Terhi Jokipii – Brian Lucey

Contagion and interdependence: measuring CEE banking sector co-movements

SUOMEN PANKKI • FINLANDS BANK •
EUROJÄRJESTELMÄ
EUROSYSTEMET

Bank of Finland Research
Discussion Papers
15 • 2006

Suomen Pankki
Bank of Finland
P.O.Box 160
FI-00101 HELSINKI
Finland
☎ + 358 10 8311

http://www.bof.fi

Bank of Finland Research
Discussion Papers
15 • 2006

Terhi Jokipii* – Brian Lucey**

Contagion and interdependence: measuring CEE banking sector co-movements

The views expressed are those of the authors and do not necessarily reflect the views of the Bank of Finland.

* Bank of Finland and Trinity College Dublin. Jokipiit@tcd.ie. Institute for International Integration Studies, Trinity College Dublin, College Green, Dublin-2. Telephone: +353-1-608-3209

** Trinity College Dublin. Blucey@tcd.ie. Institute for International Integration Studies, Trinity College Dublin, College Green, Dublin-2. Telephone: +353-1-608-1552.

We would like to thank Antonello D'Agostino, Lieven Baele, Michael Hutchinson, Esa Jokivuolle and Svitlana Voronkova as well as the audiences of the Global Finance Conference, the Second Annual DG ECFIN Research Conference and the XIV International Tor Vergata Conference on Banking and Finance for their very useful comments and suggestions.

http://www.bof.fi

ISBN 952-462-288-2
ISSN 0785-3572
(print)

ISBN 952-462-289-0
ISSN 1456-6184
(online)

Helsinki 2006

Contagion and interdependence: measuring CEE banking sector co-movements

Bank of Finland Research Discussion Papers 15/2006

Terhi Jokipii – Brian Lucey
Monetary Policy and Research Department

Abstract

Making use of ten years of daily data, this paper examines whether banking sector co-movements between the three largest Central and Eastern European Countries (CEECs) can be attributed to contagion or to interdependence. Our tests based on simple unadjusted correlation analysis uncover evidence of contagion between all pairs of countries. Adjusting for market volatility during turmoil, however, produces different results. We then find contagion from the Czech Republic to Hungary during this time, but all other cross-market co-movements are rather attributable rather to strong cross-market linkages. In addition, we construct a set of dummy variables to try to capture the impact of macroeconomic news on these markets. Controlling for own-country fundamentals, we discover that the correlations diminish between the Czech Republic and Poland, but that coefficients for all pairs remain substantial and significant. Finally, we address the problem of simultaneous equations, omitted variables and heteroskedasticity, and adjust our data accordingly. We confirm our previous findings. Our tests provide evidence in favour of parameter instability, again signifying the existence of contagion arising from problems in the Czech Republic affecting Hungary during much of 1996.

Keywords: contagion, interdependence, macroeconomic news, banking sector, stock returns

JEL classification numbers: F30, F40, G15

Tartuntaa vai riippuvuutta? Keski- ja Itä-Euroopan maiden pankkisektorien välinen korrelaatio osakemarkkinoilla

Suomen Pankin tutkimus
Keskustelualoitteita 15/2006

Terhi Jokipii – Brian Lucey
Rahapolitiikka- ja tutkimusosasto

Tiivistelmä

Tutkimuksessa tarkastellaan kolmen suurimman Keski- ja Itä-Euroopan maan pankkisektorin välisiä yhtäaikaisia hintaliikkeitä osakemarkkinoilla käyttäen päivittäistä aineistoa kymmenen vuoden ajalta. Tavoitteena on selvittää, aiheutuvatko nämä hintaliikkeet ns. tartuntailmiöstä vai pankkisektorien välisistä riippuvuuksista. Yksinkertaisen korrelaatioanalyysin perusteella kaikkien pankkisektoreiden välillä esiintyy tartuntaa. Tulokset kuitenkin muuttuvat, kun analyysissä kontrolloidaan volatiliteetin vaikutusta markkinahäiriöiden aikana. Tšekki aiheuttaa tartuntareaktion Unkarissa, mutta muissa tapauksissa kyse on pikemminkin voimakkaista riippuvuuksista markkinoiden välillä. Tutkimuksessa käytetään lisäksi dummy-muuttujia, jotta saataisiin selville makrotaloudellisten uutisten vaikutus näillä pankkimarkkinoilla. Kun tarkastelussa kontrolloidaan jokaisen maan omien makrotaloudellisten tekijöiden vaikutusta, havaitaan, että Tšekin ja Puolan välinen korrelaatio heikkenee. Kaikissa tapauksissa korrelaatiokertoimet pysyvät kuitenkin merkittävän suuruisina ja tilastollisesti merkitsevinä. Lopuksi tarkastellaan simultaanisuuden, puuttuvien selittävien muuttujien sekä heteroskedastisuuden vaikutusta. Aikaisemmin saadut tulokset pysyvät tällöinkin voimassa. Kaiken kaikkiaan tulokset kertovat sellaisesta parametrien epästabiilisuudesta, joka viittaa siihen, että ongelmat Tšekin pankkisektorilla aiheuttivat tartuntaa Unkarissa vuoden 1996 aikana.

Avainsanat: tartunta, riippuvuus, makrotaloudelliset uutiset, pankkisektori, osaketuotot

JEL-luokittelu: F30, F40, G15

Contents

Abstract 3
Tiivistelmä (abstract in Finnish) 4

1 Introduction 7

2 Contagion 9

3 Central and eastern european banking systems 12

4 Data 18

5 Testing for contagion 21
5.1 Unadjusted correlation coefficients 22
5.2 Controlling for own country fundamentals 25
5.3 Bias in the correlation coefficient 28
5.4 Heteroskedasticity, simultaneous equations and omitted variables 30

6 Conclusions 36

References 38

1 Introduction

Banking crisis is hardly a new phenomenon. In fact, the development of the international banking sector has consistently been marred by failures, generating a diverse array of mechanisms to reduce their strength and impact. In more recent times, the incidence of banking and financial sector crises has intensified and their effect on the domestic and international economy has become even more profound. Understanding both the nature and the causes of dramatic co-movements, as well as the cross-country and cross-market transmission of shocks with a view to gaining an insight into market linkages, has consequently become of major empirical and analytical interest in international finance.

Evaluating whether contagion occurs and under what circumstances, as well as gaining a better awareness of inter-market relationships is important for several reasons. Above all, policy makers are concerned with maintaining financial stability which in an enlarged economic union requires the supervision of several economies with distinct characteristics and systems. Understanding the impact that a negative shock to one country could have on another, can aid in diffusing a threat of systemic crisis, or at least in diminishing the impact on neighbouring economies should such a crisis occur. Distinguishing between contagion and interdependence has further important implications for monetary policy, optimal asset allocation, risk measurement as well as for capital adequacy, since forecasting the reaction of one country to a crisis in another is only possible if the relationship remains stable through time.

Much of the academic literature in this field has focussed on analysing the extent to which financial spillovers to both mature as well as to emerging markets exist in order to identify channels of transmission of both positive and negative shocks to foreign countries. With the recent European Union (EU) enlargement, attention has shifted towards the Central and Eastern European Countries (CEECs), concentrating on understanding the effect to which spillovers of global financial crises affect transition economies (See for example Fries, Raiser and Stern, 1999; Darvas and Szapáry, 2000; Gelos and Sahay, 2001; Murzuch and Weller, 2002). To date however, only very few empirical papers have focussed on the existence of contagion to between these countries.

Our paper contributes to this literature by analysing the CEE banking sectors during a period of development in order to gain an in-depth understanding of the relationships that have existed and how they have changed with time. Our analysis builds on the advances in the literature in this field by specifically applying the case of the CEE banking sector indices to a variety of tests that concentrate on the econometric problems that have arisen when assessing whether the transmission of shocks has intensified during a period of turbulence. We define contagion as a structural break that produces a change in the relationships between markets during a period of turbulence. Interdependence on the other hand is a divergent phenomenon whereby stability persists, and no change in the relationships between markets is evident. We employ the period between 1994 and 1998 as our period of turmoil since all three markets underwent significant market developments, policy initiatives as well as crises during this time and further aim to establish how these relationships were affected by domestic macroeconomic conditions by distinguishing between the impact of good and bad macroeconomic news announcements. Significant problems within these markets during their development have rendered them as an important as well as interesting laboratory for studying the issues of contagion versus interdependence. To the best of our knowledge, such analysis has not yet been performed for the Central and Eastern European countries.

Our tests based on the unadjusted correlation coefficients indicate the persistence of contagion between all pairs of countries. Adjusting for the increase in market volatility during the turbulent period however, we find evidence of contagion stemming only from the Czech Republic to Hungary. All other market co-movements during this time appear to rather be attributable to the continuation of strong cross-market linkages. We further correct for own country fundamentals by introducing a set of dummy variables that proxy macroeconomic news announcements. We find that correlations between the Czech Republic and Poland do diminish, but that coefficients for all pairs remain substantial and significant. Finally, following Rigobon (2003), we adjust our data to account for problems of simultaneous equations, omitted variables and heteroskedasticity. We confirm our previous findings. Our tests provide evidence in favour of parameter instability in the transmission of shocks, providing further evidence in favour of the existence of contagion between the Czech Republic and Hungary during much of 1996. The direction of causality is further confirmed through the implementation of a *granger causality test*. Our results are broadly in line with the literature whereby far less evidence of contagion is uncovered when certain econometric problems are addressed.

The remainder of the paper is organized as follows: Section 2 gives a short overview of definitions, theories and tests of contagion. In Section 3, briefly documents the evolution of the CEE banking systems. Section 4, describes the data employed in our analysis. Section 5 presents our empirical methodology and results. Section 6 briefly concludes.

2 Contagion

Contagion has been defined in many different ways in the literature, including the transfer of any shock across countries (Edwards 2000). Eichengreen and Rose (1999) and Kaminsky and Reinhart (1999) define contagion as the situation where the knowledge of crisis in one country increases the risk of crisis in another country. Edwards (2000) goes on to restrict the term economic contagion to those situations where the magnitude with which a shock is transmitted exceeds what was expected on the ex ante basis of 'fundamentals'. In this paper we consider contagion to be a structural break producing an intensification of relationships during a period of turmoil.[1]

There are several reasons why contagion can occur. One type of fundamental cause is a common shock, for example a major economic shift in industrial countries, a change in commodity prices or a reduction in global growth. Such an extreme event can trigger crisis and result in large capital outflows from emerging markets leading to increased co-movements in asset prices and capital flows.[2] Trade linkages which include linkages through direct trade and competitive devaluations can additionally cause contagion. A crisis in one country can cause a reduction in income and a corresponding reduction in demand for imports, thereby affecting exports, the trade balance and related economic fundamentals.[3] Finally, contagion can be the resultant effect of financial linkages. In a region where integration is high, a crisis in one country can have direct financing effects on other countries through trade credit reductions, foreign direct investment and other capital flows.[4]

In addition to the fundamental causes outlined above, it is possible to explain contagion through the existence of investor behaviour theories.[5] One such theory considers the role of liquidity problems, whereby losses in one country may induce investors to sell securities in other markets in order to raise cash in anticipation of greater redemptions.[6] Additionally, if banks experience a marked deterioration in the quality of their loans to one country, these banks may attempt to reduce the overall risk of their loan portfolio by also minimising their exposure in other high-risk investments, which could include other emerging markets.

[1] Other authors adopting similar definitions of contagion include Bonfiglioli, Corsetti, English, Favero, Forbes, King, Loretan, Pericoli, Sbracia, Susmel, Rigobon, Wadhwani.

[2] For theoretical models of common shocks, see Calvo and Reinhart (1996) and Masson (1998).

[3] For a detailed discussion of trade linkages, see Gerlach and Smets (1995), Eichengreen, Rose and Wyplosz (1996), Glick and Rose (1998), and Corsetti, Pesenti, Roubini and Tille (2000).

[4] For a detailed discussion on financial linkages, see Goldfajn and Valdés (1997) and Van Rijckenghem and Weder (2001).

[5] For a more detailed discussion on investor behaviour theories of contation see Classens and Forbes (2004).

[6] For examples of literature in this field, see Valdés (1997) and Kaminsky, Lyons and Schmukler (2001).

Faced with liquidity problems, investors may be required to sell other assets in their portfolios, ultimately leading to a fall in asset prices outside of the crisis country causing the disturbance to ripple through a variety of markets. Moreover, incentive structures and risk aversion can additionally add to contagion.[7] A crisis in one emerging market may prompt investors to sell holdings in other emerging markets in order to maintain a certain proportion of a country's or region's stock in their portfolio. Similarly risk aversion can cause investors to sell assets in which they are 'overweight' in order to remain close to their benchmarks. Moreover, if a large number of investors are evaluated based on similar benchmarks, or have fixed country weights in their portfolios this could lead to extreme price declines following a shock to one asset. Finally, information asymmetries and imperfect information may lead investors to believe that a crisis in one country could be followed by comparable problems in a similar or neighbouring country. Effectively, if a crisis reveals weak fundamentals, investors may rationally conclude that similar countries may face equivalent problems, thereby causing contagion.

Testing for Contagion

Much of the empirical work on measuring the existence of contagion is based on comparing correlation coefficients for interest rates, stock prices and sovereign spreads between markets during a relatively stable period with a crisis or turbulent period (King and Wadhwani, 1990; Boyer, Gibson and Loretan, 1999; Loretan and English, 2000; Forbes and Rigobon, 2002; Corsetti, Pericoli and Sbracia, 2002). According to this approach coupled with the definition adopted in this paper, if two markets are naturally moderately correlated during periods of stability, then a shock to one market will result in a significant increase in market co-movements. This increase constitutes contagion. If on the other hand, the relationships do not change significantly after a shock to one market, and stability in the transmission mechanism persists, then continued market co-movements can be inferred to as being driven by strong real linkages between the two economies. Such stability in parameters over time would denote interdependence. Based on these assumptions, contagion implies that cross-country linkages are fundamentally different after a shock to one market while interdependence implies no real change to relationships.

More recently, the literature has pointed out various flaws in the aforementioned tests stemming from data issues. Stock market data in particular suffers from problems of heteroskedasticity, simultaneous equations and omitted variables, which as a result can render traditional techniques for testing for structural changes inappropriate. More specifically, heteroskedasticity in asset

[7] See among others Schinasi and Smith (2001) and Broner, Gelos and Reinhart (2004).

price movements can cause estimated cross-market correlations to increase after a crisis, even if there is no increase in the underlying correlations. Similarly, changes in omitted variables such as economic fundamentals, risk perception and preference, can cause a similar increase in asset price correlations even when contagion is not present. Endogeneity or feedback effects add to this since it is almost impossible to control for these effects when estimating the effect of a crisis in one country on another. Recent work has thus focussed on making more restrictive identifying assumptions and has moved towards testing for the stability of parameters during a period of crisis in order to assess whether the transmission mechanism differs significantly during a high and a low volatility period. Here any rejection of parameter stability indicating instability in the transmission mechanism could be considered as evidence of contagion. Authors addressing these econometric issues have generally found far less evidence of contagion than those that fail to do so.

Most of the literature on banking contagion has generally focussed on the transfer of shocks through the interbank market. Allen and Gale (2000) show that the possibility of contagion depends strongly on the completeness of the structure of interregional claims. They find that complete claims structures are shown to be more robust than incomplete structures. Freixas, Parigi and Rochet (2000) investigate the ability of the banking sector to withstand the insolvency of one bank and whether the closure of one bank generates a rippling effect throughout the system. They find that contagion arises from unforeseen liquidity shocks ie Banks withdrawing interbank deposits from another bank. Gropp and Vesala (2004) examine the number of banks that have in a given country to experience a large shock in the same period via the use of co-exceedances. They find significant evidence of cross-border contagion in the EU, attributing their findings to cross-border interbank exposures. In our paper we consider the investor behaviour theories explained above and analyse the contagious effect that is brought about by the highly correlated abrupt decline in the prices of an entire class of stocks. In this paper, we are interested in analysing the effect that market turmoil has had on banks and therefore focus our analysis on the behaviour of banking sector indices.

3 Central and eastern european banking system

Having endured over a decade of substantial reform and stabilization, banking and financial sector development in the Czech Republic, Hungary and Poland finds itself in its final stages. The privatization of large banks has ultimately been completed, and foreign strategic owners, most of them EU-based banks, dominate the banking sector. After an enormous clean up of portfolios, the standardization of banking sector regulations according to EU rules along with the new ownership structures, the Czech Republic, Hungary and Poland are finally facing the same issues challenging most industrialized nations. Statistics relating to the evolution of the banking sectors of the Czech Republic, Hungary and Poland are presented in Table 3.1, Table 3.2 and Table 3.3.

Table 3.1 **Fiscal costs of bank recapitalization**

	Czech Republic 1997	**Hungary 1994**	**Poland 1996**
Main part of the recapitalization program completed in fiscal costs up to the year indicated in % of GDP of that year	8.9%	7.2%	1.6%
Fiscal costs of the recapitalization program up to the year 2000 in % of GDP in 2000	11.8%	6.8%	1.4%

Table 3.2 **Evolution of the central and eastern european banking sectors**

	1994	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Market value of banking index (US$)							
Czech Republic		1515	1138	1824	927	470	1433
Hungary		23	202	532	1058	1362	1627
Poland		998	1354	2849	3517	6152	8472
Foreign ownership (% of net assets)							
Czech Republic		23	24	30	39	48	55
Hungary		79	83	93	89	91	91
Poland	3	4	14	15	17	47	70

Table 3.3 **Banking sector of the Czech Republic, Poland and Hungary**

	Czech Republic				**Hungary**				**Poland**			
	1991	**1994**	**1997**	**2000**	**1991**	**1994**	**1997**	**2000**	**1993**	**1994**	**1997**	**2000**
# Active banks	24	52	53	40	36	43	44	39	104	82	83	74
% Total domestic controlled	83	65	57	35		84	37	31	55	51	47	27
% Total foreign controlled	17	35	43	65		16	63	69	45	49	53	73

The Czech Republic, Hungary and Poland all encountered similar structural problems during the development of their banking systems. The Czech Republic however faced with additional troubles relating to the dissolution of the federal country. First, the CEECs had inherited underdeveloped, undercapitalized and badly managed banks from the past, having a strong impact on developments during the 1990s. At the outset of the transition, several key reforms were implemented. A two-tier banking system with separate functions for the central bank and commercial banks was introduced in place of the traditional mono-bank system. Furthermore, privately owned banks were admitted, and foreign banks and joint ventures were granted access. The licensing policy for most kinds of banking business was liberalised and both the legal and the supervisory system were adjusted (Kawalec, 1999).

Together the largely liberal licensing policy and the unreliable legal framework and supervisory system, resulted in the establishment of a large number of newly founded banks engaged in unsound practices.[8] The state owned commercial banks which were borne from the mono-bank system, subsequently suffered from an inherited burden of bad loans. The banking system generally lacked capital and banking skills, and political intervention in the activities of state owned banks was persistent. These deficiencies, coupled with the uncertain economic environment culminated in the quick accumulation of bad loans, and the subsequent failure of several banks (Reininger et al, 2001).

The scope and severity of the banking sector distress varied substantially between countries. In the Czech Republic, the banking sector suffered probably the most prolonged period of difficulty. Problems starting already in the early 1990s had by 1993 already resulted in the closure of a number of banks. By 1996, the Czech banking system experienced a severe crisis. Initially, the problems were confined to small banks that could not meet capital requirements (IMF, 1997). In August 1996, the Kreditní and Investiční Banka, the nation’s sixth largest, collapsed. Its fall resulted in the loss of EUR 370 million. In September 1996, the CNB placed Agrobanka, the largest private bank and the fifth largest overall, under forced administration. An auditor estimated losses in that case to be EUR 280 million. In all, 12 of 60 banks failed during the crisis. Six of these due to bankruptcy, and the rest under forced administration. As of June 1996, 39 percent of bank loans were ‘classified,’ which means that ‘there existed uncertainty about their repayment’ (Freedom House, 1998). In Hungary and in Poland the problems were smaller in scale. In the second half of 1993, eight banks in Hungary, accounting for around 25 percent of the financial system assets, were deemed insolvent. In Poland on the other hand, seven out of nine treasury-owned commercial banks, accounting for 90 percent of credit, the Bank for Food

[8] The cases of Komercní Banka and credit unions in the Czech Republic serve as examples in this respect.

Economy and the co-operative banking sector in 1991 experienced insolvency problems. Recapitalization costs together amounted to around 1.9 percent of GDP by 1993 (Beim, 2005).

Although not all countries experienced a fully fledged banking crisis, all undertook large bank recapitalization programs mostly between 1992 and 1996. Table 3.1 presents the fiscal costs[9] that culminated from these bank recapitalization programs, and highlights the extent of the expenses faced by these economies during this time. The table shows the year when to a large extent the recapitalization was completed in each country. The figures are reported in percent of GDP in the year of completion as well as in percent of GDP in 2000 (Reininger et al, 2001).

By around 1997, Hungary and Poland had managed to stabilize their bank systems via these programmes. The Czech Republic however faced continuing problems. In addition to the costs borne from these programs, large amounts of public funds were used up in preparing the country's largest banks for privatization. By 2000, the accumulated fiscal costs, since the introduction of the reforms, amounted to around 11.8 percent of GDP. These costs however are separate from the failure of Investicní a Postovní Banka (IPB) which were estimated at around EUR 3 billion (around 4.8 percent of GDP in 2000). Poland was the most successful of these economies in terms of total costs. The accumulated costs of recapitalization were below 1.5 percent of GDP in 2000 (Reininger et al, 2001). At least in part, this success can be attributed to the design of the programs, which lessened the incentive for moral hazard. Bank managers were provided with incentives for improving the performance of the banking institutions, and the effective management of bad loans was encouraged. It was the early tackling of bad-loans that minimized the fiscal costs presented in Table 3.1. Poland's relative success could further be credited to the relatively small size of the Polish banking sector to GDP. Between the Czech Republic and Poland lies Hungary, with fiscal costs at around 6.8 percent of GDP.

Together market reforms and exogenous shocks worsened the stock and flow position of the state-owned commercial banks, leading to the rapid increase in the volume of bad debt and non-performing loans. Consolidation therefore became necessary and contrary to the Czech Republic and Hungary, Poland adopted a decentralized approach for the management of this problem. The Polish approach proved more efficient, disallowing the accumulation of problems, forced banks and their new owners to partly share cots of the clean-up and prevented the re-emergence of problems. By contrast, the method adopted by Hungary and the Czech Republic was full of moral hazard, inefficiency and subsequently proved costly for the banking sector in general (Hughes et al, 2001).

[9] Fiscal costs here generally refer to the costs of recapitalization and losses incurred through protecting deposits either implicitly or explicitly through government deposit insurance schemes.

Privatization and foreign ownership too played and important role in the development and transition of the banking systems of the CEECs. Generally in this respect, if the supervisory and regulatory regime is very weak, or non-existent, or if a disruption to depositor confidence occurs, then the case for swift privatization may be diminished. The privatization of state owned banks has its own distinct benefits. Private ownership generally provides better incentives for controlled risk taking behaviour of managers, limits government intervention into the allocation of credit. It further enhances the incentives to improve monitoring and screening technologies for banks, a particularly important function of banking institutions as stressed by modern financial intermediation theory (see Diamond, 1984). In the CEECs, progress in the bank privatization process differed greatly. In Poland, strong political opposition to privatization and the desire to protect domestic banks from foreign competitors and maintain restrictions on foreign participation, the sale of public assets of the banking sector proceeded at a modest pace until 1999. With the lifting of restrictions on foreign participation in the Polish banking sector in 1998, foreign ownership increased dramatically. At the end of 1998, 31 (out of 83 in total) commercial banks together with three foreign branch banks accounted for around 43.7 percent of bank equity and around 17 percent of total assets. By the end of 1999, 39 foreign-controlled banks out of a total of 77 commercial banks accounted for 50.2 percent of bank equity and around 42.7 percent of total assets (European Forecasting Network, 2004). In Hungary, privatization of the state-owned banks was considered as a final step in stabilizing and strengthening the banking system. It was agreed that banks should preferably be sold to strategic investors providing the necessary capital, technology and expertise. In practice this meant the sale of most state-owned banks to foreign banks. Six state-owned banks which together in 1995 had around 31 percent of the market share were sold to foreign banks[10] (Sherif et al, 2003). The growing participation of foreign investors in the Hungarian market was further enhanced by the liberal licensing policy in respect of foreign banks setting up branches in Hungary. In the Czech Republic, a 'voucher-type' privatization scheme was implemented, regarded as a rapid and transparent way of transferring ownership from the public to the private sector, it ended up creating more problems than benefits. As an outcome of this scheme, most corporations and banks became owned by investment funds. Due to capital requirements, legal and other considerations however, these investment funds were mostly owned by financial intermediaries, creating a very connected, cross-ownership of banks and enterprises leading to serious long-term costs for the economy. As a consequence, all major banks were sold to foreign investors. At the end of 1997, 30 (out of 53 in total) banks were controlled by Czech private and public owners, while 23 were

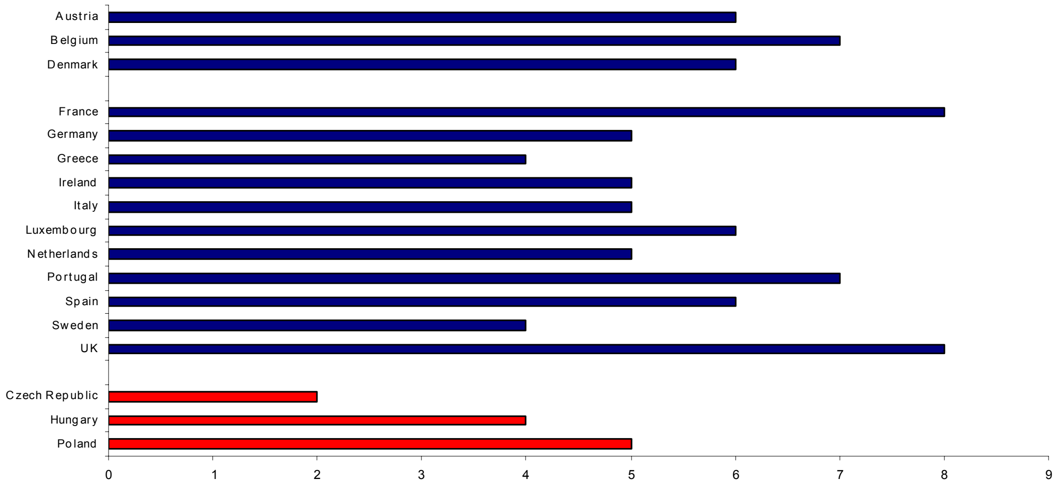
[10] In a first phase of privatization, the government retained a minority shareholding in these banks. The European Bank for Reconstruction and Development (EBRD) also participated as a minority shareholder in the privatization of three banks.

under foreign control. By the end of 2000, the total number of banks had declined to 40, with 26 controlled by foreign owners (European Forecasting Network, 2004).

Banking supervision policy generally carried out by transition or emerging markets differs from more mature markets. In the absence of a market-oriented banking system, the supervisors of these economies were actually faced with establishing 'the rules of the game' and creating a 'level playing field' for all operatives within the financial market. In effect, this was largely a 'learning-by-doing' process. Barth, Capiro and Levine (2001) provide a substantial data set relating to how regulatory regimes work and differ across nations. From their work, we are able to briefly compare the supervisory and regulatory regimes in place during the 1990s. Looking first at the degree of capital stringency the authors construct an index based on the degree of leverage potential for capital on one hand and on the sources of funds that are counted as regulatory capital on the other hand.[11] Here we see that generally, of the three countries Poland demonstrates the largest degree of capital stringency when compared to Hungary and the Czech Republic, in fact, in this respect, Poland lies at the lowest quartile of the EU group. These figures are plotted in Figure 3.1. Furthermore, in terms of supervision, their paper analyses the legal possibilities of supervisors to prevent and correct problems in the banking industry. The study captures formal power to take prompt correctitive action, to restructure and reorganise a troubled bank, or to declare a deeply troubled bank insolvent. Here, Hungary dominates the CEECs with almost maximum supervisory power. Interestingly, all three CEECs are at the upper quartile of the EU sample. These figures are shown in Figure 3.2. Finally looking at the number of supervisors per bank, the Czech Republic dominates with an average of two supervisors compared with Hungary's one and Poland with only 0.5. Both Hungary and the Czech Republic lie in the upper quartile of the EU distribution, while Poland in contrast is in the lower quartile. A comparison with a number of EU countries can be seen in Figure 3.3.

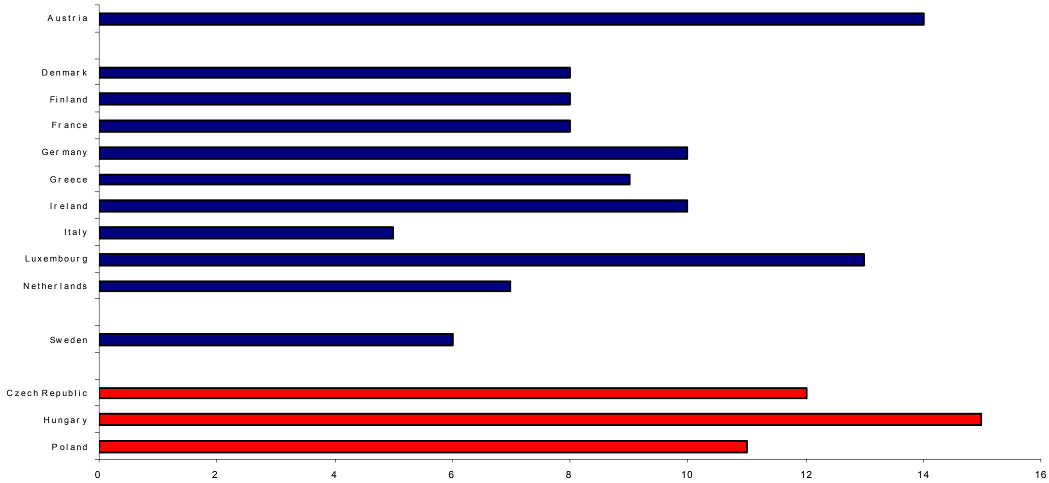
[11] Please refer to Barth, Capiro and Levine (2001) for a more detailed description of how the index is calculated.

Figure 3.1 **Capital stringency**



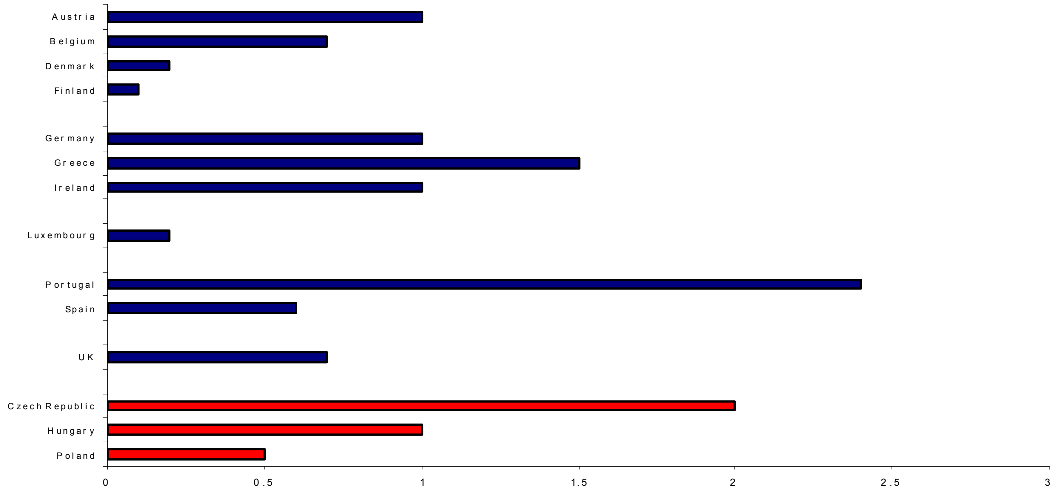
Source: Barth, Capiro and Levine (2000)
Note: The capital stringency index measures the restrictiveness on the leverage potential and on the sources of funds counted as regulatory capital. Higher values constitute greater stringency.

Figure 3.2 **Supervisory power**



Source: Barth, Capiro and Levine (2000)
Note: Index ranges from 0 to 16 with higher values indicating greater supervisory power.

Figure 3.3 **Number of supervisors per bank**



Source: Barth, Capiro and Levine (2000)

All countries covered in our analysis experienced banking crisis in the initial phase of transition. While they differed significantly in their extent, the causes can largely be attributed to a combination of an inherited burden of bad loans of state-owned banks, hugely liberal licensing policies coupled with supervisory and legal framework shortcomings. Furthermore, the lack of capital and banking skills the recessionary environment together with political intervention all contributed to turbulence in these economies during much of the 1990s.

4 Data

For our empirical analysis, we make use of nine and a half years of daily data (July 1994 to end 2004).[12] We adopt the *DataStream* banking sector indices[13] for the Czech Republic, Hungary and Poland. Adopting DataStream indices provides a comparative index for each country, which captures more than 75 percent of the total market. The *DataStream* indices are value-weighted indices based on key publicly quoted banks in the each country. The weighting is based on the market capitalization of each bank. The larger the market cap, the greater the weighting, giving an accurate reflection of the banking sector. These indices were obtained in national currency and their percentage changes were subsequently calculated.

[12] The first date on which data was available for all three markets.
[13] Analysis was conducted on both the bank and financial sector indices for all countries, however due to the largely similar results obtained only the banking sector results are presented. This similarity is hardly surprising considering that between 85–88 percent of total assets of the financial system are held by banks for all three countries under analysis.

News Releases

Furthermore, since no high frequency variables (eg daily data) that can approximate the fundamentals in each of the CEEC countries exist as far back as we would like, we employ an approach whereby we create a set of dummy variables constructed from macroeconomic news announcements. Making use of the *LexisNexis* news databank,[14] we conduct a number of searches focusing both on central bank and national statistical office releases as well as on the individual variables we wished to include. The variables of interest are: unemployment, short-term interest rates, consumer price index, terms of trade (or an indicator of market openness when not available), real gross domestic product (GDP), current account deficit. These indicators are considered to be the most widely adopted variables in the literature for assessing macroeconomic influence on the banking system stability (Demirgűç-Kunt and Detragiache, 1998; Hutchinson, 2002; Timmermans, 2001). For Hungary, Poland and the Czech Republic, we also include various other announcements; such as a change in exchange rate regime, a change in the country's credit rating by a major rating agency, namely Standard and Poor's, Moody's or Fitch, or the decision by the central bank to intervene in the foreign exchange market.

Following Baig and Goldfjn (1999), we distinguished between 'good' and 'bad' news by using simple guidelines – any credible attempt to restructure or improve the economic situation is deemed as 'good', whereas news that indicated a further decline of the real or financial sector is 'bad'. The good (bad) news dummy series is assigned a '1' on the release of favourable (unfavourable) macroeconomic news. A fall in inflation, better GDP growth, and an improvement in the terms of trade are all assigned a 'good' news dummy, as were a fall in the year-on-year consumer price index figures, lower unemployment figures, and a reduction in the current account deficit. Finally, we assume that the central banks followed a price stability or inflation targeting strategy and assign a 'good' news dummy to a decrease in the short-term interest rate, as set by the central bank. For the Czech Republic, Hungary and Poland, we additionally consider any news of the country's move towards EU membership as 'good', together with an increase in the country's credit rating by one of the major ratings agencies. Furthermore, we regard any move in exchange rate regimes towards a free-float to be positive and any rescue packages or funding given to the country by international organizations as favourable.

While the privatization of state-owned banks can in principle have benefits as well as costs, the overall general considerations of the incentive effects of private ownership, as well as empirical evidence on this issue support the view that the benefits outweigh the costs (EBRD, 1997). Private ownership generally provides

[14] Our sources were limited due to lack of alternatives on LexisNexis. We made use of MTI Econews for Hungary, CTK for the Czech Republic and the Polish News Bulletin for announcements in Poland.

better incentives for more disciplined risk taking of managers along with the limitation of government intervention into the allocation of credit. Furthermore, it enhances the incentives for more effective monitoring and screening of banking institutions, ultimately improving the general stability and soundness of the banking system in which they operate. For this reason, we further consider any increase or speeding up of the privatization process as positive.

For 'bad' news the opposite is true. We assign a 'bad' news dummy variable when the rate of inflation increased, GDP growth declined or the terms of trade index worsened. Furthermore, a rise in consumer prices, an increase in unemployment or a fall in the interest rate is considered bad for the economy. Although very general, we assume that a rise in interest rates would signal non-inflationary pressures and concerns of deflation resulting in notably below trend GDP growth and consequently a worsening economic situation. Again, for the Czech Republic, any delay in EU membership is considered 'bad', as was a fall in the country's credit rating. We further consider a delay in the privatization process for banks operating in the Czech Republic, Hungary or Poland, as negative.

Once all the good and bad news series were created for each variable separately, we aggregate the series to obtain a 'good' and a 'bad' news dummy series for each country.

Control Variables

Empirical work by Bekaert and Harvey (2000) and Henry (2000), has provided significant evidence in favour of a substantial effect that liberalization has on both liquidity and volatility. In our study, we are concerned with determining the extent to which correlations between market returns exist and therefore need to eliminate any outside effect that can affect our results.

As outlined in Section 2, each of the CEECs in our study experienced periods of significant market development during the first half of our sample, including events of both financial sector as well as stock market liberalization. We consequently include several measures to act as a control against these effects.

To capture financial market liberalization, we consider four distinct events as important; *Bank ownership*: a move towards privatization, *Interest rates*: date of liberalization; *Credit control*: elimination of controls; *Deposits*: the date when deposits in foreign currencies are allowed. Here the dummy series moves from 0 to 1 in the period where the event took place. A similar dummy is created for the date of stock market liberalization in each of the CE3 countries. The dates capturing the events of interest are presented in Table 4.1.

Table 4.1 **Financial and stock market liberalisation: event dates**

	CZ	HU	PL
Financial liberalisation			
Bank ownership	Privatization of state owned banks late 1991	01.01.95: Bank privatisation begins (creation of ÁPV Rt)	In 1993 Bank privatisation begins
Interest rates	Liberalisation of interest rates in 1992	Liberalization of interest rates in 1987 for enterprises and in 1992 for households	Liberalisation of interest rates starting with 1990
Credit control	01.04.97: Removal of credit control	01.01.00: Liberalisation of foreign currency denominated credits to non-residents from OECD countries 01.06.01: The Ministry of Finance and the MNB lifted all remaining restrictions on foreign-exchange transactions for residents and non-residents	01.01.98: Required permission needed for short-term credit to non-residents lifted. Short term financial credit from residents to non-residents prohibited above a given limit.
Deposits	01.01.01:Foreign deposits non longer require pre-approval	01.07.00: Residents allowed to deposit securities and earnings abroad	In 1990 deposits an foreign accounts allowed with limit
Stock market liberalisation			
	06.04.93: Stock exchange trading begins	01.06.90: Stock exchange established	01.08.91: Stock exchange reopened

Source: National Central Bank and National Supervisory Authority.

5 Testing for contagion

The empirical analysis in this paper focuses on assessing the nature of the relationships that have existed between the CEE economies over the last decade. In particular, we wish to determine whether different policies and regulations implemented during transition created any difference in terms of vulnerability to external shocks. We consequently test the null hypothesis H_0 of no contagion, only interdependence, against an alternative hypothesis (H_1) whereby contagion drives banking sector co-movements between the three largest CEECs.

Each of our tests is executed on the residuals of a VAR.[15] The residuals are then subsequently split between the turbulent and tranquil periods. We define our turbulent period as that between 19th July 1994 and end 1998. The tranquil period on the other hand runs from January 1999 to end 2004. The VAR model takes the following form

$$A(L)x_t + By_t = u_t \tag{5.1}$$

With

$$A(L) = 1 - A_1L - A_sL^2 - ... - A_pL^p$$

$$E(u_t) = 0, E(u_t, u_t^{'}) = \Sigma, E(u_t, u_s^{'}) = 0, \text{for } t \neq s, E(x_t, u_t) = 0,$$

$$x_t = (HU_{bank_t}, PL_{bank_t}, CZ_{bank_t})$$

and

y_t = (Const)

In this standard VAR, x is a (1xN) vector of variables, A is a (NxN) matrix of coefficients, u is a (Nx1) vector of white noise disturbance terms, and L represents the lag operator (for example, List = x_{t-1}). The x vector contains the daily change in the bank indices for Hungary (HU_{bank_t}), Poland (PL_{bank_t}) and the Czech Republic (CZ_{bank_t}). Each regression additionally includes the country control dummies outlined in Section 4, together with a world index controlling for the impact of global shocks. We estimate the VARs with the autoregressive order of two according to both the Schwarz and Hannan-Quinn information criterion. For each sub-sample, the covariance matrix is calculated from the reduced form residuals.

5.1 Unadjusted correlation coefficients

We begin by estimating the unadjusted correlation coefficients of the daily changes in the banking sector indices of the Czech Republic, Hungary and Poland. Using the variance-covariance estimates from estimating (5.1), we calculate cross market correlation coefficients between each pair of countries during the total sample, turbulent and tranquil periods. The coefficients are then used to perform

[15] The advantage of working with VAR residuals, as compared to structural residuals, is that the VAR represents and unconstrained reduced form, circumventing problems of simultaneity bias. Additionally, the use of a VAR structure allows for the controlling of serial correlation in stock returns and any exogenous global shocks.

the standard test of contagion pioneered by King and Wadhwani (1990). The results for the total sample banking sector cross-country correlations are presented in Table 5.1. All pairs demonstrate positive coefficients ranging from 0.21 for Hungary and Poland, to 0.29 for the Czech Republic and Poland. The data is further split into the turbulent and tranquil periods defined previously to allow for a comparison between sub-samples. At a first glance, we see that for all pairs of countries, turbulent period correlations appear to be larger than those for the tranquil period however from this analysis we are unable to determine whether this change in coefficients is statistically powerful enough to infer the existence of contagion.

Table 5.1 **Unadjusted correlations of the CEECs banking index returns**

	Czech Republic	Hungary	Poland
*Total sample: LR test 52.18****			
Czech Republic	1	0.28	0.21
Hungary	0.29	1	0.27
Poland	0.21	0.27	1
*Turbulent Period (1994-end 1998): LR Test 31.64****			
Czech Republic	1	0.45	0.32
Hungary	0.45	1	0.27
Poland	0.32	0.27	1
*Tranquil Period (1999-end 2004): LR Test 21.63****			
Czech Republic	1	0.10	0.11
Hungary	0.10	1	0.18
Poland	0.11	0.18	1

Note: *, **, *** denote rejection at the 10%, 5% and 1% levels respectively.
LR Test attempts to reject the null hypothesis that all pair wise correlations are 0.
Each pair wise correlation is tested for the null that the correlation is 0.

We therefore apply a two-sample *t-test*, and examine whether a significant increase in correlations in the crisis period is evident. We assume $\rho^{t}_{i,j}$ to be the correlation coefficient between country i and country j over period t. Here the post crisis period is denoted ‘0’ and crisis period as ‘1’. The subsequent test hypotheses are denoted by

$$H_0 : \rho^{0}_{i,j} \geq \rho^{1}_{i,j}$$
$$H_1 : \rho^{0}_{i,j} < \rho^{1}_{i,j}$$

The correlation coefficients are transformed using a Fisher transformation, so that they are approximately normally distributed with a mean μ_t and variance σ^2_t

$$\mu_t = \frac{1}{2}\ln\left[\frac{1+\rho_{i,j}^t}{1-\rho_{i,j}^t}\right] \tag{5.2}$$

and

$$\sigma_t^2 = \frac{1}{n_t - 3} \tag{5.3}$$

The test statistic is derived as follows

$$U = \frac{\overline{X}_0 - \overline{X}_1}{\left(\frac{S_0^2}{n_0} + \frac{S_1^2}{n_1}\right)^{\frac{1}{2}}} \tag{5.4}$$

Where X_t and S_t^2 are the estimated sample mean and variance following the Fisher transformation. The test statistic follows the t-distribution. The degrees of freedom are calculated as follows

$$\frac{\left(S_0^2/n_0 + S_0^2/n_0\right)^2}{\frac{\left(S_0^2/n_0\right)^2}{n_0 - 1} + \frac{\left(S_1^2/n_1\right)^2}{n_1 - 1}} \tag{5.5}$$

If the correlations increase significantly, then there are grounds for believing that these markets have moved away from relationships dictated by traditional movements of fundamentals. On the other hand, if the increases are not significant, then it is possible to assume that these markets are simply reacting to shocks that are common-cause. The critical value for the *t-test* at the one percent level is 1.282 so any test statistic greater than this value constitutes contagion (C), while any statistic less than that indicates no contagion (N). The test statistics for the unadjusted correlation coefficients are presented in Table 5.2. Table 5.2 additionally summarises the results presented in Table 5.1

Table 5.2 **Unadjusted correlation coefficients summary**

		Total Sample		Turbulent		Tranquil		Test Stat	Contagion?
		ρ	σ	ρ	σ	ρ	σ		
Czech Republic									
	Hungary	0.28	0.155	0.45	0.172	0.10	0.123	24.67	C
	Poland	0.21	0.121	0.32	0.153	0.11	0.134	10.11	C
Hungary									
	Czech Rep.	0.28	0.155	0.45	0.172	0.10	0.123	24.67	C
	Poland	0.27	0.105	0.27	0.112	0.18	0.101	5.62	C
Poland									
	Czech Rep.	0.21	0.121	0.32	0.153	0.11	0.134	10.11	C
	Hungary	0.27	0.105	0.27	0.112	0.18	0.101	5.62	C

Several patterns are apparent. In particular, considerable co-movement appears to be present, indicating that the banking sectors of the largest markets in Central and Eastern Europe have tended to move together, and have had a substantial influence on one another. For all pairs of countries, we find that the correlations increase significantly during the turbulent period when compared to the tranquil time. According to our definition, this provides evidence in favour of contagion. It is interesting to note that during the turbulent period, the correlations between the Czech Republic and Hungary is considerably larger (0.45) than the other pair wise correlations (Poland and Hungary; 0.27, Poland and the Czech Republic; 0.36). With respect to the differences in correlations between the turbulent and the tranquil periods, we find that the largest change appears to occur between the Czech Republic and Hungary, (around 77 percent). Correlations between the Czech Republic and Poland and Hungary and Poland on the other hand change by around 66 and 33 percent respectively.

5.2 Controlling for own country fundamentals

Contagion can be thought of as co-movements between markets in excess of those that can be explained by co-movements of fundamentals. Following Ganapolsky and Schmukler (1998), Kaminsky and Schmukler (1999) and Baig and Goldfajn (1999) who estimate the impact of various news announcements on the movements of different markets, we expand our analysis and control for own country fundamentals. Essentially we wish to analyse whether significant co-movement between the banking sector indices of the Czech Republic, Hungary and Poland exists beyond these fundamentals since any remaining or unexplained correlation may be assumed to result from contagion.

The regression takes the following form, and is run with robust coefficients controlling for heteroskedasticity

$$R_{i,t} = \alpha_i + \beta R_{it-1} + \sum \beta \text{Dummies}_x + \varepsilon_t$$
$$i = 1, 3;\ t = 1,\ldots,T \text{ and } \{\varepsilon_i\} \approx \text{N}10, \vartheta_t^2 \tag{5.6}$$

Where $x = b, g$ for good and bad news dummy variables and $\sum\text{Dummies}$ = the aggregate good and bad news dummy variable for each country. Each regression additionally includes the country control dummies outlined in Section 4 and a world index controlling for correlation with the global market. The control variables are not reported in our results.

The results from the above regression are presented in Table 5.3. Looking first at the entire sample, we find that the lagged dependent variable is significant in all three cases with 'good news' proving to be statistically significant for Hungary. Here it seems that a release of 'good news', causes a 34 percent increase in the banking sector index. During the turbulent period, the lagged dependent variables are again significant for both the Czech Republic and for Poland, while the Czech banking index further falls around 15 percent on the release of negative macro news. Finally in the tranquil period, the lagged dependent variables again prove statistically significant for all three countries, while we see that the Czech index falls around 45 percent on 'bad' macro news, while the Hungarian index rises around 32 percent on 'good' news released.

The residuals from these regressions act as a further measure of contagion controlling for own country fundamentals. The residual correlation matrices for each of the sub periods are presented in Table 5.4. The correlations between the Czech Republic and Hungary appear to decrease over the total sample, increase during turbulence and remain unchanged in the tranquil period when compared to those figures obtained via the unadjusted correlation analysis presented in Table 5.1. Despite the variance in the direction of the change between the correlation coefficients, the *LR test* statistic reveals statistically significant group-wise correlation of the residuals. This result implies that contagion exists well above and beyond the identified fundamentals, and that the banking sector correlations presented here are not principally driven by a single big macroeconomic news event.

Interestingly, the residual correlation coefficients between the Czech Republic and Poland have decreased significantly during all periods when compared to the unadjusted correlations presented in Table 5.1. Similarly there is a noticeable fall in the correlation coefficients between Poland and Hungary during all sub-samples when compared to Table 5.1. This finding is in line with the results obtained under the analysis of adjusted correlation coefficients where we found no evidence of contagion but rather an indication that co-movements between these markets are attributable to strong real linkages. Here, controlling for certain real fundamentals, we are able to diminish the extent of the co-movement. Despite the observed fall in correlations, the *LR test* statistic remains statistically significant.

Table 5.3 **Regression results with own country fundamentals**

Dependent variable: National bank index

	Czech Republic	Hungary	Poland
Total sample: 1994–2004			
Constant	0.02	0.09	0.06
	(0.08)	(0.13)	(0.21)
Bank index$_{-1}$	0.11	0.06	0.19
	(2.77)***	(1.51)*	(3.25)***
Good news	-0.03	0.34	0.11
	(0.16)	(1.52)*	(0.32)
Bad news	-0.35	-0.21	-0.49
	(1.02)	(0.77)	(1.11)
Adjusted R^2	0.52	0.44	0.37
Number of Obs.	2727	2727	2727
Turbulent period: 1994–1998			
Constant	0.05	0.09	0.01
	(0.12)	(0.22)	(0.15)
Bank index$_{-1}$	0.21	0.08	0.09
	(2.98)***	(1.08)	(3.17)***
Good news	0.06	0.15	0.09
	(0.26)	(0.31)	(0.12)
Bad news	-0.15	-0.26	-0.55
	(1.98)**	(1.31)	(1.12)
Adjusted R^2	0.34	0.46	0.53
Number of Obs.	1422	1422	1422
Tranquil period: 1999–2004			
Constant	0.09	0.08	0.09
	(0.11)	(0.08)	(0.06)
Bank index$_{-1}$	0.09	0.07	0.12
	(1.99)**	(1.52)*	(2.99)***
Good news	-0.16	0.32	0.25
	(0.99)	(2.01)**	(1.23)
Bad news	-0.45	-0.32	-0.51
	(1.73)*	(0.93)	(0.46)
Adjusted R^2	0.32	0.41	0.39
Number of Obs.	1304	1304	1304

Note: *, ** and *** denote rejection at the 10%, 5% and 1% levels respectively.
Absolute value of the t-statistic presented in parenthesis.

Table 5.4 **Residual correlation matrix**

	Czech Republic	Hungary	Poland
*Total sample: 1994–2004 (LR Test: 34.24***)*			
Czech Republic	1	0.36	0.17
Hungary	0.26	1	0.26
Poland	0.17	0.26	1
*Turbulent period: 1994–1996 (LR Test: 16.41***)*			
Czech Republic	1	0.49	0.12
Hungary	0.49	1	0.25
Poland	0.12	0.25	1
*Tranquil period: 1997–2004 (LR Test: 24.12***)*			
Czech Republic	1	0.10	0.11
Hungary	0.10	1	0.12
Poland	0.11	0.12	1

Note: The LR test attempts to reject the null hypothesis that all pair-wise correlations are equal to zero.
* denotes 10% significance level, ** denotes 5% significance level, *** denotes significance at 1% level.

5.3 Bias in the correlation coefficient

While the simple test of contagion based on correlation analysis above appears to return evidence of contagion between the banking sector indices of the CEEC economies, recent literature has highlighted a bias in the correlation coefficient central to this analysis. (Ronn, 1998; Boyer et al, 1999; Forbes and Rigobon, 2002). Effectively, during periods of calm, a standard two factor model is assumed whereby the return in each market is a linear function of a set of common shocks (w_t), which affect all markets, and an idiosyncratic shock (u_{it}). For a set of N asset markets, this relationship is presented as follows

$$x_{it} = \lambda_i w_t + \delta_i u_{it} \quad i = 1, 3;\ t = 1,\ldots,T \tag{5.7}$$

Where λ_i and δ_i are the common factor (w_i) and the idiosyncratic factor (u_{it}) loadings respectively. The bias stems from an increase in asset return volatility that arises from an increase in volatility of both the idiosyncratic and common factors above, and proves to be especially large during periods of market turmoil, which, in effect, is the focus of this test.

The use of the unadjusted (or conditional) coefficient assumes the bilateral analysis of markets x and y, and a division of the data sample into a high variance (h) and a low variance (l) group, representing the turbulent and the tranquil periods respectively. We start by estimating the correlation coefficient of the turbulent period according to the standard definition (5.1). The results are summarised in Table 5.2.

As discussed, it is possible that the increases in the correlations result from a bias due to market volatility during this time rather than purely from contagion. To assess the extent of this bias in our tests of contagion we repeat the analysis, this time adjusting the correlations to account for higher volatility of returns during periods of turmoil. This test assumes that spillovers are present only in one direction (ie from market x to market y; and not from y to market x). We consequently implement the test considering each of the three markets as the 'crisis' country in turn.

The adjustment takes the form

$$\gamma_h = \frac{\rho_h}{\sqrt{1+\left(\frac{(\sigma^2_{h,i}-\sigma^2_{l,i}}{\sigma^2_{l,i}}\right)\left(1-\rho^2_h\right)}} \qquad (5.8)$$

Where ρ_l is the low variance period correlation between market x and market y, $\sigma^2_{l,i}$ and $\sigma^2_{h,i}$ are the variance of asset returns in the low and high volatility periods of the of the 'crisis' country's asset returns respectively. The new test statistic takes the following form

$$FR = \frac{\frac{1}{2}\ln\left(\frac{1+\gamma_h}{1-\gamma_h}\right)-\frac{1}{2}\ln\left(\frac{1+\rho_l}{1-\rho_l}\right)}{\sqrt{\frac{1}{T_h-3}+\frac{1}{T_l-3}}} \qquad (5.9)$$

Where ρ_l is the correlation between x and y during the tranquil period, γ_h is the corresponding correlation coefficient in the turbulent period as obtained above.[16]

These results are presented in Table 5.5. In adjusting for an increase in market volatility, we find a significant difference in the results obtained. At the one percent level of significance, we are again able to identify the existence of contagion stemming from the Czech Republic to Hungary. The high correlations between markets for all other pairs of countries appear to be driven by strong real linkages through economic fundamentals rather than through the existence of contagion.

[16] See Forbes and Rigobon, 2002 for a more detailed discussion on the intuition behind this adjustment.

Table 5.5 **Adjusted correlation coefficients**

		Total sample ρ	Turbulent ρ	Tranquil ρ	Test stat	Contagion?
Czech Republic						
	Hungary	0.29	0.33	0.08	5.22	C
	Poland	0.21	0.22	0.07	0.96	N
Hungary						
	Czech Rep.	0.29	0.25	0.10	0.55	N
	Poland	0.27	0.21	0.24	0.32	N
Poland						
	Czech Rep.	0.21	0.19	0.09	0.12	N
	Hungary	0.27	0.16	0.11	1.08	N

This result is interesting since it highlights that fact that marked differences may have existed in the resilience of the banking sectors of Poland and Hungary to shocks coming from the Czech Republic. From the brief analysis of their development in Section 3 we found that the greatest differences that existed between Poland and Hungary stemmed from disparities in their management of bad debt and non-performing loans together with their supervisory and regulatory policies. Poland adopted a centralized approach to problem management which appeared to be more efficient and disallowed for the accumulation of problems. It may be possible that this strengthened the system to the extent that they were less vulnerable to shocks from abroad. Furthermore, the degree of capital stringency, as presented in Figure 3.1, appears to have been significantly higher in Poland than in Hungary or the Czech Republic, almost equivalent to some countries in the EU. There is scope for further research into the reasons behind the Polish resilience and the Hungarian vulnerability to banking sector contagion during this period.

5.4 Heteroskedasticity, simultaneous equations and omitted variables

As indicated by Rigobon (2003), stock market data, on which we have based our analysis, can often suffer from problems relating to heteroskedasticity, simultaneous equations and omitted variables. As a result, under the assumption of heteroskedasticity, the null hypothesis of stability can be rejected even if the coefficients are in fact stable. Consequently, the adjustment proposed by Ronn (1998), Boyer et al (1999), and Forbes and Rigobon (2002) is wrong and should not be used.

For the purpose of our estimations, we follow Rigobon (2003) in order to test whether we can verify the stability of parameters of a linear model in the presence of heteroskedasticity, simultaneous equations and omitted variables. The test provides and alternative to the *chow test* whereby coefficients in a structural model are tested for structural change. Given the relationship that exists between the *chow test* and contagion, as discussed in detail in Dungey et al (2005), we considered this as a further test of contagion.

Defining DCC window periods

The test requires the calculation of the covariance matrices for a set of random variables (in our case the daily change in the CEE banking sector return indices) for two different sub-samples. In implementing the test, there is a trade off between the length of the time-period windows and the chance of test rejection. The longer the windows, the higher the likelihood that most shocks are heteroskedastic, increasing the chance of rejection. In this case the test will be rejected since all shocks are heteroskedastic rather than because parameters are unstable. On the other hand, too narrow windows will undermine the estimation of the covariance matrices. If the covariance matrices are too noisy, then the test is never rejected, therefore there is a tension between the quality of the estimation of the matrices and the likelihood of satisfying the assumption of heteroskedasticity.

For our analysis, rather than analysing the entire sample period, we concentrate only on our turbulent period (1994-end 1999) and split the sample into six-month intervals.[17] For each time frame we assess bi-variate relationships between the three countries being analysed. The time periods are defined and presented in Table 5.7. This test essentially examines whether the propagation mechanism between the pair-wise sets of countries change during the defined windows.

Table 5.6 **DCC window periods**

Period	Window 1	Window 2
1	19th July 1994 – 31 December 1994	1 July 1995 – 31 December 1995
2	1st January 1995 – 30 June 1995	1st January 1996 – 30 June 1996
3	1 July 1995 – 31 December 1995	1 July 1996 – 31 December 1996
4	1st January 1996 – 30 June 1996	1st January 1997 – 30 June 1997
5	1 July 1996 – 31 December 1996	1 July 1997 – 31 December 1997
6	1st January 1997 – 30 June 1997	1st January 1998 – 30 June 1998
7	1 July 1997 – 31 December 1997	1 July 1998 – 31 December 1998
8	1st January 1998 – 30 June 1998	1st January 1999 – 30 June 1999
9	1 July 1998 – 31 December 1998	1 July 1999 – 31 December 1999

[17] We also run the test on three-month and one year intervals. The results are broadly in line with those obtained for the six-month windows and are therefore not presented.

DCC Test

The test is referred to as the determinant of the change in the covariance matrix (DCC), since it compares the change in the matrix determinants across sub-samples, taking the determinant to express the statistic as a scalar. The DCC statistic is formally defined by

$$DCC = \frac{\left|\hat{\Omega}_y^t - \hat{\Omega}_x^t\right|}{\hat{\sigma}_{DCC}} \tag{5.10}$$

Where $\hat{\Omega}_y^t$ and $\hat{\Omega}_x^t$ are the estimated covariance matrices between windows y and x in time period t defined in Table (5.7). $\hat{\sigma}_{DCC}$ is an estimate of the relevant standard error of the statistic. Under the null hypothesis, there is no change in the covariance structure of asset returns resulting in the change in determinant to equal zero. If however, contagion increases volatility then the determinant will be greater than zero. The test hypotheses are characterised by

$$H_0 : DCC = 0$$
$$H_1 : DCC > 0$$

Similarly to other tests of contagion, the *DCC test* is executed on the residuals of a VAR.[18] The residuals are then subsequently split between two windows y and x as defined above. For a more in depth analysis, we estimate three sets of VAR equations. The first VAR model is as per equation (5.1). Our second set of equations includes a domestic stock index for each country in order to try to capture the common factor effect. Including the domestic total market indices rules out market and sectoral effects and establishes a rough estimate of the idiosyncratic components of the country's banking sector. This equation consequently allows us to analyze the full range of interaction between the banking sector indices between all of the three countries and allows us to gain an indication of the degree to which regional shocks were responsible for banking sector index movements. Finally, we estimate a third set of equations, this time including the full set of variables described above, together with the macroeconomic dummy variables described in Section 4. Here we wish to analyse the effect of regional macroeconomic news announcements on the patterns of banking sector pressure.

For each sub-sample, the covariance matrix is calculated from the reduced form residuals and the DCC statistic computed. The distribution of the determinant of the change in covariance matrices is estimated via a bootstrapping

[18] The advantage of working with VAR residuals, as compared to structural residuals, is that the VAR represents and unconstrained reduced form, circumventing problems of simultaneity bias.

procedure based on sampling from the asymptotic distribution of the covariance matrix. The asymptotic distribution of the covariance matrix $\hat{\Omega}_i$ is given by (Hamilton, 1994, pp. 301)

$$\sqrt{T}\left[\mathrm{vech}\left(\hat{\Omega}_i\right) - \mathrm{vech}\left(\Omega_i\right)\right] \xrightarrow{L} N\left(0.2D^{+}(\Omega \otimes \Omega) * \left(D^{+}\right)\right) \quad i = x, y \qquad (5.11)$$

Where D is the duplication matrix defined as

$$\begin{aligned} &D\mathrm{vech}(\Omega) = \mathrm{vech}(\Omega) \text{ and} \\ &D^{+} = (D'D)^{-1}D' \end{aligned} \qquad (5.12)$$

is the generalised inverse of D.

The bootstrap is obtained by: first, after estimating the covariance matrix in each of the time-period windows, generating several covariance matrices for each sub-sample using the asymptotic distribution of the covariance matrices. We then compute the determinant of the change between windows and subsequently evaluate the number of realizations for which DCC is above zero. This acts as a sort of p-value since the test is rejected if the mass is lower than 0.1 or greater than 0.9. The bootstrap is implemented assuming that the covariance matrices are serially correlated across regimes and uses the point estimate of the covariance matrix in a low-volatility regime and the change in the covariance matrix across regimes to generate random draws. The use of the bootstrapping procedure in this sense is beneficial since it allows us to obtain a description of the properties of the estimators using sample data points. In essence, the procedure comprises sampling repeatedly with replacements from actual data to obtain a distribution.

Test results

Table 5.7 presents our results for each of the three sets of VAR equations.[19] Interestingly, we find slightly varying results between the different VAR specifications. The dummy variables here serve to capture the part of the propagation of shocks that could be transmitted through fundamentals. When we consider the relationship between the Czech Republic and Hungary together, this specification rejects the null of no contagion during the first half of 1996. It was during this time that in the Czech Republic, around 39 percent of banking sector loans were considered as 'classified' meaning that their existed a 'degree of uncertainty relating to their repayment' (Freedom House, 1998). Moreover this was the period directly preceding that of the crisis. During the second half of 1996, all three VAR specifications return further evidence in favour of contagion between the Czech Republic and Hungary. This is the period when the Czech

[19] For brevity, VAR results are not reported here.

Republic experienced severe banking sector distress causing a huge increase in variance of the banking sector index. These results indicate that during the second half of 1996, there is significant evidence in favour of propagation through the banking sector indices, as proxied by specification 1. Furthermore, ruling out market and sectoral effects we establish that the propagation additionally occurs through the idiosyncratic components of the country's banking sector as well as through the market fundamentals during this time.

Table 5.7 **DCC results**

VAR specification	1	2	3	1	2	3	1	2	3
Czech Republic with Hungary and Poland									
19th July 1994 – 31 December 1994				N	N	N	N	N	N
1st January 1995 – 30 June 1995				N	N	N	N	N	N
1 July 1995 – 31 December 1995				N	N	N	N	N	N
1st January 1996 – 30 June 1996				N	N	R	N	N	N
1 July 1996 – 31 December 1996				R	R	R	N	N	N
1st January 1997 – 30 June 1997				N	N	N	N	N	N
1 July 1997 – 31 December 1997				N	N	N	N	N	N
1st January 1998 – 30 June 1998				N	N	N	N	N	N
1 July 1998 – 31 December 1998				N	N	N	N	N	N
Hungary with the Czech Republic and Poland									
19th July 1994 – 31 December 1994	N	N	N				N	N	N
1st January 1995 – 30 June 1995	N	N	N				N	N	N
1 July 1995 – 31 December 1995	N	N	N				N	N	N
1st January 1996 – 30 June 1996	N	N	R				N	N	N
1 July 1996 – 31 December 1996	R	R	R				N	N	N
1st January 1997 – 30 June 1997	N	N	N				N	N	N
1 July 1997 – 31 December 1997	N	N	N				N	N	N
1st January 1998 – 30 June 1998	N	N	N				N	N	N
1 July 1998 – 31 December 1998	N	N	N				N	N	N
Poland with the Czech Republic and Hungary									
19th July 1994 – 31 December 1994	N	N	N	N	N	N			
1st January 1995 – 30 June 1995	N	N	N	N	N	N			
1 July 1995 – 31 December 1995	N	N	N	N	N	N			
1st January 1996 – 30 June 1996	N	N	N	N	N	N			
1 July 1996 – 31 December 1996	N	N	N	N	N	N			
1st January 1997 – 30 June 1997	N	N	N	N	N	N			
1 July 1997 – 31 December 1997	N	N	N	N	N	N			
1st January 1998 – 30 June 1998	N	N	N	N	N	N			
1 July 1998 – 31 December 1998	N	N	N	N	N	N			

Note: VAR specification 1 corresponds to the estimation with bank index variables only.
VAR specification 2 corresponds to the estimation with bank index variables and a domestic stock market variable.
VAR specification 3 corresponds to the estimation with bank index variables, domestic stock market variables and the full set of good and bad news dummy variables.
R denotes rejection of the null hypothesis of parameter stability and subsequent rejection of the null of 'no contagion'.

These results would tend to confirm those obtained in Section 5.3. Moreover they indicate that directly preceding the crisis, shocks appear to be propagated via market fundamentals, while during crisis, shocks seem to additionally be propagated through the banking sector indices. Criticisms of the DCC test have pointed out that the main problems lie with its inability to evaluate whether rejection of the null is due to a parameter shift, or to the violation of the assumptions made on the heteroskedasticity under the null (see among others Billio, Lo Duca and Pelizzon, 2003). Furthermore, it has been shown that the results obtained via the DCC tests are largely dependent on the size of the windows chosen.

The nature of the DCC test however, assumes that the country (or countries) generating the increase in the variance is (are) known and does not therefore allow for a test of causality. In our estimations, since we are analysing the nature of relationships between the CEECs rather than analysing a single event or crisis, we can not be sure of the origin of turbulence from the test results obtained. We therefore try to determine the direction of the instability found by implementing a *granger causality test*.

The test considers whether x causes y in order to see how much of the current y can be explained by past values of y as well as whether adding lagged values of x can improve the explanation. y can be said to be *granger-caused* by x if x helps in the prediction of y. Setting the lag length equal to two, we run the test on the full sample, the turbulent and tranquil sub-samples, as well as on the two six-month periods defined in the above analysis.[20] The results are presented in Table 5.8.

[20] Our tests of causality do not control for omitted variables, or for potential heteroskedasticity of the residuals and therefore the possibility of bias exists Cheung and Fujii (2001).

Table 5.8 **Granger-causality test results**

Null hypothesis	Obs	F-statistic	Probability
Total sample			
HU does not granger cause CZ	2727	1.62	0.19
CZ does not granger cause HU		10.04	4.60E-05
Turbulent period (1994–1998)			
HU does not granger cause CZ	1161	0.97	0.38
CZ does not granger cause HU		4.97	0.01
Tranquil period (1999–2004)			
HU does not granger cause CZ	1564	0.66	0.45
CZ does not granger cause HU		1.32	0.08
1st January 1996 – 30 June 1996			
HU does not granger cause CZ	129	0.07	0.92
CZ does not granger cause HU		3.60	5.20E-05
1 July 1996 – 31 December 1996			
HU does not granger cause CZ	130	1.02	0.36
CZ does not granger cause HU		7.37	6.40E-05

Note: CZ, HU and PL represent the Czech Republic, Hungary and Poland respectively.

In each case, the null hypothesis that the Czech Republic does not *granger-cause* Hungary is rejected. Interestingly, the causality appears to only run in one direction: from the Czech Republic to Hungary. These results confirm our previous findings and highlight the fact that problems in the Czech Republic appear to have had a significant negative impact on the banking sector of Hungary. Moreover, from these results, it is possible to assume that the rejection of parameter stability between the Czech Republic and Hungary can be pinpointed to the Czech banking crisis, and the period directly preceding that.

6 Conclusions

This paper examines the behaviour of price changes in the banking sector indices of the CEECs over the last decade. Making use of daily data for the three largest CEECs, we address various econometric issues that have arisen in the literature and apply a wide range of tests to analyse whether co-movements are attributable to contagion or to interdependence.

Our tests based on the unadjusted (conditional) correlations between a turbulent and a more tranquil period indicate that considerable co-movement appears to be present, suggesting that the banking sectors of the largest markets in Central and Eastern Europe have tended to move together, and have had a substantial influence on one another. Moreover, we find that this relationship exists above and beyond economic fundamentals identified and that banking sector correlations are not driven by a single macroeconomic news event.

We further adjust for the increase in market volatility during our high volatility period and find varying results. We see that in this case, contagion appears to run only from the Czech Republic to Hungary. Despite the high correlations between the other pairs of countries, we are unable to find evidence of contagion and infer that such co-movements are rather attributable to close linkages through economic fundamentals.

Finally, following Rigobon (2003) we additionally account for problems of simultaneous equations, omitted variables and heteroskedasticity via the implementation of the distribution of the determinant of the change in the covariance matrix methodology (DCC). Our tests confirm our previous findings and provide evidence in favour of parameter instability, again signifying the existence of contagion. In particular, these results confirm those of the adjusted correlations since they highlight the existence of parameter instability between the Czech Republic and Hungary only. This instability seems to be present during much of 1996. This test however does not allow for the analysis of direction of causality. We thus implement *granger-causality test*, and find evidence of causality running from the Czech Republic to Hungary, providing additional verification for our previous findings.

Our results are broadly in line with previous literature in this field. Focussing merely on the narrow definition of 'shift contagion', many papers have found significant evidence of large co-movements in a variety of asset returns around crisis periods. However, addressing the various econometric problems highlighted in Section 2, far less evidence in favour of the existence of contagion is uncovered.

This paper has focussed on trying to assess the impact of market turmoil on the banking sector and for this reason we adopt the use of banking sector indices. Further research at the individual bank level could be interesting in gaining additional insight into cross-market linkages between these countries. Our brief analysis of the CEE banking sectors during the period of their development highlighted differences that seemed to exist resulting from various policies implemented during this time. In particular, we find that the greatest differences that could have attributed the varying degrees of susceptibility of Hungary to contagion from the Czech Republic relate to disparities in the management of bad debt and non-performing loans inherited together with the supervisory and regulatory policies adopted. From a policy point of view it might be useful to fully understand the reasons behind the differences in vulnerability of Poland and Hungary to shocks during this time, therefore further research into this is necessary.

References

Allen, F – Gale, D (2000) **Financial Contagion.** Journal of Political Economy 108(1), 1–33.

Baig, T – Goldfajn, L (1999) **Financial Markets Contagion in the Asian Crisis.** IMF Working Paper 46(2).

Barth, J – Caprio, G – Levine, R (2001) **The Regulation and Supervision of Banks Around the World: A New Database.** In R E Litan and R Herring, (eds.) Integrating Emerging Market Countries into the Global Financial System, Brookings-Wharton Papers on Financial Services, Washington, DC, Brookings Institution Press (2001), 183–241.

Bekaert, G – Harvey, C (2000) **Foreign Speculators and Emerging Equity Markets.** Journal of Finance, 55, 565–613.

Beim, D (2005) **What Triggers a Systemic Banking Crisis?** Colombia Business School Working Paper.

Billio, M – Lo Duca, M – Pellizzon, L (2003) **The DCC Test: Powerless Evidence of No Contagion.** GRETA Working Paper 03/07.

Boyer, B – Gibson, M – Loretan, M (1999) **Pitfalls in Tests for Changes in Correlation.** Federal Reserve Board, International Finance Discussion Paper 597.

Broner, F – Gelos, G – Reinhart, C (2004) **When in Peril, Retrench: Testing the Portfolio Channel of Contagion.** IMF Working Paper 04/131.

Calvo, S – Reinhart, C (1996) **Capital Flows to Latin America: Is there Evidence of Contagion Effects, Private Capital Flows to Emerging Markets after the Mexican Crisis.** Institute for International Economics.

Cheung, Y – Fujii, E (2001) **A Note on the Power of Money-Output Causality Tests.** Oxford Bulletin of Economics and Statistics, 63, 247–261.

Classens, S – Forbes, K (2004) **International Financial Contagion.** Norwell: MA: Kluwer Academic Publishers.

Corsetti, G – Pericoli, M – Sbracia, M (2002) **Some Contagion, Some Interdependence: More Pitfalls in Tests of Financial Contagion.** CEPR Discussion Paper 3310.

Corsetti, G – Pesenti, P – Tille, C (2000) **Competitive Devaluations: Toward a Welfare-Based Approach.** Journal of International Economics, 51, 217–241.

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

Demirgűç-Kunt, A – Detragiache, E (1998) **The Determinants of Banking Crisis in Developing and Developed Countries.** IMF Staff Papers 45(1).

Diamond, D (1984) **Financial Intermediation and Delegated Monitoring.** Review of Economic Studies, 51, 393–414.

Dungey, M – Fry, R – González-Hermosillo, B – Martin, V (2005) **Empirical Modelling of Contagion: A Review.** IMF Working Paper 04/78.

Edwards, S (2000) **Contagion.** The Wold Economy, 23(7).

Eichengreen, B – Rose, A – Wyplosz, C (1996) **Contagious Currency Crises.** Scandinavian Economic Review, 98, 463–484.

Eichengreen, B – Rose, A (1999) **Contagious Currency Crises: Channels of Conveyance.** In T Ito and A Krueger, Changes in Exchange Rates Rapidly Developing Countries, U. of Chicago Press.

European Bank for Reconstruction and Development (EBRD): Transition Report 1997. London.

European Forecasting Network (2004) **The Euro Area and Acceding Countries.** Report 2004.

Forbes, K – Rigobon, R (2002) **No Contagion, Only Interdependence: Measuring Stock Market Co-Movements.** Journal of Finance, 57, 2223–2261.

Freedom House (1998) **Nations in Transit: Civil Society, Democracy and Markets in East Central Europe and the Newly Independent States.**

Freixas, X – Parigi, B – Rochet, J (2000) **Systemic Risk, Interbank Relations and Liquidity Provision by the Central Bank.** Journal of Money, Credit and Banking, 32(3).

Fries, S – Raiser, M – Stern, N (1999) **Stress Test for Reforms. Transition and East Asian 'Congation'.** Economics of Transition, 7, 535–567.

Ganapolsky, E – Schmulker, S (1998) **The Impact of Policy Announcement and News on Capital Markets: Crisis Management in Argentina during the Tequila Effect.** World Bank.

Gelos, G – Sahay, R (2001) **Financial Markets Spillovers in Transition Economies.** Economics of Transition, 9 (1).

Gerlach, S – Smets, F (1995) **Contagious Speculative Attack.** European Journal of Political Economy, 11, 5–63.

Glick, R – Rose, A (1998) **Contagion and Trade: Why are Currency Crises Regional?** Journal of International Money and Finance, 18, 603–617.

Goldfajn, I – Valdés, R (1997) **Capital Flows and Twin Crisis: The Role of Liquidity.** IMF Working Paper 97/87.

Gropp, R – Vesala, J (2004) **Bank Contagion in Europe.** Mimeo ECB (December).

Hamilton, J (1994) **Time Series Analysis.** Princeton New Jersey, Princeton University Press.

Henry, P (2000) **Stock Market Liberalization, Economic Reform and Emerging Market Equity Prices.** Journal of Finance, 55, 529–564.

Hutchinson, M (2002) **European Banking Distress and EMU: Institutional and Macroeconomic Risks.** Scandinavian Journal of Economics, 104, 365–389.

Hughes, J – Sasse, G – Gordon, C (2001) **The Regional Deficit in Regional Eastward Enlargement of the European Union: Top Down Policies and Bottom Up Reactions.** ESRC Research Programme on One Europe or Several? 29/2001 (2001).

International Monetary Fund (IMF) (1997) **World Economic Outlook: Chapter III: EMU and The World Economy.** World Economic and Financial Surveys.

Kaminsky, G – Lyons, R – Schmukler, S (2001) **Mutual Fund Investment in Emerging Markets: An Overview.** In S Classens and K Forbes (eds.) International Financial Contagion Boston: Kluwer Academic Publishers, 158–286.

Kaminsky, G – Reinhart, C (1999) **The Twin Crises: The Cause of Banking and Balance-of-Payments Problems.** American Economic Association, 89(3), 473–500.

Kaminsky, G – Schmukler, S (1999) **What Triggers Market Jitters? A Chronicle of the Asian Crisis.** Journal of International Money and Finance, 18, 537–560.

Kawalec, S (1999) **Banking Sector Systemic Risk in Selected Central European Countries- Review of Bulgaria, Czech Republic, Hungary, Poland, Romania and Slovakia.** CASE Reports 1999.

King, M – Wadhwani, S (1990) **Transmission of Volatility Between Stock Markets.** Review of Financial Studies, 3(1), 5–33.

Loretan, M – English, W (2000) **Evaluating Correlation Breakdowns During Periods of Market Volatility.** In International Financial Markets and the Implication for Monetary and Financial Stability eds. Bank for International Settlements.

Masson, P (1998) **Contagion: Monsoonal Effects, Spillovers and Jumps Between Multiple Equilibria.** IMF Working Paper 98, 142.

Murzuch, B – Weller, C (2002) **International Financial Contagion: Why Are Eastern European Banks Not Failing When Everyone Else's Are?** Economics of Transition 8(3).

Reininger, T – Schardax, F – Summer, M (2001) **The Financial System in the Czech Republic, Hungary and Poland After a Decade of Transition.** Deutsche Bundesbank Discussion Paper 16/01.

Rigobon, R (2003) **On the Measurement of the International Propagation of Shocks: Is It Stable?** Journal of International Economics, 61, 261–283.

Ronn, E (1998) **The Impact of Large Changes in Asset Prices on Intra-Market Correlations in the Stock and Bond Markets.** Mimeo.Department of Finance, University of Texas at Austin.

Schinasi, G – Smith, T (2001) **Portfolio Diversification, Leverage and Financial Contagion.** In S Classens and K Forbes (eds.) International Financial Contagion, Boston, Kluwer Academic Publishers, 187–223.

Sherif, K – Borish, M – Gross, A (2003) **State-Owned Banks in the Transition: Origins, Evolution and Policy Responses.** World Bank.

Timmermans, T (2001) **Monitoring Macroeconomic Determinants of Banking system Stability.** BIS Working Paper 1(Part 4).

Valdés, R (1997) **Emerging Market Contagion: Evidence and Theory.** Documentos de Trabajo del Banco Central de Chile.

Van Rijckeghem, C – Weder, B (2001) **Spillovers Through Banking Centres – A Panel Data Analysis.** Journal of International Economics, 54, 293–308.

BANK OF FINLAND RESEARCH
DISCUSSION PAPERS

ISSN 0785-3572, print; ISSN 1456-6184, online

1/2006 Juha-Pekka Niinimäki – Tuomas Takalo – Klaus Kultti **The role of comparing in financial markets with hidden information.** 2006. 37 p. ISBN 952-462-256-4, print; ISBN 952-462-257-2, online.

2/2006 Pierre Siklos – Martin Bohl **Policy words and policy deeds: the ECB and the euro.** 2006. 44 p. ISBN 952-462-258-0, print; ISBN 952-462-259-9, online.

3/2006 Iftekhar Hasan – Cristiano Zazzara **Pricing risky bank loans in the new Basel II environment.** 2006. 46 p. ISBN 952-462-260-2, print; ISBN 952-462-261-0, online.

4/2006 Juha Kilponen – Kai Leitemo **Robustness in monetary policymaking: a case for the Friedman rule.** 2006. 19 p. ISBN 952-462-262-9, print; ISBN 952-462-263-7, online.

5/2006 Juha Kilponen – Antti Ripatti **Labour and product market competition in a small open economy – Simulation results using the DGE model of the Finnish economy.** 2006. 51 p. ISBN 952-462-264-5, print; ISBN 952-462-265-3, online.

6/2006 Mikael Bask **Announcement effects on exchange rate movements: continuity as a selection criterion among the REE.** 2006. 43 p. ISBN 952-462-270-X, print; ISBN 952-462-271-8, online.

7/2006 Mikael Bask **Adaptive learning in an expectational difference equation with several lags: selecting among learnable REE.** 2006. 33 p. ISBN 952-462-272-6, print; ISBN 952-462-273-4, online.

8/2006 Mikael Bask **Exchange rate volatility without the contrivance of fundamentals and the failure of PPP.** 2006. 17 p. ISBN 952-462-274-2, print; ISBN 952-462-275-0, online.

9/2006 Mikael Bask – Tung Liu – Anna Widerberg **The stability of electricity prices: estimation and inference of the Lyapunov exponents.** 2006. 19 p. ISBN 952-462 276-9, print; ISBN 952-462- 277-7, online.

10/2006 Mikael Bask – Jarko Fidrmuc **Fundamentals and technical trading: behavior of exchange rates in the CEECs.** 2006. 20 p. ISBN 952-462278-5, print; ISBN 952-462-279-3, online.

11/2006 Markku Lanne – Timo Vesala **The effect of a transaction tax on exchange rate volatility.** 2006. 20 p. ISBN 952-462-280-7, print; ISBN 952-462-281-5, online.

12/2006 Juuso Vanhala **Labour taxation and shock propagation in a New Keynesian model with search frictions.** 2006. 38 p. ISBN 952-462-282-3, print; ISBN 952-462-283-1, online.

13/2006 Michal Kempa **Money market volatility – A simulation study.** 2006. 36 p. ISBN 952-462-284-X, print; ISBN 952-462-285-8, online.

14/2006 Jan Toporowski **Open market operations: beyond the new consensus.** 2006. 33 p. ISBN 952-462-286-6, print; ISBN 952-462-287-4, online.

15/2006 Terhi Jokipii – Brian Lucey **Contagion and interdependence: measuring CEE banking sector co-movements.** 2006. 42 p. ISBN 952-462-288-2, print; ISBN 952-462-289-0, online.

Suomen Pankki
Bank of Finland
P.O.Box 160
FI-00101 HELSINKI
Finland

. 2343