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Contagion and interdependence among Central European economies: the impact of common external shocks

Sébastien Wälti
Graduate Institute of International Studies

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JEL Classification: C32, F31, F41, G15

Keywords: Contagion, interdependence, international financial markets, transition economies, Eastern Europe, Russian crisis.

1 Introduction and motivation

The last decade has been one of occasional high turbulence in international financial markets. A number of currency and financial crises have brought to an end the massive increase in international capital flows towards emerging market countries.

*PhD Candidate, Graduate Institute of International Studies, Pavillon Rigot, Avenue de la Paix 11a, CH-1202 Geneva, Switzerland. Email: walti8@hei.unige.ch. I am grateful to Hans Genberg and Charles Wyplosz for insightful comments and suggestions on an earlier draft. All remaining errors are mine.

Large capital outflows have constrained these countries to adjust policies in order to respond to this sudden stop of external financing. Moreover, it is argued that these crises have been characterized by contagious effects, through which a crisis occurring in one country spreads to other countries, either in the neighbourhood or around the globe.

The new contagious feature has triggered a large research effort, both at the theoretical and empirical levels. In what follows and in line with the literature, we shall refer to contagion as a *significant change in the way that shocks are propagated across countries*. Testing for contagion requires a distinction between common external shocks, interdependence and contagion. In fact, it is of crucial importance to model the different sources of shocks, whether country-specific or external. One might conclude that contagion exists while it is really the presence of external shocks that leads a group of countries to suffer from contemporaneous speculative attacks and financial crises.

This paper aims to test for the existence of contagion across a selection of Central European stock markets, taking account of common external shocks. There is accumulating evidence that the economic policies followed by major industrialised countries have a large impact on the economies of emerging market countries. In a seminal paper on the determinants of capital flows to Latin America between the end of the "lost decade" and the early nineties, Calvo, Leiderman and Reinhart (1993) find that the large increase in capital inflows is partly due to external factors, such as lower international interest rates and the recession in the United States. Indeed, they argue that "some of the renewal of capital flows to Latin America results from external factors and can be considered an *external shock* common to the region"[1].

Needless to say, the literature has examined the importance of this type of common external shocks. Most notably, since many emerging market countries maintained a fixed exchange rate vis-à-vis the U.S. dollar, it is U.S. monetary policy that is crucial to the sustainability of the exchange rate regime and that has been the main focus of the analysis. The vast majority of studies makes use of short-term U.S. market interest rates to capture the stance of monetary policy. This paper extends previous work in this area and makes use of different measures of U.S. monetary policy, going from short-term interest rates to measures of policy surprises.

We follow the most recent literature on the analysis of contagion and interdependence and build a structural model of interdependence between stock market returns. In particular, the use of data at the daily frequency allows for a refined analysis of the international transmission of shocks. Having properly modelled the interdependence between emerging market economies and the effects of external shocks, we can then test for the existence of contagion.

The results show that common external shocks are a significant determinant of stock market returns in Russia and Central European economies. In particular, the U.S. stock market and emerging market turbulence affect the region. Moreover, we

[1] Calvo, Leiderman and Reinhart (1993), p. 109

find that although U.S. market interest rates are not significant, the federal funds rate, which is a direct measure of monetary policy, has explanatory power for the Russian stock market return. Finally, we uncover widespread evidence of contagion, in the sense that the transmission mechanism of country-specific shocks changes in the face of abnormal high-volatility events. These results shed some light on the difficulties inherent in the transition phase to EMU for Central European economies. Given that these countries are affected by a host of external shocks, pursuing sound domestic economic policies consistent with entering EMU is a necessary but not sufficient condition. Therefore, these economies should ensure enough flexibility in order to react to such shocks.

The paper is organised as follows. Section 2 provides a selective review of the literature on the importance of common external shocks. Section 3 discusses the various measures of the stance of U.S. monetary policy. Section 4 introduces briefly the structural model of interdependence that has been proposed by Favero and Giavazzi (2002), while section 5 provides a short description of the data. Section 6 presents the empirical results and draws some policy implications. Section 7 concludes.

2 Common external shocks: a selective review of the literature

This section summarizes the evidence on the impact of common external shocks. Frankel and Roubini (2001) discuss the role of the policies of industrialised countries and their effects on emerging market economies. There are three main areas where these policies matter. Firstly, macroeconomic policies have an impact on emerging markets through interdependence. Secondly, developed countries respond to emerging market crises through various mechanisms, most notably rescue packages. Thirdly, the contributions to the debate on the reform of the international financial architecture have effects on the current and future economic conditions of emerging markets. This paper deals exclusively with the first set of issues when common external shocks are considered. In other words, we will focus on the impact of industrialised countries' macroeconomic policies on emerging market economies.

Which macroeconomic variables have a significant short-term impact on emerging markets? In general, changes in aggregate income in the developed world affect emerging markets through changes in traded quantities, namely exports and imports, and changes in prices on world markets. It is often argued that the quick recovery of Mexico after the 1994/95 Tequila crisis was partly due to strong economic growth in the United States. In contrast, when the Asian crisis in 1997/98 hit many south-East Asian countries, there was no growth in the leading regional economy as Japan was having a dismal economic performance.

Interest rates in industrialised countries are important for several reasons. Firstly, low rates of return in these countries would trigger capital flows to emerging markets where rates of return are higher. In fact, Calvo, Leiderman and Reinhart (1993) have shown that capital inflows into Latin America can be partly explained by the low level of international interest rates, among other external variables. The expanding literature on early warning indicators also indicates a significant role of foreign interest rates. To this extent, abrupt reversals in the interest rates of industrial countries could cause sudden shifts in international capital flows, thereby increasing the probability of speculative attacks. Secondly, higher interest rates raise the cost of debt service for debtor countries. Thirdly, emerging markets that maintain currency pegs must set interest rates in accordance with that of the country to which they fix, given that capital mobility is sufficiently high for monetary policy to be largely ineffective domestically.

Exchange rates between the currencies of the main economies of the world also matter. The large appreciation of the U.S. dollar against the yen in 1995 and 1996 is often seen as one of the sources of the Asian crisis. The south-East Asian countries, pegging to the U.S. dollar, experienced a large loss of competitiveness, leading to wide current account deficits and significant losses of reserves. This argument has been debated and its explanatory power is not clear. However, it remains that exchange rate volatility among the largest economies is certainly detrimental to emerging markets.

Finally, one should also bear in mind that industrial country trade policies have important effects on emerging market economies. Following a balance-of-payments crisis, it remains important for any country to be able to increase exports rapidly. An improvement in the trade balance is often seen as a necessary condition for a stabilization of investors' confidence, even if most of the improvement usually stems from lower imports than from higher exports.

Having identified channels of interdependence between industrialised countries and emerging market economies, what are the main results of the empirical literature? We have already mentioned the seminal work by Calvo, Leiderman and Reinhart (1993) which illustrates the importance of the level of U.S. interest rates and U.S. growth as determinants of capital inflows to emerging markets. Following the crises that have affected many emerging market economies during the last decade, empirical evidence actually shows that common shocks are significant determinants of currency and financial crises. Frankel and Rose (1996) find that currency crashes occur when domestic output growth is low, domestic credit growth is high, and the level of foreign interest rates is high. Milesi-Ferretti and Razin (1998) also show evidence that, notwithstanding the importance of domestic macroeconomic factors, external factors such as unfavourable terms of trade and high interest rates in industrial countries trigger current-account reversals and currency crises. In a study specifically devoted to the examination of common shocks, Moreno and Trehan (2000) attempt to determine to what extent common external shocks explain the simultaneous occurrence of currency crises. It is found that this type of shocks can explain between sixty and eighty percent of the variation in the total number of currency crises over the post-Bretton-Woods period.

More generally, Frankel, Schmukler and Serven (2002) find that emerging market economies exhibit high sensitivity to international interest rates, especially under fixed exchange rate regimes. Reinhart and Reinhart (2001) present stylized facts on the impact of economic conditions in the United States on emerging markets. They conclude that economic downturns in the United States have adverse consequences on emerging markets, in particular for those whose export share to the United States is large. Moreover, capital flows to emerging markets increase markedly in years when U.S. monetary policy is easing, thereby corroborating the results obtained by Calvo, Leiderman and Reinhart (1993).

Arora and Vamvakidis (2001) test whether U.S. economic growth has any effect on other countries. They conclude that U.S. growth has a positive and significant impact on growth in other countries, especially in emerging market economies. Interestingly, this effect is considerably larger than that of the rest of the world's growth. Excluding U.S. growth and retaining only growth in the rest of the world yields a positive but insignificant coefficient. Arora and Cerisola (2000) examine the impact of U.S. monetary policy on the economic conditions in emerging markets. They build a model of sovereign bond spreads as a function of the U.S. federal funds target rate, market volatility, and country-specific fundamentals. Market volatility is measured as the spread between the three-month U.S. Treasury bill interest rate and the U.S. federal funds target rate and should reflect uncertainty about the expected stance of U.S. monetary policy. They find that the level of the U.S. federal funds target rate has a significant positive effect on emerging market spreads.

Having summarized various general studies, we now focus our attention on the Central European and Russian economies. Hayo and Kutan (2002) assess to what extent world market developments have an impact on the Russian bond and stock markets. The sample period extends from September 1995 until November 2001. They find that the U.S. stock market index Granger-causes Russian bond and stock market returns, showing that the Russian financial market has become more vulnerable to developments in global financial markets.

Habib (2002) uses a vector autoregressive specification to look at the effect of changes in German interest rates and emerging market turbulence (measured as the spread on the EMBI+ index) on the nominal exchange rates and interest rates of the Czech Republic, Hungary and Poland. Data are at the daily frequency and run from January 1998 to May 2001. The evidence shows that interest rates and exchange rates in these three countries are not affected by German interest rates. However, emerging market risk premia shocks affect all three countries' exchange rates. The reaction of interest rates to such shocks differs across countries. Whereas the Polish interest rate does not react and that of the Czech Republic is affected only marginally, Hungary exhibits a highly significant effect[2]. Habib (2002) attributes this result to

[2] Habib (2002) also studies the comovements in the volatility of domestic and external variables. The findings broadly confirm those obtained with variables in levels. The volatility of German interest rates does not have any impact on the three countries, whereas the volatility on the returns

the fixed exchange rate regime prevailing in the latter country, while both the Czech Republic and Poland had less rigid arrangements. This result is in line with Begg and Wyplosz (1999). For Hungary's exchange rate peg to survive, the authorities had to raise interest rates more than in the other countries which had more flexible exchange rates.

Mackowiak (2002) makes use of a structural VAR analysis to determine whether domestic or foreign factors are the dominant source of macroeconomic fluctuations in the Czech Republic, Hungary and Poland, over a period from 1992 to 2000. The central finding is that foreign factors, and notably German interest rates, account for a sizeable proportion of the variation in the price level, output, and interest rates in the three countries[3].

Overall, what does this selective empirical evidence have to say about the appropriate choice of variables? When modelling common external shocks, we should take into account the U.S. stock market, U.S. monetary policy, the German stock market, German monetary policy and emerging market risk premia shocks. This paper controls for these variables and makes two important new contributions. Firstly, we use different measures of the stance of foreign monetary policy. In particular, we assess whether emerging market economies are mainly affected by the level of interest rates, either market-determined or set by the monetary authorities, or rather by monetary policy surprises. Secondly, to the extent that these countries are economically interdependent, we build a structural model of interdependence between the stock markets of the region, thereby allowing for a test of nonlinearities in the transmission mechanism of country-specific shocks. The presence of such nonlinearities would have important policy implications. We return to this issue in the discussion of the empirical results.

3 Measuring U.S. monetary policy

There is an important literature on the measurement and the identification of monetary policy. The leading methodology makes use of structural vector autoregression models to obtain estimates of monetary policy and to assess the impact of monetary policy shocks on various macroeconomic variables such as price levels or output[4]. However, these models typically require monthly data. In the context of the analysis of the propagation of shocks across international financial markets, this frequency is clearly too large. This paper will focus on daily data, leading to alternative methods to measure monetary policy, and notably its unexpected component.

on the EMBI+ index is positively correlated with the volatility of exchange returns.

[3]At first sight, this conclusion about German interest rates seems to conflict with the evidence reported by Habib (2002) which relies on daily data. However, Mackowiak (2002) points out that the fraction of variation in each variable increases over time, with small short-run effects. Therefore, it is not surprising to reach opposite conclusions with respect to the impact of German interest rates.

[4]A key contribution is Christiano, Eichenbaum and Evans (1999).

Many econometric specifications that look at the impact of common external interest rate shocks make use of yields on U.S. Treasury securities, in particular the three-month U.S. Treasury bill. However, what this variable really measures is a rate of return on some asset and it is an imperfect proxy for U.S. monetary policy. In this context, we will focus on the federal funds rate, the federal funds target rate, and the discount rate, as measures of the current stance of monetary policy[5]. We also pay attention to monetary policy surprises. These are measured as changes in the federal funds target rate which surprise bond markets. In the end, we should be able to determine whether investors mostly react to changes in the rates of return on U.S. Treasury securities, or more to changes in monetary policy as such. Again, these rates of return are correlated with changes in monetary policy, but not perfectly.

3.1 The expectation hypothesis and the Fisher relation

The use of short-term U.S. market interest rates to model the influence of U.S. monetary policy may not be fully adequate. Usually, changes in the federal funds target rate are followed by changes in market interest rates in the same direction. However, there are instances where this direction reverses. Pakko and Wheelock (1996) discuss episodes in which market interest rates responded in different ways to Federal Reserve policy changes. For example, on May 17th 1994 the Fed raised its objective for the federal funds rate by 50 basis points. The market response was a decline in bond yields, both shortly before the meeting and after the announcement of the interest rate increase. To this extent, using market interest rates to capture monetary policy poses difficulties.

What is the relationship between the Federal Reserve monetary policy and market interest rate behaviour? The *expectation hypothesis* states that long-term interest rates should reflect current and expected future yields on short-term securities. The yield on three-month Treasury bills reflects the current and expected future path of the federal funds rate over the next three months. As a result, changes in current or expected future short-term interest rates will tend to cause similar changes in long-term interest rates.

Because long-term rates are linked to the current expected future path of short-term interest rates, expectations of future policy changes are important to explain the movements of current interest rates. In fact, changes in the target for the federal funds rate tend to exhibit some smoothing. This persistence could explain why the yield on a given security may respond to a change in the federal funds target rate

[5]The Federal Open Market Committee, or FOMC, determines a target for the federal funds rate. This interest rate clears the market for federal funds. Open market operations are conducted so that the federal funds rate corresponds to its target. Whenever the Fed aims to lower the federal funds rate, it purchases government securities to increase the amount of reserves available to the banking system. Although the intended funds rate may not be achieved on a daily basis, it does so on average. The discount rate is the interest rate that the Federal Reserve charges financial institutions for short-term loans of reserves.

by more than the amount of the target change. The security yield would actually incorporate expectations of future changes in the target rate in the same direction.

The expectation hypothesis provides a theoretical argument for a relationship between monetary policy and market interest rates, and provides a rationale for deviations of market interest rates from the federal funds rate. But how could one explain a movement in the opposite direction? The *Fisher relationship* states that the nominal interest rate consists of two components, the real interest rate and expected inflation. If market participants expect higher inflation in the future, they will require a higher interest rate as a compensation. Changes in the current stance of monetary policy may provide information about future inflation and market interest rates should change accordingly. This could explain opposite movements in the federal funds target rate and market interest rates. To the extent that market participants interpret a more laxist monetary policy today as increasing inflation in the future, then market interest rates should rise to account for higher expected inflation. Conversely, lowering long-term interest rates may require an increase in short-term rates.

This explanation may be valid for horizons long enough for inflation to matter. At the three-month horizon, however, it is unlikely to be very important. An alternative interpretation is that opposite movements could be due to a change in market expectations. A lower than expected interest rate reduction today would imply more of an increase in the future. Through the expectations channel, current market interest rates would rise, although the policy rate is reduced.

To summarize, the expectation hypothesis and the Fisher relationship are two theoretical arguments for a relationship between monetary policy and market interest rates. As our discussion shows, however, this link may reverse directions and its size may not be one-for-one. Thus, it is unclear whether attempting to use market rates as a proxy for monetary policy is fully adequate.

3.2 Monetary surprises

In the empirical part of this paper we also try to assess whether investors react to actual changes in monetary policy or only to unexpected policy shocks. Such a distinction requires a methodology to isolate the shocks from the expected component of monetary policy. A growing body of literature focuses on the federal funds futures rate[6]. In 1988 the Chicago Board of Trade started trading an interest-rate futures contract based on the average monthly fed funds rate. Since the fed funds rate is the main policy instrument of the Federal Reserve, and given that it remains close to its intended level, efficient futures market should set prices to reflect the expected path of monetary policy. To the extent that these prices are publicly available, it should be relatively easy to extract market expectations about the future actions of the Federal Reserve.

[6] Gürkaynak, Sack and Swanson (2002) provide a good survey on the use of market interest rates to extract expectations of the future stance of monetary policy.

Despite the attractiveness of the federal funds futures rate, there is still no consensus whether this rate is an unbiased predictor of the federal funds rate or of the federal funds target rate. Carlson, McIntire and Thomson (1995), Owens and Webb (2001) find no bias, whereas Robertson and Thornton (1997) and Söderström (2001) conclude that the futures rate features a systematic bias. More generally, this approach relies on the expectation hypothesis, so that the futures rate should be equal to the expected future spot rate on average. However, this type of proposition usually fails empirically. The forward-spot spread is generally not a good forecast of interest rate changes.

With these results in mind, we follow Cochrane and Piazzesi (2002). They measure monetary policy shocks as changes in the federal funds target rate that surprise bond markets. An attractive feature of their methodology is the reliance on daily data, which is most desirable for the ultimate goal of this paper, testing for a breakdown in the way that shocks are transmitted in international financial markets. Monetary policy shocks are obtained as the change in the one-month Eurodollar deposit rate from just before to just after the target change. Importantly, this measure relies on the fact that there is a change in the target rate, thereby eliminating from the shocks all dates on which the target rate may have been expected to change, but it did not.

Figure 1 shows the one-month Eurodollar rate and the federal funds target rate between 1st September 1998 and 20th November 1998. During this period the Federal Reserve decreased its target by a quarter percentage point three times, on 29th September, 15th October and 17th November.

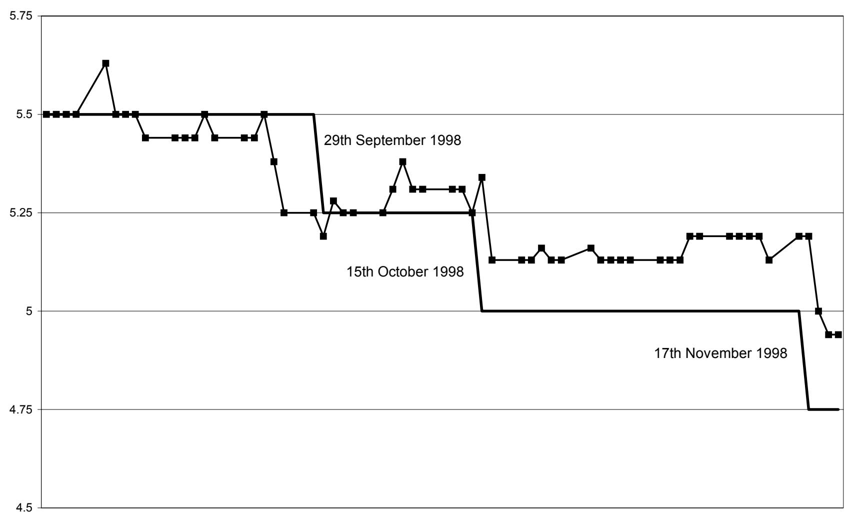

Figure 1: Federal funds target rate and one-month Eurodollar rate

Both series of data are retrieved from the Federal Reserve Bank of New York's web site. One-month Eurodollar rates are measured at 9.30 a.m. every day, Eastern time. Changes in the target for the federal funds rate are always announced later on during the day. Therefore, the monetary surprise is measured as the difference between the one-month Eurodollar rate prevailing the next day minus that prevailing on the day of the policy change.

Figure 1 illustrates which federal funds target rate changes were expected and unexpected. The change on 29th September was largely expected as the one-month Eurodollar rate had been declining gradually to 5.19. Indeed, market participants expected a slightly larger decrease in the target than was announced. In contrast, the changes on 15th October and 17th November were completely unexpected by the markets. For example, focusing on 17th November, although the Federal Reserve lowered its target to 4.75, the one-month Eurodollar rate was back to 5.19! Market participants expected that the target would be raised. In what follows, we shall use a series of monetary policy shocks as a measure for the unexpected component of monetary policy.

4 A structural model of interdependence

We build upon the work by Favero and Giavazzi (2002). This approach relies on a three-step procedure and is used to study the propagation of devaluation expectations among ERM members. The first step is to estimate a reduced-form vector autoregression model and to identify with dummy variables residuals corresponding to observations which represent market turbulence. The second step is to estimate a structural model of interdependence and finally, we can test for the existence of contagion.

Suppose two countries, 1 and 2, with corresponding stock market returns denoted by s_1 and s_2. Consider the following dynamic structural model of interdependence, allowing for all contemporaneous feedbacks and one-lagged endogenous responses.

$$s_{1,t} = \beta_{12} s_{2,t} + \gamma_{11} s_{1,t-1} + \gamma_{12} s_{2,t-1} + \varepsilon_{1,t} \tag{1}$$

$$s_{2,t} = \beta_{21} s_{1,t} + \gamma_{21} s_{1,t-1} + \gamma_{22} s_{2,t-1} + \varepsilon_{2,t} \tag{2}$$

In matrix form, we have

$$BS = \Gamma(L)S + E \tag{3}$$

This is the model in structural form. The conditional distribution of s_1 and s_2 is described by a reduced-form VAR model which is given by

$$S = \Pi(L)S + B^{-1}E \tag{4}$$

In the usual form, the reduced-form model is given by

$$\begin{pmatrix} s_{1,t} \\ s_{2,t} \end{pmatrix} = \begin{pmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{pmatrix} \begin{pmatrix} s_{1,t-1} \\ s_{2,t-1} \end{pmatrix} + B^{-1} \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} \tag{5}$$

$$B^{-1}E = \begin{pmatrix} u_{1,t} \\ u_{2,t} \end{pmatrix} |I_{t-1} \sim \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \Sigma_t \right] \tag{6}$$

where the residuals in (5) are heteroscedastic and non-normal. This implies that the sample contains episodes of high market turbulence to be identified with dummy variables, thereby filtering out heteroscedasticity and non-normality.

$$\begin{pmatrix} s_{1,t} \\ s_{2,t} \end{pmatrix} = \begin{pmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{pmatrix} \begin{pmatrix} s_{1,t-1} \\ s_{2,t-1} \end{pmatrix} + B^{-1} \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} \quad (7)$$

$$\begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} = \left(I + \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{pmatrix} d_{1,t} & 0 \\ 0 & d_{2,t} \end{pmatrix} \right) \begin{pmatrix} \varepsilon^l_{1,t} \\ \varepsilon^l_{2,t} \end{pmatrix} \quad (8)$$

$$\begin{pmatrix} \varepsilon^l_{1,t} \\ \varepsilon^l_{2,t} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \Sigma \right] \quad (9)$$

The partitioning of the matrix containing the dummy variables is conditional on the country in which the shock originates. $\varepsilon^l_{1,t}$ and $\varepsilon^l_{2,t}$ are the structural shocks in periods of low volatility, that is, they are homoscedastic and normally distributed. The off-diagonal blocks in the matrix of a_{ij}'s allow for nonlinearities in the propagation of shocks between countries. Therefore, a simple test for the absence of nonlinearities[7] specifies the following null hypothesis:

$$H_0 : a_{ij} = 0, \forall \; i \neq j \quad (10)$$

The estimation of the reduced-form model (5) is the first step of the methodology. Then, large residuals are defined as events and represented by dummy variables. Again, this allows to filter out heteroscedasticity and non-normality. The second step is to estimate the structural model of interdependence. Unfortunately, this system of simultaneous equations is not identified. To remedy this problem, we impose restrictions on the lag structure of the model, assuming that the own lagged dependent variable is assumed to be sufficient to capture the structural dynamics[8], i.e. $\gamma_{ij} = 0, \forall \; i \neq j$. In this way, the system of equations is exactly identified as each equation in the system is itself identified.

A remark is worth mentioning. The specification of the null hypothesis in this framework is more general than in various earlier studies of correlations. Favero and Giavazzi (2002) adopt the following hypothesis to test for the existence of contagion:

$$H_0 : a_{12} = a_{21} = 0 \quad (11)$$

[7] Favero and Giavazzi (2002) use the term "nonlinearities" to refer to the phenomenon of contagion. The reason is to avoid the implicit meaning of the word "contagion" as a significant increase in cross-market relationships during crisis episodes. In fact, it is also possible that there is a significant decrease in cross-market relationships, which is also interpreted as contagion.

[8] This assumption is not uncontroversial. Rigobon (2001) argues that the theoretical foundations are extremely weak. Consider two countries, home and foreign. If it is true that the home returns are explained by current foreign as well as past home returns, it seems reasonable that past foreign returns should also have some explanatory power for current home returns. This is without any doubt the major drawback of the approach of Favero and Giavazzi (2002).

In contrast, the core idea of the former correlation approach is a comparison of the correlation (or covariance) between two asset returns during a relatively stable period to that during a period of turbulence. In that context, contagion is defined as a significant *increase* in the cross-market correlation during the period of turmoil. In terms of the full-information approach, the alternative hypothesis would be that a_{12} or a_{21} or both are strictly greater than zero. However, when testing for nonlinearities, we allow for a more general alternative hypothesis which is that either a_{12} or a_{21} or both are different from zero. In particular, these could be significantly negative.

Finally, the explicit modelling of common external shocks is straightforward. To achieve this task, we introduce a matrix C of common shocks into the model of interdependence, so that the structural model is now given by

$$BS = \Gamma(L)S + \Psi C + E \tag{12}$$

and the reduced-form model is obtained as

$$S = \Pi(L)S + \Phi C + B^{-1}E \tag{13}$$

This extended specification allows to capture common external shocks separately. Therefore, when constructing the dummy variables which capture events, we retain only purely country-specific events.

5 Data

We study the propagation of country-specific shocks across stock markets and the impact of common external shocks for a sample of four countries, namely Russia, the Czech Republic, Hungary and Poland. The sample period extends from 1st July 1998 until 31st December 1999. Stock market returns are obtained as percentage changes in corresponding stock market indices expressed in U.S. dollars and retrieved from Datastream. Common external shocks include the U.S. stock market return, the German stock market return and German and U.S. interest rates. Data on the German and U.S. stock market indices, as well as the German three-month interbank interest rate, are also retrieved from Datastream. Data on various U.S. interest rates are taken from the Board of Governors of the Federal Reserve's web site. Since the sample period includes the 1999 Brazilian crisis, we control for the effects of Brazilian market turbulence by including the EMBI+ index for Brazil in our regressions.

U.S. market interest rates are the three-month Treasury bill interest rate and the three-month interbank interest rate. The choice for this maturity is made for two complementary reasons. On the one hand, we need a horizon long enough to capture expectations of exchange rates changes, in which case interest rates do not reflect money intervention by central banks. On the other hand, we need a horizon short enough so that spreads do not average expectations of exchange rate changes over a long period of time. To measure monetary policy as such, we make use of the federal funds rate, the federal funds target rate and the discount rate.

Finally, we construct measures of the unexpected component of monetary policy following Cochrane and Piazzesi (2002). When there is a change in the federal funds target rate on day t, we measure a shock as the difference between the one-month Eurodollar rate on that day t and the day $t+1$. Then, we construct a variable which observations are zero except at the dates of changes in the federal funds target rate where this variable equals the size of the surprise.

6 Empirical results

Since the empirical approach relies upon three steps, this section presents the results in three sub-sections. Firstly, we estimate the reduced form of the model and identify idiosyncratic shocks with dummy variables. Secondly, we reintroduce the shocks into the structural model and we make use of three-stage least squares to obtain parameter estimates of the exactly identified model. Then, we conduct a simplification search which yields an simpler overidentified model. Finally, we can test for the existence of nonlinearities in the international transmission of country-specific shocks.

6.1 The reduced-form model

We start by estimating the reduced form of the model. Again, it turns out to be a vector autoregressive specification. Therefore, we must determine the optimal lag length to be used. We rely on the Schwarz criterion which selects a unit lag length. Other information criterion such as the sequential modified likelihood ratio test or the Akaike criterion remain highly sensitive to the hypothesized maximum lag length, whereas the Schwarz criterion systematically selects the same unit lag length[9].

Standard tests indicate that the null hypothesis of homoscedasticity of the residuals is largely rejected. Therefore, the sample includes abnormal events. We identify country-specific shocks with dummy variables. Such shocks correspond to residuals which are greater than 2.5 times their standard deviation. Table 1 describes the number of shocks in each country in our sample, depending on which U.S. interest rate is used. The left-hand column features U.S. interest rates. Therefore, we estimate six different specifications. TB3M is the three-month Treasury bill interest rate, IBK the three-month interbank interest rate, FFR the federal funds rate, FFTR the federal funds target rate, DISC the discount rate, and SH is our measure of the unexpected component of monetary policy.

[9] This result should not come as a surprise. Information criteria yield a number which represents the trade-off between goodness-of-fit and parsimony. Since the Schwarz criterion penalizes more the addition of lags relative to other criteria, it should be expected that it selects a lower optimal lag length.

Table 1: Number of shocks				
	Russia	Czech Rep	Hungary	Poland
TB3M	13	7	13	6
IBK	13	8	14	6
FFR	14	8	13	5
FFTR	13	7	14	6
DISC	13	7	14	6
SH	13	6	14	6

Several comments are noteworthy. Firstly, the computed number of shocks in each country is remarkably stable across the different measures of U.S. interest rates. *Prima facie*, we could conclude that whichever interest rate is used does not change the results markedly. However, such an inference is wrong, as we shall see. Secondly, excluding all common external shocks from our baseline specification would increase the number of country-specific shocks. Typically, such an exclusion restriction yields three or four more shocks. To this extent, we would identify shocks as being idiosyncratic while these are actually common to the four countries under study. Hence, it remains very important to control for common external shocks explicitly, by introducing such variables into the structural model. Thirdly, it seems that countries with relatively flexible exchange rate regimes such as the Czech Republic and Poland exhibit less shocks than a country like Hungary with its more rigid exchange rate peg[10]. The relatively high number of Russian shocks stems from the fact that the sample period includes the 1998 Russian currency and financial crisis.

Turning to common external shocks, the initial specification includes the U.S. and German stock market returns and interest rates. Interestingly, whereas the coefficient on the German stock market return is significant, that on the U.S. stock market return is not. However, if we exclude the German interest rate from our regression, then the U.S. stock market return becomes significant with the expected positive sign. This result raises the issue of colinearity among these explanatory variables. The correlation among these is quite high, 0.4 in changes and 0.7 in levels. We use Granger-causality tests to assess how returns in the United States and Germany affect each other. We find that the U.S. return Granger causes the German return while the reverse is not true. Therefore, it looks like when both variables are introduced, the effect of the United States on Central European stock markets works is captured by the German stock market return. On the basis of our Granger-causality tests, and given that German interest rates are never significant, we exclude the German stock market return and the German interest rate.

[10]Overal our sample period, the Czech Republic had a floating exchange rate whereas Hungary had a crawling parity with narrow bands of fluctuation. Poland also had a crawling peg with bands which were enlarged after successive shocks, thereby signalling that the authorities were not ready to defend the parity at any cost.

6.2 Measuring interdependence and common external shocks

The second step of the methodology requires the estimation of the structural model. Initially, this specification is exactly identified by the restriction that the own lagged variable is sufficient to capture the structural dynamics. We carry out a simplification procedure by introducing zero restrictions on parameters, thereby obtaining an overidentified model. This new specification is estimated by three-stage least squares.

Tables 2 to 5 in the appendix summarize the results. Each table contains a p-value corresponding to a test for overidentifying restrictions. The null hypothesis is that the restrictions which narrow down the initial exactly identified model are not rejected by the data. We focus only on three different cases because the results are highly similar across different measures of U.S. monetary policy. In particular, we present estimations making use of the three-month Treasury bill interest rate, the federal funds rate and our measure of monetary policy surprises. To this extent, we can determine whether investors react to market rates, monetary policy as such, or to monetary policy surprises.

In general, the results are very similar across the three specifications. Two noticeable differences occur in the case of the federal funds rate. Firstly, the constant term is significantly positive for Russia. Secondly, Hungary is negatively related to Poland through interdependence. Otherwise, the magnitudes of the coefficients do not change too much depending on the measure of U.S. monetary policy.

The model exhibits almost no interdependence between the three Central European economies and Russia, except for a contemporaneous effect of Russia on Poland. Otherwise, as expected, we find interdependence among the Czech Republic, Hungary and Poland. For example, in the case of the three-month Treasury bill rate, an increase of one percent in the Hungarian stock market triggers an increase of 0.27 percent in the Czech stock market. Importantly, this result does not imply that large shocks are transmitted across stock markets in the region, but that these markets are permanently related. Hence, we refer to this evidence as interdependence, in contrast with contagion which is discussed in the next sub-section.

Turning to common external shocks, we find strong evidence that U.S. stock market returns and the Brazilian crisis affect Russia, Hungary and Poland, but never the Czech Republic. The magnitude of the coefficients on these two variables are especially high in the case of Russia. One possible interpretation for the lack of effects on the Czech Republic is that the exchange rate regime was more flexible in this country during our sample period, thereby allowing the exchange rate to absorb external shocks and reducing their impact on the economy.

The results on U.S. interest rates are particularly interesting. Many studies control for external monetary policy shocks using the three-month Treasury bill rate. In our specification, this interest rate is highly insignificant (p-value: 0.86 in the Russian equation) for all countries[11]. However, in the case of Russia the coefficient on the

[11] Three-month interbank bank interest rates yield the same conclusion.

federal funds rate is highly significant (p-value: 0.0018 in the Russian equation) with the expected sign. Monetary easing in the United States brings about an increase in the Russian stock market. Finally, we also find that monetary surprises have an impact on the Czech Republic. This result was largely unexpected and we could not find any good economic interpretation. In any case, it may imply that further research should make use of alternative measures of monetary policy surprises to determine whether our result is robust.

Overall, our evidence points to the fact that investors react more to monetary policy changes and not to changes in market-determined interest rates. The generality of this conclusion should not be overstated, however. Our sample period spans over times of high turbulence in emerging markets. It may be that in normal times investors respond mostly to relative rates of return, whereas they would be highly sensitive to policy responses in times of heightened market volatility. Such an interpretation could explain why in our specification only the federal funds rate is significant, and why it is so only for Russia which was going through a currency and financial crisis.

6.3 Evidence of contagion

Tables 5 to 7 in the appendix present the results regarding the existence of contagion. We interpret as evidence of nonlinearities coefficients on country-specific shocks in three other countries which are significant in a given country equation. The null hypothesis of no nonlinearities can be interpreted as the complete absence of bold coefficients in our tables. Clearly, the null hypothesis is rejected for our three specifications. Therefore, we can conclude that the transmission mechanism of shocks among the four countries is not stable, that is, it changes in periods of unusual market turbulence.

This result contrasts with earlier findings by Gelos and Sahay (2001). These authors analyze changes in correlations among stock market returns between tranquil and crisis periods. In this context, contagion is defined as a significant increase in the adjusted correlation coefficient between two stock market returns[12]. In the fourth section of this paper, we discuss why specifying the null hypothesis in this way can be misleading. In a nutshell, contagion should be interpreted as a change in cross-market linkages, and not exclusively an increase. Gelos and Sahay (2001) conclude in favour of the absence of structural breaks, contrasting with our results.

Although correlation analysis has been used in numerous studies, it is subject to important drawbacks which imply that we should take such results with caution. Firstly, Baumann (2000) points out that the adjustment procedure for the correlation

[12] Forbes and Rigobon (2002) show that the correlation coefficient can increase in the crisis period not because of a change in cross-market linkages but simply because of the higher variance in the high-volatility sub-sample. To this extent, the correlation coefficient is biased upwards, hence requiring an adjustment procedure.

coefficient relies upon an assumption of exogeneity in the underlying model. Relaxing this assumption indicates that the bias may be positive or negative and that it is sensitive to the parameters of the underlying model, making the adjustment problematic. Secondly, Corsetti, Pericoli and Sbracia (2002) show that the adjustment procedure is rooted on an arbitrary assumption about the variance of the shocks specific to the country where the crisis originates.

Gelos and Sahay (2001) also study the interesting question of the asymmetry of transmission between positive and negative shocks. They find that "around the Russian crisis the difference between the impact of positive and negative shocks is larger, and there is no significant effect of positive Russian stock returns on the other markets"[13]. The full-information methodology that we follow yields very different results. For example, irrespective of the measure of U.S. monetary policy, we find that the Russian shock on 6th October 1998 is transmitted beyond the normal channels of interdependence, positively to Hungary and negatively to the Czech Republic.

In general, the methodology allows to study how shocks propagate across stock markets. Focusing on the estimations with the federal funds rate, we have thirty instances of contagion[14]. These correspond to positive shocks in 21 cases, and by definition to negative shocks in 9 cases. Among the positive country-specific shocks, twelve out of twenty-one yield a positive effect and nine yield a negative effect on other markets. Among the negative shocks, seven out of nine shocks trigger a fall in other markets, whereas the remaining two shocks lead to an increase in other markets. Therefore, negative shocks to one market imply adverse consequences in other markets in almost all cases, whereas positive shocks can lead to increases or decreases in other markets with a probability close to half. This asymmetry would mean that when markets are hit by negative shocks, investors sell in all markets indiscriminately, while their reaction to positive shocks exhibits more country discrimination. We interpret such discriminating behaviour as evidence of rebalancing effects in the sense that investors reshuffle their portfolios among the four stock markets in our sample.

6.4 Policy implications

In this sub-section we draw some tentative policy implications. Our econometric computations show that the Central European countries are vulnerable to a wide variety of external shocks, be it high turbulence in other emerging markets, most notably Russia, or abrupt adjustments in the U.S. stock market.

The Czech Republic, Hungary and Poland will soon be members of the European Union. The most likely date is 1st January 2004. However, they will not be able to adopt the euro immediately. One of the conditions to be fulfilled to adopt the single currency is membership without devaluation in the Exchange Rate Mechanism, known as ERM2, for a minimal period of two years. Moreover, candidate countries

[13] Gelos and Sahay (2001), p. 73.

[14] In other words, we count thirty bold coefficients.

are not allowed to enter this mechanism before becoming a member of the European Union. After the two-year membership the Commission and the European Central Bank establish the "Convergence Reports" which examine the readiness of an EU member state to adopt the euro. In particular, any candidate country to EMU must satisfy the Maastricht criteria and comply with the acquis communautaire related to monetary union[15]. Importantly, all accession countries must comply with the full liberalization of the capital account by the date of their accession to the EU.

Therefore, the transition phase to EMU will be characterized by fixed exchange rates (with wide exchange rate bands) and full capital mobility. We know from standard macroeconomic theory that the sustainability of such an arrangement will require domestic macroeconomic policies to be set in accordance with the external constraint. In turn, policymakers will have limited means to offset external shocks. Our results imply that having sound domestic economic policies is a necessary but not sufficient condition for a smooth transition to EMU. Central European economies should retain enough flexibility in order to counteract external shocks which may jeopardize their strategy towards EMU. Moreover, our results on the existence of contagion imply that any simulation of the transmission effects of country-specific shocks should take into account that the propagation mechanism is not stable when large abnormal events occur.

It has been argued that the width of the bands of fluctuation for the exchange rate is large enough to absorb external shocks. However, whether or not $\pm 15\%$ is wide enough remains ultimately an empirical question. Future research should assess the impact of common external shocks on the exchange rates of these countries. Our study focuses on international stock markets and the linkages between the stock market and the foreign exchange market remain too little understood to draw strong statistical conclusions based upon our results[16].

7 Concluding remarks

This paper studies the cross-market linkages among four Central European economies. We rely on the full-information approach proposed by Favero and Giavazzi (2002) and test for the existence of contagion, defined as a change in the way that country-specific shocks are transmitted internationally. Given the importance of common external shocks for emerging stock markets we control for the U.S. stock market, U.S. monetary policy and the impact of the 1999 Brazilian crisis.

We find that the U.S. stock market and turbulence in Brazil affect significantly

[15] The Maastricht criteria require inflation rates, long-term interest rates and ratios of government debt and budget deficit relative to GDP to be below given thresholds. The fifth criterion is the two-year membership without devaluation in ERM2.

[16] Hau and Rey (2002) build a model which determines exchange rates, equity prices and capital flows jointly. Under certain conditions, they find that exchange rates are almost as volatile as equity prices.

Russia, Hungary and Poland, whereas these have no effect on the Czech Republic. We interpret this result as evidence that countries with more flexible exchange rate arrangements are better able to offset external shocks. Interestingly, our different controls for U.S. monetary policy perform differently. Although the three-month Treasury bill interest rate is never significant, the federal funds rate affects Russia. We also find that monetary policy surprises do not matter, except for the Czech Republic. We cannot provide a strong explanation for this surprising result.

The propagation mechanism of country-specific shocks changes in the face of large abnormal events, thereby contrasting with earlier empirical evidence. Whereas positive shocks can trigger positive or negative effects on neighbouring stock markets, with a nearly equal probability, negative shocks are almost always having negative effects on other stock markets. This asymmetry could reflect the fact that investors do not discriminate among countries when facing bad news, while they do when news are good.

We discuss some policy implications regarding the transition phase to EMU. To the extent that the Czech Republic, Hungary and Poland are vulnerable to external shocks, and that Maastricht rules require a fixed exchange rate with full capital mobility, having sound domestic economic policies is a necessary but not sufficient condition for a smooth transition process. These countries should ensure enough flexibility to respond to such shocks in an appropriate manner.

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Appendix

This appendix contains the results from our econometric computations. Tables 2 to 4 present the parameter estimates of the overidentified structural model of interdependence, respectively using the three-month Treasury bill interest rate, the federal funds rate, and our measure of monetary policy surprises. The left-hand column lists the explanatory variables for our four equations. Coefficients in normal font are significant at the 5 percent level. Blank cells correspond to coefficients which are not significantly different from zero and are not reported.

Tables 5 and to 7 list the country-specific shocks which are obtained, explicitly specifying the type of shock (positive or negative). All unstarred coefficients are significant at the 5 percent level, starred coefficients are significant at the 10 percent level. Coefficients which are not significant are not reported for clarity. Finally, coefficients in normal font deal with own-country dummy variables, whereas coefficients in bold format measure nonlinearities.

Table 2: Three-month Treasury bill interest rate

Test for overidentifying restrictions: p-value = 0.9280

	s_{RU}	s_{CZ}	s_{HU}	s_{PO}
Constant				
s_{RU}	X			0.0699
s_{CZ}		X	0.7400	0.8405
s_{HU}		0.2657	X	
s_{PO}				X
Lagged dep. var.	0.1357	0.1276	-0.0865	
U.S. int. rate				
U.S. stock market	0.5783		0.1851	0.6283
Brazilian EMBI+	0.5611		0.2352	0.2167

Table 3: Federal funds rate

Test for overidentifying restrictions: p-value = 0.3637

	s_{RU}	s_{CZ}	s_{HU}	s_{PO}
Constant	0.0800			
s_{RU}	X			0.1734
s_{CZ}		X	0.4741	0.7793
s_{HU}		0.3284	X	-0.4027
s_{PO}				X
Lagged dep. var.	0.1039	0.1325	-0.0874	
U.S. int. rate	-0.0158			
U.S. stock market	0.5632		0.2452	0.6344
Brazilian EMBI+	0.5748		0.2215	0.2614

Table 4: Monetary policy surprises

Test for overidentifying restrictions: p-value = 0.5647

	s_{RU}	s_{CZ}	s_{HU}	s_{PO}
Constant				
s_{RU}	X			0.0932
s_{CZ}		X	0.8184	0.7507
s_{HU}		0.3808	X	
s_{PO}				X
Lagged dep. var.	0.1415	0.1146	-0.0763	
U.S. int. rate		-0.0786		
U.S. stock market	0.6006		0.1911	0.6306
Brazilian EMBI+	0.5552		0.1990	0.2190

Table 5: Contagion with TB3M						
Date	Country	Type	s_{RU}	s_{CZ}	s_{HU}	s_{PO}
03/07/98	RU	+	0.1137	**0.0214**		
11/08/98	CZ, HU	-, -	**-0.1053**		-0.0557	
13/08/98	CZ, PO	-, -	**-0.1337**	-0.0338		
14/08/98	RU	+	0.1499			
26/08/98	RU, CZ, HU	-, -, -	-0.1525		-0.0452	
27/08/98	RU, HU	-, -	-0.1623		-0.0814	
02/09/98	PO	+		**0.0213**		0.0434
07/09/98	PO	+	**-0.0845**			0.0624
10/09/98	RU	+	0.2343			
11/09/98	HU	-			-0.0649	
16/09/98	RU	-	-0.2049			
21/09/98	HU	-			-0.0511	
24/09/98	HU	+			0.0766	**0.0443**
06/10/98	RU	+	0.1307	**-0.0388**	**0.0492**	
14/10/98	RU	+	0.1435			**-0.0297***
21/10/98	RU	+	0.1194		**-0.0357**	
02/11/98	HU	+			0.0645	
16/11/98	PO	+				0.0557
04/01/99	PO	+				0.0502
07/01/99	HU	+		**-0.0372**	0.0930	**0.0517**
13/01/99	CZ, HU	-, -			-0.0516	
15/01/99	HU	-	**-0.1096**		-0.0499	
25/01/99	HU	+			0.0420	
26/01/99	PO	+				0.0629
23/02/99	CZ	-		-0.0291		
08/03/99	HU	+		**-0.0318**	0.0819	**0.0372***
05/05/99	RU	+	0.1339			
06/05/99	HU	+			0.0422	
12/05/99	RU, CZ	-, -	-0.1771	-0.0296		**0.0299***
17/05/99	RU	+	0.1508			
20/07/99	CZ	+		0.0266		
31/12/99	RU	+	0.1558			

Table 6: Contagion with FFR

Date	Country	Type	s_{RU}	s_{CZ}	s_{HU}	s_{PO}
03/07/98	RU	+	0.1143	**0.0226**		
14/07/98	RU	+	0.1199		**0.0279***	**0.0315***
11/08/98	CZ, HU	-, -	**-0.1023**		-0.0651	
13/08/98	CZ	-	**-0.1318**	-0.0255	**-0.0619**	
14/08/98	RU	+	0.1541		**0.0253***	
26/08/98	RU, CZ, HU	-, -, -	-0.1454		-0.0556	
27/08/98	RU, HU	-, -	-0.1625		-0.0853	
02/09/98	PO	+		**0.0239**		0.0443
07/09/98	PO	+	**-0.0671***			0.0820
10/09/98	RU	+	0.2402			**-0.0372***
11/09/98	HU	-		**0.0239***	-0.0801	**-0.0544**
16/09/98	RU	-	-0.1880	**-0.0244***		
21/09/98	HU	-			-0.0570	
24/09/98	HU	+		**-0.0243***	0.0905	**0.0719**
06/10/98	RU	+	0.1363	**-0.0367**	**0.0386**	
14/10/98	RU	+	0.1518			**-0.0475**
21/10/98	RU	+	0.1221		**-0.0418**	
26/10/98	HU	+			0.0484	**0.0433**
02/11/98	HU	+			0.0726	**0.0364***
16/11/98	PO	+		**0.0185***		0.0532
04/01/99	PO	+				0.0531
07/01/99	HU	+		**-0.0437**	0.0906	**0.0688**
13/01/99	CZ, HU	-, -				**-0.0365***
15/01/99	HU	-	**-0.1165**		-0.0520	
25/01/99	HU	+			0.0420	
26/01/99	PO	+				0.0615
23/02/99	CZ	-		-0.0235		
08/03/99	HU	+		**-0.0370**	0.0789	**0.0536**
05/05/99	RU	+	0.1305			**-0.0291***
12/05/99	RU, CZ	-, -	-0.1816	-0.0327		**0.0476**
17/05/99	RU	+	0.1470			
26/05/99	CZ	-		-0.0305		
20/07/99	CZ	+		0.0306		
31/12/99	RU	+	0.1552			

Table 7: Contagion with SH						
Date	Country	Type	s_{RU}	s_{CZ}	s_{HU}	s_{PO}
03/07/98	RU	+	0.1140	**0.0173***		
11/08/98	CZ, HU	-, -	**-0.1053**		-0.0508	
13/08/98	CZ, PO	-, -	**-0.1344**	-0.0289		
14/08/98	RU	+	0.1498		**0.0270***	
26/08/98	RU, CZ, HU	-, -, -	-0.1574		-0.0418	
27/08/98	RU, HU	-, -	-0.1640		-0.0685	
02/09/98	PO	+		**0.0169***		0.0481
07/09/98	PO	+	**-0.0844**			0.0657
10/09/98	RU	+	0.2319			
11/09/98	HU	-		**0.0274**	-0.0775	**-0.0392***
16/09/98	RU	-	-0.1983	**-0.0266**	**0.0298***	
21/09/98	HU	-			-0.0465	
24/09/98	HU	+		**-0.0305**	0.0894	**0.0570**
06/10/98	RU	+	0.1331	**-0.0359**	**0.0452**	
14/10/98	RU	+	0.1489			**-0.0359**
21/10/98	RU	+	0.1238		**-0.0443**	
26/10/98	HU	+			0.0389	**0.0331***
02/11/98	HU	+			0.0591	
16/11/98	PO	+				0.0559
04/01/99	PO	+				0.0498
07/01/99	HU	+		**-0.0459**	0.0935	**0.0533**
13/01/99	HU	-			-0.0544	
15/01/99	HU	-	**-0.1123**		-0.0427	
25/01/99	HU	+			0.0352	
26/01/99	PO	+				0.0610
23/02/99	CZ	-		-0.0259		
08/03/99	HU	+		**-0.0399**	0.0830	**0.0384***
05/05/99	RU	+	0.1353			
06/05/99	HU	+			0.0367	
12/05/99	RU, CZ	-, -	-0.1772	-0.0242		
17/05/99	RU	+	0.1493			
20/07/99	CZ	+		0.0227		
31/12/99	RU	+	0.1542			