Contagion in Global Equity Markets in 1998: The Effects of the Russian and LTCM Crises*

Mardi Dungey[+%], Renée Fry[%+],
Brenda González-Hermosillo[*] and Vance L. Martin[#]

[+]CFAP, University of Cambridge
[%]CAMA, Australian National University
[*]International Monetary Fund
[#]University of Melbourne

May 2007

Abstract

The Russian and LTCM financial crises in the second half of 1998 originated in bond markets, but were rapidly transmitted through international equity markets. A multi-factor model of financial markets with multiple regimes is used to estimate the transmission effects in equity markets due to global, regional and potentially contagious transmission mechansims during the twin crises. Using a panel of 10 emerging and industrial financial markets the empirical results show that contagion is significant and widespread in international equity markets during the LTCM crisis, while its impact is more selective during the Russian crisis. Contagion effects in the equity markets are found to be stronger than those previously noted in the bond markets for this period.

Key Words: Contagion, Russian crisis, LTCM, factor models, multiple regimes

JEL Classification: C32, F36

---

*This project was funded under ARC large grant A00001350. The views expressed in this paper are those of the authors and do not necessarily coincide with those of the IMF or IMF policy. The authors contact details are respectively: m.dungey@cerf.cam.ac.uk; renee.fry@anu.edu.au; bgonzalez@imf.org; vance@unimelb.edu.au.

1 Introduction

The year of 1998 was a time of tremendous turmoil in financial markets. Throughout this year market reports presented evidence of continuous nervousness about the Russian banking and financial sectors culminating with the suspension of payment on sovereign debt and the float of the rouble in August. These events were soon followed by the not unrelated near-default of the US hedge fund Long-Term Capital Management (LTCM). The shocks during this period had far reaching effects on global financial markets and to some observers the period represented the worst turbulence in international financial markets that had occurred in the past decades (Upper (2001), Committee on the Global Financial System (1999)).

While the primary shocks in the Russian and LTCM crises began in bond markets, their repercussions were felt throughout the financial sector, and much volatility appeared in international equity markets. This paper looks at the transmission of crises during 1998 in international equity markets and finds results which are starkly different from those for international bond markets. In equity markets the majority of the transmission of the shocks across international borders is attributable to contagion effects whereas in bond markets contagion effects are relatively small, although in both cases contagion effects are significant.

The empirical results also show that the most influential source of contagion effects also differs across the two asset types during this period: the majority of the contagion effects in equity markets are sourced through the US equity market, while in bond markets contagion is primarily associated with events in Russia (Dungey, Fry, González-Hermosillo and Martin (2006)). The importance of the US market in distributing equity market shocks supports the hypothesis of Kaminsky and Reinhart (2002) that large markets act as centres in distributing shocks to the periphery markets.

The empirical results of this paper contribute to the existing literature that focuses on the role of equity markets in acting as a conduit during the Russian bond crisis and the LTCM near collapse, by adopting a more general model that looks at a range of factors linking both industrial and emerging equity markets during the financial crises of 1998. The earlier work of the Committee on the Global Financial System (1999) focuses on industrial countries, whereas Rigobon (2003) and Hernández and Valdés (2001) concentrate on emerging markets. More recently, Kaminsky and Reinhart (2003) look at the interrelationships between industrial and emerging markets, while Baig and Goldfajn (2001) specifically focus on the transmissions to Brazil. The effects of the Russian and LTCM shocks on international bond markets are studied by Dungey, Fry, González-Hermosillo and Martin (2006), Jorion (2000) and the Committee on the Global Financial System (1999).

To identify the linkages across international equity markets during financial crises, a factor model is developed that extends the international capital asset pricing model of Solnik (1974) and the multi-factor extensions proposed by King, Sentana and Wadhwani (1994). A feature of the model is that it allows for not only common and regional factors but also for contagion; see Dornbusch, Park and Claessens (2000) and Pericoli and Sbracia (2003) for a review of definitions of contagion. An important theoretical extension over these earlier models is the identification of contagion through multiple regime shifts in the factor structures. The approach represents a multivariate extension of the correlation change test of Forbes and Rigobon (2002), and is also related to the recent contagion tests proposed by Favero and Giavazzi (2003) based on threshold models.

The remainder of this paper is organized as follows. A multi-regime factor model of financial crises is specified in Section 2. A number of preliminary empirical issues are discussed in Section 3, including data filtering, identification of equity market shocks, and estimation strategies. The main empirical results are presented in Section 4, while Section 5 contains some concluding comments and suggestions for future research.

2 A Model of Financial Turmoil in Equity Markets During 1998

In this section a multi-regime factor model of equity markets is specified to identify the transmission mechanisms of financial crises between international equity markets. The model builds on the earlier work of Solnik (1974) and in particular, the factor model of King, Sentana and Wadhwani (1994), by allowing for additional linkages arising from contagion during the Russian and LTCM crises. An important theoretical extension of this earlier class of factor models is the identification of contagion during the crisis periods by allowing for multiple regime shifts in the factor structures.

Let $s_{i,t}$ represent the equity returns of country i at time t. A total of 10 equity markets is used in the empirical analysis including 6 emerging equity markets (Argentina (AR), Brazil (BR), Hong Kong SAR (HK), Thailand (TH), Poland (PO) and Russia (RU)) and 4 industrial equity markets (Germany (GE), Japan (JA), United Kingdom (UK) and the United States (US)). Defining s_t as a (10×1) vector of all equity returns, the dynamics of equity markets are assumed to be represented by the following vector autoregression (VAR)

$$s_t = \mu + A_1 s_{t-1} + A_2 s_{t-2} + \cdots + A_p s_{t-p} + u_t, \tag{1}$$

where μ is a (10×1) vector of parameters to allow for non-zero means in equity returns, A_i is a (10×10) matrix of autoregressive parameters corresponding to the i^{th} lag, and u_t is a (10×1) multivariate disturbance process with zero mean, variance-covariance matrix Ω, and $Eu_t u_{t-k} = 0, \forall k \neq 0$. The length of the lag distribution of the VAR is given by p.

The disturbance term u_t in (1) represents shocks to equity markets which are assumed to be derived from a set of factors. In specifying the factor structure, the model distinguishes between a benchmark period where the factors represent the market fundamentals which link international equity markets, and a crisis period where the benchmark factor structure is augmented with additional linkages that capture contagion caused by shocks which increase the comovements of international equity markets. These factor structures are formally specified below.

2.1 A Benchmark Model

The factor structure of u_t in (1) during the benchmark period is specified as

$$u_t = \left[\begin{array}{ccc} A & \vdots & \Phi_1 \end{array} \right] f_t = \Gamma_1 f_t, \tag{2}$$

where f_t represents the full set of factors

$$f_t = \left[w_t, e_t, d_t, r_t, v_{AR,t}, v_{BR,t}, \cdots, v_{US,t} \right], \tag{3}$$

and

$$A = \begin{bmatrix} \lambda_{AR} & \gamma_{AR} & 0 & \psi_{AR} \\ \lambda_{BR} & \gamma_{BR} & 0 & \psi_{BR} \\ \lambda_{HK} & \gamma_{HK} & 0 & 0 \\ \lambda_{TH} & \gamma_{TH} & 0 & 0 \\ \lambda_{PO} & \gamma_{PO} & 0 & 0 \\ \lambda_{RU} & \gamma_{RU} & 0 & 0 \\ \lambda_{GE} & 0 & \delta_{GE} & 0 \\ \lambda_{JA} & 0 & \delta_{JA} & 0 \\ \lambda_{UK} & 0 & \delta_{UK} & 0 \\ \lambda_{US} & 0 & \delta_{US} & \psi_{US} \end{bmatrix}, \qquad \Phi_1 = diag \begin{bmatrix} \phi_{AR} \\ \phi_{BR} \\ \phi_{HK} \\ \phi_{TH} \\ \phi_{PO} \\ \phi_{RU} \\ \phi_{GE} \\ \phi_{JA} \\ \phi_{UK} \\ \phi_{US} \end{bmatrix}. \tag{4}$$

The factor w_t in (3) represents shocks that simultaneously impact upon all equity markets with the size of the impact determined by the loading parameter λ_i. For this reason this factor is referred to as a world factor. Typical examples of world factors would be the global effects of changes in US monetary policy on world equity markets (Forbes and Rigobon (2002)), or the simultaneous impact on international equity markets of an oil price shock. Rather than specifying particular observable factors w_t in (3) is treated as a latent factor.

The model in (3) contains two factors to distinguish emerging and developed markets, which are represented by e_t and d_t respectively; see also Kaminsky and Reinhart (2002); and the Committee on the Global Financial System (1999). The factor e_t, captures those shocks which specifically affect the six emerging markets where the size of the impact is governed by the parameter γ_i. The factor d_t captures those shocks which just affect the four industrial equity markets, with the size of the impact controlled by the parameter δ_i.

To allow for shocks which solely capture a common regional interest, such as proposed by Glick and Rose (1996), the factor r_t impacts only upon Argentina (AR), Brazil (BR) and the US, with loading parameters given by ψ_i. There are insufficient countries in any other common regional grouping to warrant the inclusion of further regional factors in the set of equity markets used in the empirical application.

The last set of factors in (3) are given by $v_{i,t}$, which represent shocks that are specific to each of the 10 equity markets with loading parameters given by ϕ_i. The full set of factors can be classified into two broad groups, with the first four factors (w_t, e_t, d_t, r_t) representing systematic factors whose risks are not diversifiable, whilst the country specific factors $(v_{i,t})$ represent idiosyncratic factors whose risks are diversifiable (Solnik (1974)).[1]

To complete the specification of the benchmark model, the set of systematic and idiosyncratic factors are assumed to be independent with zero means and unit variances

$$f_t \sim (0, 1) . \tag{5}$$

In this specification the series are assumed to be homoscedastic.[2] This choice of the normalization of the factors provides a convenient decomposition of equity volatility into the contributions of each of the underlying factors during the benchmark period

$$Var(u_{i,t}) = \lambda_i^2 + \gamma_i^2 + \delta_i^2 + \psi_i^2 + \phi_i^2. \tag{6}$$

2.2 A Model Incorporating Contagion

The crisis model of equity shocks is characterized by the inclusion of additional transmission mechanisms linking global equity markets during periods of crisis, over and above the mechanisms identified by the benchmark model in (2). The approach to modelling these additional linkages is to include the Russian $(v_{RU,t})$ and US $(v_{US,t})$ idiosyncratic shocks defined in (2), into the factor structure of the remaining countries during periods in which crises are present. Following Masson (1999), Forbes and Rigobon (2002), Pericoli and Sbracia (2003) and Dungey, Fry, González-Hermosillo, and Martin (2006), these linkages are referred to as contagion as they represent additional shocks over and above the shocks that occur during the benchmark period linking equity markets, which contribute to the volatility of asset markets during periods of crisis.

[1] The choice of factors is based on some preliminary empirical analysis. Some robustness checks and tests of the specified factors stucture are discussed in the empirical section.

[2] Some preliminary ARCH tests on equity returns during the benchmark period find no strong evidence of time-varying volatility. However, to guard against potential time varying volatility, the GMM standard errors are adjusted for heteroskedasticity.

2.2.1 Incorporating Contagion from Russia

To incorporate contagion from Russia, the factor model is specified as

$$u_t = \left[\begin{array}{ccc} A & \vdots & \Phi_2 \end{array} \right] f_t = \Gamma_2 f_t, \tag{7}$$

where A and f_t are respectively given in (4) and (3), and Φ_2 is specified as

$$\Phi_2 = \begin{bmatrix} \phi_{AR} & & & & & \alpha_{AR} & & & & \\ & \phi_{BR} & & & & \alpha_{BR} & & & & \\ & & \phi_{HK} & & & \alpha_{HK} & & & & \\ & & & \phi_{TH} & & \alpha_{TH} & & & & \\ & & & & \phi_{PO} & \alpha_{PO} & & & & \\ & & & & & \alpha_{RU} & & & & \\ & & & & & \alpha_{GE} & \phi_{GE} & & & \\ & & & & & \alpha_{JA} & & \phi_{JA} & & \\ & & & & & \alpha_{UK} & & & \phi_{UK} & \\ & & & & & \alpha_{US} & & & & \phi_{US} \end{bmatrix}, \tag{8}$$

where blank cells represent zeros. The strength of contagion from Russia to international equity markets is controlled by the parameter α_i. Equation (7) also allows for the effect of Russian idiosyncratic shocks to differ across regimes by allowing the parameter ϕ_{RU} in (4) to differ from α_{RU} in (8). Dungey, Fry, González-Hermosillo and Martin (2005) interpret this as an idiosyncratic structural break.

Following the benchmark decomposition of the variance in (6), equity market volatility with contagion from Russia is decomposed as

$$Var\left(u_{i,t}\right) = \lambda_i^2 + \gamma_i^2 + \delta_i^2 + \psi_i^2 + \phi_i^2 + \alpha_i^2. \tag{9}$$

This suggests that the contribution of contagion to volatility in the i^{th} country when there is potentially contagion from Russia compared with the benchmark model is simply

$$\Delta Var\left(u_{i,t}\right) = \alpha_i^2. \tag{10}$$

Hence, a test of contagion emanating from the Russian equity market can be performed by testing the restriction

$$H_0 : \alpha_i = 0, \qquad \forall i \neq RU. \tag{11}$$

The specification in (8) allows for an exogenous change in the volatility of idiosyncratic shocks in Russia between the benchmark and Russian crisis period. This constitutes a structural break in the Russian idiosyncratic factor which can be tested via the restriction

$$H_0 : \phi_{RU} = \alpha_{RU}. \tag{12}$$

2.2.2 Incorporating Contagion from LTCM

An important feature of the LTCM crisis is that it occurs in conjunction with the Russian crisis, but is of shorter duration. The LTCM liquidity crisis is viewed to have ended at the time of the surprise inter-FOMC meeting to cut interest rates on October 15th. The implication of this characteristic of the twin-crisis periods, is that the contagious channel used to model the transmission of shocks from Russia, is still active during the LTCM crisis period. This feature of the problem imposes additional structure on the factors across the regimes.

Following the approach to modelling contagion during the Russian period, contagion emanating from the LTCM crisis is modelled by including US equity shocks $v_{US,t}$ during the time of the LTCM crisis as well as the Russian shocks $v_{RU,t}$ in the factor representation of the other equity markets. The LTCM crisis model is specified as

$$u_t = \left[\begin{array}{ccc} A & \vdots & \Phi_3 \end{array} \right] f_t = \Gamma_3 f_t. \tag{13}$$

where A and f_t are respectively given in (4) and (3), and Φ_3 is specified as

$$\Phi_3 = \begin{bmatrix} \phi_{AR} & & & & & \alpha_{AR} & & & & \beta_{AR} \\ & \phi_{BR} & & & & \alpha_{BR} & & & & \beta_{BR} \\ & & \phi_{HK} & & & \alpha_{HK} & & & & \beta_{HK} \\ & & & \phi_{TH} & & \alpha_{TH} & & & & \beta_{TH} \\ & & & & \phi_{PO} & \alpha_{PO} & & & & \beta_{PO} \\ & & & & & \alpha_{RU} & & & & \beta_{RU} \\ & & & & & \alpha_{GE} & \phi_{GE} & & & \beta_{GE} \\ & & & & & \alpha_{JA} & & \phi_{JA} & & \beta_{JA} \\ & & & & & \alpha_{UK} & & & \phi_{UK} & \beta_{UK} \\ & & & & & \alpha_{US} & & & & \beta_{US} \end{bmatrix}, \tag{14}$$

where blank cells represent zeros. The strength of contagion from LTCM to international equity markets is controlled by the parameter β_i. As in the case of the model including contagion from Russia, the specification of the LTCM crisis model allows for a structural break in the idiosyncratic shock of the US, with the parameter β_{US} in (14) being allowed to differ from the parameter ϕ_{US} in (4). As the LTCM crisis coincides with potential contagion from the Russian crisis, the Russian idiosyncratic shock $v_{RU,t}$, is also included in the factor specification of the other equity markets to reflect the twin nature of the crises during the time of the LTCM crisis. A comparison of (7) and (13) shows that the parameters measuring the strength of contagion from Russia (α_i) to equity markets are the same across the two regimes.

During the LTCM crisis the decomposition of equity market volatility is given by

$$Var\left(v_{i,t}\right) = \lambda_i^2 + \gamma_i^2 + \delta_i^2 + \psi_i^2 + \phi_i^2 + \alpha_i^2 + \beta_i^2. \tag{15}$$

The change in volatility between the benchmark and LTCM crisis periods is

$$\Delta Var\left(v_{i,t}\right) = \alpha_i^2 + \beta_i^2, \tag{16}$$

which shows that the total contribution of contagion to volatility during the LTCM crisis period can be decomposed into two elements, emanating from the Russian based shocks and the US based LTCM shocks. A test of contagion emanating from the LTCM shock can be performed by testing the restriction

$$H_0 : \beta_i = 0, \qquad \forall i \neq US. \tag{17}$$

A joint test of contagion from both Russia and the US is given by

$$H_0 : \alpha_i = 0; \beta_j = 0, \qquad \forall i \neq RU, \quad j \neq \forall US. \tag{18}$$

A test of a structural break in the US idiosyncratic factor is given by testing the restriction

$$H_0 : \phi_{US} = \beta_{US}. \tag{19}$$

3 Empirical Issues

3.1 Data

The sample consists of daily share prices $(P_{i,t})$ on 10 countries, beginning January 2, 1998 and ending December 31, 1998, a total of $T = 260$ observations. Local equity market data are used which are sourced from Bloomberg.[3] Extending the sample period either before or after 1998 would complicate estimating the model as it would involve including additional regimes to capture the East Asian currency crisis and the Brazilian crisis of 1999 respectively.

Daily percentage equity returns of the i^{th} country at time t are computed as

$$s_{i,t} = 100 \left(\ln \left(P_{i,t} \right) - \ln \left(P_{i,t-1} \right) \right). \tag{20}$$

Missing observations are treated by using the lagged price.[4] To capture differences in time zones of equity markets, a 2-day moving average is chosen following the approach of Forbes and Rigobon (2002), with the first observation of the moving average set equal to the realized returns on January 5th.[5] Thus, the effective sample of returns data

[3]The particular stock market indices used are: Argentina Merval Index, Brazil Bovespa Stock Exchange, Hang Seng Stock Index, Thai SET Index, Warsaw Stock Exchange Total Return Index, Russian RTS Index $, Deutsche Borse DAX Index, Nikkei 225 Index, FTSE 100, Dow Jones Industrial Index.

[4]Filling in missing observations by use of a linear interpolation between observed prices does not change the qualitative results of the estimated factor model.

[5]Another approach to addressing the problem of different time zones is to follow Dungey, Fry, González-Hermosillo, and Martin (2003) and treat time zones as a missing observation problem. This makes estimation more involved as it requires simulating a high frequency model to generate 'hourly' data which is converted into 'daily' data and then calibrated with the actual data.

begins January 5, 1998 and ends December 31, 1998, a total of $T = 259$ observations. A plot of the filtered equity returns is given in Figure 1.

The benchmark period is chosen to begin on January 5 and end July 31, while the crisis period is taken as the second half of 1998, beginning August 3 and ending December 31. The Russian crisis is chosen to occur over the full crisis period. The start of the Russian crisis on August 3, is chosen to begin before Russia's unilateral debt restructuring on August 17, and to take into account the early concerns of investors about the underlying stability of the Russian GKO[6] debt market, as well as the ongoing problems in the Russian economy.[7]

The LTCM crisis period is chosen as a sub-period of the overall crisis period, running from August 31 to October 15. The start of this crisis is chosen to reflect that the plight of LTCM had gradually became more public by the end of August, culminating in the public announcement of a recapitalization package in late September. The LTCM crisis is taken to end with the surprise cut in US interest rates between FOMC meetings on October 15, 1998; see Kumar and Persuad (2002), Upper and Werner (2002) Committee on the Global Financial System (1999). A full chronology of these events is given by Lowenstein (2001), Jorion (2000) and Kharas, Pintos and Ulatov (2000).

The choice of the crisis dates is clearly partly subjective. This choice is also complicated by the occurrence of other events over the period, such as the period of August 14 to 28 where the Hong Kong Monetary Authority intervened in the Hong Kong equity market to support the Hong Kong currency board (Goodhart and Dai (2003)). As the dating of the regimes is important in identifying the parameters of each regime, some robustness checks are discussed in the empirical section where the model is reestimated for alternative crisis dates.

Some descriptive statistics of the data are presented in Table 1 for the three sample periods, with variances and covariances given in Table 2. Inspection of the covariances show the increase in comovements between equity returns between the benchmark and crisis periods. The diagonal elements in Table 2 reveal that volatility in equity returns increased for most countries in the Russian crisis period, and increased even further

[6] GKO stands for Gosudarstvennoe Kratkosrochnoe Obyazatelstvo and is the acronymn for state bonds issued in Russia.

[7] Even though many of the investments in Russia were hedged by forward rouble contracts with the Russian banking system, those very exposures contributed to the fragility of the banking system itself (Steinherr (2004)).

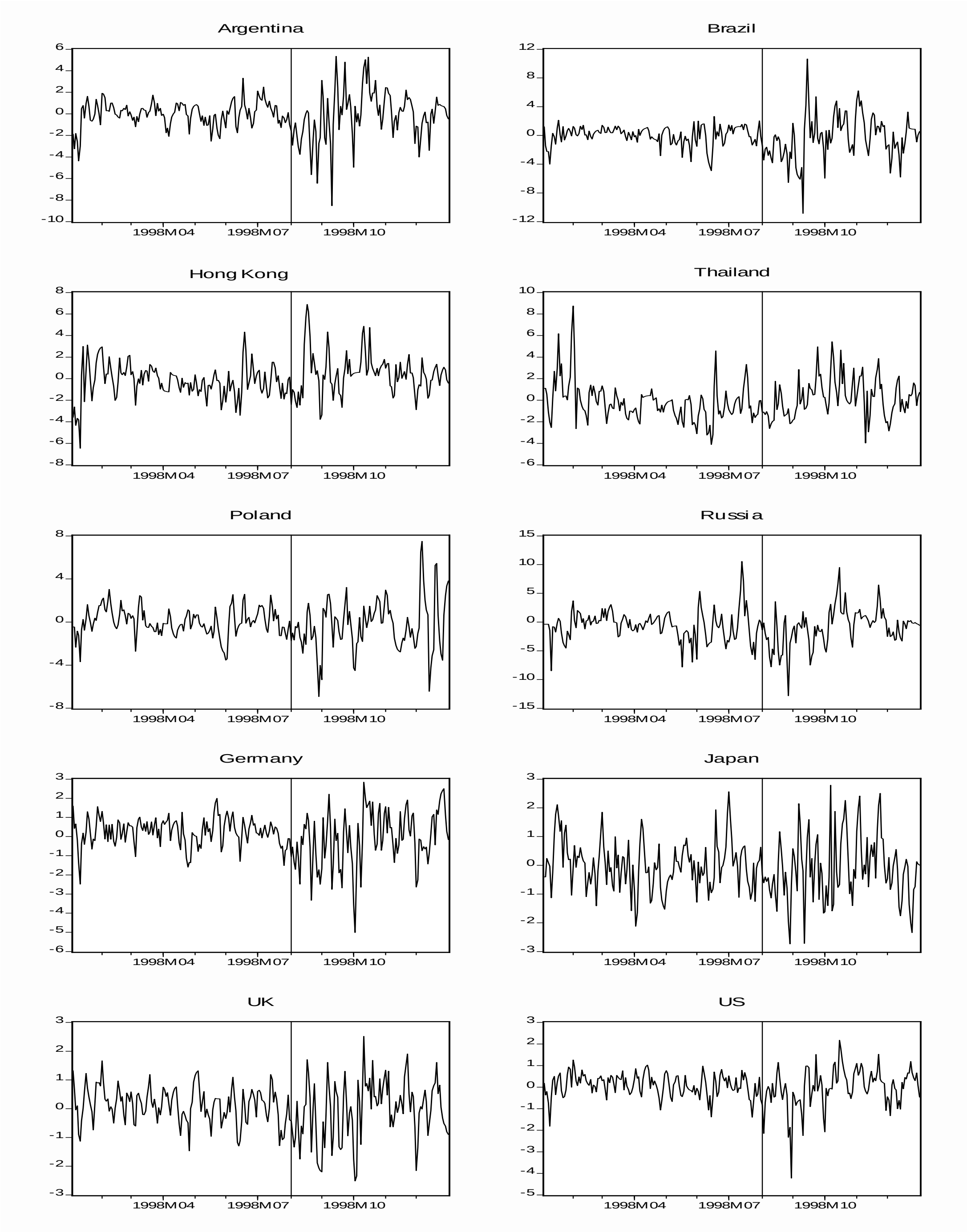

Figure 1: Equity market returns (2 day moving average), January 5, 1998 to December 31, 1998. The vertical line represents July 31, 1998, which corresponds to the end of the benchmark period.

Table 1:
Descriptive statistics of daily percentage equity returns in 1998 for selected sample periods.[(a)]

Country	Benchmark Period Jan. 5 to Jul. 31			Russian Crisis Period Aug. 3 to Dec. 31			LTCM Crisis Period Aug. 31 to Oct. 15		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
AR	-0.005	3.304	-4.359	-0.408	3.104	-6.442	0.512	5.344	-8.522
BR	0.045	2.638	-4.909	-0.345	6.210	-6.547	-0.200	10.653	-10.844
HK	-0.259	4.320	-6.462	0.465	6.891	-2.874	0.505	4.872	-3.783
TH	-0.200	8.756	-4.108	0.025	4.653	-3.979	0.772	5.422	-2.090
PO	0.018	3.040	-3.687	-0.214	7.496	-6.922	-0.450	3.219	-5.352
RU	-0.562	10.548	-8.476	-0.950	6.469	-12.828	-0.764	9.496	-7.478
GE	0.252	1.998	-2.485	0.072	2.497	-3.324	-0.473	2.841	-5.003
JA	0.011	2.558	-2.119	-0.097	2.500	-2.734	-0.131	2.785	-2.720
UK	0.130	1.664	-1.467	0.045	1.899	-2.156	-0.276	2.515	-2.517
US	0.090	1.254	-1.814	0.061	1.789	-2.333	-0.205	2.174	-4.225

(a) Equity returns are filtered for time-zone effects using a 2-day moving average.

during the LTCM crisis.

3.2 GMM Estimator

The model is estimated using generalized method of moments (GMM); see also Rigobon and Sack (2004) for a recent application, and Sentana and Fiorentini (1991) for identification conditions. This has the advantage of not having to specify the distribution of the factors in (5). Let the sample periods for the three regimes be respectively T_1 (benchmark), T_2 (Russian crisis) and T_3 (LTCM crisis). Associated with each regime is the empirical variance-covariance matrix

$$\Omega_1 = \frac{1}{T_1}\sum_{t=1}^{T_1} u_t u_t', \qquad \Omega_2 = \frac{1}{T_2}\sum_{t=1}^{T_2} u_t u_t', \qquad \Omega_3 = \frac{1}{T_3}\sum_{t=1}^{T_3} u_t u_t', \tag{21}$$

where u_t is the (10×1) vector of shocks from the VAR in (1).

Table 2:
Variance-covariance matrices of daily percentage equity returns in 1998 for selected sample periods.[(a)]

	AR	BR	HK	TH	PO	RU	GE	JA	UK	US
					Benchmark Period: Jan. 5 to Jul. 31					
AR	1.246									
BR	0.873	1.638								
HK	0.837	0.817	2.384							
TH	0.599	0.859	1.640	3.143						
PO	0.609	0.488	1.047	0.972	1.489					
RU	1.016	1.507	1.309	1.489	1.368	6.473				
GE	0.138	0.267	0.512	0.402	0.214	0.505	0.499			
JA	0.142	0.211	0.482	0.470	0.257	0.099	0.123	0.682		
UK	0.210	0.375	0.373	0.477	0.278	0.680	0.247	0.096	0.356	
US	0.290	0.390	0.393	0.347	0.206	0.435	0.192	0.055	0.197	0.259
					Russian Crisis Period: Aug. 3 to Dec. 31					
AR	3.406									
BR	3.728	6.198								
HK	1.053	0.859	3.384							
TH	1.730	1.936	1.216	2.902						
PO	1.578	1.976	1.105	1.010	6.650					
RU	3.950	4.777	0.329	2.048	1.308	9.484				
GE	1.570	1.546	0.973	1.094	0.578	1.965	1.550			
JA	1.119	1.512	0.524	0.759	1.029	1.610	0.316	1.168		
UK	1.081	0.978	0.914	0.744	0.841	1.291	0.813	0.466	0.807	
US	1.060	1.295	0.600	0.672	0.656	1.164	0.618	0.387	0.453	0.584
					LTCM Crisis Period: Aug. 31 to Oct. 15					
AR	8.702									
BR	10.406	16.549								
HK	1.721	0.494	3.714							
TH	0.691	0.445	1.977	3.233						
PO	1.159	0.024	2.218	1.344	4.089					
RU	3.586	2.532	2.544	0.952	2.099	11.720				
GE	2.975	2.444	1.819	0.339	2.572	3.726	3.082			
JA	0.985	0.596	0.819	0.43	1.352	0.635	1.022	1.437		
UK	1.972	1.891	1.585	0.709	1.736	2.436	1.909	0.751	1.528	
US	2.665	3.397	0.911	0.674	0.758	1.515	1.043	0.265	0.795	1.335

(a) Equity returns are filtered for time-zone effects using a 2-day moving average.

The factor model is compactly written as

$$u_t = \Gamma_k f_t, \qquad k = 1, 2, 3, \tag{22}$$

where Γ_1, Γ_2 and Γ_3 are defined in equations (2), (7) and (13) respectively and f_t is the set of all factors defined in equation (3). Using the property that the factors are independent with zero means and unit variances, as in equation (5), the theoretical variance-covariance matrices for the three regimes are conveniently given by

$$E\left[u_t u_t'\right] = \Gamma_k \Gamma_k', \qquad k = 1, 2, 3. \tag{23}$$

The total number of unknown parameters in Γ_1, Γ_2 and Γ_3 is 53. The GMM estimator is obtained by choosing the parameters of the factor model in Γ_1, Γ_2 and Γ_3, and matching the empirical moments in (21) with the theoretical moments in (23). Associated with each empirical variance-covariance matrix are $10 \times 11/2 = 55$ unique moments. In total there are $3 \times 55 = 165$ moments across all three regimes. As the LTCM crisis period is relatively short, it is necessary to control the number of moments used in the GMM procedure. The strategy is to choose for the LTCM crisis period the 10 variances, the 9 covariances between the US and the remaining countries, and the 8 covariances between Russia and the remaining countries, excluding the US. This means that there are $2 \times 55 + 27 = 137$ empirical moments used to identify the 53 unknown parameters, a total of 84 excess moment conditions.

Defining the set of excess moment matrices for the three regimes as

$$\begin{aligned} M_1 &= vech\left(\Omega_1\right) - vech\left(\Gamma_1 \Gamma_1'\right) \\ M_2 &= diag\left(\Omega_2\right) - diag\left(\Gamma_2 \Gamma_2'\right) \\ M_3 &= diag\left(\Omega_3\right) - diag\left(\Gamma_3 \Gamma_3'\right), \end{aligned} \tag{24}$$

the GMM estimator is obtained by choosing the parameters of the factor model to minimize the following objective function

$$Q = M_1' W_1^{-1} M_1 + M_2' W_2^{-1} M_2 + M_3' W_3^{-1} M_3, \tag{25}$$

where W_1, W_2 and W_3 represent the optimal weighting matrices corresponding to the respective regimes (Hamilton, (1994)) which correct the standard errors for heteroskedasticity in each regime. Equation (25) is minimized with u_t in (21) replaced by the residuals of the estimated VAR in (1) where the lag structure is set at $p = 1$ lags. The computations are performed using the Broyden, Fletcher, Goldfarb and Shanno (BFGS) algorithm in GAUSS Version 7, with a convergence criterion of 0.00001.

4 Empirical Results

4.1 Parameter Estimates

The GMM point estimates of the factor model in (2), (7) and (13) are given in Table 3 with standard errors reported in parentheses. An overall test of the model is given by testing the 84 over-identifying restrictions. Under the null hypothesis that the restrictions are satisfied, the value of the objective function in (25) is asymptotically distributed as χ^2 with 84 degrees of freedom. The reported value of the test statistic is 97.785. This yields a p-value of 0.144, showing that the restrictions are not rejected at conventional significance levels. A test of the factor specification of the benchmark model is given by testing the $55 - 33 = 22$ over-identifying restrictions in the non-crisis period. The test statistic is given by the first term in (25) which has a value of 29.177. The p-value is 0.140, showing that the benchmark factor structure is not rejected at the 5% level.

The parameter estimates associated with the common factors highlight the factor structure underlying international equity returns during the benchmark period. The parameter estimates of the common factor (λ_i) show that all equity markets react in the same direction to world shocks, with the effects on emerging equity markets tending to be larger than on they are on industrial equity markets. A similar result occurs for the emerging market factor where the parameter estimates (γ_i) show that all emerging equity markets respond in the same direction. The parameter estimates of the industrial factor (δ_i), show that Germany, the UK and the US all respond in the same way by a similar amount. In contrast, Japan moves in the opposite direction $(\delta_{JA} = -0.323)$, although this parameter estimate is statistically insignificant with a standard error of 0.356. The parameter estimates of the regional factor (ψ_i), show that the Latin American countries experience more than double the impact of shocks to this factor compared with the US.

A comparison of the contagion parameter estimates stemming from Russia (α_i), shows that the effects of contagion on international equity markets during the Russian crisis is selective, although it does affect both emerging and industrial equity markets. The largest (absolute) impact is felt by Germany (−0.686) and the UK (−0.459) , which are both statistically significant at conventional significance levels. Performing a joint test of no contagion from Russia to all 4 industrial equity markets in Table 4, shows that these restrictions are rejected at the 5% level.

Of the emerging markets during the Russian crisis, the strongest contagion channels from Russia are to Argentina (−0.294) and Thailand (0.313), although Table 3 shows that neither parameter estimates are statistically significant at the 5% level. However, a joint test of no contagion from Russia to the 5 emerging equity markets given in Table 4, is rejected at the 5% level.

In contrast to the Russian contagion results, the effects of contagion from the LTCM crisis (β_i) on emerging and industrial countries are more widespread. The greatest impact of contagion during the LTCM crisis is on the two Latin American countries. An overall test of contagion from the US to all emerging equity markets presented in Table 4 is found to be statistically significant. The industrial countries, Germany, Japan and the UK, experience contagion levels less than the two Latin American countries, but these linkages are nonetheless individually (Table 3) and jointly (Table 4) statistically significant.

4.2 Volatility Decompositions

An alternative way of identifying the relative importance of contagion is by computing the variance decompositions in (6) for the benchmark period, and (9) and (15) in the Russian and LTCM crisis periods respectively. The results of the volatility decomposition in the benchmark period are given in Table 5, where the decompositions are expressed as a percentage of the total. This Table shows the importance of idiosyncratic shocks in explaining equity market volatility in many of the countries investigated, with Russia (73.452%) followed by Poland (64.451%) exhibiting the highest proportions.

The volatility decompositions during the Russian crisis reported in Table 6 support the previous results showing that equity markets in Germany (57.176%) and the UK (48.671%) are the most affected of all equity markets by contagion from Russia. This first result in particular, is consistent with the heavy banking exposure of Germany to Russia documented by Van Rijckeghem and Weder (2003). The maximum affect of

Table 3:
GMM parameter estimates of the multi regime factor model in equations (2), (7) and (13), with standard errors based on the optimal weighting matrix in parentheses.

Country	Common Factors				Idiosyncratic	Contagion from	
(i)	World	Emerging	Industrial	Regional	Factors	Russia	LTCM
	λ_i	γ_i	δ_i	ψ_i	ϕ_i	α_i	β_i
AR	0.370	0.266	-	0.636	0.369	-0.294	-1.455
	(0.147)	(0.135)		(0.088)	(0.105)	(0.312)	(0.307)
BR	0.444	0.205	-	0.610	0.677	0.083	-2.226
	(0.158)	(0.161)		(0.108)	(0.074)	(0.478)	(0.527)
HK	0.699	0.544	-	-	0.660	-0.091	0.638
	(0.110)	(0.131)			(0.079)	(0.219)	(0.337)
TH	0.592	0.604	-	-	0.960	0.313	0.550
	(0.165)	(0.137)			(0.113)	(0.172)	(0.583)
PO	0.340	0.399	-	-	0.706	-0.080	-0.991
	(0.091)	(0.095)			(0.057)	(0.175)	(0.360)
RU	0.526	0.596	-	-	1.322	-2.265	-0.160
	(0.166)	(0.184)			(0.135)	(0.320)	(0.359)
GE	0.416	-	0.135	-	-0.401	-0.686	0.701
	(0.069)		(0.117)		(0.034)	(0.128)	(0.195)
JA	0.345	-	-0.323	-	0.431	-0.127	-1.117
	(0.086)		(0.356)		(0.316)	(0.186)	(0.194)
UK	0.362	-	0.160	-	-0.255	-0.459	0.458
	(0.051)		(0.081)		(0.039)	(0.099)	(0.161)
US	0.258	-	0.175	0.243	-0.223	-0.080	-0.109
	(0.057)		(0.117)	(0.039)	(0.053)	(0.122)	(0.062)

Table 4:
Joint tests of contagion and structural breaks. Wald statistics based on the unconstrained parameter estimates reported in Table 3.

Test		Statistic	DOF	p-value
No contagion from Russia to				
All other	$\alpha_i = 0, \forall i, i \neq RU$	78.114	9	0.000
Industrial	$\alpha_i = 0, \forall i, i = GE, JA, UK, US$	31.051	4	0.000
Emerging	$\alpha_i = 0,$ $i = AR, BR, HK, TH, PO$	16.573	5	0.005
No contagion from LTCM to				
All other	$\beta_i = 0, \forall i, i \neq US$	151.827	9	0.000
Industrial	$\beta_i = 0, i = GE, JA, UK$	56.323	3	0.000
Emerging	$\beta_i = 0,$ $i = AR, BR, HK, TH, PO, RU$	45.448	6	0.000
Joint test of				
No contagion	$\alpha_i = \beta_j = 0, i \neq RU, j \neq US$	250.960	18	0.000
No structural break in idiosyncratic factor of				
Russia	$\phi_{RU} = \alpha_{RU}$	7.036	1	0.008
US	$\phi_{US} = \beta_{US}$	1.806	1	0.179

contagion from Russia on the emerging markets during this period is felt by Argentina (10.377%) . In contrast, US equity markets (3.046%) appear to be hardly affected by contagion from Russia.

The volatility decompositions during the LTCM crisis reported in Table 7 further highlight the relative importance and widespread effects of contagion from the US during this period. Of the emerging markets, Argentina (71.739%) and Brazil (82.158%) are particularly affected by contagion from the US, as is Poland (55.757%). Hong Kong (24.897%) and Thailand (14.855%) are less affected by contagion from the US, suggesting that either these countries acquired some immunity by the second half of 1998, or that these economies were still suffering from their previous crises. Russian equities (0.443%) show no effect of contagion from the US, which are still dominated by their own idiosyncratic shocks (88.641%) . Of the industrials, Japanese (74.585%) equity markets are the most affected by contagion from the US, followed by Germany (37.392%) and the UK (32.661%).

4.3 Structural Break Tests

Table 4 also gives the results of two structural break tests. The first is a test of a structural break in the Russian idiosyncratic parameter. From Table 3 the parameter estimate nearly doubles in magnitude from (1.322) in the benchmark period to (2.265) in the Russian crisis period. The p-value of this structural break test is 0.008 showing evidence of a significant structural break. The second structural break test reported in Table 3 is for the US idiosyncratic parameter. The test yields a p-value of 0.179 showing that the null of no structural break is not rejected at conventional significance levels.

4.4 Robustness Checks

The robustness of the empirical results are investigated by subjecting the multi-regime factor model to a number of robustness checks. To save space, the results are summarized below with the output available from the authors upon request.

The first robustness check consists of extending the factor structure to allow for an additional common factor in the benchmark model. The results of the variance decompositions show no qualitative change to the results reported above. The biggest

Table 5:
Variance decomposition in proportions (%): Benchmark period. Row totals sum to 100%. Based on (6).

Country	Common Factors				Idiosyncratic
	World	Emerging	Industrial	Regional	Factors
AR	18.32	9.45	-	54.04	18.19
BR	18.45	3.91	-	34.79	42.85
HK	40.03	24.24	-	-	35.74
TH	21.42	22.30	-	-	56.28
PO	14.95	20.60	-	-	64.45
RU	11.61	14.93	-	-	73.45
GE	49.07	-	5.20	-	45.73
JA	29.13	-	25.57	-	45.31
UK	59.07	-	11.57	-	29.36
US	32.28	-	14.90	28.66	24.16

Table 6:
Variance decomposition in proportions (%): Russian crisis period. Row totals sum to 100%. Based on (9).

Country	Common Factors				Idiosyncratic	Contagion from
	World	Emerging	Industrial	Regional	Factors	Russia
AR	16.42	8.47	-	48.44	16.30	10.38
BR	18.34	3.89	-	34.57	42.58	0.63
HK	39.76	24.07	-	-	35.49	0.68
TH	20.22	21.04	-	-	53.11	5.63
PO	14.83	20.43	-	-	63.92	0.83
RU	4.80	6.17	-	-	89.04	0.00
GE	21.01	-	2.23	-	19.58	57.18
JA	28.03	-	24.60	-	43.60	3.76
UK	30.32	-	5.94	-	15.07	48.67
US	31.30	-	14.45	27.79	23.43	3.05

Table 7:
Variance decomposition in proportions (%): LTCM crisis period. Row totals sum to 100%. Based on (15).

Country	Common Factors				Idiosyncratic	Contagion from	
	World	Emerging	Industrial	Regional	Factors	Russia	LTCM
AR	4.64	2.39	-	13.69	4.61	2.93	71.74
BR	3.27	0.69	-	6.17	7.60	0.11	82.16
HK	29.86	18.08	-	-	26.66	0.51	24.90
TH	17.21	17.92	-	-	45.22	4.80	14.86
PO	6.56	9.04	-	-	28.28	0.37	55.76
RU	4.78	6.14	-	-	88.64	0.00	0.44
GE	13.16	-	1.39	-	12.26	35.80	37.39
JA	7.12	-	6.25	-	11.08	0.96	74.59
UK	20.42	-	4.00	-	10.15	32.78	32.66
US	38.08	-	17.58	33.81	6.82	3.71	0.00

contribution to the variance decomposition in the second common factor is for Russia where the weight is 6.937%.

The second robustness check consists of reestimating the model for different crisis dates. In each case, the variance decompositions reported above did not change qualitatively. In addition, for the alternative sample periods investigated, the value of the objective function from the GMM procedure is maximized using the sample period chosen above.

4.5 Comparison with Bond Market Transmissions

In a companion paper, Dungey, Fry, González-Hermosillo and Martin (2006), measure the effects of contagion on international bond markets using a similar framework to the approach adopted here. There are a number of important differences in the bond market paper, including a broader range of countries and some methodological differences. A number of the countries across the two applications, and the definition of the shocks as emanating from either the Russian market or the US market, are similar. The LTCM sample period in the bond market paper is slightly shorter than in the current paper, where the start of the LTCM crisis period was defined to coincide with the public recapitalization announcement on 23 September. Table 8 shows the extent of the contribution of contagion as a proportion of total volatility during the LTCM crisis period for the bond market and equity market results, with blank cells indicating countries not included in a particular study.

It is clear in Table 8 that contagion effects dominate the observed volatility in equity market returns, while in the bond market premia results contagion effects are relatively much smaller. Additionally, the source of the majority of the contagion in the equity market application is the US based shock, while in the bond premia application the majority arises from the Russian shock in general. These results suggest that crises may be propagated differently through different asset markets, across the same geographical borders, in which case the influences of trade and other regional considerations such as suggested in Glick and Rose (1996) and Van Rijckeghem and Weder (2001), where transmission is based on observable trade or financial linkages cannot constitute the entire story. The preliminary evidence presented here suggests that the nature of particular assets or asset markets may hold important information on the transmission of shocks.

5 Conclusions and Suggestions for Future Research

This paper has provided a framework for modelling the transmission of contagion in international equity markets during the complex period of the Russian bond default and the LTCM crisis in 1998. The model was based on extending the existing class of latent factor models commonly adopted in finance by allowing for additional transmission mechanisms between global equity markets during periods of financial crises arising from contagion. Contagion was identified as the impact of shocks from either Russia or the US on global equity markets, having conditioned on both world and regional factors, as well as country specific shocks in equity markets. A property of the model was that the volatility of equity returns could be decomposed in terms of the underlying factors, thereby providing a measure of the relative strength of contagion. A number of hypothesis tests of contagion and structural breaks were also carried out. The model was applied to ten equity markets consisting of 4 developed markets, and 6 emerging markets from three regions (Latin America, Asia, and Eastern Europe), using daily equity returns over 1998. A GMM estimator which matched the theoretical moments of

Table 8:
Variance decomposition of daily equity returns and daily bond market premia in proportions (%) for various countries during the LTCM crisis period.[(a)]

Country		Equity Markets			Bond Markets		
	Contagion from:	Russia	US	Total	Russia	US	Total
Argentina		2.93	71.74	74.67	0.35	0.10	0.45
Brazil		0.11	82.16	82.27	16.41	0.25	16.66
Mexico					0.15	0.11	0.26
Hong Kong		0.51	24.90	25.41			
Indonesia					0.30	0.38	0.68
Korea					1.57	3.75	5.32
Thailand		4.80	14.86	19.66	6.18	1.60	7.78
Bulgaria					7.57	0.37	7.94
Poland		0.37	55.76	56.13	5.31	0.27	5.58
Russia		-	0.44	0.44	-	0.10	0.10
Netherlands					16.94	0.25	17.19
Germany		35.80	37.39	73.19			
Japan		0.96	74.59	75.55			
UK		32.78	32.66	65.44	0.10	0.15	0.25
US		3.71	-	3.71	3.20	-	3.20

(a) Bond market results from Dungey, Fry, González-Hermosillo, and Martin (2006). In the bond market application the LTCM crisis period runs from 23 September 1998 to 15 October 1998, and the Russian crisis is concurrent. The equity market results are as reported in Table 7.

the factor model with the empirical moments of the data across regimes, was presented.

The key result of the paper was that contagion was significant and widespread to a variety of international equity markets during the LTCM crisis, with the effects of contagion being strongest on the industrial markets and the geographically close Latin American markets. The contagion transmission mechanisms emanating from the Russian equity market tended to be more selective during the Russian crisis, but nonetheless still impacted upon both emerging and industrial equity markets. Moreover, rather than the Russian crisis being seen as an emerging market phenomenon, as suggested by the Committee on the Global Financial System (1999, pp.7-8), contagion from Russia was found to be more statistically significant in industrial countries than in emerging markets.

In related work on contagion during the Russian and LTCM crises, Dungey, Fry, González-Hermosillo and Martin (2006) found that contagion in bond markets also affected a wide variety of economies. The combination of the results from that paper and the current one suggest that it would be informative to construct a more general model of asset markets, combining both bonds and equities to test the importance of contagious transmission mechanisms between markets across international borders. A step in this direction has been recently undertaken in Ehrmann, Fratzscher and Rigobon (2005), while Granger, Huang and Yang (2000) and Hartmann, Straetmans and de Vries (2004) focussed on bivariate relationships between asset markets during financial crises.

An important feature of the proposed model is the specification of a multiple regime model to allow for multiple crises. This suggests that the framework could be applied to model several crises simultaneously by extending the sample period adopted in the current application. By extending the sample period backwards to include 1997 would enable the Asian financial crisis to be modelled, while extending the sample period forwards would enable the Brazilain crisis of 1999 to be modelled for example. This latter extension is particularly interesting given the empirical results presented here, as Brazil was the next country to experience a financial crisis in January 1999. Moreover, Brazilian financial markets seem to have experienced several hits from the Russian and LTCM crises during 1998: the Brazilian bond market was impacted by the Russian crisis (Dungey, Fry, González-Hermosillo, and Martin (2006), and Baig and Goldfajn

(2001)) and the equity market by the LTCM near-collapse as shown here.

References

[1] Baig, T. and Goldfajn, I. (2001). The Russian default and the contagion to Brazil, in S. Claessens and K. Forbes (eds) International financial contagion: how it spreads and how it can be stopped. World Bank, Washington.

[2] Committee on the Global Financial System, (1999). A review of financial market events in Autumn 1998. Bank for International Settlements, Basel, Switzerland.

[3] Dornbusch, R., Park, Y.C. and Claessens, S. (2000). Contagion: understanding how it spreads. The World Bank Research Observer, 15, 177-197.

[4] Dungey, M., Fry, R.A., González-Hermosillo, B. and Martin, V.L. (2006). International contagion effects from the Russian crisis and the LTCM near-collapse. Journal of Financial Stability, 2, 1-27.

[5] Dungey, M., Fry, R.A., González-Hermosillo, B. and Martin, V.L. (2005). Empirical modelling of contagion: a review of methodologies. Quantitative Finance, 5, 1-16.

[6] Dungey, M., Fry, R.A., González-Hermosillo, B. and Martin, V.L. (2003). Unanticipated shocks and systemic influences: the impact of contagion in global equity markets in 1998. IMF Working Paper WP/03/84.

[7] Ehrmann, M., Fratzscher, M. and Rigobon, R. (2005). Stocks, bonds, money markets and exchange rates: measuring international financial transmission. ECB Working Paper No. 452.

[8] Favero, C.A. and Giavazzi, F. (2002). Is the international propagation of financial shocks non-linear? evidence from the ERM. Journal of International Economics, 57, 231-246.

[9] Forbes, K. and Rigobon, R. (2002). No contagion, only interdependence: measuring stock market co-movements. Journal of Finance, 57, 2223-2261.

[10] Glick, R. and Rose, A.K. (1999). Contagion and trade: why are currency crises regional? Journal of International Money and Finance, 18, 603-617.

[11] Goodhart, C. and Dai, L. (2003) Intervention to save Hong Kong: counter-speculation in financial markets. Oxford University Press, Oxford.

[12] Granger, C., Huang, B. and Yang, C. (2000) A bivariate causality between stock prices and exchange rates: evidence from recent Asian Flu. The Quarterly Review of Economics and Finance, 40, 337-354.

[13] Hamilton, J (1994). Time series analysis. Princeton University Press, Princeton New Jersey.

[14] Hartmann, P., Straetmans, S. and de Vries, C.G. (2004). Asset market linkages in crisis periods. Review of Economics and Statistics, 86, 313–326.

[15] Hernandéz, L. and Valdés, R. (2001). What drives contagion: trade, neighborhood, or financial links? International Review of Financial Analysis, 10, 203-218.

[16] Jorion, P. (2000). Risk management lessons from Long-Term Capital Management. European Financial Management, 6, 277-300.

[17] Kaminsky, G.L. and Reinhart, C.M. (2003). The center and the periphery: the globalization of financial turmoil. NBER Working Paper #9479.

[18] Kharas, H., Pintos, B. and Ulatov, S. (2001). An analysis of Russia's 1998 meltdown: fundamentals and market signals. Brookings Papers on Economic Activity, Brookings Institution, 1, 1-68.

[19] King, M., Sentana, E. and Wadhwani, S. (1994). Volatility and links between national stock markets. Econometrica, 62, 901-933.

[20] Kumar, M. and Persaud, A. (2002) Pure contagion and investors' shifting risk appetite: analytical issues and empirical evidence. International Finance, 5, 401-436.

[21] Lowenstein, R. (2001) When genius failed: the rise and fall of Long-Term Capital Management. Fourth Estate, London.

[22] Masson, P. (1999). Contagion: macroeconomic models with multiple equilibria. Journal of International Money and Finance, 18, 587-602.

[23] Pericoli, M. and Sbracia, M. (2003). A primer on financial contagion. Journal of Economic Surveys, 17, 571-608.

[24] Rigobon, R. (2003). On the measurement of the international propagation of shocks: is the transmission stable? Journal of International Economics, 61, 261-283.

[25] Rigobon, R. and Sack, B. (2004). Measuring the reaction of monetary policy to the stock market. Quarterly Journal of Economics, 118, 639-669.

[26] Sentana, E. and Fiorentini, G. (2001). Identification, estimation and testing of conditionally heteroskedastic factor models. Journal of Econometrics, 102, 143-164.

[27] Solnik, B.H. (1974). The international pricing of risk: an empirical investigation of the world capital market structure. Journal of Finance, 29, 365-378.

[28] Steinherr, A. (2004). Russian banking since the crisis of 1998. Centre for European Policy Studies Working Document No. 209.

[29] Upper, C. (2001). How safe was the 'safe haven'? financial market liquidity during the 1998 turbulences. Bank for International Settlements Papers No. 2, April, Basel, Switzerland, 241-266.

[30] Upper, C. and Werner, T. (2002). How resilient are financial markets to stress? bund futures and bonds during the 1998 turbulence. Bank for International Settlements Papers No. 12, June, Basel, Switzerland, 110-123.

[31] Van Rijckeghem, C. and Weder, B. (2003). Spillovers through banking centers: a panel data analysis of bank flows. Journal of International Money and Finance, 22, 483-509.

[32] Van Rijckeghem, C. and Weder, B. (2001). Sources of contagion: is it finance or trade? Journal of International Economics, 54, 293-300.