Financial Contagion Vulnerability and Resistance: A Comparison of European Stock Markets*

Dobromił Serwa and Martin T. Bohl**
European University Viadrina Frankfurt (Oder)

January 2005

Abstract: This paper investigates contagion to European stock markets associated with seven big financial shocks between 1997 and 2002. We apply methods using heteroscedasticity adjusted correlation coefficients to discriminate between contagion, interdependence, and breaks in stock markets relationships. The analysis focuses on a comparison between developed Western European markets and emerging stock markets in Central and Eastern Europe. We find modest evidence of significant instabilities in cross-market linkages after the crises. The Central and Eastern European stock markets are not more vulnerable to contagion than Western European markets.

JEL Classification: G15, C12

Keywords: Financial Contagion, financial shocks, Western, Central and Eastern European stock markets, adjusted correlation coefficient

* We are grateful to Szymon Bielecki, Janusz Brzeszczyński, Harald Henke, Michał Rubaszek, Shauna Selvarajah, Aleksander Welfe as well as seminar participants at the Warsaw School of Economics, the University of Łódź, the European University Viadrina and the Second Annual European Economics and Finance Society Conference in Bologna who greatly improved the paper. Furthermore, we would like to thank two anonymous referees for their helpful comments on an earlier draft of the paper.

** Corresponding author: Martin T. Bohl, Faculty of Economics, European University Viadrina, Große Scharrnstraße 59, 15230 Frankfurt (Oder), Germany, Phone: ++ 49 335 5534 2984, Fax: ++ 49 335 5535 2959, E-mail: bohl@euv-frankfurt-o.de

1. Introduction

There has been great interest in empirical and analytical studies on cross-country and cross-market transmission of financial crises over the last decade. Most of the empirical work has been undertaken to measure the extent of financial spillovers to mature and emerging markets and to find channels of transmission of shocks to foreign countries. Earlier studies have often focused on contagion to emerging stock markets in South America and Asia due to the crises in the U.S. in 1987, Mexico in 1994, East Asia in 1997, and Russia in 1998.[1]

Recently, the discussion regarding the enlargement of the European Union (EU) shifted attention to transition countries in Central and Eastern Europe (CEE). However, until now very few empirical studies have concentrated on contagion to CEE markets. Darvas and Szapáry (2000) provide evidence that spillovers from the Russian crisis to CEE were due to shifts in market sentiments and Krzak (1998) argues that the CEE countries have been hit by the Russian crash most heavily through trade rather than through any financial linkages. Gelos and Sahay (2001) outline that the behavior of the emerging CEE markets after the Russian crisis was similar to that of their counterparts in Asia and Latin America during the Asian crisis. Furthermore, they observe increasing correlations across CEE stock markets during the 1994 – 1999 period. Fries, Raiser, and Stern (1999) find that CEE stock markets were generally not as vulnerable to financial contagion during the Asian and Russian crashes as the less developed stock markets from the former Soviet Union.

Contagion has been commonly defined as a transmission of shocks from a crisis-country to other countries, which can be observed through co-movements of different financial indices on multiple markets or rising probabilities of default. In this paper, we apply the definition put forward

[1] Surveys on this issue can be found in Claessens and Forbes (2001), Goldstein, Kaminsky, and Reinhart (1999), Calvo, Goldstein, and Hochreiter (1996), and IMF (1999).

by Forbes and Rigobon (2002) and distinguish between common shocks and contagion.[2] Accordingly, contagion requires a change in the structure of stock market linkages. The increase in cross-market linkages during the crisis must be significant to be called contagion, not just interdependence. Contagion is then an excessive transmission of shocks from one crisis stock market to others, beyond any idiosyncratic disturbances and fundamental links among them. Fundamental financial links constitute interdependence.

Many empirical methods measuring contagion are based on cross-market correlation coefficient estimates.[3] Forbes and Rigobon (2002) demonstrate that the rise in correlation does not necessarily imply contagion as defined above. The authors propose a test to distinguish between contagion and co-movement of stock index returns driven by bilateral linkages. Their most striking empirical result from using this procedure is that in the majority of countries one cannot observe contagion during the 1987 U.S. crash, the 1994 Mexican collapse, and the 1997 Asian crisis. Gelos and Sahay (2001) also apply a simplified version of this methodology and find no contagion from the Czech Republic, Asia, and Russia to CEE stock markets. The method is attractive because it does not assume any specific structure of financial spillovers and allows for a straightforward interpretation of empirical results on cross-market interdependence. Furthermore, some recent

---

[2] See also Masson (1998), Kaminsky and Reinhart (2000), Karolyi (2003), and Moser (2003). Discussions on different definitions of contagion may be found in Edwards (2000), Forbes and Rigobon (2001), and Pericoli and Sbracia (2003).

[3] See, for example, King and Wadhwani (1990), Lee and Kim (1993), Longin and Solnik (2001). An overview of most methods can be found in Forbes and Rigobon (2001, 2002), Rigobon (2001), Claessens and Forbes (2001), and Pericoli and Sbracia (2003).

testing methodologies extend or are based on the Forbes-Rigobon approach (e.g., Corsetti, Pericoli, and Sbracia (2005), Bekaert, Harvey, and Ng (2003), Rigobon (2003))[4].

Although some new definitions and approaches to test contagion have appeared in the literature (for example, Chan-Lau, Mathieson, and Yao (2002) and Bae, Karolyi, and Stulz (2003)), we concentrate on a correlation based analysis. As noted by Billio and Pellizon (2003) and Forbes and Rigobon (2002) this concept suits better than other approaches the issues of international diversification, the role of international institutions and bail-out funds, as well as propagation mechanisms. We utilize the methodologies introduced by Forbes and Rigobon (2002) and Corsetti, Pericoli, and Sbracia (2005) and extend their empirical investigation in three directions. First, a different timeframe to explore new crises is used. To our best knowledge, no investigation has focused on spillover effects of new financial crashes to transition countries in CEE. Studying these crises provides new evidence on financial spillovers to emerging stock markets.

Second, it is of considerable interest to investors and financial market regulators to examine how vulnerable the European stock markets are to different financial shocks. Therefore, in contrast to most previous studies related to contagion, we provide additional evidence on breaks in linkages between crisis and non-crisis capital markets (Billio and Pellizon (2003)). Third, our investigation focuses on a comparison between emerging CEE and mature Western European stock markets. The process of integration between the fast developing and well-developed markets in Europe is an example of successful financial liberalization in terms of macroeconomic and institutional fundamentals. Thus, the emerging stock markets appear as an interesting option for diversification of international capital portfolios (Chen, Firth, and Rui (2002), Bekaert and Harvey (2002, 2003)). Our empirical results offer new evidence of whether emerging stock markets in Europe are more

[4] Ronn (1998), Boyer, Gibson, and Loretan (1999), and Loretan and English (2000) investigated adjusted correlation measures analogous to the one proposed by Forbes and Rigobon.

vulnerable to financial crises than well-developed European markets and which recent crises were most contagious.

In the next section we describe the methods applied to investigate the existence of contagion following Forbes and Rigobon (2002) and Corsetti, Pericoli, and Sbracia (2005). In section 3 we present the data and a method to identify the crises. Section 4 contains our empirical results and section 5 concludes.

2. Methodology

Forbes and Rigobon (2002) and Corsetti, Pericoli, and Sbracia (2005) propose alternative models of inter-market dependencies that allow for constructing measures of correlation between stock returns on the crisis and calm stock market during crisis periods. These correlation measures, adjusted for volatile periods, are functions depending on the specification of the proposed models. Forbes and Rigobon consider a model, where stock returns on the crisis market, y_t, are exogenous and influence returns on the calm market, x_t:

$$\begin{aligned} x_t &= a_1 + c_1 y_t + \varepsilon_t^x \\ y_t &= \varepsilon_t^y \end{aligned}, \tag{1}$$

where ε_t^x and ε_t^y are idiosyncratic shocks to the respective stock markets. Forbes and Rigobon assume that volatility of stock returns on the crisis market increases during turbulent periods, but the parameters in the model and the volatility of idiosyncratic shocks in the non-crisis market, ε_t^x, remain constant.

High volatility of stock returns on the crisis market, which is transferred to the non-crisis market through stable fundamental linkages, induces higher correlation between the stock markets even when contagion does not occur. Correlation is conditional on the volatility of stock returns in the crisis market and, therefore, an increase in correlation is not necessarily caused by contagion, but may be due to higher volatility of stock returns as well. Analytical and empirical results confirm this hypothesis (King and Wadhwani (1990), Corsetti, Pericoli, and Sbracia (2005), Longin and Solnik (2001), Forbes and Rigobon (2002)).

Forbes and Rigobon (2002) show that under the assumption of no omitted disturbances to a non-crisis country or any feedback shocks from the non-crisis market to the turmoil country the adjusted correlation coefficient, which does not depend on the volatility of returns in the crisis market, satisfies:

$$\rho^{FR} = \frac{\rho^{crisis}}{\sqrt{1+\delta[1-(\rho^{crisis})^2]}}. \tag{2}$$

ρ^{crisis} is the correlation coefficient between the crisis and the non-crisis market observed during the crisis period. The parameter δ represents the relationship between the variances of stock returns from the crisis country during the turmoil period, $Var^{turmoil}(y_t)$, and during the calm period, $Var^{stable}(y_t)$:

$$\delta = \frac{Var^{turmoil}(y_t)}{Var^{stable}(y_t)} - 1. \tag{3}$$

Forbes and Rigobon compare the correlation coefficient in the stable period, ρ^{stable}, with the adjusted correlation measure in the crisis period, ρ^{FR}, to test for a change in linkages between stock markets during crises. A significant positive (negative) difference between both correlation values is interpretable as evidence of contagion (a break in inter-market linkages).

In a more general model presented by Corsetti, Pericoli, and Sbracia (2005) stock returns of two markets consist of a factor common for both markets (e.g., a global factor), f_t, and idiosyncratic factors independent of any non-domestic influences, ε_t^x and ε_t^y:

$$\begin{aligned} x_t &= a_1 + c_1 f_t + \varepsilon_t^x \\ y_t &= a_2 + c_2 f_t + \varepsilon_t^y \end{aligned} \tag{4}$$

In this model volatilities of idiosyncratic and common shocks on the crisis market may increase during turbulent periods, but only the common factor influences stock returns on the non-crisis market.

As argued by Corsetti, Pericoli, and Sbracia, empirical results show that the volatility of idiosyncratic shocks ε_t^y on the crisis market, independent from the common factor, is different from zero. If model (4) is correct, then y_t is correlated with the residual factor in the first equation of model (1) and variance of this residual factor increases always when the volatility of ε_t^y increases. The above facts violate the assumptions of the Forbes-Rigobon approach. Thus, the adjusted correlation measure proposed by Forbes and Rigobon will usually be biased.

Instead, Corsetti, Pericoli, and Sbracia propose a formula for the correlation between markets during a crisis period that would be generated by the model with stable inter-market linkages:

$$\rho_{crisis}^{CPS} = \rho^{stable}\left[\left(\frac{1+\lambda_y^{stable}}{1+\lambda_y^{crisis}}\right)^2 \frac{1+\delta}{1+\left(\rho^{stable}\right)^2\left[(1+\delta)\frac{1+\lambda_y^{stable}}{1+\lambda_y^{crisis}}-1\right]\left(1+\lambda_y^{stable}\right)}\right]^{\frac{1}{2}}, \quad (5)$$

where:

$$\lambda_y^{stable} = \frac{Var^{stable}(\varepsilon_t^y)}{(c_2)^2 Var^{stable}(f_t)}, \quad (6)$$

$$\lambda_y^{crisis} = \frac{Var^{crisis}(\varepsilon_t^y)}{(c_2)^2 Var^{crisis}(f_t)}. \quad (7)$$

$Var^{stable}(\cdot)$ and $Var^{crisis}(\cdot)$ denote variances of argument variables computed in stable and crisis periods, respectively. Corsetti, Pericoli, and Sbracia compare the correlation coefficient, ρ_{crisis}^{CPS}, with the sample correlation coefficient, ρ^{crisis}, computed in the turbulent period between a crisis and a non-crisis market, to test for the existence of contagion or breaks in linkages.

Recent empirical studies find a dependence of stock returns on mature and emerging markets on returns from other markets or regions even after controlling for the impact of the global market (e.g., Eun and Shim (1989), Malliaris and Urrutia (1992), Masih and Masih (2001), Scheicher (2001), Climent and Meneu (2003)). In fact, our empirical investigation also shows that different measures of a common factor like world market stock returns, US market stock returns, and factors derived from the principle component analysis (Corsetti, Pericoli, and Sbracia (2005)) are unable to reduce the correlation between idiosyncratic shocks on the crisis and non-crisis markets to zero. Taking into account direct inter-market dependencies leads to an extension of the Corsetti-Pericoli-Sbracia approach:

$$\begin{aligned} x_t &= a_1 + c_1 f_t + b_1 y_t + \varepsilon_t^x \\ y_t &= a_2 + c_2 f_t + b_2 x_t + \varepsilon_t^y \end{aligned}, \tag{8}$$

where f_t denotes a measure of a global factor or a common factor after excluding direct interdependencies. After controlling for the direct inter-market relationship, idiosyncratic shocks ε_t^x and ε_t^y remain independent. The parameters b_1 and b_2 are measures of direct dependences between stock markets beyond the influence of the global market. The attractive feature of specification (8) is that its reduced form:

$$\begin{aligned} x_t &= a_1^* + c_1^* f_t + \eta_t^x \\ y_t &= a_2^* + c_2^* f_t + \eta_t^y \end{aligned} \tag{9}$$

is analogous to the one proposed by Corsetti, Pericoli, and Sbracia. The non-zero correlation between residuals of the reduced-form specification, η_t^x and η_t^y, is the sole but crucial difference. It implies that the adjusted correlation function derived by Corsetti, Pericoli, and Sbracia, although theoretically appealing, may be biased in empirical exercises, as shown in our Appendix.

From the discussion above we can draw the following conclusion. The adjusted correlation coefficients of Forbes and Rigobon (2002) and Corsetti, Pericoli, and Sbracia (2005), independent from calm and crisis periods, may in some situations be biased. However, the latter approach is more general and requires less assumptions. The test of Corsetti, Pericoli, and Sbracia rejects the hypothesis of stable inter-market linkages more often than the test of Forbes and Rigobon in empirical studies. Similar test results from both specifications provide more robust evidence in favor or against the hypothesis of contagion.

In our empirical investigation we report results from both correlation measures to check how robust the findings are with respect to different model specifications. Additionally, we compute correlation coefficients using the reduced-form residuals of specification (9). We interpret these residuals as unpredictable stock returns or excess stock returns beyond any external and lagged domestic influence. The estimated correlation coefficients between excess stock returns allow for testing how the direct linkages between stock markets (beyond those with a global factor) change during crisis periods. The correlation measures between reduced-form residuals, adjusted for crisis and calm periods, can be computed using the Forbes-Rigobon method under condition that $b_2 = 0$ in model (8). Thus, we test stability of the following data-generating process:

$$\begin{aligned} \eta_t^x &= b_1 \varepsilon_t^y + \varepsilon_t^x \\ \eta_t^y &= \varepsilon_t^y \end{aligned} . \qquad (10)$$

This approach assumes that any direct dependences between markets beyond the influence of the global factor (or some measure of a common factor) are allowed only in the direction from the crisis market to the non-crisis market. Volatility of ε_t^x is required to be constant in stable and crisis periods. [5] The other assumptions are analogous to the Forbes-Rigobon approach, but they consider residual returns instead of market returns here. We add lagged returns from both stock markets to

---

[5] Alternatively, a method of Corsetti, Pericoli, and Sbracia (2005) could be used. Forbes and Rigobon (2002) show that their test is also valid for sufficiently low (but different from zero) values of b_2. We expect b_2 to be close to zero, because the global factor has a major impact on local stock index returns.

the equations in (9) to adjust for autocorrelation in stock returns, spillovers and causality between markets, analogously to Forbes and Rigobon (2002).

After calculation of the correlation coefficients for the stable period and the correlation coefficients for the crisis period, ρ^{crisis}, ρ^{FR}, and ρ^{CPS}_{crisis}, all coefficients are converted using a Fisher transformation into approximately normally distributed variables and can be compared by employing standard tests (Gelos and Sahay (2001), Corsetti, Pericoli, and Sbracia (2005)). We investigate the null hypotheses of no increase and no decrease in the relationship between crisis and non-crisis countries using standard one tail t statistics. The corresponding alternative hypotheses are that there is an increase (a decrease) in correlation coefficients. A significant positive change in correlation coefficients between the stable period and the turmoil period is interpreted as a shift in the structure of those relationships and, hence, provides evidence in favor of contagion. Furthermore, a significant decrease in correlation between stock markets returns can be interpreted as a break in links between them (Billio and Pellizon (2003), Corsetti, Pericoli, and Sbracia (2005)).

Billio and Pellizon (2003) and Dungey and Zhumabekova (2001) raise problems of omitted variables, feedback dependencies between stock markets, different time zones, and arbitrary choices of the crisis window, which all can affect tests of contagion. We deal with these aspects by employing different model specifications, different tests, different measures of global shocks, inclusion of lagged stock returns into the models, and using daily as well as two-day stock indices denominated in local currencies and in U.S. dollars. Moreover, different crisis windows from two weeks up to three months are investigated.

3. Data and Identification of Crises

In our empirical analysis we utilize time series returns from 17 stock markets, calculated in both U.S. dollars and local currencies. We concentrate on the four largest markets in CEE (The Czech Republic, Hungary, Poland, and Russia) and on selected West European markets, which are members of the EU. They range from the biggest and most developed financial centers (France, Germany, and The United Kingdom) to less developed stock markets (Greece, Ireland, Portugal, and Spain). The latter four represent the countries that entered the EU in the seventies and eighties as emerging markets and may now be considered – according to MSCI measures – as developed stock markets. Thus, we are able to investigate differences in vulnerability to financial crises depending on the development and importance of the stock market. In addition, six stock markets in which crises took place (Argentina, Brazil, Hong Kong, Korea, Turkey, and the U.S.) are selected.

Seven crises are analyzed. We start with the Asian crisis, the Russian financial failure and its expansion to Brazil. We then continue with the investigation on financial turmoil in Turkey at the beginning of 2001, the terrorist act on the U.S., and the Argentinean insolvency collapse in 2002. Our analysis ends with the American stock market crash after the Enron and WorldCom bankruptcies. The five non-American crises are significant with respect to their extent. The indices in crisis markets in each case fell more than 40% during the turmoil. The two American crashes in 2001 and 2002 are included in line with Mishkin and White (2003) who found that the 2000 – 2001 crisis was among the fifteen biggest crashes in the U.S. during the last century.[6] We separately investigate two important events within this long-term downturn, namely the terrorist act which caused the U.S. index to fall by about 18% and the second accounting scandal when the same index fell by an additional 20%.[7]

It is obvious from the discussion of our methodology that an important step in the analysis is the identification of the crisis interval. It requires a separation of a turmoil period from a stable period in order to accurately investigate the existence of contagion. We use two approaches for identifying stable and turmoil periods. First, starting dates of the crises are known and reported in

---

[6] The actual decline lasted until September 2002. Crashes are defined in Mishkin and White as a 20% drop in the market index value during a period which may range from one day to one year.

[7] The Morgan Stanley Capital International database of standardized country equity indices is used as a proxy for the U.S. stock index.

the literature. The lengths of the turmoil intervals are chosen to be one or two months depending on the crisis' development.[8] Second, the starting date is the day when a country index has its local maximum and the ending date is the local minimum during the crisis. Using this criterion we analyze periods when indices fell at the highest rate and the downfall was significant (Mishkin and White (2003)). Similarly, the stable intervals start two months before the initial shock. As a check of robustness we choose as the stable period the maximum possible length from the end of the last crisis to the beginning of the next one. The results (not reported but available on request) do not change our general conclusion. All analyzed periods are presented in Table 1.

Table 1 about here

The crisis intervals denoted with a bold font in Table 1 are based on dates reported in the literature. All empirical results presented in this paper rely on these dates.[9] The Asian crisis periods are similar to those chosen by Rigobon (2001). The crisis in East Asia started in Thailand in June 1997, but the most remarkable collapse was observed on the Hong Kong capital market a few months later and persisted there for about two weeks. October 23, 1997, is the day of the drastic increase (over 30 percentage points) of short-term interest rates in Hong Kong. The dates for the financial collapses in Russia and Brazil are based on Rigobon (2001, 2003) and Baig and Goldfajn (1998). The initial shock to the Russian financial markets took place on August 6, 1998, and persisted till the end of September.[10] The Brazilian collapse, which has been often associated with

[8] We have also experimented with shorter periods of two weeks and longer periods of three months. The results do not change our general conclusions.

[9] The findings from the other intervals are also discussed in our sensitivity analysis in the next section.

[10] The initial shock was to the bond market and the stock market reacted one week later.

contagion from the Russian crisis, lasted from October 1998 till March 1999, but the capital market suffered mostly during the period from the end of November 1998 to January 1999.

The duration of the Turkish crisis was chosen following Alper (2001) and Yeldan (2002) and an interval for the Argentinean collapse is based on information from daily newspapers. The Turkish financial crisis started already in November 2000, but it developed after a dispute between the Turkish Prime Minister and President on February 15, 2001. The central bank stopped defending the Turkish lira against capital outflows on February 21, 2001, and let it float freely. In Argentina martial law was declared on December 18, 2001, after some protests, violent demonstrations and looting of supermarkets. Two days later the Argentinean President resigned. On February 1, 2002, a decree restricting bank withdrawals was brought into force.

The starting dates of the two American market crashes are taken from daily newspaper headlines (Mishkin and White (2003)). The terrorist acts in New York and Washington took place on September 11, 2001, and WorldCom revealed its great accounting fraud on June 25, 2002. Nevertheless, as mentioned by Mishkin and White (2003) the prolonged downturn of the U.S. stock market was also heavily influenced by a slowdown of the American economy.

The standardized, comparable time series on stock market returns were obtained from the MSCI internet database (www.msci.com). Due to the crises analyzed, the time series used in the study range from September 1997 to September 2002.

4. Empirical Results

In this section, we compare correlation coefficients between stock returns of crisis countries and selected European stock markets during stable and turmoil periods. This part of our investigation is based on the methodology outlined in section 2 and uses the crisis periods described in section 3. The models of Forbes and Rigobon (2002), Corsetti, Pericoli, and Sbracia (2005), and additionally model (9) are employed to estimate the correlation coefficients among crisis and non-crisis stock markets. Following Forbes and Rigobon (2002) we use two-day average rolling log stock returns to control for different opening hours of national stock exchanges around the world. Corsetti, Pericoli, and Sbracia (2005) propose different measures of a common factor influencing both crisis and non-crisis stock markets. Similarly, we employ world market and US index returns from the MSCI database, and the first principal component computed from a group of all investigated stock markets. We check which of these measures of the common factor reduces the absolute value of correlation measures between idiosyncratic shocks on the crisis and non-crisis markets to minimum. Empirical distributions of correlation coefficient estimates between idiosyncratic shocks for the different measures of the common factor are presented in Figure 1.

Figure 1 about here

For each measure, we find cases of significant deviations of the estimated correlation coefficients from zero. However, the best results are obtained with the principal component measure. Therefore, we employ this measure in our main investigation and discuss results from other measures in a sensitivity analysis. In case of the extended model (9), we compute correlation coefficients ($\rho_{residuals}^{stable}$ for tranquil periods and $\rho_{residuals}^{crisis}$ for turbulent periods) between excess returns (reduced-form residuals) from both markets. In this specification, we include the first lag of stock returns as explanatory variables to control for serial correlation in stock returns, causality, and lagged spillovers between markets. Moreover, stock returns from the U.S. market as a proxy for shocks from the global market are used. In Table 2 we present correlation coefficients from stable and crisis periods and the results of all three test statistics.[11]

---

[11] The 5% significance level is throughout used in our tests, except for the Corsetti-Pericoli-Sbracia tests which are computed at the 10% significance level to approximate the true 5% level and to show that our results are robust.

Table 2 about here

The main finding from Table 2 is that in the majority of cases there was neither contagion to the CEE nor to the West European markets. Hence, linkages between the stock markets of the crisis and the non-crisis countries remained stable during turmoil periods. Contagion is rather a rare phenomenon. Gelos and Sahay (2001), using a similar methodology, also found weak evidence in favor of contagion to CEE markets during the Czech crisis in 1997 and crashes in Asia and Russia. According to our results, there is some evidence of contagion to Western European markets during the Asian crisis (to Germany and Ireland), during the Brazilian crisis (to the United Kingdom), and after both shocks to the U.S. (to Ireland and Greece). There are only four cases of contagion to CEE markets, namely to Polish and Czech markets after shocks to the U.S., and to Russia during the Turkish crisis. Only two cases of contagion are robust to the model and test specification (Ireland and Greece).

Other interesting findings are the cases of significant negative changes in linkages between crisis and non-crisis stock markets. Some evidence of structural breaks in linkages can be found during the Hong Kong collapse for Greece, Portugal, and the Czech Republic, during the Brazilian crisis for Poland, and during the Turkish crisis for Greece, Portugal, Ireland, the Czech Republic, as well as Poland. Moreover, breaks of linkages can be found after the terrorist acts in the U.S. for Portugal, Russia, and Poland, during the Argentinean crisis for Ireland, Germany, and the United Kingdom. However, only one case of a break in linkages is robust to the model specification. During the “Russian virus” there was also a negative shift in adjusted correlations between almost all studied countries and Russia, but the change was not statistically significant.

In contrast to Glick and Rose (1999), our results related to the crisis in Russia indicate that geographical proximity is not always an important driver of contagion. The causality tests implemented by Gelos and Sahay (2001) provide evidence of strong interdependence between Russia and Central European countries at the time of collapse in 1998, but their correlation analysis results are in line with ours.[12] A decline in linkages with crisis stock markets during different crashes is as common as contagion overall.

We can observe a few patterns of stock market behavior regarding contagion and breaks in linkages. The crises in Russia, Brazil, and Argentina induce less contagion compared to the rest of the crises under investigation. Relatively few cases of breaks in linkages can be found for the Russian and the Brazilian crisis as well as the second U.S. scandals. During most downfalls the CEE stock markets acted similarly to the Western European ones. Our sensitivity analyses show approximately the same relative number of cases of contagion to CEE and Western European countries, i.e., 10% and 12%, respectively. Moreover, a similar picture appears with respect to breaks in linkages. These results indicate that the CEE stock markets were not more vulnerable to contagion than the developed European markets during the analyzed period.

Interestingly, correlations between residual returns from the extended models are significantly greater (lower) than zero in 33% (25%) cases during tranquil times and in 38% (30%) cases during turbulent periods at the 0.05 significance level. This could suggest that in some cases the bias in the Corsetti-Pericoli-Sbracia approach is not severe. Moreover, the residual correlation increases in 54% cases (in 16% cases significantly) and decreases in 46% cases (in 22% cases significantly) during turmoil. These outcomes also indicate limited evidence of contagion.

We checked the robustness of our results by using daily and two-day returns of stock indices, denominated in local currencies and in U.S. dollars, in our tests of contagion. We also applied different model specifications and tests. The findings of our sensitivity analysis are not reported but available on request. As expected, using the approach proposed by Corsetti, Pericoli and Sbracia (2005) we find more evidence of contagion and less evidence of breaks in inter-market linkages. Nevertheless, we find that CEE stock markets are usually not more vulnerable to financial crises than Western European markets.

[12] See also Krzak (1998), Darvas and Szapary (2000) for studies on contagion from Russia to CEE.

Our results are also robust against many different settings of stable and turmoil periods. It is interesting to note that any contagion effects in Europe are usually strongest within the first two-week periods, but still rare in comparison to cases of interdependence. Generally, either the CEE stock markets are no more vulnerable to contagion than Western European markets or contagion is limited in all investigated stock markets.

5. Summary and Conclusions

Forbes and Rigobon (2002) showed that higher stock return volatility on a crisis market induces higher correlation between this market and other non-crisis markets even when there is no shift in fundamental relationships between any of them (Ronn (1998), Boyer, Gibson, and Loretan (1999), Loretan and English (2000)). They call such behavior of international stock market returns "interdependence". In contrast, "contagion" is caused by a significant change in fundamental linkages between the crisis market and non-crisis markets. We utilize the methodologies introduced by Forbes and Rigobon (2002) and Corsetti, Pericoli, and Sbracia (2005) as well as an extension of the Corsetti-Pericoli-Sbracia approach to determine whether several financial shocks have any impact on linkages between crisis markets and European stock markets. We focus our investigation on a comparison between the behavior of Western and CEE stock markets during the period prior to the entrance of the first CEE countries to the EU. Crises in East Asia (1997), Russia (1998), Brazil (1999), Turkey (2000), Argentina (2001), and the U.S. (2001, 2002) are analyzed. They originate from macroeconomic fundamentals as well as from political affairs (e.g., terrorist acts).

Our main conclusion is that contagion to CEE stock markets was not more frequent than to Western European stock markets. Depending on the model specification, contagion occurred hardly ever or not frequently during the investigated crises and it is rather interdependence than contagion that characterizes co-movements between the crisis and non-crisis stock markets. This result is important for investors willing to allocate their financial capital to emerging markets in Europe.

During the analyzed period the CEE stock markets appeared to be quite robust against different external shocks. One explanation of this result could be poor integration of CEE stock markets with world capital markets. Measures of integration like the rate of volatility on the local market explained by U.S. or world market volatility (Baele (2005)), indicate that Portugal, Greece, and Ireland were not notably more integrated with the world stock market, but the other Western European markets were. In the analyzed period, CEE emerging stock markets did not always react in the same manner to important financial shocks as more developed markets in Western Europe. However, the direction of change in heteroscedasticity adjusted correlation coefficients between crisis and non-crisis markets is common for both groups of countries. In this sense, the behavior of CEE stock markets had a regional character. The examples of Russia and Argentina show that crises in some emerging capital markets may have an opposite effect on other developing countries. The main reason for the lack of financial contagion between these countries might be the limited importance of the crisis markets.

The crises on financial markets in the U.S. and Hong Kong had the most significant impact on the non-crisis European stock markets. In addition, we investigate breaks in relationships between crisis and non-crisis capital markets during turmoil periods. The results for European stock markets show that cases of breaks in linkages are usually as frequent as cases of contagion. This evidence may suggest that some stock markets are independent of certain crises or even benefit from crises elsewhere. The explanation of this phenomenon could be the flow of capital from the crisis market to the non-crisis market and, therefore, further studies in this direction are certainly needed.

References

Alper, C. Emre (2001), The Liquidity Crisis of 2000: What Went Wrong?, Russian and East European Finance and Trade 37, 54 – 75.

Bae Kee-Hong, G. Andrew Karolyi, and René M. Stulz (2003), A New Approach to Measuring Financial Contagion, Review of Financial Studies 16, 717 – 763.

Baig, Taimur and Ilan Goldfajn (1998), Financial Market Contagion in the Asian Crisis, IMF Working Paper 98/155.

Baele, Lievien (2005), Volatility Spillover Effects in European Equity Markets, Journal of Financial and Quantitative Analysis, forthcoming

Bekaert, Geert and Campbell R. Harvey (2002), Research in emerging markets finance: looking to the future, Emerging Markets Review 3, 429 – 448.

Bekaert, Geert and Campbell R. Harvey (2003), Emerging markets finance, Journal of Empirical Finance 10, 3 – 55.

Bekaert, Geert, Campbell R. Harvey, and Angela Ng (2003), Market Integration and Contagion, NBER Working Paper 9510.

Billio, Monica and Loriana Pelizzon (2003), Contagion and Interdependence in Stock Markets: Have they been misdiagnosed?, Journal of Economics and Business 55, 405 – 426.

Boyer, Brian H., Michael S. Gibson, and Mico Loretan (1999), Pitfalls in tests for changes in correlations, Federal Reserve Board, IFS Discussion Paper No. 597R.

Calvo, Guillermo A., Morris Goldstein, and Eduard Hochreiter, eds., (1996), Private Capital Flows to Emerging Markets After the Mexican Crisis, Institute for International Economics, Washington, DC.

Chan-Lau, Jorge A., Donald J. Mathieson, and James Y. Yao (2002), Extreme Contagion in Equity Markets, IMF Working Paper 02/98.

Chen, Gong-meng, Michael Firth and Oliver Meng Rui (2002), Stock market linkages: Evidence from Latin America, Journal of Banking and Finance 26, 1113 – 1141.

Claessens, Stijn and Kristin J. Forbes, eds., (2001), International Financial Contagion: How It Spreads and How It Can Be Stopped, Kluwer Academic Publishers, Boston, MA.

Climent Francisco J. and Vicente Meneu (2003), Has 1997 Asian crisis increased information flows between international markets? International Review of Economics and Finance 12, 111 – 134.

Corsetti, Giancarlo, Marcello Pericoli, and Massimo Sbracia (2005), Some Contagion, Some Interdependence, More Pitfalls in Tests of Financial Contagion, Journal of International Money and Finance, forthcoming.

Darvas, Zsolt and György Szapáry (2000), Financial Contagion in Five Small Open Economies: Does the Exchange Rate Regime Really Matter? International Finance 3, 25 – 51.

Dungey, Mardi and Diana Zhumabekova (2001), Testing for Contagion using Correlations: Some Words of Caution, Federal Reserve Bank of San Francisco, Pacific Basin Working Paper PB01-09.

Edwards, Sebastian (2000), Interest Rates, Contagion and Capital Controls, NBER Working Paper 7801.

Eun, Cheol S. and Sangdal Shim (1989), International transmission of stock market movements, Journal of Financial and Quantitative Analysis 24, 241 – 256.

Forbes, Kristin J. and Roberto Rigobon (2001), Measuring Contagion: Conceptual and Empirical Issues, in: Stijn Claessens and Kristin J. Forbes (eds.), International Financial Contagion: How It Spreads and How It Can Be Stopped, Kluwer Academic Publishers, 43 – 66.

Forbes, Kristin J. and Roberto Rigobon (2002), No Contagion, Only Interdependence: Measuring Stock Market Co-Movements, Journal of Finance 57, 2223 – 2261.

Fries, Steven, Martin Raiser, and Nicholas Stern (1999), Stress test for reforms. Transition and East Asian 'contagion', Economics of Transition 7, 535 – 567.

Gelos, R. Gaston and Ratna Sahay (2001), Financial Spillovers in Transition Economies, Economics of Transition 9, 53 – 86.

Glick, Reuven and Andrew K. Rose (1999), Contagion and Trade: Why are Currency Crises Regional?, Journal of International Money and Finance 18, 603 – 617.

Goldstein, Morris, Graciela Kaminsky, and Carmen Reinhart (1999), Assessing Financial Vulnerability: An Early Warning System for Emerging Markets, Institute for International Economics, Washington DC.

IMF (1999), International Financial Contagion, World Economic Outlook, IMF, Washington.

Kaminsky, Graciela and Carmen Reinhart (2000), On Crises, Contagion, and Confusion, Journal of International Economics 51, 145 – 168.

Karolyi, G. Andrew (2003), Does International Financial Contagion Really Exist?, International Finance 6, 179 – 199.

King, Mervyn A. and Sushil Wadhwani (1990), Transmission of Volatility between Stock Markets, The Review of Financial Studies 3, 5 – 33.

Krzak, Maciej (1998), Contagion Effects of the Russian Financial Crisis on Central and Eastern Europe: The Case of Poland, in: Focus on Transition, Österreichische Nationalbank, 22 – 37.

Lee, Sang Bin and Kwang Jung Kim (1993), Does the October 1986 Crash Strengthen the Co-Movements among National Stock Markets?, Review of Financial Economics 3, 89 – 102.

Longin, François M. and Bruno Solnik (2001), Extreme Correlation of International Equity Markets, Journal of Finance 56, 649 – 676.

Loretan, Mico and William B. English (2000), Evaluation "correlation breakdowns" during periods of market volatility. Federal Reserve Board, mimeo.

Malliaris, A. G. and Jroge L. Urrutia (1992), The international crash of October 1987: Causality tests, Journal of Financial and Quantitative Analysis 27, 353 – 364.

Masih, Rumi and Abul M.M. Masih (2001), Long and short-term dynamic casual transmission amongst international stock markets, Journal of International Money and Finance 20, 563 – 587.

Masson, Paul (1998), Contagion – Monsoonal Effects, Spillovers, and Jumps Between Multiple Equilibria, IMF Working Paper 98/142.

Mishkin, Frederic and Eugene N. White (2003), U.S. Stock Market Crashes and Their Aftermath: Implications for Monetary Policy, in William C. Hunter, George G. Kaufmann, and Michael Pomerleano, eds., Asset Price Bubbles: The Implications for Monetary Regulatory, and International Policies, The MIT Press, 53 – 79.

Moser, Thomas (2003), What Is International Financial Contagion?, International Finance 6, 157 – 178.

Pericoli, Marcello and Massimo Sbracia (2003), A Primer on Financial Contagion, Journal of Economic Surveys 17, 571 – 608.

Rigobon, Roberto (2003), On the Measurement of the International Propagation of Shocks: Are they Stable?, Journal of International Economics 61, 261 – 283.

Rigobon, Roberto (2001), Contagion: How to Measure It? NBER Working Paper 8118.

Ronn, E. (1998), The impact of large changes in asset prices on intra-market correlations in the stock and bond markets, mimeo.

Scheicher, Martin (2001), The comovements of stock markets in Hungary, Poland and the Czech Republic, International Journal of Finance and Economics 6, 27 – 39.

Yeldan, Erinc (2002), Behind the 2000/2001 Turkish Crisis: Stability, Credibility, and Governance, for Whom? Working Paper, Bilkent University, Ankara, Turkey.

Appendix

In this appendix, we propose an extension of the model presented by Corsetti, Pericoli, and Sbracia (2005), where additional direct inter-market dependencies are allowed. Typical measures of common factors like world stock market returns, U.S. stock market returns, factors estimated using the principal component analysis fail to reduce the correlation between residual factors to zero. We show that omitting this direct relationship between the crisis and the non-crisis market in any measure of the common factor, f_t, used in the model of Corsetti, Pericoli, and Sbracia (2005) can lead to a bias in their test of contagion, because the residual factors on both markets are correlated.

Let f_t be a measure of a global or common factor after excluding direct interdependencies between stock markets. The model controlling for these linkages takes the following form:

$$\begin{aligned} x_t &= a_1 + c_1 f_t + b_1 y_t + \varepsilon_t^x \\ y_t &= a_2 + c_2 f_t + b_2 x_t + \varepsilon_t^y \end{aligned} . \tag{8}$$

The parameters of the structural form are not identified, but the reduced form of the model can be constructed. In matrix notation it takes the following form:

$$\begin{bmatrix} x_t \\ y_t \end{bmatrix} = \frac{1}{1-b_1 b_2}\begin{bmatrix} 1 & b_1 \\ b_2 & 1 \end{bmatrix}\begin{bmatrix} a_1 & c_1 \\ a_2 & c_2 \end{bmatrix}\begin{bmatrix} 1 \\ f_t \end{bmatrix} + \frac{1}{1-b_1 b_2}\begin{bmatrix} 1 & b_1 \\ b_2 & 1 \end{bmatrix}\begin{bmatrix} \varepsilon_t^x \\ \varepsilon_t^y \end{bmatrix}. \tag{A.1}$$

After re-writing the equations, the reduced-form model satisfies:

$$\begin{aligned} x_t &= a_1^* + c_1^* f_t + \eta_t^x \\ y_t &= a_2^* + c_2^* f_t + \eta_t^y \end{aligned} , \tag{9}$$

where:

$$a_1^* = \frac{a_1 + a_2 b_1}{1-b_1 b_2},\ a_2^* = \frac{a_2 + a_1 b_2}{1-b_1 b_2},\ c_1^* = \frac{c_1 + b_1 c_2}{1-b_1 b_2},\ c_2^* = \frac{c_2 + b_2 c_1}{1-b_1 b_2} \tag{A.2}$$

and:

$$\begin{aligned} \eta_t^x &= \frac{1}{1-b_1 b_2}\varepsilon_t^x + \frac{b_1}{1-b_1 b_2}\varepsilon_t^y \\ \eta_t^y &= \frac{b_2}{1-b_1 b_2}\varepsilon_t^x + \frac{1}{1-b_1 b_2}\varepsilon_t^y \end{aligned} . \tag{A.3}$$

Expression (9) is analogous to the one used by Corsetti, Pericoli, and Sbracia. However, formula (A.3) implies that the residuals η_t^x and η_t^y are in general correlated, because η_t^x can be written as a linear function of η_t^y:

$$\eta_t^x = b_1\eta_t^y + \frac{1-b_1b_2(1-b_1b_2)}{1-b_1b_2}\varepsilon_t^x . \tag{A.4}$$

The reduced-form residuals η_t^x and η_t^y are uncorrelated only if the parameters b_1 and b_2 are equal to zero. However, the empirical literature suggests the existence of strong direct (e.g., regional or interregional) linkages between stock markets, as discussed in section 2. Additionally, model (A.3) is equivalent to model (10) in the main text, when $b_2 = 0$:

$$\begin{aligned} \eta_t^x &= b_1\varepsilon_t^y + \varepsilon_t^x \\ \eta_t^y &= \varepsilon_t^y \end{aligned} . \tag{10}$$

Corsetti, Pericoli, and Sbracia (2005) show that the correlation coefficient between stock returns on two markets, generated by the model (9) under assumptions of no contagion, no breaks in linkages between the markets, and no correlation between idiosyncratic factors η_t^x and η_t^y (i.e. the model of Corsetti, Pericoli, and Sbracia), is given by:

$$\rho_{crisis}^{CPS} = \rho_{stable}^{CPS}\left[\left(\frac{1+\lambda_y^{stable}}{1+\lambda_y^{crisis}}\right)^2 \frac{1+\delta}{1+\left(\rho_{stable}^{CPS}\right)^2\left[(1+\delta)\dfrac{1+\lambda_y^{stable}}{1+\lambda_y^{crisis}}-1\right]\left(1+\lambda_y^{stable}\right)}\right]^{\frac{1}{2}}, \tag{A.5}$$

or equivalently by:

$$\rho_{crisis}^{CPS} = \frac{\dfrac{Cov^{crisis}(x_t, y_t)}{\sqrt{(c_1^*)^2 Var^{crisis}(f_t)}\sqrt{(c_2^*)^2 Var^{crisis}(f_t)}}}{\left[1+\dfrac{Var^{crisis}(\varepsilon_t^x)}{(c_1^*)^2 Var^{crisis}(f_t)}\right]^{\frac{1}{2}}\left[1+\dfrac{Var^{crisis}(\varepsilon_t^y)}{(c_2^*)^2 Var^{crisis}(f_t)}\right]^{\frac{1}{2}}} = \tag{A.6}$$

$$= \frac{1}{\left[1+\frac{Var^{crisis}(\varepsilon_t^x)}{(c_1^*)^2 Var^{crisis}(f_t)}\right]^{\frac{1}{2}}\left[1+\frac{Var^{crisis}(\varepsilon_t^y)}{(c_2^*)^2 Var^{crisis}(f_t)}\right]^{\frac{1}{2}}} = \frac{c_1^*}{c_2^*}\left(\frac{1}{1+\lambda_y^{crisis}}\right)\left(\frac{Var^{crisis}(x_t)}{Var^{crisis}(y_t)}\right)^{-\frac{1}{2}},$$

where ρ_{stable}^{CPS} is assumed to be the same as ρ^{stable}. In the presence of correlated residuals η_t^x and η_t^y the correlation between stock returns x_t and y_t becomes:

$$\rho_{stable}^* = \left(1+\frac{Cov^{stable}(\eta_t^x,\eta_t^y)}{c_1^* c_2^* Var^{stable}(f_t)}\right)\left[\frac{c_1^*}{c_2^*}\left(\frac{1}{1+\lambda_y^{stable}}\right)\left(\frac{Var^{stable}(x_t)}{Var^{stable}(y_t)}\right)^{-\frac{1}{2}}\right] \tag{A.7}$$

during tranquil periods and

$$\rho_{crisis}^* = \left(1+\frac{Cov^{crisis}(\eta_t^x,\eta_t^y)}{c_1^* c_2^* Var^{crisis}(f_t)}\right)\left[\frac{c_1^*}{c_2^*}\left(\frac{1}{1+\lambda_y^{crisis}}\right)\left(\frac{Var^{crisis}(x_t)}{Var^{crisis}(y_t)}\right)^{-\frac{1}{2}}\right] \tag{A.8}$$

during crisis periods. c_1^* and c_2^* are assumed to be positive here. The linkages between stock returns beyond the world market influence are often positive, i.e., $Cov^{crisis}(\eta_t^x,\eta_t^y) > 0$ (see also Figure 1). When $Cov(\eta_t^x,\eta_t^y) > 0$ during the stable or the crisis period, the correlation generated by the model (9) is larger than the correlation generated by the model that assumes $Cov(\eta_t^x,\eta_t^y) = 0$ in this period (i.e. the model of Corsetti, Pericolli, and Sbracia).

Note that the ratio of volatilities on both markets during crises can be expressed as:

$$\frac{Var^{crisis}(x_t)}{Var^{crisis}(y_t)} = \frac{Var^{stable}(x_t)+(c_1^*)^2\psi Var^{stable}(f_t)}{(1+\delta)Var^{stable}(y_t)} =$$

$$= \frac{Var^{stable}(x_t)}{(1+\delta)Var^{stable}(y_t)} + \frac{(c_1^*)^2\psi}{(1+\delta)(c_2^*)^2(1+\lambda_y^{stable})}, \tag{A.9}$$

as in the Corsetti-Pericoli-Sbracia approach, where

$$\psi = \frac{\delta(1+\lambda_y^{stable})+(\lambda_y^{stable}-\lambda_y^{crisis})}{1+\lambda_y^{crisis}}.$$

Hence, the correlation between returns on both markets during crises becomes:

$$\rho^*_{crisis} = \left(1 + \frac{Cov^{crisis}(\eta^x_t, \eta^y_t)}{c^*_1 c^*_2 Var^{crisis}(f_t)}\right)\left(\frac{(c^*_2)^2(1+\lambda^{crisis}_y)^2 Var^{stable}(x_t)}{(c^*_1)^2(1+\delta)Var^{stable}(y_t)} + \frac{(c^*_2)^2(1+\lambda^{crisis}_y)^2(c^*_1)^2\psi}{(c^*_1)^2(1+\delta)(c^*_2)^2(1+\lambda^{stable}_y)}\right)^{-\frac{1}{2}} =$$

$$= \left(1 + \frac{Cov^{crisis}(\eta^x_t, \eta^y_t)}{c^*_1 c^*_2 Var^{crisis}(f_t)}\right)\left(\frac{(1+\lambda^{crisis}_y)^2}{(1+\delta)}\frac{(c^*_2)^2 Var^{stable}(x_t)}{(c^*_1)^2 Var^{stable}(y_t)} + \frac{(1+\lambda^{crisis}_y)^2\psi}{(1+\delta)(1+\lambda^{stable}_y)}\right)^{-\frac{1}{2}}. \quad \text{(A.10)}$$

After substituting (A.7) into (A.10) we get:

$$\rho^*_{crisis} = \left(1 + \frac{Cov^{crisis}(\eta^x_t, \eta^y_t)}{c^*_1 c^*_2 Var^{crisis}(f_t)}\right)\left(\frac{(1+\lambda^{crisis}_y)^2(1+\phi^{stable})}{(1+\delta)(\rho^*_{stable})^2(1+\lambda^{stable}_y)^2} + \frac{(1+\lambda^{crisis}_y)^2\psi(\rho^*_{stable})^2(1+\lambda^{stable}_y)}{(1+\delta)(1+\lambda^{stable}_y)^2(\rho^*_{stable})^2}\right)^{-\frac{1}{2}} =$$

$$= \left(1+\phi^{crisis}\right)\rho^*_{stable}\left(\frac{(1+\lambda^{crisis}_y)^2[(1+\phi^{stable}) + \psi(\rho^*_{stable})^2(1+\lambda^{stable}_y)]}{(1+\delta)(1+\lambda^{stable}_y)^2}\right)^{-\frac{1}{2}} = \quad \text{(A.11)}$$

$$= \left(1+\phi^{crisis}\right)\rho^*_{stable}\left[\left(\frac{1+\lambda^{stable}_y}{1+\lambda^{crisis}_y}\right)^2 \frac{1+\delta}{1+\phi^{stable} + \left(\rho^*_{stable}\right)^2\left[(1+\delta)\frac{1+\lambda^{stable}_y}{1+\lambda^{crisis}_y} - 1\right]\left(1+\lambda^{stable}_y\right)}\right]^{\frac{1}{2}},$$

where $\frac{Cov(\eta^x_t, \eta^y_t)}{c^*_1 c^*_2 Var(f_t)}$ is denoted by ϕ to simplify notation.

Since the test of Corsetti, Pericolli, and Sbracia (2005) typically derives the correlation for the tranquil period ρ^{CPS}_{stable} from the sample correlation, then the estimate of the true correlation generated by the model (9) in the stable period is not biased. The correlation in the crisis period ρ^{CPS}_{crisis} is obtained using formula (A.5) and the unbiased estimate of the correlation from the stable period. ρ^{CPS}_{crisis} is likely to be different from the true ρ^*_{crisis} if residuals η^x_t and η^y_t are correlated, i.e. $\phi^{stable} \neq 0$ or $\phi^{crisis} \neq 0$. The direction of the bias depends on values of ϕ^{stable} and ϕ^{crisis}. Thus, the test of Corsetti, Pericolli, and Sbracia may be biased, but the direction of the bias is difficult to assess *a priori* without knowing the values of suitable parameters in (A.11). [13]

---

[13] We thank an anonymous referee for suggesting an equivalent relationship.

Table 1: Duration of the Crises

Crisis Name	Crisis Country	Stable Periods	Crisis Periods
Asian "Flu"	Hong Kong	**1997:9:1 – 1997:10:22**	**1997:10:23 – 1997:11:22**
		1997:9:1 – 1997:10:16	1997:10:17 – 1998:1:12
	Korea	1997:9:17 – 1997:12:14	1997:12:15 – 1998:1:12
Russian "Virus"	Russia	**1998:6:6 – 1998:8:5**	**1998:8:6 – 1998:10:5**
		1998:2:1 – 1998:6:19	1998:6:30 – 1998:9:30
		1998:2:1 – 1998:6:19	1998:7:20 – 1999:10:5
Brazilian Crisis	Brazil	**1998:11:1 – 1998:12:31**	**1999:1:1 – 1999:3:1**
		1998:10:6 – 1998:11:26	1998:11:27 – 1999:1:14
		1998:10:6 – 1998:11:26	1998:11:27 – 1999:1:26
Turkish Collapse	Turkey	**2000:12:5 – 2001:2:14**	**2001:2:15 – 2001:3:13**
		1999:5:1 – 2000:11:3	2001:2:15 – 2001:4:03
		2000:9:6 – 2000:11:3	2000:11:6 – 2000:12:4
Terrorist Acts and Economic Slowdown	U.S.	**2001:6:27 – 2001:8:26**	**2001:9:14 – 2001:10:13**
		2001:7:14 – 2001:9:13	2001:8:27 – 2001:9:21
		2001:4:14 – 2001:9:13	2001:9:14 – 2001:10:13
Argentinean Crisis	Argentina	**2001:10:13 – 2001:12:12**	**2001:12:27 – 2002:2:26**
		2001:11:4 – 2002:1:3	2002:1:4 – 2002:1:17
		2001:10:14 – 2002:1:3	2001:1:4 – 2002:3:4
Accounting Scandals	U.S.	**2002:4:25 – 2002:6:24**	**2002:6:25 – 2002:7:24**
		2002:3:20 – 2002:5:20	2002:6:25 – 2002:7:23

Note: The samples used for the main analysis are reported in the first rows in bold. These dates are applied to calculate correlation coefficients between crisis and non-crisis markets using a VAR model.

Table 2: Correlation Coefficients Between Crisis Market and Non-Crisis Markets Before and During the Crisis

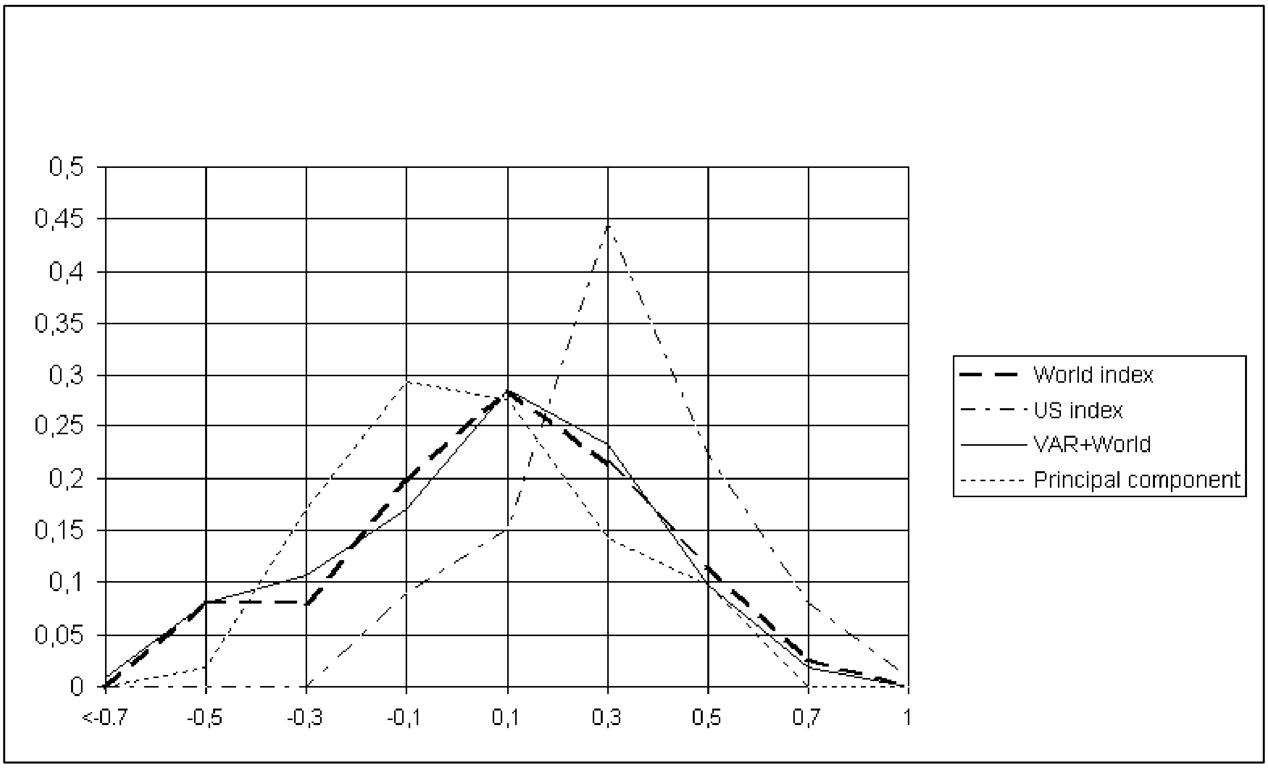
Crisis Market	Date of the Crisis	Explanation of Results			Poland			Czech Republic			Hungary			Russia			United Kingdom			France		
		FR	CPS	RES	FR	CPS	RES	FR	CPS	RES	FR	CPS	RES	FR	CPS	RES	FR	CPS	RES	FR	CPS	RES
Hong Kong	1997:10:23 – 1997:11:22	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	0.19	0.19	0.30	0.12	0.12	0.06	0.25	0.25	0.23	0.34	0.34	0.37	0.30	0.30	0.23	0.44	0,44	0,40
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	0.56	0.56	0.76	-0.12	-0.12	-0.21	0.56	0.56	0.80	0.70	0.70	0.85	0.72	0.72	0.59	0.74	0,74	0,65
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	0.28	0.44	0.48	-0.05	0.30	-0.10	0.28	0.52	0.54	0.39	0.61	0.60	0.41	0.58	0.33	0.43	0,67	0,36
		Test Results (– / / +)							–													
Russia	1998:08:06 – 1998:10:05	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	0.55	0.55	0.54	0.57	0.57	0.57	0.61	0.61	0.55				0.57	0.57	0.44	0.44	0,44	0,25
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	0.44	0.44	0.39	0.58	0.58	0.56	0.53	0.53	0.49				0.51	0.51	0.52	0.55	0,55	0,56
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	0.38	0.52	0.27	0.51	0.53	0.41	0.46	0.56	0.35				0.44	0.54	0.39	0.48	0,43	0,40
		Test Results (– / / +)																				
Brazil	1999:01:01 – 1999:03:01	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	0.49	0.49	0.13	0.01	0.01	-0.06	0.43	0.43	0.13	0.35	0.35	0.03	0.23	0.23	-0.15	0.40	0,40	0,03
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	0.30	0.30	0.01	0.21	0.21	0.05	0.35	0.35	0.16	0.37	0.37	0.19	0.59	0.59	0.45	0.39	0,39	0,14
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	0.21	0.61	0.01	0.14	0.02	0.02	0.25	0.57	0.08	0.27	0.50	0.09	0.45	0.36	0.23	0.28	0,54	0,07
		Test Results (– / / +)				–												+				
Turkey	2001:02:15 – 2001:03:13	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	0.30	0.30	0.44	0.36	0.36	0.20	0.30	0.30	0.39	0.33	0.33	0.36	0.17	0.17	-0.25	0.23	0,23	-0,07
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	0.04	0.04	-0.23	-0.14	-0.14	0.04	0.25	0.25	0.22	0.35	0.35	0.09	-0.21	-0.21	-0.37	0.20	0,20	0,27
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	0.03	0.00	-0.21	-0.12	0.00	0.04	0.21	0.00	0.21	0.30	0.00	0.08	-0.18	0.00	-0.33	0.17	0,00	0,25
		Test Results (– / / +)					–	–							+							
U.S.	2001:09:14 – 2001:10:13	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	0.26	0.26	0.01	-0.03	-0.03	0.03	0.27	0.27	0.10	0.40	0.40	0.33	0.63	0.63	0.56	0.47	0,47	0,28
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	0.26	0.26	0.20	0.31	0.31	0.25	0.45	0.45	0.32	0.28	0.28	0.47	0.66	0.66	0.58	0.63	0,63	0,55
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	0.13	0.61	0.10	0.16	-0.12	0.13	0.24	0.63	0.20	0.14	0.71	0.26	0.40	0.77	0.32	0.37	0,74	0,30
		Test Results (– / / +)				–			+						–							
Argentina	2001:12:27 – 2002:02:26	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	0.03	0.03	-0.09	0.04	0.04	-0.03	0.04	0.04	-0.16	0.03	0.03	-0.04	0.36	0.36	0.21	0.35	0,35	0,20
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	-0.17	-0.17	0.14	-0.10	-0.10	-0.15	-0.19	-0.19	-0.09	0.00	0.00	0.06	0.00	0.00	0.22	0.11	0,11	0,25
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	-0.09	0.00	0.07	-0.05	0.00	-0.06	-0.10	0.00	-0.04	0.00	0.00	0.02	0.00	0.06	0.10	0.06	0,06	0,11
		Test Results (– / / +)															–					
U.S.	2002:06:25 – 2002:07:23	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	-0.17	-0.17	-0.16	-0.19	-0.19	-0.19	-0.07	-0.07	-0.04	0.20	0.20	0.34	0.29	0.29	0.30	0.49	0,49	0,44
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	0.19	0.19	0.25	0.25	0.25	0.13	0.06	0.06	-0.08	0.33	0.33	0.23	0.45	0.45	0.40	0.53	0,53	0,50
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	0.12	-0.32	0.18	0.16	-0.35	0.09	0.04	-0.15	-0.06	0.21	0.36	0.15	0.29	0.45	0.31	0.36	0,57	0,42
		Test Results (– / / +)				+			+													

Table 2 (Continued): Correlation Coefficients Between Crisis Market and Non-Crisis Markets Before and During the Crisis

Crisis Market	Date of the Crisis	Explanation of Results			Germany			Spain			Ireland			Portugal			Greece		
					FR	CPS	RES	FR	CPS	RES	FR	CPS	RES	FR	CPS	RES	FR	CPS	RES
Hong Kong	1997:10:23 – 1997:11:22	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	0.33	0.33	0.12	0.48	0.48	0.29	0.23	0.23	0.09	0.72	0.72	0.63	0.62	0.62	0.57
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	0.84	0.84	0.88	0.70	0.70	0.63	0.76	0.76	0.88	0.72	0.72	0.73	-0.12	-0.12	-0.24
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	0.55	0.60	0.66	0.39	0.69	0.35	0.45	0.49	0.75	0.40	0.75	0.42	-0.05	0.73	-0.11
		Test Results (– / / +)				+	+					+	+	–			–	–	–
Russia	1998:08:06 – 1998:10:05	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	0.62	0.62	0.55	0.56	0.56	0.53	0.40	0.40	0.23	0.48	0.48	0.47	0.42	0.42	0.31
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	0.54	0.54	0.55	0.50	0.50	0.52	0.28	0.28	0.24	0.48	0.48	0.51	0.39	0.39	0.39
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	0.47	0.57	0.39	0.43	0.53	0.40	0.23	0.39	0.17	0.41	0.46	0.40	0.33	0.40	0.29
		Test Results (– / / +)																	
Brazil	1999:01:01 – 1999:03:01	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	0.36	0.36	-0.07	0.51	0.51	0.07	0.12	0.12	0.13	0.38	0.38	0.10	0.40	0.40	0.06
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	0.35	0.35	0.12	0.56	0.56	0.37	0.39	0.39	0.29	0.36	0.36	0.23	0.39	0.39	0.24
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	0.25	0.51	0.06	0.42	0.62	0.19	0.28	0.21	0.14	0.26	0.52	0.11	0.28	0.55	0.12
		Test Results (– / / +)																	
Turkey	2001:02:15 – 2001:03:13	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	0.25	0.25	-0.13	0.27	0.27	0.12	0.36	0.36	0.35	0.28	0.28	0.05	-0.12	-0.12	-0.06
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	-0.08	-0.08	-0.11	0.01	0.01	-0.21	-0.24	-0.24	-0.28	-0.28	-0.28	-0.04	-0.64	-0.64	-0.33
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	-0.07	0.00	-0.10	0.01	0.00	-0.19	-0.21	0.00	-0.26	-0.24	0.00	-0.04	-0.58	0.00	-0.30
		Test Results (– / / +)									–		–	–			–	–	
U.S.	2001:09:14 – 2001:10:13	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	0.64	0.64	0.54	0.41	0.41	0.21	0.07	0.07	-0.10	0.28	0.28	0.20	0.10	0.10	0.06
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	0.75	0.75	0.69	0.60	0.60	0.57	0.76	0.76	0.74	0.26	0.26	0.48	0.72	0.72	0.70
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	0.49	0.78	0.42	0.35	0.72	0.32	0.50	0.24	0.46	0.13	0.64	0.25	0.46	0.34	0.44
		Test Results (– / / +)									+	+	+		–		+	+	+
Argentina	2001:12:27 – 2002:02:26	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	0.35	0.35	0.22	0.41	0.41	0.25	0.23	0.23	-0.02	0.41	0.41	0.35	0.14	0.14	0.21
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	-0.07	-0.07	0.01	0.24	0.24	0.28	-0.29	-0.29	-0.22	0.17	0.17	0.20	-0.01	-0.01	-0.19
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	-0.04	0.05	0.00	0.13	0.07	0.12	-0.15	0.03	-0.09	0.09	0.08	0.08	-0.01	0.02	-0.08
		Test Results (– / / +)			–						–	–							
U.S.	2002:06:25 – 2002:07:23	ρ^{stable}	ρ^{stable}	$\rho^{stable}_{residuals}$	0.53	0.53	0.51	0.51	0.51	0.52	-0.16	-0.16	-0.09	0.08	0.08	0.19	-0.01	-0.01	0.13
		ρ^{crisis}	ρ^{crisis}	$\rho^{crisis}_{residuals}$	0.73	0.73	0.78	0.56	0.56	0.47	0.08	0.08	-0.14	0.44	0.44	0.44	0.37	0.37	0.06
		$\rho^{crisis}_{adjusted}$	$\rho^{stable}_{adjusted}$	$\rho^{crisis}_{adjusted}$	0.55	0.58	0.77	0.39	0.58	0.38	0.05	-0.30	-0.12	0.29	0.16	0.32	0.24	-0.01	0.04
		Test Results (– / / +)										+						+	

Note: The calculation of the correlation coefficients follow the approaches by Forbes and Rigobon (FR), Corsetti, Pericoli, and Sbracia (SPC), and from the extended model (9) (RES). "+" and "–" denote evidence of contagion and a break in financial linkages, respectively. $\rho^{crisis}_{adjusted}$ denotes an appropriate adjusted correlation coefficient for the crisis period

Figure 1: Empirical Density Functions of Correlations between Residual Factors



Note: World index returns, U.S. index returns, World returns and lagged returns from both markets, and principle component are measures of the common factor employed in the model of Corsetti, Pericoli, and Sbracia (2005). We compute the correlations for all investigated stable periods between all crisis and non-crisis markets.