external shocks on interest rates and exchange rates. VAR analysis.

Figure 1 plots interest rates and exchange rates in the three CEECs over the period mid-1997 – mid-2001. The three vertical lines in the charts correspond to large falls in the EMBI+ bond index and identify the major emerging market financial crises: the drop in the Hong Kong stock market, the Russian devaluation and the Brazilian devaluation. In the Czech Republic, these crises coincided with the sharp depreciation of the koruna against the German mark, while interest rates seemed to react after the Asian crisis and shortly after the devaluation of the Russian rouble. The 1998 Russian crisis had the most remarkable impact on Hungarian interest rates, which rose from 16 percent in mid-August to 20 percent at the end of September that same year. Note that the increase in Hungarian interest rates took place well after the beginning of the Russian crisis in mid-August 1998, which, however, caused turbulence in the emerging financial markets for a long period, until the end of September. The explanation of this apparently long lag between the outset of the crisis and the interest rate reaction may be found in the nature of the Hungarian exchange rate regime. Before the beginning of the Russian financial turmoil, the Hungarian forint was on the strong edge of its narrow fluctuation band. The Russian crisis coincided with an increase in the rate of depreciation of the forint, which quickly reached the weak edge of the fluctuation band. Hence, the rise in interest rates may reflect the successful intervention of Hungarian monetary authorities to defend the peg of the forint[9]. In Poland, interest rates did not show any unusual reaction in correspondence with emerging market financial crises, apart from a steep decline after the Brazilian crisis. In contrast, large devaluations of the Polish zloty approximately coincided with the three major crises.

The purpose of the VAR analysis is to model the behaviour of domestic interest rates and nominal exchange rates and detect the impact of external shocks on these variables. For each country, I estimated a VAR model including domestic 3-month interest rates, the logarithm of the nominal exchange rate against the DM, 3-month German interest rates (GE3M) and the spread on the EMBI+ bond index (EMSPR). Since the latter variable is only available starting from January 1998, the impact of the 1997 Asian crisis is not considered in these regressions. A specification with 11 lags was used to eliminate serial correlation in the residuals. In order to identify the impulse responses, errors were orthogonalised by a Cholesky decomposition assuming the following order of variables: German interest rates, the EMBI+ spread, the domestic interest rate and the logarithm of the exchange rate. Figure 2 shows the set of impulse response functions with respect to a one percentage point German interest rate shock. First, it is worth noting that the impact of a German interest rate shock to itself reaches its peak after two weeks and is highly persistent. Second, the estimated impact effect on interest rates is always positive but never significantly different from zero, confirming that interest rates in the three CEECs are not affected by German rates. Finally, the reaction of nominal exchange rates to German interest rate shocks is also not significant.

Impulse responses to a one percentage point shock to the EMBI+ spread – in Figure 3 – present a more interesting picture. Impulse responses of the EMBI+ spread with respect to shocks to itself show that these shocks are persistent and still significantly different from zero after two months in two of the three regressions. Moreover, the reaction of the EMBI+

[9] See Darvas and Szapary (1999) for a detailed account of the intervention carried out by the National Bank of Hungary during the Russian crisis.

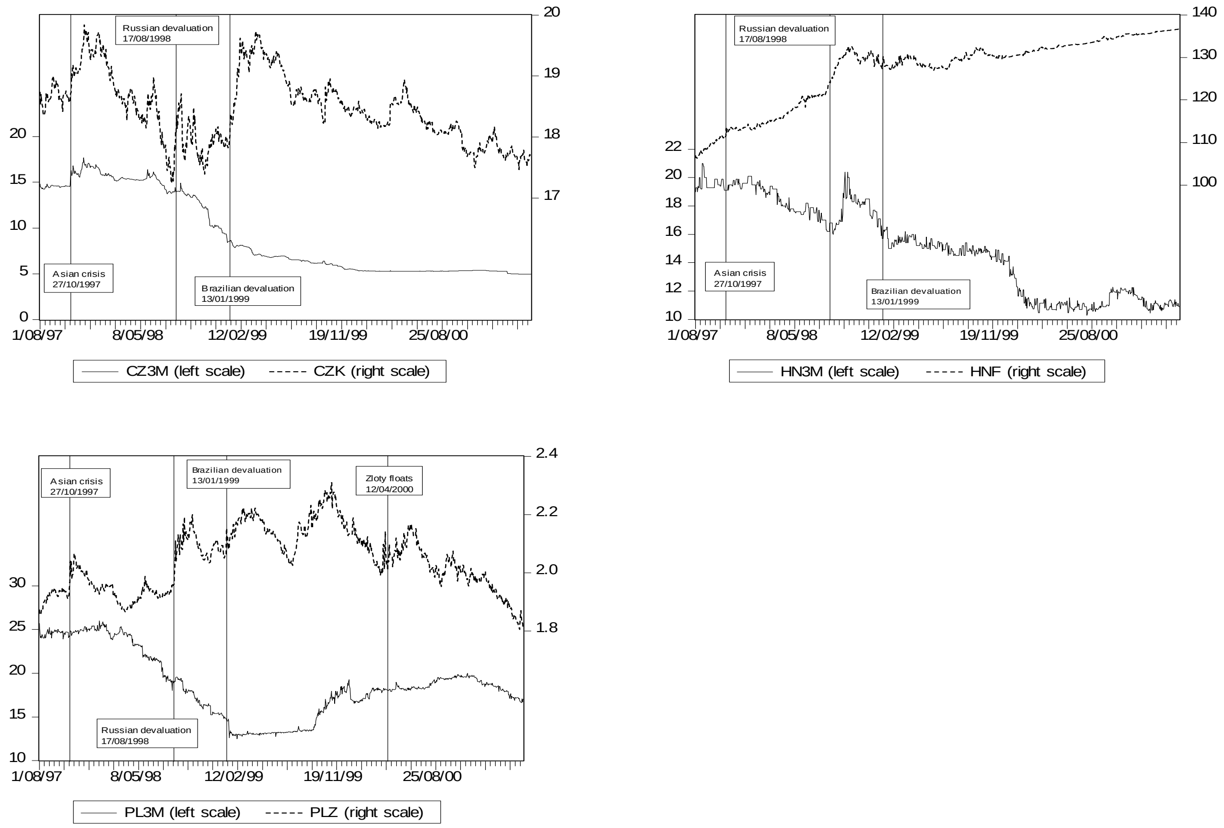
to its shock is particularly noisy, displaying some overshooting after two weeks. This noise is reflected in the corresponding impulse responses of the other variables.

Impact effects on interest rates and exchange rates in the three CEECs generally confirm the findings of the previous descriptive analysis. Note that interest rates react to emerging-market risk premia shocks in a different way. In the Czech Republic, there is a significant positive response of interest rates to the shock over the first two weeks; nevertheless the pass-through is rather small, around 7-8 basis points with respect to a 100 basis-point shock to the EMBI+ spread. The impact on Hungarian interest rates is the largest among the three countries, with a pass-through of around 30 basis points for a 100 basis-point shock. It is interesting to note that the impact on Hungarian interest rates becomes significant after one month, capturing the long lag in the reaction after the Russian crisis, and is strongly persistent. In Poland, instead, interest rates do not significantly react to emerging market risk premia shocks.

All of the three exchange rates show a significant positive response to EMBI+ shocks. The largest impact of these shocks is on the Polish zloty, which devalues by almost one percent in response to a one percentage point innovation in the EMBI+ spread. The reaction of the Czech koruna is quantitatively lower, with a peak of a 60 basis-point depreciation for a 100 basis-point shock, and tends to decay fast. The reaction of the Hungarian forint seems to be influenced by its regime, a narrow crawling band, and by domestic interest rate response to emerging-market shocks. Both factors tend to build up the effect of external shock over time, producing a high persistence of these shocks on the Hungarian exchange rate.

Summing up, the analysis in this paragraph produces a blurred picture of the trade-off between interest rates and exchange rates. On the one hand, Hungary and Poland confirm the conventional view about the trade-off. Hungary – which had the most rigid exchange rate regime – showed the largest interest rate reaction, while the exchange rate in Poland – which fluctuated in a quite wide band – absorbed external shocks, insulating interest rates. On the other hand, the Czech Republic does not offer the same support for the role of a floating exchange rate as shock absorber. In fact, the Czech koruna significantly reacts to emerging market risk premia shocks, but seems to be unable to insulate domestic interest rates completely.

Figure 1. Interest rates and nominal exchange rates in the Czech Republic, Hungary and Poland. Levels. (Daily: 01/08/1997-01/05/2001)



Notes: 3-month interbank interest rates (percentages) in the Czech Republic (CZ3M), Hungary (HN3M) and Poland (PL3M) and nominal exchange rates (domestic currency units per German mark) for the Czech koruna (CZK), the Hungarian forint (HNF) and the Polish zloty (PLZ).

Figure 2. Impulse response functions: innovations +/- 2 standard errors. Impact on interest rates and exchange rates (logs) of percentage point shock to German interest rates (GE3M). Czech Republic and Hungary: 05/01/1998 – 01/05/2001, Poland: 05/01/1998 - 24/03/2000

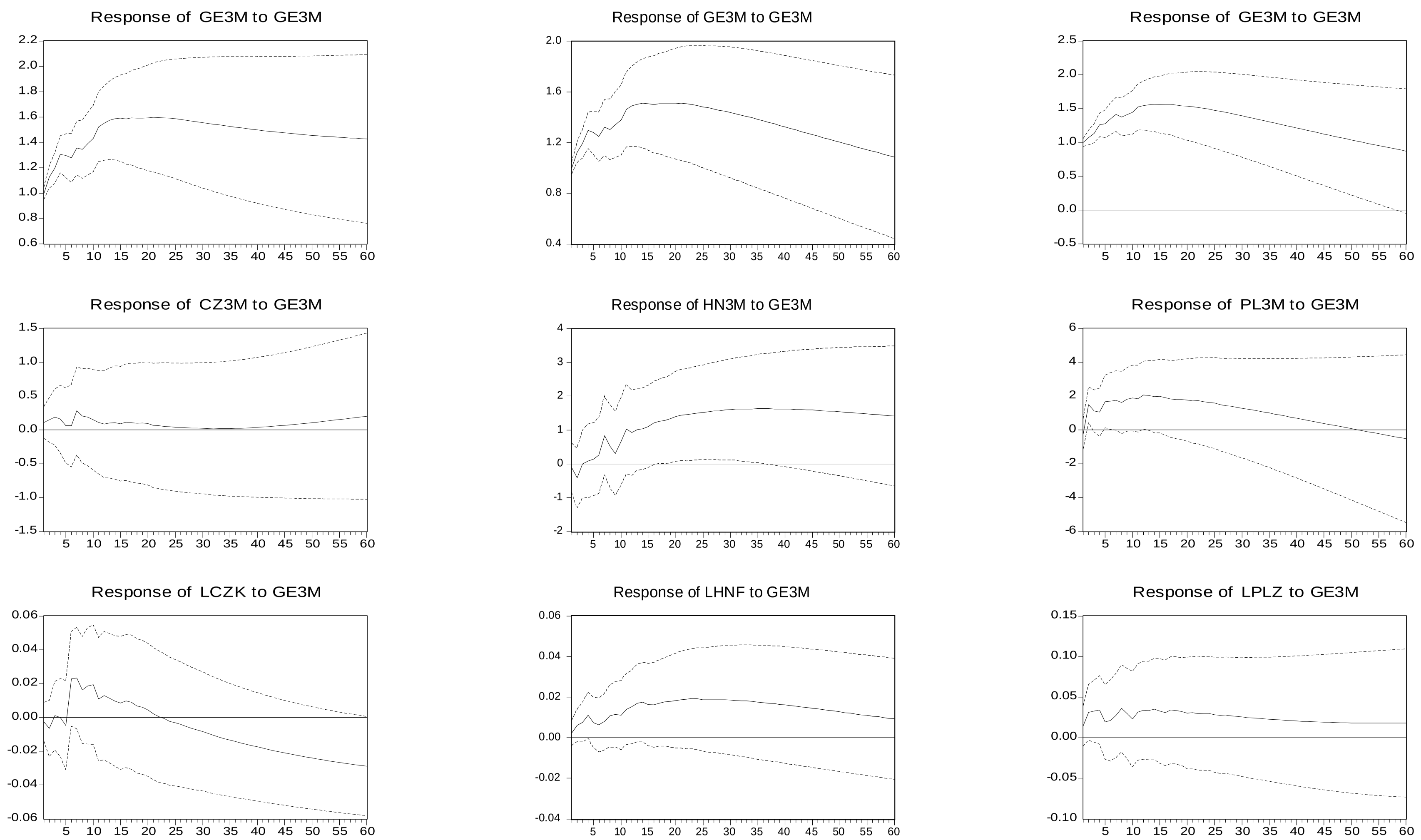
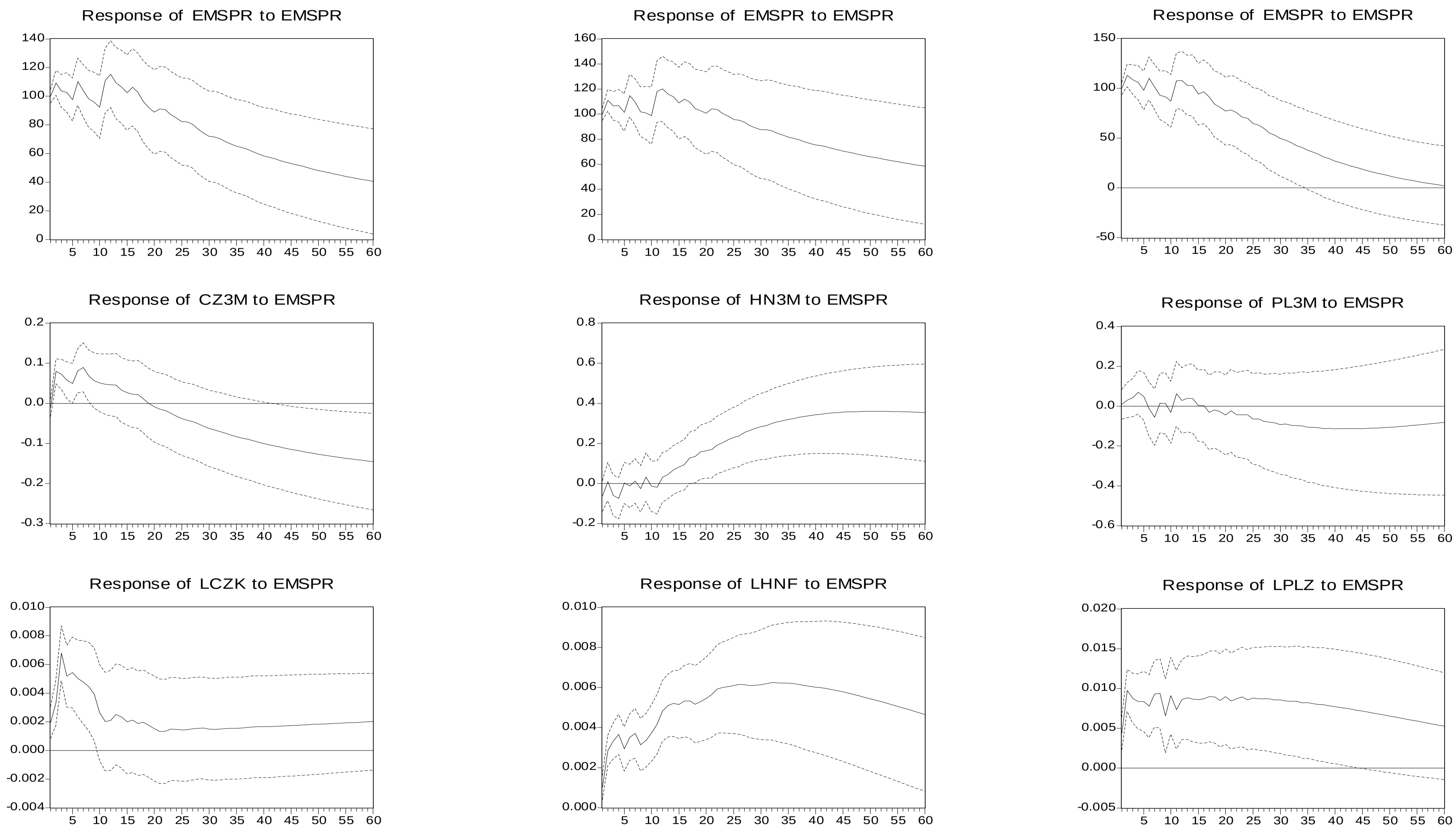


Figure 3. Impulse response functions: innovations +/- 2 standard errors. Impact on interest rates and exchange rates (logs) of 100 basis point shock to emerging market risk premia (EMSPR). Czech Republic and Hungary: 05/01/1998 - 01/05/2001, Poland: 05/01/1998 - 24/03/2000



5 Volatility contagion. A preliminary analysis

In this section, I extend the previous analysis, considering the effect of the volatility of external factors – such as German interest rates and emerging financial markets – on the volatility of domestic interest rates and exchange rates, investigating whether there is any correlation between the volatility of these external factors and the volatility of domestic variables. The previous analysis showed that, in some cases, external shocks may have a significant impact and a different degree of persistence on interest rates and exchange rates in the three CEECs. The high persistence of shocks depends on the statistical properties of interest rates and exchange rates. If the variables are stationary, shocks to them are temporary and will decay; if the variables are instead nonstationary, shocks will persist through time. Moreover, it is important to remember that a stationary series has a finite time-invariant variance, while a nonstationary series has a time-dependent variance that goes to infinity as time approaches infinity[10].

Table 3 reports the results of the Dickey-Fuller or Augmented-Dickey-Fuller test for levels and first differences of interest rates and logarithms of exchange rates in the CEECs. As one would expect, exchange rates are not stationary and integrated of order one. Interest rates in Hungary and Poland are also non-stationary, while in the Czech Republic it is possible to reject the null hypothesis of a unit-root at a five percent level of significance.

Table 3. Interest rates and exchange rates. Unit root tests.

	Interest rates			Exchange rates (logs)		
	Czech Rep.	Hungary	Poland(1)	Czech Rep.	Hungary	Poland(1)
Levels						
Test	ADF	ADF	ADF	DF	ADF(α)	ADF
β	-0.00090	-0.00115	-0.00093	-2.36E-05	-0.00306	1.02E-04
t-statistic	-2.43772*	-1.64913	-1.74162	-0.46342	-2.51282	0.26083
First Differences						
Test	ADF	ADF	ADF	DF	ADF(α)	ADF
β	-0.77691	-1.66234	-1.41785	-1.03718	-1.01885	-1.29957
t-statistic	-8.15164**	-17.6090**	-23.8903**	-32.4435**	-8.58236**	-11.2304**

Notes: Table reports results of unit root tests of interest rates and logarithms of exchange rates in the Czech Republic, Hungary and Poland. DF(α) is the Dickey-Fuller test: $\Delta x_t = \alpha + \beta x_{t-1} + \varepsilon_t$. ADF(α) is the Augmented Dickey-Fuller test, which was used when residuals presented serial correlation: $\Delta x_t = \alpha + \beta x_{t-1} + \Sigma p_{i=1} \gamma_i \Delta x_{t-i} + \varepsilon_t$. Δ is the first difference operator, ε_t is an independent and normally distributed innovation. (α) indicates that a constant was included in the regressions. There was no significant deterministic trend in the series. (*) Denotes rejection of the null hypothesis: $\beta = 0$ at a 5% significance level. (**) Denotes rejection of the null hypothesis: $\beta = 0$ at a 1% significance level. Sample: 01/08/1997 – 01/05/2001. (1) Sample: 01/08/1997 – 24/03/2000.

[10] See Enders (1995).

These results suggest that is more convenient to continue the analysis of volatility working with the first differences of the variables, calculating daily first differences of interest rates in the Czech Republic (DCZ3M), in Hungary (DHN3M) and in Poland (DPL3M), and daily changes in the logarithm of the exchange rate for the Czech koruna (CZKRTN), the Hungarian forint (HNFRTN) and the Polish zloty (PLZRTN).

Figure 4 plots the first differences of interest rates and logarithms of exchange rates. The figure shows that the volatility of all variables changes over time. As in the previous section, three vertical lines identify the emerging-market financial crises. It is possible to note that, in some cases, especially for exchange rate returns, large movements in the variables follow the crises.

Table 4 reports the sample standard deviation of the variables. The sample has been split in two sub-samples in order to isolate the period of major financial turbulence in the emerging markets – from July 1997 to March 1999 when the impact of the Brazilian crisis fades away – from the more tranquil subsequent period, and check for major changes between the two sub-periods. As regards the comparison of volatility across countries, Hungarian interest rates present the highest volatility, while Czech interest rates are the least volatile, suggesting a potential positive role for the flexible exchange rate regime in stabilising interest rates. As expected, the Hungarian forint has the lowest volatility, and – quite surprisingly – the Polish zloty is more volatile than the Czech koruna. This result indicates that, in practice, it could be extremely difficult to distinguish between the behaviour of the exchange rate under a crawling band regime and under a managed float[11]. Apart from the Polish exchange rates, all of the variables exhibit greater volatility in the first sub-period compared to the following period. The presence of emerging-market 'volatility contagion' might be an explanation of this result. The volatility of the Polish zloty is approximately similar in the two sub-periods, but it is worth noting that the switch to the floating regime during the second sub-period is associated with an increase in volatility (see Figure 4).

[11] Note that the whole sample includes the floating of the zloty since April 2000; however, the volatility of the zloty is higher than the volatility of the Czech koruna in the first sub-sample, when in Poland the currency regime was a crawling band.

Table 4. Sample standard deviations of interest rates (first differences) and exchange rates (daily returns) in the CEECs.

Sample	DCZ3M	DHN3M	DPL3M	CZKRTN	HNFRTN	PLZRTN
01/08/97-01/05/01	0.1160	0.2957	0.2521	0.4649	0.2586	0.8024
01/08/97-31/03/99	0.1717	0.3313	0.2905	0.6006	0.3496	0.7904
01/04/99-01/05/01	0.0246	0.2642	0.2154	0.3175	0.1492	0.8112

In order to understand the behaviour of interest rate and exchange rate volatility over time and contrast it with that of the volatility of external factors, I calculated the sample standard deviation for each variable in four-week centred rolling windows over the whole sample. As terms of comparison, I calculated the same statistics for first differences of German interest rates (DGE3M) and daily changes in the logarithm of the EMBI+ bond index (EMRTN).

Figure 5 contrasts the volatility of domestic interest rates with the volatility of German rates and the volatility of the EMBI+ index. The vertical line separates the two sub-periods of high and low emerging-market financial turbulence, while the three large peaks in the EMBI+ index identify the financial crises. Some of the peaks in Czech interest rate volatility roughly coincide with peaks in the volatility of the EMBI+ bond index, while other charts do not display any clear common pattern among the variables. Figure 6 shows a similar comparison between the volatility of external factors and exchange rates. The volatility of the Czech and the Polish exchange rate seems to increase in correspondence to the emerging market financial crises. This correspondence is particularly suggestive in the case of the Polish zloty. Note also that the Czech koruna shares a peak in volatility with German interest rates in the second sub-period.

A simple way to quantify the degree of co-movement among the volatility of these variables is to calculate their correlation. Table 5 reports correlation coefficients between domestic and external indicators of volatility, which confirm the results of the inspection of volatility charts. The highest positive correlations are between PLZRTN and EMRTN (0.75), CZKRTN and EMRTN (0.63), and DCZ3M and EMRTN (0.66). Correlation coefficients between domestic variables and the emerging-market bond index are always positive in the whole sample and in the first sub-period, which include the three crises. In contrast, the second sub-period exhibits much lower, or negative, correlation coefficients. The correlation coefficient between the volatility of the Polish zloty and the volatility of the EMBI+ bond index is particularly high in the first sub-sample (0.92). Results including benchmark German rates are quite different. German interest rate volatility is often negatively correlated with the volatility of interest rates and exchange rates in the three CEECs. Even when German correlation coefficients are positive, they are quite low, apart from the coefficient with the Czech koruna in the second sub-period (0.51).

Table 5. Volatility of interest rates (first differences) and exchange rates (daily returns) in the Czech Rep., Hungary and Poland. Correlation with the volatility of German interest rates (first differences) and the EMBI+ bond index (daily returns).

Sample		DCZ3M	DHN3M	DPL3M	CZKRTN	HNFRTN	PLZRTN
01/08/1997 -	DGE3M	-0.1406	-0.1745	-0.0396	-0.0911	-0.0669	0.0578
16/04/2001	EMRTN	0.6566	0.2285	0.1535*	0.6320	0.4273	0.7462*
Subs. 1							
01/08/1997 -	DGE3M	0.0540	-0.0327	-0.1530	-0.2832	0.2816	0.0023
31/03/1999	EMRTN	0.5417	0.1931	0.2295	0.6712	0.3212	0.9150
Subs. 2							
01/04/1999 -	DGE3M	0.2782	-0.2540	0.2057	0.5130	-0.0015	0.0583
16/04/2001	EMRTN	0.0970	-0.0971	-0.5785**	0.1189	0.2998	-0.6738**

*01/08/1997 –15/03/2000. **01/04/1999-15/03/2000
Volatility is calculated as the standard deviation of the variables in 4-week centred rolling windows.

Overall, these results provide some support for the hypothesis of volatility contagion coming from emerging markets. In contrast, it is difficult to detect any significant impact of the volatility of benchmark German rates on the volatility of domestic interest rates and exchange rates. In order to make this conclusion robust, I formally test the hypothesis of volatility contagion with an augmented GARCH model in the next section.

Figure 4. Interest rates and natural logarithm of nominal exchange rates against the DM. First differences. Czech Republic, Hungary and Poland: 01/08/1997 – 01/05/2001.

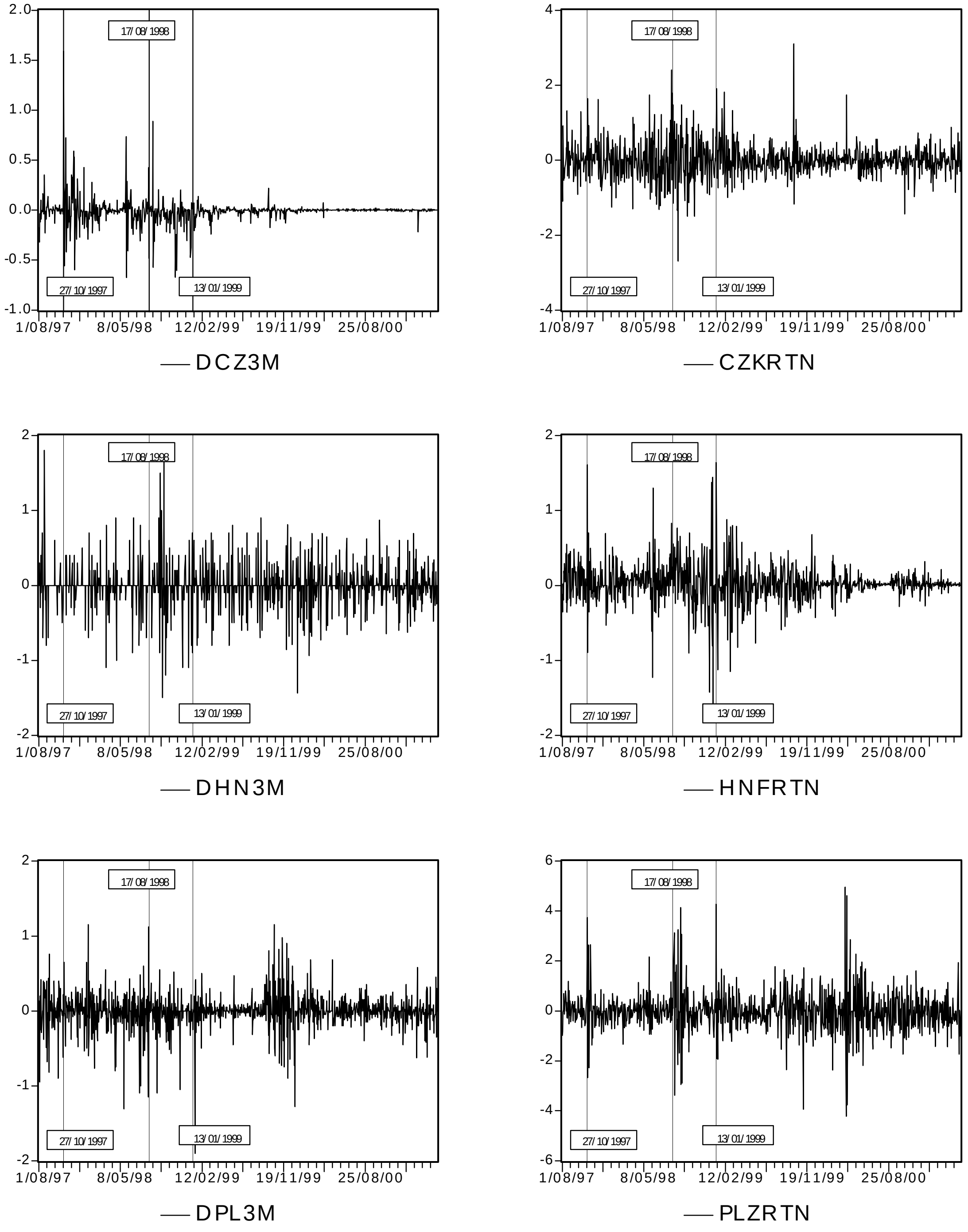
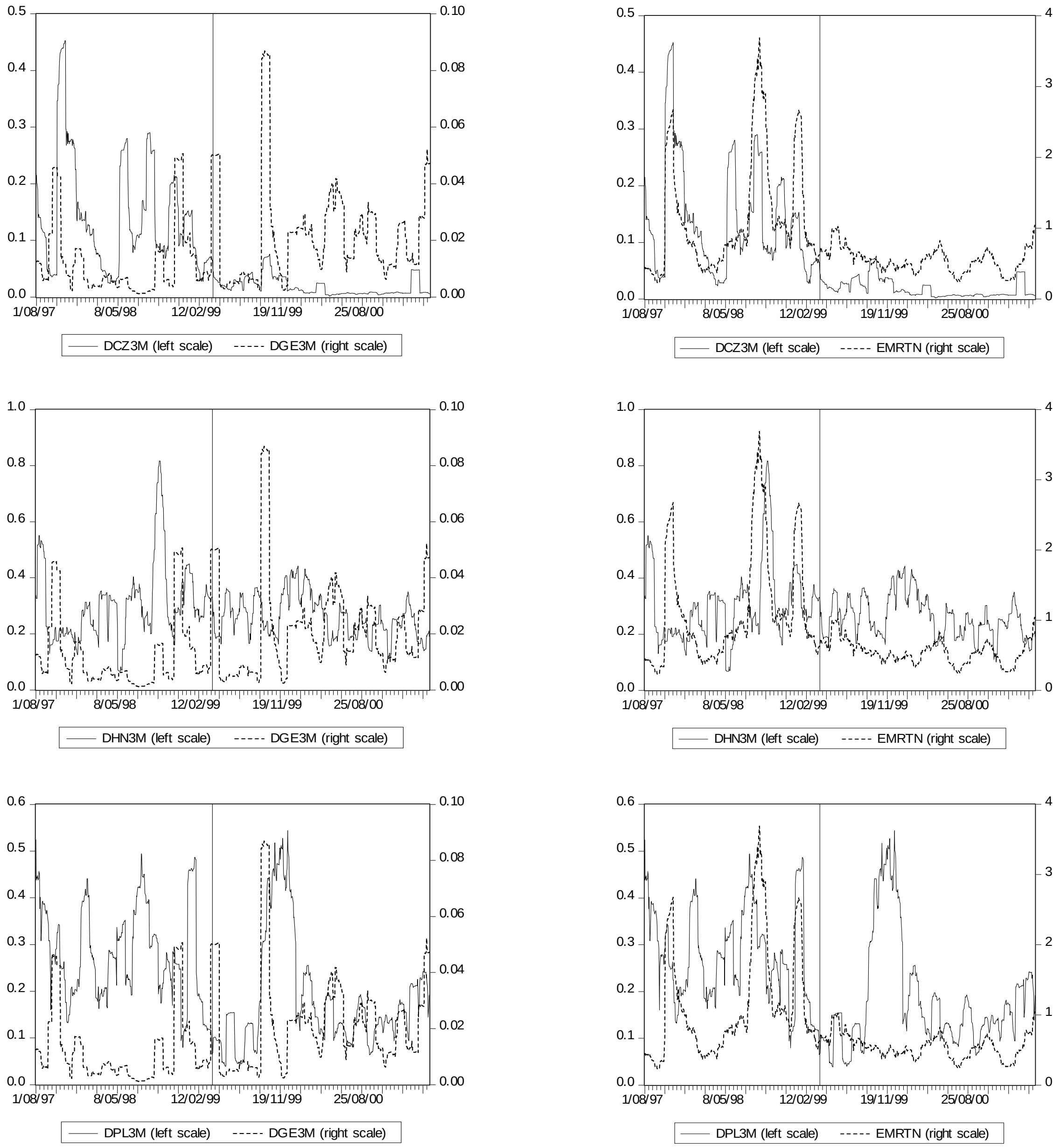
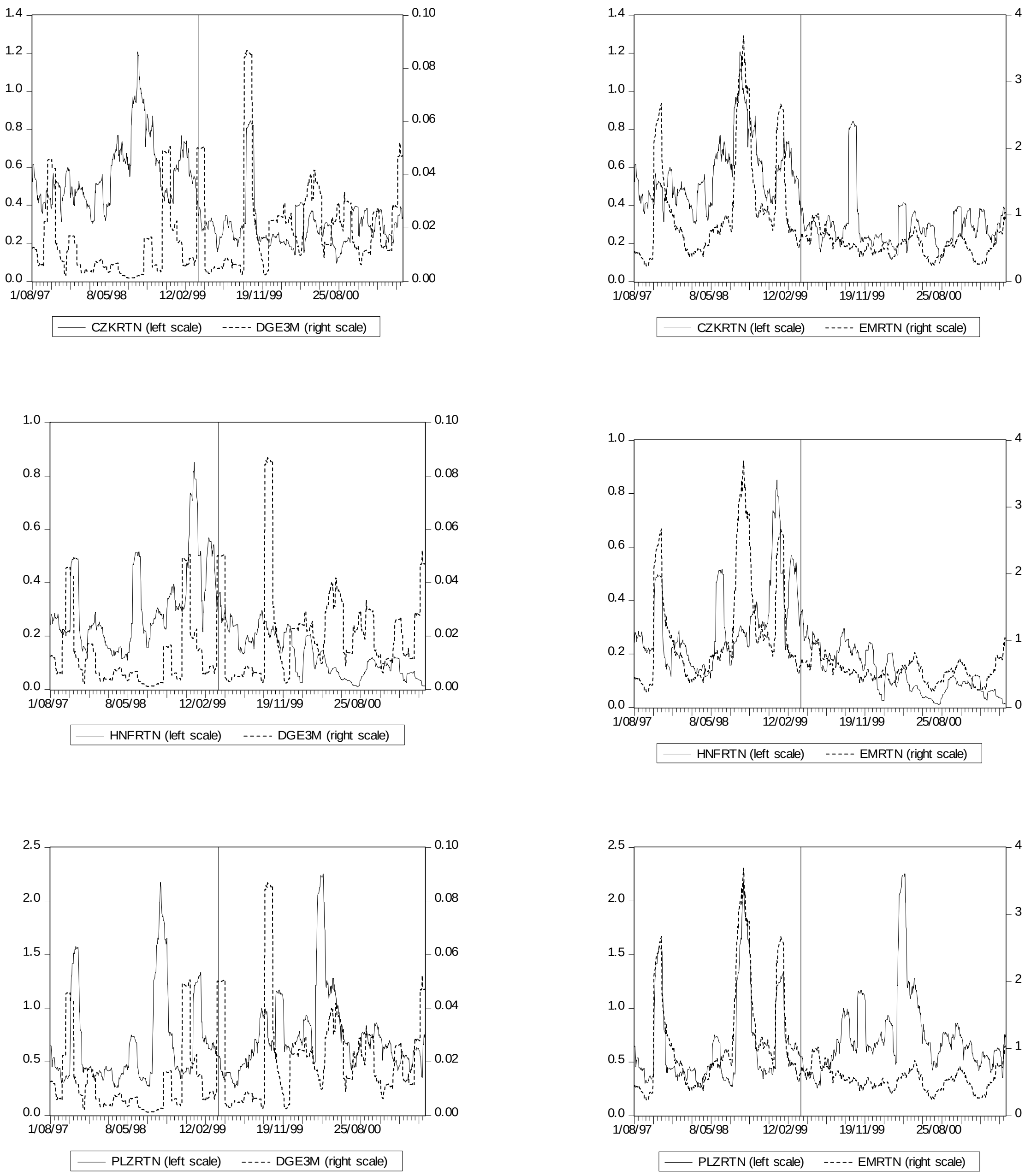


Figure 5. Volatility of interest rates in the Czech Rep. Hungary and Poland. Comparison with the volatility of German interest rates and volatility of daily returns on the EMBI+. Daily: 01/08/1997-16/04/2001.



Notes. Volatility of the first differences of 3-month interbank interest rates in the Czech Republic (DCZ3M), Hungary (DHN3M) and Poland (DPL3M) against the volatility of first differences of comparable interest rates in Germany (DGE3M) and against the volatility of daily returns on the EMBI+ emerging market bond index (EMRTN). Volatility is calculated as a 4-week centred rolling windows sample standard deviation.

Figure 6. Volatility of daily exchange rate returns in the Czech Republic, Hungary and Poland. Comparison with the volatility of German interest rates and the volatility of daily returns on the EMBI+. Daily: 01/08/1997 – 16/04/2001.



Notes. Volatility of daily returns on nominal exchange rates against the DM in the Czech Republic (CZKRTN), Hungary (HNFRTN) and Poland (PLZRTN) against the volatility of first differences of 3-month interbank interest rates in Germany (DGE3M) and against the volatility of daily returns on the EMBI+ emerging market bond index (EMRTN). Volatility is calculated as a 4-week centred rolling windows sample standard deviation.

6 Testing for volatility contagion. A GARCH model of interest rates and exchange rates

The fact that high frequency financial data exhibit volatility clustering is widely recognised by a large body of empirical studies. One of the most popular models that allows us to capture the time-varying nature of second-order moments is the GARCH model developed by Bollerslev (1986), following the seminal work of Engle (1982). One of the most attractive characteristics of the GARCH model is its versatility, since the model is able to deal with different financial time series such as stock prices, interest rates and exchange rates[12]. In this study, versatility is particularly useful, since I want to model and compare the time-varying volatility of *both* interest rates and exchange rates, testing for the significance of additional regressors in the conditional variance equation. The following GARCH (p,q) model was estimated by using the Quasi-Maximum-Likelihood method, computing Bollerslev-Wooldrige robust standard errors[13]:

(5) $$y_t = c_0 + \sum_{1}^{m} c_m y_{t-m} + \varepsilon_t$$

(6) $$\varepsilon_t \mid I_{t-1} \sim N(0, \sigma_t^2)$$

(7) $$\sigma_t^2 = \alpha_0 + \sum_{1}^{q} \alpha_q \varepsilon_{t-q}^2 + \sum_{1}^{p} \beta_p \sigma_{t-p}^2 + \gamma VOL_t$$

where y_t represents the first differences of daily interest rates or the first differences of the logarithm of daily exchange rates in the three CEECs at time t; ε_t is the innovation the conditional distribution of which, given the information set I_{t-1} at time $t-1$, is distributed as a normal with zero mean and time-varying conditional variance σ_t. The exogenous regressor VOL_t in the conditional variance equation refers to indicators of German interest rate volatility or indicators of emerging-market volatility. The estimation of coefficient γ should capture the effect of these external factors on the conditional variance of y_t. The hypothesis of 'volatility contagion' will be accepted if the coefficient γ is positive and significantly different from zero. The following exogenous regressors have been included in the conditional variance:

The estimated conditional variance from a GARCH(0,1) model of first differences of German interest rates (GEVOL1).

The sample variance of first differences of German interest rates, computed over rolling windows through the four weeks preceding time t (GEVOL2).

[12] See Bollerslev et al. (1992) for a review of the theory and empirical evidence using GARCH models in finance.

[13] Before performing the estimation of the GARCH model, I estimated equation (5) for each variable by ordinary least squares in order to check for the presence of heteroskedasticity in the residuals. Ljung-Box Q-statistics rejected the null hypothesis of no autocorrelation in the squared residuals at conventional levels, confirming the presence of heteroskedasticity in all of the series, except for Polish interest rates. However, the first differences of Polish 3-month interest rates display some volatility clustering (see Figure 4). Moreover, the absence of heteroskedasticity was dependent on the choice of the sample. For this reason, I estimated the GARCH model for this variable too and reported the results when GARCH coefficients (α and β) were significantly different from zero.

The estimated conditional variance from a GARCH(0,4) model of daily returns on the EMBI+ bond index (EMVOL1).

The sample variance of daily returns on the EMBI+ bond index, computed over rolling windows through the four weeks preceding time t (EMVOL2).

A first set of estimations - over the whole sample period and over the two sub-periods identified in the previous section - included the two indicators of German interest rate volatility. Detailed results are reported in the appendix (see Tables A1-A3). Estimated coefficients of the two exogenous regressors were often negative, and positive estimated coefficients were never significantly different from zero at the five percent level. Therefore it can be safely concluded that German interest rate volatility did not have any remarkable impact on the volatility of interest rates and exchange rates in the three CEECs.

A second set of estimations included the variables that capture emerging financial market volatility. Coefficient estimates of the variables EMVOL1 and EMVOL2 are reported in Table 6 and the main interesting results can be summarised as follows.

First, coefficients of the indicators of emerging-market volatility are always positive when estimated over the entire period and over the first sub-period (August 1997 – March 1999), which isolates the three emerging market financial crises.

Second, the impact of emerging financial market volatility on domestic interest rates is not statistically significant, since coefficients are not significantly different from zero at the five percent level. Only Czech interest rates seem to be slightly affected by the emerging market crises, since the hypothesis of 'volatility contagion' cannot be rejected at the ten percent level of significance in the first sub-sample. Note that the GARCH model of Czech interest rates confirms the result in the previous section and is in line with the analysis of external shocks in section 4.

Third, the results provide substantial evidence of transmission of emerging-market volatility on foreign exchange markets in the three CEECs. Regression results for the Czech koruna and the Polish zloty are clear-cut. Both exogenous regressors, EMVOL1 and EMVOL2, are positive and significantly different from zero at the one percent level in the first sub-period, while they are negative or not significant in the following sub-period. This result, which supports the findings of the descriptive analysis in the previous section, proves that the Czech koruna and the Polish zloty were subject to 'volatility contagion' caused by the financial turbulence in the emerging markets during the period 1997-1999. The Hungarian forint was also significantly affected by emerging market volatility. The two indicators of volatility of the EMBI+ bond index are significant in the regressions over the entire sample and over the second more tranquil sub-period. This outcome is puzzling, since one would instead expect a significant impact of emerging volatility during the turbulent period, and might be due to a spurious correlation between the forint and the emerging-market volatility.

Finally, in several regressions the sum of the GARCH coefficients (α and β) was close to one, implying high volatility persistence. When this sum is equal to one, the GARCH process is defined as Integrated in variance, or IGARCH. The presence of a high degree of persistence in GARCH models is a common feature of many financial time series. Some authors, such as Diebold (1986) and Lamourex and Lastrapes (1990), suggest that the presence of IGARCH effects may be caused by the misspecification of the variance equation, which would fail to capture structural shifts. Table 6 reports statistics of the Wald test for the presence of an IGARCH process in the estimations. It is worthwhile noting that – excluding regressions for the Hungarian forint – when the indicators of emerging-market volatility are significantly positive, the null hypothesis of an IGARCH process is rejected at the usual level of significance, providing robustness to the augmented-GARCH specification.

Table 6. Coefficient estimates of the regressors EMVOL1 and EMVOL2 in the conditional variance of a GARCH (p,q) model of daily interest rates (first differences) and daily exchange rates (returns).

Main sample: Czech Republic and Hungary: 01/08/1997-01/05/2001.
Poland: 01/08/1997- 4/03/2000

Variable	DCZ3M		DHN3M		DPL3M		CZKRTN		HNFRTN		PLZRTN	
Model	Garch(1,1)		Garch(1,1)		Garch(1,1)		Garch(1,1)		Garch(1,1)		Garch(1,1)	
EMVOL1	0.0005	-	0.0014	-	0.0032	-	**0.0121**	-	**0.0023**	-	0.0531	-
	(0.1686)	-	*(0.2574)*	-	*(0.3307)*	-	***(0.0273)***	-	***(0.0095)***	-	*(0.2934)*	-
EMVOL2	-	0.0010	-	0.0019	-	0.0023	-	**0.0101**	-	**0.0033**	-	0.0704
	-	*(0.1611)*	-	*(0.2791)*	-	*(0.4927)*	-	***(0.0482)***	-	***(0.0191)***	-	*(0.3024)*
$\alpha_1+\beta_1$	1.1304	1.1076	0.8094	0.7902	0.8485	0.8141	0.9210	0.9137	1.0057	1.0066	0.8267	0.7204
IGARCH	2.3787	1.4151	2.4744	2.0604	4.8855	4.1736	6.1473	4.8822	0.0904	0.0712	2.8964	2.3738
	(0.1230)	*(0.2342)*	*(0.1157)*	*(0.1512)*	*(0.0271)*	*(0.0411)*	*(0.0132)*	*(0.0271)*	*(0.7637)*	*(0.7896)*	*(0.0888)*	*(0.1234)*

Subsample 1: Czech Republic, Hungary and Poland: 01/08/1997 – 31/03/1999.

Variable	DCZ3M		DHN3M		DPL3M		CZKRTN		HNFRTN		PLZRTN	
Model	Garch(1,1)		Garch(1,1)				Garch(0,2)		Garch(1,1)		Garch(0,1)	
EMVOL1	**0.0019**	-	0.0007	-			**0.0487**	-	0.0012	-	**0.2307**	-
	(0.0706)	-	*(0.4847)*	-			***(0.0005)***	-	*(0.4278)*	-	***(0.0000)***	-
EMVOL2	-	**0.0047**	-	0.0010			-	**0.0478**	-	0.0008	-	**0.1712**
	-	***(0.0508)***	-	*(0.4566)*			-	***(0.0004)***	-	*(0.4156)*	-	***(0.0000)***
$\Sigma\alpha+\Sigma\beta$	0.7924	0.7777	0.8472	0.8373			0.1886	0.2051	0.9649	0.9714	0.1270	0.2383
IGARCH	4.9581	3.5327	1.5127	1.4710			92.508	85.777	0.4403	0.2819	158.72	127.78
	(0.0260)	*(0.0602)*	*(0.2187)*	*(0.2252)*			*(0.0000)*	*(0.0000)*	*(0.507)*	*(0.5954)*	*(0.0000)*	*(0.0000)*

Notes*:* Polish short-term interest rates did not present heteroskedasticity within this sample.

Subsample 2: Czech Republic and Hungary: 01/04/1999-01/05/2001. Poland: 01/04/1999-24/03/2000.

Variable	DCZ3M		DHN3M		DPL3M		CZKRTN		HNFRTN		PLZRTN	
Model	Garch(1,1)		Garch(1,1)		Garch(1,1)		Garch(1,1)		Garch(1,1)		Garch(1,1)	
EMVOL1	0.0008	-	0.0031	-	0.0026	-	0.0753	-	**0.0023**	-	-0.0345	-
	(0.2014)	-	*(0.6013)*	-	*(0.3655)*	-	*(0.1064)*	-	***(0.0279)***	-	*(0.0000)*	-
EMVOL2	-	-0.0003	-	-0.0087	-	0.0028	-	0.0121	-	**0.0035**	-	-0.1787
	-	*(0.0829)*	-	*(0.4497)*	-	*(0.6478)*	-	*(0.3264)*	-	***(0.0354)***	-	*(0.0132)*
$\alpha_1+\beta_1$	0.7584	0.8481	0.6707	0.6837	1.0616	1.0582	0.4634	0.8304	0.9970	0.9843	0.9694	0.7294
IGARCH	1.5254	0.4892	4.1502	4.3477	1.3048	1.4248	8.0173	0.6290	0.0139	0.2978	3.6132	3.4252
	(0.2168)	*(0.4843)*	*(0.0416)*	*(0.0371)*	*(0.2533)*	*(0.2326)*	*(0.0046)*	*(0.4277)*	*(0.9061)*	*(0.5852)*	*(0.0573)*	*(0.0642)*

Notes: The tables report coefficient estimates of the exogenous regressor EMVOL in the conditional variance of a Garch(p,q) model of daily 3-month interbank interest rates (first differences) in the Czech Rep. (DCZ3M), Hungary (DHN3M) and Poland (DPL3M); and daily foreign exchange returns (Δlogs of spot exchange rates) in the Czech Rep. (CZKRTN), Hungary (HNFRTN) and Poland (PLZRTN). IGARCH is a Wald test for the null hypothesis: $\Sigma\alpha+\Sigma\beta=1$, the statistic is distributed as $\chi^2_{(1)}$. The estimation method is Quasi-Maximum Likelihood, computing Bollerslev-Wooldrige robust standard errors. P-values are in parentheses. Coefficients in bold denote significance at the 10% level of positive coefficients. Detailed results of the regressions are in the appendix, Tables A4-A6.

Summing up, the GARCH analysis produces a picture that is fully consistent with previous findings in the paper. German interest rate volatility did not affect the volatility of interest rates and exchange rates in the three CEECs, while emerging-market financial instability had a significant impact on exchange rate volatility. Nevertheless, the hypothesis of a volatility trade-off between interest rates and exchange rates is not supported by the analysis. In Poland the exchange rate absorbed the volatility coming from emerging-market financial turbulence, while interest rate volatility was independent from external volatility. However, counter-factual evidence from Hungary and the Czech Republic does not coincide with the trade-off hypothesis. In Hungary, neither the interest rate nor the exchange rate were affected by emerging-market volatility during the period of financial turbulence. In the Czech Republic, the exchange rate was significantly subject to volatility contagion coming from emerging markets, but it did not fully absorb the external volatility, since the interest rates do not seem to have been completely immune from contagion.

7 Conclusions

This paper investigated the impact of external factors on the behaviour of interest rates and exchange rates in the Czech Republic, Hungary and Poland. The VAR analysis over the period from 5 January 1998 to 1 May 2001 showed that shocks to emerging-market risk premia had a significant impact on exchange rates in the three CEECs, which depreciated after a negative shock affecting the emerging markets. Shocks to emerging market risk premia had a significant impact on short-term interest rates in the Czech Republic and Hungary, but not in Poland. In contrast, shocks to benchmark German interest rates affect neither domestic interest rates nor exchange rates.

The analysis of co-movements in the volatility of domestic and external variables, over the period from 1 August 1997 to 1 May 2001, is consistent with the analysis of external shocks. The volatility of domestic interest rates and exchange rate returns is not correlated with the volatility of German interest rates and there is no evidence of contagion through this channel. Instead, the volatility of returns on the EMBI+ emerging-market bond index is positively correlated with the volatility of exchange rate returns in the three CEECs. In the case of the Czech koruna and the Polish zloty, this correlation is remarkably higher over the period of emerging-market financial instability - from August 1997 to March 1999. The GARCH analysis confirms that indicators of emerging-market volatility can help in explaining the conditional variance of exchange rate returns in these two countries during the emerging market financial instability. There is also some support for the hypothesis of 'volatility contagion' on Czech interest rates over the same turbulent period. These findings provide mixed support for the theoretical trade-off between interest rate and exchange rate reaction to external shocks and volatility contagion under alternative exchange rate regimes. It is true that the largest impact of external shocks on interest rates was in Hungary, where the exchange rate fluctuated within a narrow band. Nevertheless, the Czech floating exchange rate failed to insulate domestic interest rates. Czech interest rates were significantly affected by shocks to the emerging-market risk premia and were probably subjected to 'volatility contagion' coming from emerging markets. The fact that the exchange rate of the koruna was 'managed', and not purely floating, might be an explanation of this result, thereby re-establishing some credibility of the theory. The role of the exchange rate as shock absorber is supported somewhat by the Polish experience. By fluctuating in a relatively large band, the Polish zloty absorbed the emerging-market financial turbulence, while interest rates were not affected by international factors. However, other similar exchange rate regimes succumbed to speculative attacks during the nineties. As a subject of further research, it would be interesting to investigate whether capital controls played a significant role in keeping Polish interest rates safe from external influences.

Appendix

Table A1. GARCH (p,q) model of daily interest rates (first differences) and daily exchange rates (returns). Impact of German interest rate volatility on the Czech Republic and Hungary (01/08/1997 - 01/05/2001) and Poland (01/08/1997 - 24/03/2000).

	DCZ3M		DCZ3M		DHN3M		DHN3M		DPL3M		DPL3M	
c0	-0.0028	*0.5024*	-0.0007	*0.6559*	-0.0147	*0.1117*	-0.0156	*0.0887*	-0.0129	*0.1435*	-0.0132	*0.1383*
c1	0.2471	*0.0843*	0.1907	*0.0299*	-0.3238	*0.0000*	-0.3200	*0.0000*	-0.3555	*0.0000*	-0.3548	*0.0000*
c2					-0.2553	*0.0000*	-0.2508	*0.0000*	-0.0926	*0.0420*	-0.0931	*0.0408*
c3					-0.1806	*0.0000*	-0.1774	*0.0000*				
c4					-0.1177	*0.0023*	-0.1210	*0.0016*				
dum1	1.6564	*0.0000*	1.7465	*0.0000*								
α0	0.0019	*0.0109*	0.0001	*0.3577*	0.0135	*0.1236*	0.0141	*0.0932*	0.0164	*0.0574*	0.0160	*0.0594*
α1	0.4383	*0.0854*	0.2697	*0.0065*	0.0965	*0.0107*	0.0855	*0.0228*	0.1422	*0.0057*	0.1372	*0.0062*
β1	0.5871	*0.0024*	0.7994	*0.0000*	0.7186	*0.0000*	0.7383	*0.0000*	0.6404	*0.0000*	0.6479	*0.0000*
γ1	-0.3911	*0.0001*			0.9789	*0.7567*			0.2583	*0.9240*		
γ2			-0.0054	*0.9432*			-1.0856	*0.1571*			0.3995	*0.8711*
α1+β1	1.0254		1.0690		0.8151		0.8238		0.7826		0.7851	
IGARCH	0.0292	*0.8644*	1.1861	*0.2761*	2.4409	*0.1182*	2.6027	*0.1067*	5.9416	*0.0148*	5.8007	*0.0160*
LM(2)	0.8183	*0.6642*	0.4083	*0.8154*	0.1429	*0.9311*	0.1042	*0.9492*	0.3237	*0.8506*	0.3017	*0.8600*
LM(5)	1.0014	*0.9625*	0.5856	*0.9887*	3.4645	*0.6288*	3.2686	*0.6587*	0.6214	*0.9870*	0.5642	*0.9896*
Skewness	1.2588		-0.2300		-0.0067		-0.0722		-1.6009		-1.6236	
Kurtosis	36.484		41.167		7.9816		7.9617		14.927		14.950	
JB	45947	*0.0000*	59369	*0.0000*	1011.3	*0.0000*	1004.0	*0.0000*	4390.7	*0.0000*	4415.0	*0.0000*
Obs.	978		978		978		978		691		691	

	CZKRTN		CZKRTN		HNFRTN		HNFRTN		PLZRTN		PLZRTN	
c0	-0.0149	*0.1995*	-0.0141	*0.2335*	0.0207	*0.0000*	0.0145	*0.0000*	-0.0195	*0.3770*	-0.0142	*0.5115*
c1					-0.1147	*0.0031*	-0.1174	*0.0078*				
α0	0.0008	*0.9136*	0.0049	*0.1784*	0.0019	*0.0001*	0.0001	*0.2439*	0.0405	*0.0148*	0.0242	*0.0092*
α1	0.0651	*0.0001*	0.0952	*0.0006*	0.3324	*0.0006*	0.1154	*0.0069*	0.1980	*0.0094*	0.1564	*0.0114*
β1	0.9065	*0.0000*	0.8688	*0.0000*	0.7026	*0.0000*	0.8966	*0.0000*	0.7467	*0.0000*	0.7915	*0.0000*
γ1	6.3378	*0.5317*			-0.5554	*0.0000*			-3.4716	*0.6822*		
γ2			5.3056	*0.4574*			-0.0586	*0.1449*			16.530	*0.0779*
α1+β1	0.9716		0.9640		1.0350		1.0120		0.9448		0.9480	
IGARCH	2.2942	*0.1299*	2.2904	*0.1302*	0.7957	*0.3724*	0.7707	*0.3800*	2.4190	*0.1199*	3.6088	*0.0575*
LM(2)	0.2801	*0.8693*	0.0685	*0.9663*	2.0030	*0.3673*	8.3447	*0.0154*	0.4813	*0.7861*	0.9190	*0.6316*
LM(5)	1.2793	*0.9370*	1.4713	*0.9164*	4.0592	*0.5409*	10.213	*0.0694*	1.5472	*0.9076*	2.2549	*0.8129*
Skewness	0.6555		0.6925		0.7910		0.3660		1.0533		1.0012	
Kurtosis	7.8939		7.9927		8.6518		8.2158		11.471		10.345	
JB	1046.0	*0.0000*	1093.9	*0.0000*	1403.6	*0.0000*	1130.4	*0.0000*	2194.0	*0.0000*	1668.9	*0.0000*
Obs.	978		978		978		978		691		691	

Notes. The table reports coefficient estimates of a Garch(p,q) model of daily 3-month interbank interest rates (first differences) in the Czech Rep. (DCZ3M), Hungary (DHN3M) and Poland (DPL3M); and daily foreign exchange returns (Δlogs of spot exchange rates) in the Czech Rep. (CZKRTN), Hungary (HNFRTN) and Poland (PLZRTN).

Cond. Mean: $y_t = c_0 + \sum_1^m c_m y_{t-m} + \varepsilon_t$; $\varepsilon_t \mid I_{t-1} \sim N(0, \sigma^2)$

Cond. Var: $\sigma_t^2 = \alpha_0 + \sum_1^q \alpha_q \varepsilon_{t-q}^2 + \sum_1^p \beta_p \sigma_{t-p}^2 + \gamma_{1,2} GEVOL_{1,2}$

γ_1 is the coefficient associated with $GEVOL_1$, which is the conditional variance of an ARCH(1) model of daily first differences of German interest rates (DGE3M). γ_2 is the coefficient associated with $GEVOL_2$, which is a 4-week rolling window sample variance of DGE3M. A dummy variable (dum1) taking value 1 on the 27/10/97 (Asian crisis) was included in Czech interest rate regressions in order to specify the conditional mean correctly. The estimation method is Quasi-Maximum Likelihood, computing Bollerslev-Wooldrige robust standard errors. P-values are in italics. Estimation was performed in EVIEWS. The table also reports results of several diagnostic tests with associated p-values in italics. IGARCH is the Wald test for the null hypothesis: $\Sigma\alpha+\Sigma\beta=1$, the statistic is distributed as $\chi2(1)$. LM(n) is the Engle Lagrange Multiplier test for autoregressive conditional heteroskedasticity in the residuals up to n lags, the corresponding statistic is asymptotically distributed as $\chi2(n)$ under the null of no heteroskedasticity. Skewness and Kurtosis are the usual descriptive statistics of the standardised residuals. JB is the Jarque-Bera test for normality of standardised residuals, the reported statistic is distributed as $\chi2(2)$ under the null hypothesis of normality. In addition, Ljung-Box Q-statistics up to 30 lags were computed for all regressions. Serial correlation in residuals and squared residuals was always rejected at the 5% level. These results are not shown for reasons of space.

Table A2. GARCH (p,q) model of daily interest rates (first differences) and daily exchange rates (returns). Sub-sample 1. Impact of German interest rate volatility on the Czech Republic, Hungary and Poland 01/08/1997 – 31/03/1999).

	DCZ3M		DCZ3M		DHN3M		DHN3M	
c0	-0.0140	*0.0121*	-0.0146	*0.0084*	-0.0076	*0.6168*	-0.0067	*0.6612*
c1	0.2242	*0.0041*	0.2118	*0.0075*	-0.2209	*0.0002*	-0.2205	*0.0003*
c2					-0.1502	*0.0099*	-0.1548	*0.0080*
Dum1	1.7712	*0.0000*	1.7694	*0.0000*				
$\alpha 0$	0.0083	*0.0106*	0.0086	*0.0155*	0.0111	*0.3473*	0.0144	*0.2251*
$\alpha 1$	0.6099	*0.0012*	0.6238	*0.0010*	0.0937	*0.0766*	0.1003	*0.0532*
$\beta 1$	0.2065	*0.1023*	0.1823	*0.1428*	0.7609	*0.0000*	0.7421	*0.0000*
$\gamma 1$	-0.7462	*0.0025*			5.6927	*0.5912*		
$\gamma 2$			-1.4181	*0.4150*			5.7791	*0.4608*
$\alpha 1+\beta 1$	0.8164		0.8062		0.8545		0.8423	
IGARCH	1.7356	*0.1877*	1.6835	*0.1945*	1.6227	*0.2027*	1.3530	*0.2448*
LM(2)	0.1475	*0.9289*	0.1418	*0.9316*	0.1880	*0.9103*	0.2538	*0.8808*
LM(5)	0.3468	*0.9967*	0.4084	*0.9951*	1.5452	*0.9078*	1.7101	*0.8876*
Skewness	1.2169		1.1108		0.2648		0.3124	
Kurtosis	15.454		14.705		9.1447		9.1491	
JB	2912.0	*0.0000*	2566.8	*0.0000*	687.85	*0.0000*	690.81	*0.0000*
Obs.	434		434		434		434	

	CZKRTN		CZKRTN		HNFRTN		HNFRTN		PLZRTN		PLZRTN	
c0	-0.0014	*0.9543*	-0.0021	*0.9300*	0.0631	*0.0000*	0.0597	*0.0000*	0.0196	*0.4523*	0.0142	*0.5480*
c1					-0.1234	*0.0215*	-0.1205	*0.0220*				
$\alpha 0$	0.2400	*0.0000*	0.2543	*0.0000*	-0.0119	*0.1269*	0.0042	*0.0489*	0.0457	*0.0222*	0.0159	*0.1768*
$\alpha 1$	0.0918	*0.0914*	0.0759	*0.1356*	0.1108	*0.0097*	0.1624	*0.0005*	0.2030	*0.0437*	0.1400	*0.1082*
$\alpha 2$	0.2610	*0.0058*	0.2547	*0.0076*								
$\beta 1$					0.8549	*0.0000*	0.7744	*0.0000*	0.7412	*0.0000*	0.8072	*0.0000*
$\gamma 1$	-9.2095	*0.0093*			27.788	*0.0534*			-10.854	*0.0678*		
$\gamma 2$			-43.315	*0.0914*			17.870	*0.1295*			58.026	*0.1349*
$\Sigma\alpha+\Sigma\beta$	0.3528		0.3306		0.9657		0.9368		0.9442		0.9472	
IGARCH	37.762	*0.0000*	41.093	*0.0000*	2.8850	*0.0894*	2.4868	*0.1148*	1.5986	*0.2061*	3.1878	*0.0742*
LM(2)	0.0576	*0.9716*	0.0504	*0.9751*	0.4555	*0.7963*	0.1206	*0.9415*	0.8236	*0.6625*	2.6380	*0.2674*
LM(5)	4.6482	*0.4603*	6.0927	*0.2973*	5.3006	*0.3803*	5.0823	*0.4059*	1.3023	*0.9347*	3.9443	*0.5575*
Skewness	0.4042		0.3812		0.1752		0.1462		1.8668		1.2713	
Kurtosis	3.7013		3.7333		5.1369		4.7720		14.239		8.4952	
JB	20.711	*0.0000*	20.235	*0.0000*	84.798	*0.0000*	58.325	*0.0000*	2536.4	*0.0000*	662.97	*0.0000*
Obs.	434		434		434		434		434		434	

Notes: See explanatory notes to Table A1. Polish short-term interest rates did not present heteroskedasticity within this sample.

Table A3. GARCH (p,q) model of daily interest rates (first differences) and daily exchange rates (returns). Sub-sample 2. Impact of German interest rate volatility on the Czech Republic and Hungary (01/04/1999 - 01/05/2001) and Poland (01/04/1999-24/03/2000).

	DCZ3M		DCZ3M		DHN3M		DHN3M		DPL3M		DPL3M	
c0	-0.0019	*0.0085*	-0.0013	*0.0408*	-0.0176	*0.1313*	-0.0173	*0.1287*	0.0073	*0.3522*	0.0072	*0.3691*
c1	0.2196	*0.0138*	0.2138	*0.0024*	-0.4345	*0.0000*	-0.4294	*0.0000*	-0.4131	*0.0000*	-0.4141	*0.0000*
c2					-0.3409	*0.0000*	-0.3351	*0.0000*				
c3					-0.2555	*0.0000*	-0.2529	*0.0000*				
c4					-0.1438	*0.0010*	-0.1506	*0.0006*				
α0	0.0003	*0.0131*	0.0004	*0.0757*	0.0194	*0.0556*	0.0212	*0.0471*	0.0014	*0.2792*	0.0014	*0.2578*
α1	0.1471	*0.1004*	0.3242	*0.0884*	0.1626	*0.0024*	0.1526	*0.0020*	0.2639	*0.0019*	0.2641	*0.0016*
β1	0.6553	*0.0000*	-0.0713	*0.1261*	0.5210	*0.0035*	0.5197	*0.0036*	0.7495	*0.0000*	0.7529	*0.0000*
γ1	-0.0718	*0.0011*			-0.0369	*0.9718*			0.0266	*0.9362*		
γ2			0.1346	*0.5490*			-1.6898	*0.0898*			-0.1045	*0.8693*
α1+ β1	0.8024		0.2529		0.6836		0.6723		1.0134		1.0169	
IGARCH	2.1587	*0.1418*	11.334	*0.0008*	4.2371	*0.0395*	4.3406	*0.0372*	0.0550	*0.8146*	0.1024	*0.7490*
LM(2)	0.0997	*0.9514*	0.0245	*0.9878*	0.1861	*0.9112*	0.1983	*0.9056*	0.0003	*0.9998*	0.0005	*0.9997*
LM(5)	7.2731	*0.2011*	0.6111	*0.9875*	3.3746	*0.6424*	3.5072	*0.6223*	0.0898	*0.9999*	0.1064	*0.9998*
Skewness	-1.2463		-3.9509		-0.0438		-0.0553		0.1409		0.1479	
Kurtosis	48.118		46.167		5.8998		5.7347		8.9154		8.8462	
JB	46281	*0.0000*	43652	*0.0000*	190.77	*0.0000*	169.80	*0.0000*	375.55	*0.0000*	366.92	*0.0000*
Obs.	544		544		544		544		257		257	

	CZKRTN		CZKRTN		HNFRTN		HNFRTN		PLZRTN		PLZRTN	
c0	-0.0250	*0.0417*	-0.0194	*0.1123*	0.0141	*0.0000*	0.0120	*0.0009*	-0.0674	*0.0862*	-0.0854	*0.0334*
c1					-0.1402	*0.0095*	-0.1385	*0.0086*				
α0	0.0029	*0.2536*	0.0729	*0.0024*	0.0004	*0.1145*	0.0004	*0.1680*	0.0074	*0.1112*	0.0315	*0.0274*
α1	-0.0234	*0.0022*	0.0114	*0.6949*	0.1967	*0.0001*	0.2131	*0.0003*	0.0579	*0.0323*	0.1955	*0.0517*
β1	0.8990	*0.0000*	-0.1635	*0.5037*	0.8063	*0.0000*	0.7900	*0.0000*	0.9450	*0.0000*	0.7603	*0.0000*
γ1	10.943	*0.0982*			-0.1316	*0.0620*			-5.7849	*0.0199*		
γ2			44.466	*0.1008*			-0.1840	*0.1714*			0.6608	*0.8822*
α1+ β1	0.8757		-0.1522		1.0030		1.0031		1.0030		0.9558	
IGARCH	3.8327	*0.0503*	21.569	*0.0000*	0.0239	*0.8772*	0.0225	*0.8807*	0.0460	*0.8301*	0.8233	*0.3642*
LM(2)	0.1082	*0.9474*	0.4187	*0.8111*	1.4993	*0.4725*	1.4499	*0.4843*	1.5568	*0.4591*	1.2029	*0.5480*
LM(5)	0.4923	*0.9924*	0.8602	*0.9730*	1.8349	*0.8715*	1.7647	*0.8807*	2.4504	*0.7839*	3.1732	*0.6733*
Skewness	0.2924		0.5407		-0.0016		0.0146		-0.4527		-0.2732	
Kurtosis	6.8391		8.2100		8.8291		8.3691		6.2058		5.4719	
JB	341.82	*0.0000*	641.78	*0.0000*	770.18	*0.0000*	653.44	*0.0000*	118.83	*0.0000*	68.629	*0.0000*
Obs.	544		544		544		544		257		257	

Notes: See explanatory notes to Table A1.

Table A4. GARCH (p,q) model of daily interest rates (first differences) and daily exchange rates (returns). Impact of emerging-market volatility on the Czech Republic and Hungary (01/08/1997 - 01/05/2001) and Poland (01/08/1997 - 24/03/2000).

	DCZ3M		DCZ3M		DHN3M		DHN3M		DPL3M		DPL3M	
c0	-0.0012	*0.3165*	-0.0016	*0.1516*	-0.0167	*0.0686*	-0.0168	*0.0666*	-0.0117	*0.170*	-0.0115	*0.1905*
c1	0.1711	*0.0126*	0.2213	*0.0030*	-0.3259	*0.0000*	-0.3266	*0.0000*	-0.3786	*0.0000*	-0.3696	*0.0000*
c2	-	-	-	-	-0.2526	*0.0000*	-0.2533	*0.0000*	-0.0864	*0.0675*	-0.0872	*0.0657*
c3	-	-	-	-	-0.1833	*0.0000*	-0.1823	*0.0000*	-	-	-	-
c4	-	-	-	-	-0.1185	*0.0023*	-0.1171	*0.0024*	-	-	-	-
dum1	1.6772	*0.0000*	1.7369	*0.0000*	-	-	-	-	-	-	-	-
$\alpha0$	-0.0001	*0.1928*	-0.0001	*0.1735*	0.0129	*0.1147*	0.0140	*0.1433*	0.0082	*0.0347*	0.0121	*0.0438*
$\alpha1$	0.4659	*0.0012*	0.5061	*0.0007*	0.0804	*0.0057*	0.0797	*0.007*	0.1666	*0.0023*	0.1687	*0.0079*
$\beta1$	0.6645	*0.0000*	0.6015	*0.0000*	0.7291	*0.0000*	0.7105	*0.0000*	0.6819	*0.0000*	0.6455	*0.0000*
$\gamma1$	0.0005	*0.1686*	-	-	0.0014	*0.2574*	-	-	0.0032	*0.3307*	-	-
$\gamma2$	-	-	0.0010	*0.1611*	-	-	0.0019	*0.2791*	-	-	0.0023	*0.4927*
$\alpha1+\beta1$	1.1304	-	1.1076	-	0.8094	-	0.7902	-	0.8485	-	0.8141	-
IGARCH	2.3787	*0.1230*	1.4151	*0.2342*	2.4744	*0.1157*	2.0604	*0.1512*	4.8855	*0.0271*	4.1736	*0.0411*
LM(2)	0.3187	*0.8527*	0.1601	*0.9231*	0.2550	*0.8803*	0.2524	*0.8814*	0.7333	*0.6930*	0.5227	*0.7700*
LM(5)	0.8883	*0.9711*	0.5061	*0.9919*	2.4314	*0.7868*	2.3697	*0.796*	1.2845	*0.9365*	0.8842	*0.9714*
Skewness	-0.2732	-	-0.9310	-	-0.0721	-	-0.0672	-	-1.0909	-	-1.3297	-
Kurtosis	26.299	-	34.816	-	8.0058	-	8.0383	-	11.011	-	12.948	-
JB	22133	*0.0000*	41391	*0.0000*	1022.0	*0.0000*	1035.2	*0.0000*	1984.7	*0.0000*	3053.0	*0.0000*
Obs.	978		978		978		978		691		691	

	CZKRTN		CZKRTN		HNFRTN		HNFRTN		PLZRTN		PLZRTN	
c0	-0.0098	*0.4922*	-0.0085	*0.5567*	0.0150	*0.0000*	0.0165	*0.0000*	-0.0221	*0.3410*	-0.0268	*0.2639*
c1	-	-	-	-	-0.1271	*0.0013*	-0.1153	*0.0028*	-	-	-	-
$\alpha0$	0.0050	*0.1658*	0.0092	*0.0861*	-0.0005	*0.0038*	-0.0002	*0.0129*	0.0388	*0.0357*	0.0779	*0.0175*
$\alpha1$	0.0585	*0.0063*	0.0690	*0.0056*	0.2008	*0.0001*	0.2539	*0.0000*	0.2190	*0.0036*	0.2913	*0.0002*
$\beta1$	0.8625	*0.0000*	0.8447	*0.0000*	0.8049	*0.0000*	0.7527	*0.0000*	0.6077	*0.0000*	0.4292	*0.0259*
$\gamma1$	0.0121	*0.0273*	-	-	0.0023	*0.0095*	-	-	0.0531	*0.2934*	-	-
$\gamma2$	-	-	0.0101	*0.0482*	-	-	0.0033	*0.0191*	-	-	0.0704	*0.3024*
$\alpha1+\beta1$	0.9210	-	0.9137	-	1.0057	-	1.0066	-	0.8267	-	0.7204	-
IGARCH	6.1473	*0.0132*	4.8822	*0.0271*	0.0904	*0.7637*	0.0712	*0.7896*	2.8964	*0.0888*	2.3738	*0.1234*
LM(2)	0.0573	*0.9717*	0.0018	*0.9991*	2.9429	*0.2296*	2.1303	*0.3447*	0.0806	*0.9605*	0.5497	*0.7597*
LM(5)	0.6455	*0.9858*	0.5876	*0.9886*	4.3820	*0.4958*	4.0503	*0.5422*	1.7183	*0.8866*	1.4071	*0.9235*
Skewness	1.0446	-	1.1013	-	0.4509	-	0.3461	-	0.4427	-	0.3696	-
Kurtosis	12.096	-	12.514	-	7.3075	-	6.7180	-	7.6119	-	7.6828	-
JB	3549.2	*0.0000*	3885.9	*0.0000*	789.23	*0.0000*	582.82	*0.0000*	634.96	*0.0000*	647.08	*0.0000*
Obs.	978		978		978		978		691		691	

Notes. The table reports coefficient estimates of a Garch(p,q) model of daily 3-month interbank interest rates (first differences) in the Czech Rep. (DCZ3M), Hungary (DHN3M) and Poland (DPL3M); and daily foreign exchange returns (Δlogs of spot exchange rates) in the Czech Rep. (CZKRTN), Hungary (HNFRTN) and Poland (PLZRTN).

Cond. Mean: $y_t = c_0 + \sum_1^m c_m y_{t-m} + \varepsilon_t$; $\varepsilon_t \mid I_{t-1} \sim N(0, \sigma^2)$

Cond. Var: $\sigma_t^2 = \alpha_0 + \sum_1^q \alpha_q \varepsilon_{t-q}^2 + \sum_1^p \beta_p \sigma_{t-p}^2 + \gamma_{1,2} EMVOL_{1,2}$

γ_1 is the coefficient associated with $EMVOL_1$, which is the conditional variance of an ARCH(4) model of daily returns on the EMBI+ emerging market bond index (EMRTN). γ_2 is the coefficient associated with $EMVOL_2$, which is a 4-week rolling window sample variance of EMRTN. A dummy variable (dum1) taking value 1 on the 27/10/97 (Asian crisis) was included in Czech interest rate regressions in order to specify the conditional mean correctly. The estimation method is Quasi-Maximum Likelihood, computing Bollerslev-Wooldrige robust standard errors. P-values are in italics. Estimation was performed in EVIEWS. The table also reports results of several diagnostic tests with associated p-values in italics. IGARCH is the Wald test for the null hypothesis: $\Sigma\alpha+\Sigma\beta=1$, the statistic is distributed as $\chi2(1)$. LM(n) is the Engle Lagrange Multiplier test for autoregressive conditional heteroskedasticity in the residuals up to n lags, the corresponding statistic is asymptotically distributed as $\chi2(n)$ under the null of no heteroskedasticity. Skewness and Kurtosis are the usual descriptive statistics of the standardised residuals. JB is the Jarque-Bera test for normality of standardised residuals, the reported statistic is distributed as $\chi2(2)$ under the null hypothesis of normality. In addition, Ljung-Box Q-statistics up to 30 lags were computed for all regressions. Serial correlation in residuals and squared residuals was always rejected at the 5% level. These results are not shown for reasons of space.

Table A5. GARCH (p,q) model of daily interest rates (first differences) and daily exchange rates (returns). Sub-sample 1. Impact of emerging- market volatility on the Czech Republic, Hungary and Poland (01/08/1997 – 31/03/1999).

	DCZ3M		DCZ3M		DHN3M		DHN3M	
c0	-0.0082	*0.0701*	-0.0041	*0.3398*	-0.0115	*0.4532*	-0.0119	*0.4370*
c1	0.1833	*0.0120*	0.1950	*0.0071*	-0.2151	*0.0001*	-0.2155	*0.0001*
c2	-	-	-	-	0.1467	*0.0070*	-0.1475	*0.0054*
dum1	1.5757	*0.0000*	1.5683	*0.0000*	-	-	-	-
$\alpha 0$	0.0026	*0.0252*	0.0010	*0.0369*	0.0139	*0.2195*	0.0141	*0.2310*
$\alpha 1$	0.3781	*0.0167*	0.4324	*0.0105*	0.0775	*0.0594*	0.0721	*0.0647*
$\beta 1$	0.4143	*0.0008*	0.3453	*0.0524*	0.7697	*0.0000*	0.7652	*0.0000*
$\gamma 1$	0.0019	*0.0706*	-	-	0.0007	*0.4847*	-	-
$\gamma 2$	-	-	0.0047	*0.0508*	-	-	0.0010	*0.4566*
$\alpha 1+\beta 1$	0.7924	-	0.7777	-	0.8472	-	0.8373	-
IGARCH	4.9581	*0.0260*	3.5327	*0.0602*	1.5127	*0.2187*	1.4710	*0.2252*
Skewness	0.1873	-	0.4006	-	0.1382	-	0.1427	-
Kurtosis	10.696	-	9.8238	-	9.4262	-	9.5321	-
JB	1073.5	*0.0000*	853.63	*0.0000*	748.16	*0.0000*	773.07	*0.0000*
Obs.	434		434		434		434	

	CZKRTN		CZKRTN		HNFRTN		HNFRTN		PLZRTN		PLZRTN	
c0	-0.0015	*0.9518*	-0.0074	*0.7633*	0.0641	*0.0000*	0.0635	*0.0000*	0.0173	*0.5062*	0.0179	*0.4805*
c1	-	-	-	-	-0.1275	*0.0247*	-0.1265	*0.0276*	-	-	-	-
$\alpha 0$	0.1948	*0.0000*	0.1908	*0.0000*	0.0053	*0.1012*	0.0055	*0.1099*	0.0736	*0.0001*	0.0915	*0.0000*
$\alpha 1$	0.0446	*0.4412*	0.0199	*0.6236*	0.2342	*0.0131*	0.2424	*0.0197*	0.1270	*0.0668*	0.2384	*0.0004*
$\alpha 2$	0.1440	*0.0372*	0.1851	*0.0273*	-	-	-	-	-	-	-	-
$\beta 1$	-	-	-	-	0.7307	*0.0000*	0.7291	*0.0000*	-	-	-	-
$\gamma 1$	0.0487	*0.0005*	-	-	0.0012	*0.4278*	-	-	0.2307	*0.0000*	-	-
$\gamma 2$	-	-	0.0478	*0.0004*	-	-	0.0008	*0.4156*	-	-	0.1712	*0.0000*
$\Sigma\alpha+\Sigma\beta$	0.1886	-	0.2051	-	0.9649	-	0.9714	-	0.1270	-	0.2383	-
IGARCH	92.508	*0.0000*	85.777	*0.0000*	0.4403	*0.507*	0.2819	*0.5954*	158.72	*0.0000*	127.78	*0.0000*
Skewness	0.3691	-	0.3622	-	0.3807	-	0.4182	-	0.7201	-	0.7764	-
Kurtosis	3.6802	-	3.6607	-	5.7429	-	5.9158	-	5.1099	-	5.5946	-
JB	18.220	*0.0001*	17.380	*0.0002*	146.53	*0.0000*	166.39	*0.0000*	118.01	*0.0000*	165.34	*0.0000*
Obs.	434		434		434		434		434		434	

Notes: See explanatory notes to Table A4. Polish short-term interest rates did not present hetero-skedasticity within this sample.

Table A6. GARCH (p,q) model of daily interest rates (first differences) and daily exchange rates (returns). Sub-sample 2. Impact of emerging- market volatility on the Czech Republic and Hungary (01/04/1999 -01/05/2001) and Poland (01/04/1999 - 24/03/2000).

	DCZ3M		DCZ3M		DHN3M		DHN3M		DPL3M		DPL3M	
c0	-0.0010	*0.2180*	0.0003	*0.4263*	-0.0178	*0.1256*	-0.0172	*0.1367*	0.0082	*0.1550*	0.0075	*0.1899*
c1	0.1948	*0.0164*	0.1549	*0.1558*	-0.4351	*0.0000*	-0.4327	*0.0000*	-0.4047	*0.0000*	-0.4148	*0.0000*
c2	-	-	-	-	-0.3416	*0.0000*	-0.3375	*0.0000*	-	-	-	-
c3	-	-	-	-	-0.2555	*0.0000*	-0.2552	*0.0000*	-	-	-	-
c4	-	-	-	-	-0.1442	*0.0010*	-0.1433	*0.0009*	-	-	-	-
α0	-0.0001	*0.3311*	0.0003	*0.0890*	0.0186	*0.0628*	0.0222	*0.0522*	-0.0008	*0.6136*	-0.0004	*0.8785*
α1	0.4185	*0.0084*	0.4114	*0.1047*	0.1657	*0.0024*	0.1595	*0.0017*	0.3225	*0.0003*	0.3121	*0.0001*
β1	0.3399	*0.0892*	0.4366	*0.0065*	0.5050	*0.0070*	0.5242	*0.0024*	0.7391	*0.0000*	0.7461	*0.0000*
γ1	0.0008	*0.2014*	-	-	0.0031	*0.6013*	-	-	0.0026	*0.3655*	-	-
γ2	-	-	-0.0003	*0.0829*	-	-	-0.0087	*0.4497*	-	-	0.0028	*0.6478*
α1+ β1	0.7584	-	0.8481	-	0.6707	-	0.6837	-	1.0616	-	1.0582	-
IGARCH	1.5254	*0.2168*	0.4892	*0.4843*	4.1502	*0.0416*	4.3477	*0.0371*	1.3048	*0.2533*	1.4248	*0.2326*
Skewness	-1.0468	-	-1.1374	-	-0.0485	-	-0.0197	-	0.9092	-	0.5990	-
Kurtosis	33.826	-	54.164	-	5.8917	-	5.7947	-	6.7485	-	7.8198	-
JB	21638	*0.0000*	59452	*0.0000*	189.76	*0.0000*	177.07	*0.0000*	185.87	*0.0000*	264.13	*0.0000*
Obs.	544		544		544		544		257		257	

	CZKRTN		CZKRTN		HNFRTN		HNFRTN		PLZRTN		PLZRTN	
c0	-0.0193	*0.1419*	-0.0165	*0.2470*	0.0132	*0.0000*	0.0151	*0.0000*	-0.0577	*0.1028*	-0.0928	*0.0120*
c1	-	-	-	-	-0.1469	*0.0063*	-0.1250	*0.0202*	-	-	-	-
α0	0.0177	*0.2043*	0.0133	*0.4356*	-0.0005	*0.0134*	-0.0002	*0.0310*	0.0347	*0.0003*	0.2011	*0.0126*
α1	0.0238	*0.5909*	0.0212	*0.3971*	0.2318	*0.0000*	0.2566	*0.0000*	0.0139	*0.3473*	0.2117	*0.0273*
β1	0.4396	*0.0268*	0.8092	*0.0004*	0.7652	*0.0000*	0.7277	*0.0000*	0.9555	*0.0000*	0.5177	*0.0002*
γ1	0.0753	*0.1064*	-	-	0.0023	*0.0279*	-	-	-0.0345	*0.0000*	-	-
γ2	-	-	0.0121	*0.3264*	-	-	0.0035	*0.0354*	-	-	-0.1787	*0.0132*
α1+ β1	0.4634	-	0.8304	-	0.9970	-	0.9843	-	0.9694	-	0.7294	-
IGARCH	8.0173	*0.0046*	0.6290	*0.4277*	0.0139	*0.9061*	0.2978	*0.5852*	3.6132	*0.0573*	3.4252	*0.0642*
Skewness	1.7061	-	1.9931	-	0.3206	-	0.2756	-	-0.4914	-	-0.4209	-
Kurtosis	20.269	-	23.700	-	7.7397	-	7.3960	-	5.9159	-	5.3213	-
JB	7023.7	*0.0000*	10072	*0.0000*	518.52	*0.0000*	444.91	*0.0000*	101.39	*0.0000*	65.289	*0.0000*
Obs.	544		544		544		544		257		257	

Notes: See explanatory notes to Table A4.

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