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Are Financial Crises Alike?*

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Abstract

This paper investigates whether financial crises are alike by considering whether a single modelling framework can fit multiple distinct crises in which contagion effects link markets across national borders and asset classes. The crises considered are Russia and LTCM in the second half of 1998, Brazil in early 1999, dot-com in 2000, Argentina in 2001-2005, and the recent U.S. subprime mortgage and credit crisis in 2007. Using daily stock and bond returns on emerging and developed markets from 1998 to 2007, the empirical results show that financial crises are indeed alike, as all linkages are statistically important across all crises. However, the strength of these linkages does vary across crises. Contagion channels are widespread during the Russian/LTCM crisis, are less important during subsequent crises until the subprime crisis, where again the transmission of contagion becomes rampant.

Keywords: Financial crises, Contagion, Factor models

JEL Classification: C51, G15

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1 Introduction

There is a common presumption that financial crises are not alike as the triggers of crises differ, and the economic and institutional environments in which crises take place vary amongst countries. Recent triggers for crises include sovereign debt default (the Russian crisis in August 1998), risk management strategies (the near collapse of Long-Term Capital Management, LTCM, in September 1998), sudden stops in capital flows (Brazil in early 1999), collapses of speculative bubbles (the dot-com crisis in 2000), inconsistencies between fundamentals and policy settings (as in Argentina in 2001) and a liquidity squeeze (associated with the pressure in the U.S. subprime mortgage market from mid-2007).[1] These examples involve countries with highly developed financial markets as well as a number of emerging markets.

This lack of commonality amongst crisis affected countries is reflected in the development of theoretical models of financial turmoil. The first generation models emphasize the role of macroeconomic variables in causing currency crises in the presence of fixed exchange rates (Flood and Marion (1999)); the second generation models focus on the role of speculative attacks; while more recently models focus on institutional imbalances, information asymmetries and network effects (Allen and Gale (2000); Kaminsky and Reinhart (2003); Kodres and Pritsker (2002); Yuan (2005), Pavlova and Rigobon (2007) and Allen and Babus (2008)).

The identification of shocks triggering a crisis is just one dimension to understanding financial crises. A second, and arguably more important dimension, is to identify the transmission mechanisms that propagate shocks from the source country across national borders and across financial markets. The literature draws a distinction between the transmission of crises through normal relationships between markets, and transmission through additional linkages which occur during crisis periods only. These additional linkages are known as contagion (see Dornbusch, Park and Claessens (2000); Pericoli and Sbracia (2003)). Dungey, Fry, González-Hermosillo and Martin (2005) show how this definition of contagion nests the existing empirical bivariate correlation tests of Forbes and Rigobon (2002) (and its multivariate extension), the coexceedances test of Bae, Karolyi and Stulz (2003), the exchange market pressure approach of Eichengreen, Rose and Wyplosz (1995),.and the outlier approaches of Favero and Giavazzi (2002) and Pesaran and Pick (2007).[2]

[1] Further analysis of these crises are given in Lowenstein (2001); Jorion (2000); Baig and Goldfajn (2000); del Torre, Levy, Yeyati and Schmulker (2003); and the IMF (2008) Global Financial Stability Report, in the case of the U.S. subprime crisis.

[2] Other important empirical work on contagion includes Bekaert, Harvey and Ng (2005), Caporale,

It is not entirely straightforward to combine existing theoretical models into a general empirical framework in which to model and test the relative strengths of alternative transmission mechanisms operating during financial crises.[3] The strategy followed in this paper is to adopt a broader approach and focus on the factor structures of the transmission mechanisms linking international asset markets. Formally the model is based on the theoretical framework of Kodres and Pritsker (2002). This leads to a latent factor structure which is transformed into a model that admits three broad contagious transmission mechanisms according to the classification proposed by Dungey and Martin (2007). The first corresponds to shocks originating in a particular asset market within a particular country (Idiosyncratic) which transmit to all financial markets. The second represents mechanisms originating in a specific asset market class (Market), for example stocks or bonds, that jointly impact alternative classes of asset market. The third mechanism represents shocks beginning in a particular country which impact upon the asset markets of other countries (Country). If the structure of these three transmission mechanisms is found to be common across different financial crises, this would suggest that all crises are indeed alike regardless of the nature of the initial shock and the economic and institutional environments of the affected country. Alternatively, if the propagation mechanisms vary across crises, perhaps as a result of the development of new strains of contagion, this would suggest that crises are indeed unique at least across their source and their transmission mechanism.

The factor model is successfully implemented for a series of five crises across six countries over the period 1998 to 2007; the Russian/LTCM crisis; the Brazilian crisis; the dot-com crisis; the Argentinian crisis and the recent U.S. subprime mortgage and credit crisis.[4] A key empirical result is that a general model can be specified to explain the contagious linkages operating over a broad array of financial crises. Moreover, as all possible transmission mechanisms are found to be statistically significant in each crisis investigated, this suggests that the answer to the title of the paper is 'Yes'. The crises which generated the most contagion are the Russian/LTCM and U.S. subprime crises, which both began in credit markets and spread to stock markets. However, this conclusion needs qualification as the relative contribution of each channel to the

Cipollini and Spagnolo (2005), Billio and Pelizzon (2003).

[3] Some previous attempts are by van Rijckeghem and Weder (2001) who focus on banking channels; Glick and Rose (1999) who look at regional linkages; and Boyer, Kumagai and Yuan (2006) who emphasise liquidity effects. Perhaps the most extensive recent work is by Kaminsky (2006) who considers a broad range of variables, classified according to alternative theoretical crisis models.

[4] Other financial crisis have also occured during this period including Iceland and Turkey (mid 2006) and China (late February 2007). To control the dimension of the empirical application the approach is to condition the empirical results on these crisis.

volatility of returns in asset markets does vary across crises.

The rest of the paper proceeds as follows. The theoretical model is outlined in Section 2 where the excess returns on assets are specified in terms of a set of latent factors. The form of these factors are discussed in Section 3. The factors are expressed (rotated) following the classification proposed by Dungey and Martin (2007). Section 4 provides a discussion of the data, key empirical results are reported in Section 5, while some additional robustness checks and sensitivity analyses are conducted in Section 6. Concluding comments are provided in Section 7. For convenience the Appendices contain the mathematical details of the derivation of the theoretical model, data sources and additional empirical results.

2 A Model of Contagion

In this section a theoretical model of contagion is developed whereby excess returns on financial assets for N countries are expressed in terms of a set of latent factors. These factors capture a range of channels that link asset markets including common factors that simultaneously impact upon all asset markets, idiosyncratic factors that are specific to a single market, and contagion which transmits through additional channels arising during times of financial stress. The approach is related to the work of Kodres and Pritsker (2002) with one important difference: the solution is derived in terms of asset returns instead of asset prices. Formally this is achieved by changing the preference function of agents and the underlying distributional assumptions of the model.

The model consists of heterogenous international agents who choose portfolios from N risky assets with return vector R, and a risk-free asset R_f, across a set of countries. Three groups of agents consist of informed investors (denoted as I), uninformed investors (denoted as U) and noise traders. The informed and uninformed investors are assumed to derive portfolios based on optimizing behavior, whereas the noise traders do not. In the specification of the model, each country is assumed to be a two-period endowment economy with a fixed net supply X_T, that provides one risky asset. This assumption is relaxed in the empirical application where the number of risky assets of each country is extended to two assets. Investors in each economy trade assets in the first period at a price vector P, and consume the liquidation value v, of assets in the second period. Market equilibrium is where the supply of the risky asset X_T, equals the sum of the demands of the three groups of agents

$$X_T = \mu_I \alpha_I^* W_1 + \mu_U \alpha_U^* W_1 + \ln \epsilon, \tag{1}$$

where μ_I and μ_U are respectively the number of informed and uninformed investors, α_k^* is a $(N \times 1)$ vector of the optimal proportions of risky assets held by investor $k = I, U$, and W_1 is period 1 wealth. The term $\mu_I \alpha_I^* W_1$ is the optimal demand for risky assets of informed agents, $\mu_U \alpha_U^* W_1$ is the optimal demand for risky assets of uninformed agents, and $\ln \epsilon$ is the total demand of risky assets of noise traders.

In period 1, the informed and uninformed investors are assumed to choose between the proportion of the portfolio held in risky assets and the proportion of the portfolio held in a risk free asset $(1 - \alpha_k' \imath)$, that maximizes expected utility from wealth in period two (W_2)

$$\max_{\alpha_k} E[V(W_2)|\Omega_k] = \max_{\alpha_k} \left\{ \ln E\left[W_2^{(1-\gamma)} \middle| \Omega_k \right] \right\}, \qquad k = I, U, \tag{2}$$

subject to the wealth constraint

$$W_2 = (1 + R_p) W_1, \tag{3}$$

where γ is the relative risk aversion parameter and

$$R_p = \alpha_k' R + (1 - \alpha_k' \imath) R_f, \tag{4}$$

is the return on the portfolio where $\imath$ is a $(N \times 1)$ vector of ones. The information set of investor $k = I, U$, is represented by Ω_k.

The return on the i^{th} risky asset is defined as the percentage difference between the unknown liquidation value of the asset in period two (v_i), and its price in period one (P_i)

$$R_i = \frac{v_i - P_i}{P_i}, \qquad i = 1, 2, \cdots, N. \tag{5}$$

The liquidation values of the N assets in the next period are determined according to

$$\ln v = \ln \theta + \ln u, \tag{6}$$

where θ represents an information factor with distribution

$$\ln \theta \sim N\left(\overline{\theta}, \Sigma_\theta\right),$$

and u is decomposed into a set of K macroeconomic factors in the next period $(\ln f_{+1})$ with loadings β, and N idiosyncratic factors $(\ln \eta)$

$$\ln u = \beta \ln f_{+1} + \ln \eta. \tag{7}$$

The macroeconomic and idiosyncratic factors are assumed to have the following representations

$$\begin{aligned}
\ln f_{+1} &= \ln f + \ln \delta \\
\ln \eta &\sim N(0, \Sigma_\eta) \\
\ln \delta &\sim N(0, I_N),
\end{aligned} \tag{8}$$

whereby the macroeconomic factors are integrated processes of order one while the idiosyncratic factors are white noise. The assumption that the variance-covariance matrix of $\ln \delta$ is the identity matrix I_N, is a standard condition adopted to identify latent factors in state-space models.

The optimal solution to the portfolio problem of the informed and the uninformed investors is of the form (see Appendix A1)

$$\alpha_k^* = \frac{1}{\gamma}\left[E[r|\Omega_k] - r_f + \frac{1}{2}Covar[r|\Omega_k]\right] Covar[r|\Omega_k]^{-1}, \qquad k = I, U, \tag{9}$$

where $r = \ln(1+R)$ and $r_f = \ln(1+R_f)$ represent logarithmic returns. In contrast to the informed and uninformed investors, noise traders are assumed to buy and sell assets based solely on their own idiosyncratic need for liquidity which does not depend upon the fundamental value of assets (v).

The information set of the informed investor is defined as

$$\Omega_I = \{\ln \theta, \ln P\}, \tag{10}$$

in which case the conditional moments in (9) are given by (see Appendix A2)

$$\begin{aligned}
E[r|\Omega_I] &= \ln \theta + \beta \ln f - \ln P \\
Var[r|\Omega_I] &= \beta\beta' + \Sigma_\eta.
\end{aligned} \tag{11}$$

The information set of the uninformed investor is defined as

$$\Omega_U = \{\ln P\}, \tag{12}$$

in which case the conditional moments in (9) are given by (see Appendix A3)

$$\begin{aligned}
E[r|\Omega_U] &= \ln P + \overline{\theta} + \Sigma_\theta \left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1}\right)^2 (\beta\beta' + \Sigma_\eta)\Sigma_\epsilon(\beta\beta' + \Sigma_\eta)'\right]^{-1} \\
&\quad \times \left[\ln \theta + \frac{\gamma(\beta\beta' + \Sigma_\eta)}{\mu_I W_1}\ln \epsilon - \overline{\theta}\right], \\
Var[r|\Omega_U] &= [\Sigma_\theta + \Sigma_u] - \Sigma_\theta \left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1}\right)^2 \right. \\
&\quad \left. (\beta\beta' + \Sigma_\eta)\Sigma_\epsilon(\beta\beta' + \Sigma_\eta)' \right]^{-1} \Sigma_\theta'.
\end{aligned} \tag{13}$$

To complete the specification of the demand for risky assets in (1), the net demand of noise traders, $\ln \epsilon$, is assumed to have the distribution

$$\ln \epsilon \sim N(0, \Sigma_\epsilon).$$

To derive an expression of the model in terms of excess asset returns, let

$$y = \ln P_{+1} - \ln P - r_f,$$

represent the vector of N realized excess returns, where P and P_{+1}, are respectively the current and next period price vectors. In Appendix A4, it is shown that in equilibrium the solution of the model is characterized by y being expressed in terms of the latent factors $\{\ln \theta, \ln \epsilon, \ln f, \ln \zeta\}$ according to

$$y = C_0 + C_1 \ln \theta + C_2 \ln \epsilon + C_3 \ln f + C_4 \ln \zeta, \tag{14}$$

where $\ln \zeta = \ln P_{+1} - E\left[\ln v|_U\right]$ is an expectations error which is assumed to be *iid*. The C_i matrices are functions of the parameters of the model and the conditional expectations expressions in (11) and (13) (see Appendix A4 for details). This specification represents a multifactor model of asset markets similar to the class of empirical contagion models proposed by Dungey and Martin (2007). An important empirical implication of this equation is that the effect of contagion during financial crises is to change the structure of the C_i matrices. For example, in a noncrisis period where there is no contagion, this is represented by $\beta\beta'$ and Σ_η in (7) and (8) being diagonal matrices, with the model reducing to the class of factor models used in international finance to price assets in "normal times" as proposed by Bekaert and Hodrick (1992), Solnik (1974), Dumas and Solnik (1995) and Longin and Solnik (1995). It is this property which is exploited in the empirical application to identify the parameters of the model.

3 Empirical Factor Specification

The linear factor representation in (14) expresses excess returns on assets as a function of factors that encapsulate shocks to information ($\ln \theta$), noise traders ($\ln \epsilon$), macroeconomic shocks ($\ln f$) and the expectation errors from forecasting future prices on assets ($\ln \zeta$). An alternative representation is to rotate the factors into global (w_t), market (m_t), country (c_t) and idiosyncratic (v_t) components according to Dungey and Martin (2007). In the empirical analysis $N = 12$, which consists of six countries Argentina (A), Brazil (B), Canada (C), Mexico (M), Russia (R) and the United States (U), each with two asset markets stocks (s_t), and bonds (b_t). Of the six countries used in the empirical analysis, Argentina, Brazil, Mexico and Russia represent the emerging financial markets, and the U.S. and Canada represent the industrial financial markets. In the second quarter of 2007, Mexico, Brazil and Argentina accounted for 46 percent of total emerging market bond trading. Russia accounted for an additional 4 percent. Thus, the four emerging countries examined here account for about 50 percent of the total emerging market debt (see EMTA Survey (2007)). The set of countries is expanded in Section 6.

In specifying the empirical factor model, care is taken to distinguish between the factors operating during noncrisis and crisis periods. Five crisis specifications are considered corresponding to the Russia/LTCM crisis in the second half of 1998, the Brazilian crisis in early 1999, the dot-com crisis in 2000, the Argentinian crisis 2001-2005, and the recent U.S. subprime crisis beginning mid 2007. The choice of crisis dates is discussed in Section 4.1.

3.1 Noncrisis Specification

The factor specification during the noncrisis period decomposes excess returns of the six stock ($s_{i,t}$) and bond ($b_{i,t}$) markets into four broad sets of factors. The noncrisis specification is

$$
\begin{bmatrix} s_{A,t} \\ s_{B,t} \\ s_{C,t} \\ s_{M,t} \\ s_{R,t} \\ s_{U,t} \\ \cdots \\ b_{A,t} \\ b_{B,t} \\ b_{C,t} \\ b_{M,t} \\ b_{R,t} \\ b_{U,t} \end{bmatrix}
=
\underbrace{\begin{bmatrix}
\lambda_A^s & \beta_A^s & \pi_A^s \\
\lambda_B^s & \beta_B^s & \pi_B^s \\
\lambda_C^s & \beta_C^s & \\
\lambda_M^s & \beta_M^s & \\
\lambda_R^s & \beta_R^s & \pi_R^s \\
\lambda_U^s & \beta_U^s & \\
\lambda_A^b & \beta_A^b & \pi_A^b \\
\lambda_B^b & \beta_B^b & \pi_B^b \\
\lambda_C^b & \beta_C^b & \\
\lambda_M^b & \beta_M^b & \\
\lambda_R^b & \beta_R^b & \pi_R^b \\
\lambda_U^b & \beta_U^b &
\end{bmatrix}
\begin{bmatrix} w_t^1 \\ w_t^2 \\ w_t^3 \end{bmatrix}}_{\text{Common}}
+
\underbrace{\begin{bmatrix}
\gamma_A^s & \\
\gamma_B^s & \\
\gamma_C^s & \\
\gamma_M^s & \\
\gamma_R^s & \\
\gamma_U^s & \\
 & \gamma_A^b \\
 & \gamma_B^b \\
 & \gamma_C^b \\
 & \gamma_M^b \\
 & \gamma_R^b \\
 & \gamma_U^b
\end{bmatrix}
\begin{bmatrix} m_t^s \\ m_t^b \end{bmatrix}}_{\text{Market}}
$$

$$
+ \underbrace{\begin{bmatrix}
\kappa_A^s & & & & & \\
 & \kappa_B^s & & & & \\
 & & \kappa_C^s & & & \\
 & & & \kappa_M^s & & \\
 & & & & \kappa_R^s & \\
 & & & & & \kappa_U^s \\
\kappa_A^b & & & & & \\
 & \kappa_B^b & & & & \\
 & & \kappa_C^b & & & \\
 & & & \kappa_M^b & & \\
 & & & & \kappa_R^b & \\
 & & & & & \kappa_U^b
\end{bmatrix}
\begin{bmatrix} c_{A,t} \\ c_{B,t} \\ c_{C,t} \\ c_{M,t} \\ c_{R,t} \\ c_{U,t} \end{bmatrix}}_{\text{Country}}
+ \underbrace{diag \begin{pmatrix} \phi_A^s \\ \phi_B^s \\ \phi_C^s \\ \phi_M^s \\ \phi_R^s \\ \phi_U^s \\ \phi_A^b \\ \phi_B^b \\ \phi_C^b \\ \phi_M^b \\ \phi_R^b \\ \phi_U^b \end{pmatrix}
\begin{bmatrix} \upsilon_{A,t}^s \\ \upsilon_{B,t}^s \\ \upsilon_{C,t}^s \\ \upsilon_{M,t}^s \\ \upsilon_{R,t}^s \\ \upsilon_{U,t}^s \\ \upsilon_{A,t}^b \\ \upsilon_{B,t}^b \\ \upsilon_{C,t}^b \\ \upsilon_{M,t}^b \\ \upsilon_{R,t}^b \\ \upsilon_{U,t}^b \end{bmatrix}}_{\text{Idiosyncratic}} . \tag{15}
$$

The first set of factors are referred to as the common factors. The first two factors within this set (w_t^1, w_t^2) impact upon all asset markets, across all countries with loadings given by $\left(\lambda_i^j, \beta_i^j\right)$ for asset market $j = s, b$, in country i. The third factor in the common set of factors (w_t^3) represents the set of emerging markets where crises originated during the sample period: Argentina, Brazil and Russia, with loadings $\left(\pi_i^j\right)$. The second set of factors is the market factor, which captures respectively shocks to stock markets (m_t^s) and bond markets $\left(m_t^b\right)$ with loadings (γ_i^s) and $\left(\gamma_i^b\right)$. The set of country factors are given by $c_{A,t}, c_{B,t}, c_{C,t}, c_{M,t}, c_{R,t}, c_{U,t}$, which represent shocks specific to both the stock and bond market of each of the six countries where the loadings for the i^{th}country are

κ_i^s (stocks) and κ_i^b (bonds). Finally, the set of idiosyncratic factors are given by the $v_{i,t}^j$ factors with loading $\left(\phi_i^j\right)$, which represent shocks that are specific to a particular asset market in a particular country.

The noncrisis factor specification in (15) is conveniently expressed as

$$y_t = A_w w_t + A_m m_t + A_c c_t + A_v v_t, \tag{16}$$

where y_t is the (12×1) vector of excess returns, w_t is the (3×1) vector of common factors, m_t is the (2×1) vector of market factors, c_t is the (6×1) vector of country factors, and v_t is the (12×1) vector of idiosyncratic factors. The A_j, $j = w, m, c, v$, are parameter matrices of conformable order to the empirical factors w_t, m_t, c_t and v_t,and correspond to those in (15). From the properties of the factors in (14), $\{w_t, m_t, c_t, v_t\}$ are all assumed to be independent with zero means and normalised to have unit variances.

3.2 Crisis Specification

The crisis model is an extension of the noncrisis model by allowing for additional channels representing contagion, which link international asset markets during financial crises. Three broad channels are specified following Dungey and Martin (2007):

1. Market shock: the shock originates in a specific class of asset markets globally, which impacts simultaneously on all other asset markets.
2. Country shock: the shock originates in a particular country which transmits to the asset markets of other countries.
3. Idiosyncratic shock: the shock originates in a specific asset market of a country which impacts upon global asset markets.

3.2.1 The Russian/LTCM Crisis

The Russian crisis is specified to begin in the Russian bond market. The LTCM crisis is interpreted as a credit shock and is assumed to originate in the U.S. bond market. It is not possible to separate out the two crises and model the full set of transmission mechanisms for each as a result of the shortness of the LTCM crisis period.[5] The strategy adopted is to model both crises jointly by including idiosyncratic shocks arising from the Russian bond market and the U.S. bond market, together with

[5] Dungey, Fry, González-Hermosillo and Martin (2006, 2007) separate the effects of the Russian and LTCM crises, by looking at just one type of asset and a restricted number of propagation mechanisms.

the asset market and country contagion channels. The crisis sample period is taken as the Russian crisis period, namely August to the end of 1998. This may have the effect of underestimating the importance of the LTCM crisis as its effects may be partly diluted by using a longer sample period than is necessary.

The Russian/LTCM crisis model is specified as

$$y_t = B_w w_t + B_m m_t + B_c c_t + B_v v_t, \tag{17}$$

where the parameter matrices are defined as

$$B_w = \begin{bmatrix} \lambda_A^s & \beta_A^s & \pi_A^s \\ \lambda_B^s & \beta_B^s & \pi_B^s \\ \lambda_C^s & \beta_C^s & \\ \lambda_M^s & \beta_M^s & \\ \lambda_R^s & \beta_R^s & \pi_R^s \\ \lambda_U^s & \beta_U^s & \\ \cdots & \cdots & \cdots \\ \lambda_A^b & \beta_A^b & \pi_A^b \\ \lambda_B^b & \beta_B^b & \pi_B^b \\ \lambda_C^b & \beta_C^b & \\ \lambda_M^b & \beta_M^b & \\ \lambda_R^b & \beta_R^b & \pi_R^b \\ \lambda_U^b & \beta_U^b & \end{bmatrix}, \qquad B_m = \begin{bmatrix} \gamma_A^s + \tau_A^s & \delta_{A,b}^s \\ \gamma_B^s + \tau_B^s & \delta_{B,b}^s \\ \gamma_C^s + \tau_C^s & \delta_{C,b}^s \\ \gamma_M^s + \tau_M^s & \delta_{M,b}^s \\ \gamma_R^s + \tau_R^s & \delta_{R,b}^s \\ \gamma_U^s + \tau_U^s & \delta_{U,b}^s \\ \cdots & \cdots \\ \delta_{A,s}^b & \gamma_A^b + \tau_A^b \\ \delta_{B,s}^b & \gamma_B^b + \tau_B^b \\ \delta_{C,s}^b & \gamma_C^b + \tau_C^b \\ \delta_{M,s}^b & \gamma_M^b + \tau_M^b \\ \delta_{R,s}^b & \gamma_R^b + \tau_R^b \\ \delta_{U,s}^b & \gamma_U^b + \tau_U^b \end{bmatrix},$$

$$B_c = \begin{bmatrix} \kappa_A^s & & & & \delta_{A,R}^s & \\ & \kappa_B^s & & & \delta_{B,R}^s & \\ & & \kappa_C^s & & \delta_{C,R}^s & \\ & & & \kappa_M^s & \delta_{M,R}^s & \\ & & & & \kappa_R^s + \tau_{R,R}^s & \\ & & & & \delta_{U,R}^s & \kappa_U^s \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \kappa_A^b & & & & \delta_{A,R}^b & \\ & \kappa_B^b & & & \delta_{B,R}^b & \\ & & \kappa_C^b & & \delta_{C,R}^b & \\ & & & \kappa_M^b & \delta_{M,R}^b & \\ & & & & \kappa_R^b + \tau_{R,R}^b & \\ & & & & \delta_{U,R}^b & \kappa_U^b \end{bmatrix},$$

and

$$B_v = \begin{bmatrix}
\phi^s_A & & & & & & & & & & \delta^s_{A,Rb} & \delta^s_{A,Ub} \\
& \phi^s_B & & & & & & & & & \delta^s_{B,Rb} & \delta^s_{B,Ub} \\
& & \phi^s_C & & & & & & & & \delta^s_{C,Rb} & \delta^s_{C,Ub} \\
& & & \phi^s_M & & & & & & & \delta^s_{M,Rb} & \delta^s_{M,Ub} \\
& & & & \phi^s_R & & & & & & \delta^s_{R,Rb} & \delta^s_{R,Ub} \\
& & & & & \phi^s_U & & & & & \delta^s_{U,Rb} & \delta^b_{U,Ub} \\
& & & & & & \phi^b_A & & & & \delta^b_{A,Rb} & \delta^b_{A,Ub} \\
& & & & & & & \phi^b_B & & & \delta^b_{B,Rb} & \delta^b_{B,Ub} \\
& & & & & & & & \phi^b_C & & \delta^b_{C,Rb} & \delta^b_{C,Ub} \\
& & & & & & & & & \phi^b_M & \delta^b_{M,Rb} & \delta^b_{M,Ub} \\
& & & & & & & & & & \phi^b_R + \tau^b_{R,Rb} & \delta^b_{R,Ub} \\
& & & & & & & & & & \delta^b_{U,Rb} & \phi^b_U + \tau^b_{U,Ub}
\end{bmatrix}.$$

The parameter matrices are specified by augmenting the noncrisis parameter matrices in (15) and (16) to allow for contagion as well as structural breaks in the factor structures during the crisis period. The market contagion channels are represented by the parameter $\delta^b_{i,s}$ in the matrix B_m which measures the strength of the stock market factor in the crisis period on the bond market in country i, while the parameter $\delta^s_{i,b}$ measures the strength of the bond market factor on the stock market in country i. The country contagion channel from Russia to asset market j in country i, is controlled by the parameter $\delta^j_{i,R}$. The strength of the idiosyncratic contagion channel from the Russian (U.S.) bond market to asset market j in country i, is determined by the parameter $\delta^j_{i,Rb}$ $\left(\delta^j_{i,Ub}\right)$. All structural breaks in the factors during the crisis period are controlled by the parameter τ. For example, the effects of a structural break in the stock and bond market factors during the crisis period on country i, are respectively given by τ^s_i and τ^b_i. A structural break in the Russian country factor corresponding to its stock and bond markets in the crisis are given by respectively $\tau^s_{R,R}$ and $\tau^b_{R,R}$. The structural breaks in the Russian and U.S. idiosyncratic bond factors during the crisis are represented by respectively $\tau^b_{R,Rb}$ and $\tau^b_{U,Ub}$. The common factors (w_t) are assumed not to exhibit structural breaks during the crisis period.

3.2.2 The Brazilian Crisis

The specification of the Brazilian crisis model is similar to the Russian/LTCM crisis model in (17), with the exception that there is just one idiosyncratic shock now arising from the Brazilian bond market. The two market channels of contagion are as before, which are represented by columns 4 and 5 of the B_m matrix in (17). The country channel of contagion switches from column 5 (Russian country factor) to column 2

(Brazilian country factor) of the B_c matrix. The idiosyncratic contagion channel arising from the Brazilian bond market shock is specified by switching column 11 in the B_v matrix in (17) to column 8 (Brazilian bond factor), and deleting column 12 with the exception of the parameter ϕ_U^b.

3.2.3 The Dot-Com Crisis

The dot-com crisis model has a similar structure to the Brazilian crisis model. The country channel of contagion is now found in column 6 of the B_c matrix (U.S. country factor), and the idiosyncratic contagion channel is specified in column 6 of the B_v matrix (U.S. stock factor) in (17).

3.2.4 The Argentinian Crisis

The Argentinian crisis model follows the same form as the previous two models. The country channel of contagion is now found in column 1 of the B_c matrix (Argentinian country factor), and the idiosyncratic contagion channel is specified in column 7 of the B_v matrix (Argentinian bond factor) in (17).

3.2.5 The U.S. Subprime Mortgage and Credit Crisis

The specification of the U.S. subprime mortgage and credit crisis is similar to the dot-com crisis specification with one important exception. In the dot-com crisis there is a single idiosyncratic channel of contagion operating through the U.S. stock market as it is clear that this crisis originated in the U.S. stock market. The U.S. subprime mortgage and credit crisis is characterized by turbulence that spread from subprime mortgage markets to credit markets more generally, and then to short-term interbank markets as liquidity dried up in certain segments of the markets, particularly in structured credits. As the U.S. crisis manifested itself mainly in credit markets, this suggests that contagion should run from bond markets to stock markets in the model specified here. To test this proposition, both stock and bond U.S. idiosyncratic channels of contagion are allowed for in the subprime crisis specification. In which case the idiosyncratic contagion channels are specified in columns 6 and 12 of the B_v matrix in (17). As idiosyncratic shocks are allowed for in both U.S. asset markets, no country contagion channel from the U.S. is considered for this crisis.

4 Data

The data consist of daily excess returns on stocks and bonds, all expressed in U.S. dollars, beginning March 31, 1998 and ending December 31, 2007. The daily data are constructed from bond yields and stock indices. All data sources and formal definitions of the variables are given in Appendix B.

The U.S. and Canadian bonds are modelled using 10 year corporate BBB yields, with the Canadian yields converted into U.S. dollars. Bond returns are constructed for the two developed markets as

$$b_t = -n\left(r_{n,t} - r_{n-1,t-1}\right), \tag{18}$$

where $r_{n,t}$ is the yield on a bond with term to maturity, $n = 10$ years. That is, returns are computed simply by taking the first difference of the yields, multiplying this change in yields by the maturity and then changing the sign (Campbell, Lo and MacKinlay (1997)).[6]

Emerging market bonds are represented by U.S. dollar denominated sovereign debt to avoid the lack of liquidity in emerging market domestic currency denominated bonds. As bonds are issued only sporadically in the emerging countries it is not possible to derive a daily 10-year bond series as with the developed countries. The approach adopted is to choose a 10 year bond issued near the start of the sample period for an emerging country and track this bond over the sample period. For these bonds, the returns are computed using (18) with the term to maturity, n, now declining monotonically over the sample. However, as the sample covers approximately 9 years, this bond will become less liquid as it approaches maturity near the end of the sample. In the case of the Argentinian bond used, this bond actually matures before the end of the sample period. To circumvent potential liquidity problems the approach is to choose another set of 10 year bonds beginning July 1, 2004 and track these bonds through the remaining part of the sample. Although this involves using bonds of differing maturities, by working with returns instead of yields, or even yield changes, makes the returns data on bonds commensurate.

The stock market indices are those for the major indices in each country, given in Appendix B. All indices are expressed in domestic currencies and converted into USD equivalents using daily exchange rates. Missing observations arising from the terrorist attacks of September 11, 2001 are replaced by the previously observed price. Stock

[6] The formula for converting bond yields into returns is just an approximation, but as the data are daily the error from using the approximation should be small (Craine and Martin (2008)).

returns are computed by taking the first difference of the natural logarithm of the stock prices.

All bond and stock returns are expressed in terms of excess returns by subtracting the returns on a risk-free rate, as represented by the U.S. Treasury 10-year benchmark bond yield. The excess returns are expressed in percentage terms by multiplying each series by 100. Time series plots of the excess returns on stocks and bonds are presented in Figure 1. The shaded regions presented in the figure correspond to the period of the five crises investigated, whose dates are discussed below.

Two filters are applied to the raw returns presented in Figure 1 before estimating the model. First, all 12 excess returns are adjusted for any dynamics by estimating a 12-variate VAR with a constant and two lags. Pre-diagnostic checking shows that higher order lags do not qualitatively change the empirical properties of the model.

Second, the VAR contains a set of dummy variables to capture institutional changes which have a once-off big impact on excess returns. A dummy variable is included in the Russian bond equation of the VAR to account for the large fall in excess bond returns from 57.727% to 44.969%, arising from the change in the Russian Finance Minister on May 25, 1999. Inspection of the excess returns of Argentinian bonds in Figure 1 shows that there are five large spikes that occur during the Argentinian crisis: the dates are April 4 and October 4 in 2002, April 4 and October 6 in 2003, and April 6 in 2004. These dates correspond to the coupon dates after all Argentinian sovereign debt went into default, with the price for these bonds declining because of uncertainty surrounding the scheduled coupon payment. To correct for these outliers a dummy variable is included in the Argentinian bond equation of the VAR, which has a value of one on the five dates and zero otherwise. Finally, there are a number of crises that have occurred which are potentially too small to be able to model individually. To condition the results on these crises additional dummy variables are also included into the VAR specification. The dummy variables consist of the Turkish crisis May 1 to June 30 in 2006, and the large movements in asset returns on February 27 and March 13 in 2007, during the concerns over Chinese stock markets.

The residuals from estimating the VAR are taken to be the filtered excess returns subsequently used in the empirical analysis.[7] The final data set of filtered excess returns

[7]Further filtering of the data could be entertained, such as allowing for time-varying volatility during each sub-period. Some strategies would be to incorporate GARCH specifications either using the approach of Bekaert, Harvey and Ng (2005), or the factor GARCH specification of Dungey and Martin (2004) and Dungey, Fry, González-Hermosillo and Martin (2006). However, conditional moment tests of conditional volatility applied to the VAR standardized residuals given in Section 6 of the paper, show little evidence of time-varying volatility within asset markets during the crisis periods. Empirically this result is partly a reflection of the small duration of the crisis periods.

comprises 2544 observations across bond and stock markets for the six countries.

4.1 Crisis Dates

The choice of the dates of the crisis periods are summarized in Table 1. This choice is based on important institutional events surrounding each crisis, together with empirical pre-testing and sensitivity analysis to fine-tune the timing of the crisis dates. Details of the empirical methods together with some additional sensitivity analysis of the chosen dates, are presented below in Section 6. The Russian crisis is chosen to begin with the announcement of the Russian Government's deferral of its bond repayments on August 17, 1998, while the end of the crisis is taken as the end of 1998, following Dungey, Fry, González-Hermosillo and Martin (2006) for commensurability. The LTCM crisis begins when the Federal Reserve orchestrated the bailout of LTCM on September 23, and ends with the inter-FOMC Federal Reserve rate cut on October 15 (see also Committee on the Global Financial System (1999)).

The start of the Brazilian crisis is chosen as January 7, 1999, before the effective devaluation of the real on January 15, 1999, which followed the loss of nearly USD$14 billion of reserves in two days. The end of the crisis occurs in the next month on February 25, after several new governors of the Central Bank had been appointed and prior to the agreement of a revised IMF program in early March 1999.

The dating of the dot-com crisis is based on inspection of stock returns given in Figure 1, which shows that the main impact of the crisis occurs in the second quarter of 2000, especially in the case of the stock markets of the U.S., Canada and Mexico. Combined with econometric sensitivity analysis, the dot-com crisis is chosen to begin on February 28, 2000, and end on June 7, of the same year.

The start of the crisis in Argentina is chosen to begin October 11, 2001. This date occurs one month prior to the introduction of the partial deposit freeze (corralito) and capital controls (Cifarelli and Paladino (2004)), but occurs after the increase in volatility that began following the "mega-swap" announced on June 3, 2001. The end of the crisis is taken as 3 March 2005, commensurate with the agreement for debt rescheduling and Argentina's return to the voluntary market.[8] These dates correspond quite closely to those found using a threshold bond spread in Wälti and Weder (2008). Given the length of the crisis period in Argentina, some sensitivity experiments are

[8]The period of the Argentinian crisis also coincides with an increase in volatility in the Brazilian asset markets during the Brazilian Presidential election campaign of the first part of 2002. As the duration of this increase in volatility is very short and primarily limited to Brazil, it is not modelled here as a separate regime.

conducted in Section 6.1 to determine the robustness of the results to this choice of dates.

Turbulence in the U.S. subprime mortgage markets began in mid 2007. A broad range of markets worldwide experienced heightened risk aversion and a sharp fall in liquidity. By early August, credit spreads had widened substantially, stock markets had fallen significantly, and term premia in interbank markets rose. The U.S. Federal Reserve reduced the federal funds rate sharply by 50 basis points on August 18, reducing volatility in stock and credit markets, however liquidity concerns persisted. Hence the U.S. subprime crisis model in this paper contains data from July 26, 2007, until the end of our sample on December 31, 2007.

The noncrisis period is constructed by combining together all of the data between the crisis dates in Table 1. Selected descriptive statistics of the filtered excess returns on stocks and bonds during the noncrisis and crisis periods are presented in Tables 2 and 3 respectively. All filtered returns have zero sample means as a result of including a constant in the VAR to filter returns for lags and the identified institutional changes discussed above.

5 Empirical Results

The crisis and noncrisis models specified in the previous section are estimated using a generalized method of moments (GMM) estimator. This involves computing the unknown parameters by equating the theoretical moments of the model to the empirical moments of the data for both the noncrisis and the crisis periods. As a result of the large number of parameters in the model, the full system containing the noncrisis model and the five crisis models are not estimated jointly. The approach is to estimate the noncrisis model jointly with each of the crisis models one at a time.[9]

The objective function of the GMM estimator is specified as

$$q = M'WM, \tag{19}$$

where M is a vector containing the differences between the empirical and theoretical moments and W is the optimal weighting matrix. All calculations are undertaken using the library MAXLIK in GAUSS Version 7.0. The GMM estimates are computed by

[9] In estimating the model the parameters $\pi_B^b, \kappa_U^s, \kappa_U^b, \phi_U^s$, were found to be small, in which case they were restricted to be zero. The restriction $\kappa_U^s = \kappa_U^b = 0$, means that there is no U.S. country factor. Setting $\phi_U^s = 0$ in (15) has the effect of making the U.S. equity market the common equity market factor.

iterating over the parameters and the optimal weighting matrix W, using the BFGS algorithm with the gradients computed numerically.

An overall test of the model is based on testing the number of overidentification restrictions using Hansen's J-statistic

$$J = Tq, \tag{20}$$

where q is defined in (19) and $T = 2544$ is the sample size. The results of the overidentification test for the full model are presented in Table 4 for each crisis, in the column corresponding to three common factors. The specification of the model satisfies this test at the 1% level for all crises and at the 5% level for all but the dot-com and Argentinian crises.

Further tests of the number of common factors underlying the factor structure of each crisis model are presented in Table 4. Apart from testing the most general common factor structure, which corresponds to a three common factor model, tests of two, one and no common factors are also presented. These tests amount to imposing restrictions on the parameters in the matrices A_w and B_w in (16) and (17) and testing if the restrictions are consistent with the data using the J-statistic in (20). Reducing the number of common factors from three to two, is satisfied for the Brazilian and U.S. subprime crisis models at the 5% level where the p-values of the test are respectively 0.624 and 0.619. This restriction is also satisfied for the Russian/LTCM and Argentinian crises at the 1% level, but not for the dot-com crisis model. Further restricting the number of common factors from two to one leads to a clear rejection of the null hypothesis for all crisis models at the 5% level with the exceptions of the Brazilian model where the p-value is 0.056 and the U.S. subprime crisis model where the p-value is 0.060. Further testing of the Brazilian and U.S. subprime crisis models for no common factors is clearly rejected where both the p-values are 0.000. Given that the approach adopted in this paper is to specify a model that is common for all crises, for the rest of the paper the number of common factors is chosen to be three for all crisis models.

5.1 Evidence of Contagion

In presenting the results, the relative strength of contagion is highlighted in terms of its contribution to the total volatility of asset returns during the crisis periods. Given the independence and normalization assumptions of the factors, the (12×12) theoretical variance-covariance matrix of returns during the crisis period is immediately obtained from (17), as

$$E\left[y_t y_t'\right] = B_w B_w' + B_m B_m' + B_c B_c' + B_v B_v', \tag{21}$$

where it is assumed that y_t is standardized to have zero mean. The variance decompositions are simply the individual components of the diagonal terms of (21), expressed as a percentage of the total, with the parameter values replaced by their GMM parameter estimates. For example, from (17) the contribution of the bond market factor to the variance of stocks in Argentina is

$$Var = \frac{100 \times \left(\delta^s_{A,b}\right)^2}{Total},$$

where

$$\begin{aligned} Total &= \left(\lambda^s_A\right)^2 + \left(\beta^s_A\right)^2 + \left(\pi^s_A\right)^2 + \left(\gamma^s_A + \tau^s_A\right)^2 + \left(\delta^s_{A,b}\right)^2 \\ &\quad + \left(\kappa^s_A\right)^2 + \left(\delta^s_{A,R}\right)^2 + \left(\phi^s_A\right)^2 + \left(\delta^s_{A,Rb}\right)^2 + \left(\delta^s_{A,Ub}\right)^2 . \end{aligned}$$

Table 5 gives the percentage contribution of contagion to total volatility in stock and bond markets for the five crisis periods. Complete variance decompositions which contain both noncrisis and crisis factor contributions for the five crisis periods, are given in Appendix C. For comparative purposes, Table 5 also gives the sample variance. This table highlights three important points concerning the overall size of contagion from 1998 to 2007. First, the Russian/LTCM crisis is widespread as it affects all countries, developed and emerging, and both classes of asset markets, stocks and bonds. The stock markets hit hardest during this crisis are Brazil (98.63%) , the U.S. (63.74%) , Argentina (43.98%) , Canada (41.46%) , Mexico (35.65%) , with Russia (25.88%) being the least affected. The bond markets most affected during this crisis are Brazil (89.33%) , Mexico (85.67%) , Canada (45.92%) , the U.S. (31.38%) , and Argentina (31.01%). The low contribution of contagion to Russian bonds (4.55%) in Table 5, simply reflects that the Russian crisis originated in this market. In the case of Brazil, these results support Baig and Goldfajn (2000) and Dungey, Fry, González-Hermosillo and Martin (2007), who document the portfolio effects of the Russian crisis on Brazil.

Second, comparison of the relative importance of contagion during the financial crises chronologically between Russia/LTCM in 1998 and the U.S. subprime crisis in 2007, shows that the strength of contagion tends to become weaker in the intervening crises, with the effects becoming more fragmented across asset markets and national borders. The Brazilian crisis mainly impacts emerging markets, with the effects on the developed markets except U.S. stocks being relatively small. In particular, the effects on Russian stock (27.20%) and bond (65.09%) markets potentially reflect an overhang of the Russian crisis. There are also important effects on the stock market in Argentina (62.26%) and the bond market in Mexico (82.48%). During the dot-com and Argentinian crises, the main effects are on stocks, with very little impact on bond markets, although the dot-com crisis affects the Brazilian bond market markedly (94.06%). The South American stock markets are affected most during the dot-com crisis where the contributions of contagion to total volatility are Argentina (92.47%), Mexico (88.50%) and Brazil (39.63%) . The Canadian and Russian stock markets are not particularly affected by the dot-com crisis. These results not only confirm that the dot-com crisis is a crisis in stocks, but also suggest that Russian asset markets had finally settled down after the Russian crisis. There is a further reduction in the overall relative impact of contagion on South American stock markets during the Argentinian crisis compared to the dot-com and previous crises, with the exception of Brazil. The largest impact occurs in Brazilian stocks (61.93%) and U.S. bond markets (34.59%) .

Third, and in stark contrast to the diminishing strength of contagion channels during the previous financial crises and the apparent far lower impact of contagion on bond markets during the dot-com and Argentinian financial crises, the effects of contagion during the U.S. subprime crisis are widespread with no country immune. In bond markets the contagion effects in Argentina (94.31%) and the U.S. (92.19%) account for almost all of the volatility in these markets, while in stock markets three of the six countries, Brazil, Canada and Mexico, have contagion effects greater than 40.00% percent of volatility. A similar result occurs during the Russian/LTCM crisis where the contribution of contagion to stock market volatility is greater than 40% for four stock markets and four bond markets. Given that the Russian asset markets are largely immune to the dot-com and Argentinian crises, it is interesting to observe that Russia is also affected by the subprime crisis in bond markets, where approximately 30% in Russian bonds is the result of contagion.[10]

5.2 Comparison of Contagion Channels Across Crises

The previous discussion highlights the changes in the relative importance of contagion in contributing to asset market volatility across crises. In this section the estimated factor model is used to breakdown the relative contribution of contagion into its separate components. Tables 6 and 7 provide the variance decompositions of the contagion transmission mechanisms for stocks and bonds respectively, due to market, country and idiosyncratic channels, across the five crisis periods.

The Russian/LTCM crisis results in Table 6 show that idiosyncratic bond shocks and Russian country shocks are important in transmitting contagion to stock markets. The dominant mechanism is the country channel where stocks in the U.S. (40.97%)

[10]Both the Argentine and Russian central banks injected liquidity into their respective financial systems during this period (see Fitch Ratings (2007)).

and Argentina (38.05%) are hardest hit, whilst Brazilian stocks (51.95%) are affected by the direct link from Russian bonds, and U.S. and Canadian stocks (both 21.57%) are affected by the direct link from U.S. bonds. In the case of bond markets, Table 7 shows that all channels are operating. The most affected country during the LTCM phase of the Russian/LTCM crisis is Brazil, where stocks (51.95%) and bonds (15.67%) are affected directly by Russian bonds. The Mexican bond market is also particularly affected by the Russia/LTCM crisis, with almost one quarter (24.85%) coming through the idiosyncratic U.S. bond channel. Mexican stock markets are much less affected by this source of contagion.

The effects on the Russian asset markets during the Brazilian crisis can be attributed to an idiosyncratic channel from the Brazilian bond market in the case of Brazilian bonds (34.62%) and channels through the bond and stock market channels. In other asset markets affected by this crisis it is the country channel that transmits contagion to the Argentinian stock market (51.51%) and the Mexican bond market (77.52%) .

All three contagion channels are at play in transmitting the dot-com crisis to stock markets. The largest effect is on the stock markets in Argentina (85.40%) through the country channel, and Mexico (76.35%) through the bond market channel. Effects via the idiosyncratic channel from U.S. stocks on Brazilian (20.36%) and Mexico (10.20%) stocks, are relatively larger than they are for Argentina and Canada. Russian stocks are immune to the dot-com crisis as are all but the Brazilian bond markets, where strong effects come from the stock market (42.91%) and idiosyncratic channel from U.S. stocks (50.82%).

The contagion channels operating during the Argentinian crisis are even more selective than they are in the previous crises, with just the stock market in Brazil being affected with (18.77%) through the bond market channel, and (43.23%) through the Argentinian bond channel. However, as the results in Table 7 show that with the exception of the U.S. most bond markets are immune to the Argentinian crisis, suggesting that the market linkage transmitting contagion to the Brazilian stock market is being transmitted via the developed U.S. markets. This result is in line with the role of developed markets in spreading crises between developing markets highlighted in Kaminsky and Reinhart (2003) .

Table 6 shows that during the subprime crisis in the U.S. all channels are operating to transmit the crisis to stock markets. No one channel dominates, although the idiosyncratic link from U.S. stock markets is of lesser importance than the remaining links. The results for the bond markets in Table 7 show that the effects of the subprime crisis are also widespread, with the main effects felt by Argentina (84.90%) through the idiosyncratic U.S. stock market channel, and Russia (30.11%) through the U.S. bond market idiosyncratic channel. The U.S. bond market (87.98%) is affected through the stock market channel, which represents a second-round effect of the credit market shock that occurred first in the U.S. bond market.[11]

5.3 Testing the Channels of Contagion

The variance decompositions discussed above provide a descriptive measure of the relative impact of contagion on the volatility of asset returns during financial crises. To formalize the strength of these mechanisms, Wald tests of the statistical significance of the market, country and idiosyncratic contagion channels for each crisis period, are presented in Table 8.[12] As an example of the way the Wald test is performed, in the case of the Russian/LTCM crisis, the Wald test of contagion from the stock market factor to the six bond markets consists of testing that the joint restriction $\delta^{b}_{i,s} = 0 \ \forall i$ in the matrix B_m in (17). Testing in the reverse direction from the bond market factor to the six stock markets is given by testing the joint restriction $\delta^{s}_{i,b} = 0 \ \forall i$ in the matrix B_m in (17). The test of the country channel from Russia to the 10 non-Russian asset markets is given by testing the parameter $\delta^{j}_{i,R}$ in the matrix B_c in (17). The test of the idiosyncratic contagion channel from Russian bonds to the other 11 asset markets is given by testing $\delta^{s}_{i,Rb} = \delta^{b}_{i,Rb} = 0$, whereas the test of the idiosyncratic contagion channel from U.S. bonds to the other 11 asset markets during the LTCM crisis, is given by testing $\delta^{s}_{i,Ub} = \delta^{b}_{i,Ub} = 0$. The form of the tests is similar for the other three crises.

The results of the Wald tests given in Table 8 reveal that all contagion channels are statistically significant at the 5% level. These tests provide strong support for the importance of all contagion channels operating during all crises. These results also highlight the fact that whilst some of the channels may not be economically significant given the results of the variance decompositions presented above, nonetheless these channels may still be statistically significant.

6 Robustness Checks and Additional Diagnostics

An important feature of the empirical model is that identification of the parameters depends in a fundamental way on the dating of the crisis periods and the set of countries

[11] At the time of writing the paper, the sub-prime crisis had not ended. Extending the dataset to the end of February 2008 made no substantive difference to the results reported here.

[12] Dungey, Fry, González-Hermosillo and Martin (2005) show the relationship between testing for contagion using the factor model, and existing tests of contagion.

used to identify the common factors. In this section a number of additional robustness checks and diagnostic tests are performed on the factor model specification, with special attention given to looking at the sensitivity of the results to changes in the crisis dates and the choice of countries.

6.1 Crisis Dating Sensitivity Analysis

The empirical results presented are based on joint estimation of the model over a noncrisis and crisis period. To examine the sensitivity of these results to the choice of crisis dates, Figure 2 gives the p-values from performing the moment overidentification test based on the J-statistic in (20), for changes in the start and the end dates of the five crises. A maximum window of 5 days is chosen where either the start of the crisis period (continuous line) or the end of the crisis period (dashed line) are adjusted. A zero day signifies the crisis dates given in Table 1. The U.S. subprime crisis end date is not extended by 5 days as this crisis is assumed to continue until the end of the sample. The p-values reported in Figure 2 in general are qualitatively insensitive to changes in the dating of the five crises.[13]

Given that the Argentinian crisis period (11 October 2001 to 3 June 2005) is much longer than the other crisis periods identified here, some additional sensitivity analysis is conducted on Argentina by considering shorter crisis periods.[14] Three crisis sub-periods are investigated consisting of the first year of the crisis (11 October 2001 to 10 October 2002), the first two years of the crisis (11 October 2001 to 10 October 2003) and the first three years of the crisis (11 October 2001 to 10 October 2004). The results are in Table 9, which gives the variance decompositions for the three crisis sub-periods and the total crisis period, where the total period results are taken from Tables 6 and 7.

Comparing the contagion results across the four alternative crisis periods reveals that the qualitative analysis of the contagion effects is in general robust to the different sample periods. The exceptions are mainly for Brazil and the U.S. asset markets. In the case of the shorter crisis sample, Brazilian stocks receive around 4% contagion from the Argentinian bond market channel, compared with 43% from both these channels in the total sample. In the case of the two year sample Brazilian bonds receive almost 36% via the Argentinian country channel, compared with less than 1% in the total sample. For the U.S., the shorter sample periods result in contagion effects from

[13]For each of the p-values reported in Figure 2, variance decompositions of the relative importance of the factors are also computed, but not reported here to save space. In general, the variance decompositions are insensitive to the choice of the crisis dates for the window of dates investigated.

[14]W would like to thank Roberto Rigobon for suggesting this to us.

the idiosyncratic Argentinian bond channel on U.S. stocks being as high as 55%, in the third subsample, compared with the less than 1% for the total sample period. These results suggest that although there are potentially some changes in the way that contagion is transmitted during the Argentinian crisis, especially from late 2004 to mid 2005, nonetheless contagion is important during the total crisis period which provides support for the choice of the crisis dates.

6.2 Extension of Countries

An important feature of the model to identify contagion during the crisis period, is the specification of a set of common factors that operate during both the noncrisis and crisis periods. As the common factors are latent, they are identified from the volatility structure of the set of countries chosen in the sample. By extending the set of countries investigated this improves the precision of the common factor estimates, and in turn, the estimates of contagion.

To examine the robustness of the model of contagion to the inclusion of additional countries asset markets, the subprime crisis model is extended to accommodate four additional developed countries consisting of Australia, Germany, Japan and the U.K.[15] The volatility decompositions for the stock and bond markets of the extended set of countries are presented in Table 10. Consistent with the existing empirical results for the subprime crisis presented in Tables 6 and 7, the additional countries all receive substantial amounts of contagion in both stocks and bonds, further supporting the widespread nature of this crisis. A comparison of the variance decompositions of the stock markets in Table 10 (extended country results) and Table 6 (existing country stock market results) shows that the two sets of decompositions are similar overall, with the extended results actually showing a slight increase in the relative strength of contagion across all six stock markets. A similar result occurs for the bond markets in Brazil, Canada and Mexico, which also show some increases in the relative importance of contagion. The main differences in the existing and extended results are with the bonds markets of Argentina and the U.S. and to a lesser extent with Russia's bond market, where the extended results yield smaller estimates of contagion than the estimates reported in Table 7, but nonetheless are still significant both economically and statistically.

[15] See Appendix B for data sources and codes for the additional countries.

6.3 Conditional Moment Tests

Conditional moment tests of first order autocorrelation $AR(1)$ and first order conditional volatility $ARCH(1)$ in the standardized residuals of the VAR, are given in Table 11. The results of these tests are reported in terms of p-values, for different crisis models. In practically all cases considered, the p-values are greater than 0.01, showing that the null hypothesis of no autocorrelation or no conditional volatility, is not rejected at the 1% level, and in most cases is also not rejected at the 5% level.

6.4 Structural Break Tests

The specification of the model allows for the idiosyncratic parameters to exhibit a structural break between the noncrisis and crisis periods. Tests of the significance of the structural break are presented in Table 12 using a Wald test. In the case of the Russian/LTCM crisis, from equation (17) the structural break tests are performed on the loadings of the stock market (τ_i^s) and the bond market (τ_i^b) factors where $i = A, B, C, M, R, U$, the loadings of the Russian country factor $(\tau_{R,R}^s, \tau_{R,R}^b)$, and the loadings of the Russian and U.S. idiosyncratic bond factors $(\tau_{R,Rb}^b, \tau_{U,Ub}^b)$. Similar restrictions hold for the other three crisis models. All tests are calculated using a Wald test that the parameter θ, is zero. Under the null hypothesis of no structural break, this amounts to the parameters associated with each factor being the same in the noncrisis and crisis periods.

The results in Table 12 show strong evidence of structural breaks in practically all factors investigated, across all five financial crises, with all p-values being less than 0.05. The strength of these results are consistent with the empirical findings of Forbes and Rigobon (2002) who emphasize the important of allowing for increases in volatility in the source country when testing for contagion (see also Dungey, Fry, González-Hermosillo and Martin (2005), for further discussion of the role of structural break tests in tests of contagion).

7 Conclusions

This paper investigated whether financial crises were alike by considering whether a single modelling framework could fit multiple distinct crises. On this basis, financial crises were alike. The framework introduced three potential channels for contagion effects during a financial crisis, and the empirical evidence showed that statistically each of these operated during every crisis examined - again on this basis, financial crises are alike. Economically, however, the importance of the channels of contagion differs across crises.

The modelling framework was derived by respecifying the theoretical model of Kodres and Pritsker (2002) for solution in terms of the excess returns on assets, rather than prices. The empirical implementation was a latent factor representation of the equilibrium solution of that model. Three potential channels for contagion effects were simultaneously identified and quantified. The channels were: idiosyncratic channels which provided a direct link from the nominated source asset market to international asset markets; market channels which operated through either the bond or stock markets; and country channels which operated through the asset markets of a country jointly.

The empirical investigation considered a common dataset over the period March 1998 to December 2007 consisting of the stock and bond markets of six countries: Argentina, Brazil, Canada, Mexico, Russia and the U.S, although the results were also extended to allow for a broader range of develop countries. The sample period covered five major crisis instances, from the Russian and LTCM crises in 1998, the Brazilian crisis in 1999, the dot-com crisis in 2000, the Argentinian crisis in 2002-2005 to the recent crisis associated with the U.S. subprime market beginning mid 2007.

The Russian/LTCM crises had a widespread impact. All three contagion channels were active in this period. The Brazilian crisis had greater impact on emerging markets than developed markets, with a pronounced effect on Russian asset markets, via all but the country channel. Russian stock markets, however, were immune to the dot-com crisis, which mainly affected stock markets. Although all three contagion channels operated during the dot-com crisis the effects on bond markets were limited to the Brazilian bond market. Bond markets were also little affected by the Argentinian crisis, despite all three contagion channels being present and statistically significant. This was not the case in the U.S. subprime crisis, where not only were all contagion channels statistically significant, but the effects of contagion were widespread across asset markets and countries.

Contagion effects were greatest in the Russian/LTCM crisis, and dissipated in the subsequent Brazilian, dot-com and Argentinian crises, but returned with vehemence in the U.S. subprime crisis. Using the extent of contagious effects as a metric, the worst crises of the past decade were the Russian/LTCM crisis in 1998 and the recent 2007 U.S. subprime crisis, which interestingly both began in bond markets.

The empirical results presented have a number of important lessons for the building of theoretical models of contagion. First, the empirical results suggest that it is feasible to specify a unifying theoretical model that is applicable for modelling a range of crises regardless of the nature of the initiating shock. Second, a number of potential mechanisms will need to be specified to explain asset market returns and the transmission of contagion across international asset markets. In the empirical model these mechanisms were classified broadly as common, market, country and idiosyncratic transmission mechanisms according to the decomposition proposed by Dungey and Martin (2007), whilst in the theoretical model these mechanisms represented information asymmetries, noise trading, macroeconomic shocks and expectation errors, following the theoretical framework of Kodres and Pritsker (2002). The empirical results showed that contagion operated via a range of channels, although the relative importance of each channel was found to vary across crises.

Table 1:
Summary of crisis dates.

Crisis	Origin of Shock	Start of Crisis Date	End of Crisis Date
Russia	Russian bonds	17 August 1998	31 December 1998
LTCM	U.S. bonds	23 September 1998	15 October 1998
Brazil	Brazilian bonds	7 January 1999	25 February 1999
Dot-com	U.S. stocks	28 February 2000	7 June 2000
Argentina	Argentinian bonds	11 October 2001	3 March 2005
U.S. Subprime	U.S. bonds, stocks	26 July 2007	31 December 2007

Table 2:
Descriptive statistics of filtered excess stock returns for selected periods.

Period/Crisis	Statistic	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
Russia		*17 August 1998 - 31 December 1998*					
	Max.	7.840	10.788	4.934	11.503	40.090	4.033
	Min.	-9.408	-9.596	-6.913	-11.963	-58.845	-3.576
	St. dev.	3.129	3.972	1.682	3.344	11.837	1.445
LTCM		*23 September 1998 - 15 October 1998*					
	Max.	6.728	5.221	4.934	6.328	9.956	3.722
	Min.	-6.494	-6.135	-5.254	-8.917	-12.271	-3.576
	St. dev.	3.425	3.456	2.482	3.880	6.757	1.687
Brazil		*7 January 1999 - 25 February 1999*					
	Max.	6.849	12.614	2.539	6.012	9.063	2.564
	Min.	-8.366	-11.555	-2.228	-6.136	-10.212	-4.239
	St. dev.	2.728	5.052	1.152	2.404	4.223	1.272
Dot-com		*28 February 2000 - 7 June 2000*					
	Max.	2.844	4.732	4.423	6.944	6.949	4.364
	Min.	-5.236	-5.708	-4.845	-8.506	-7.192	-4.320
	St. dev.	1.620	1.920	1.709	2.662	3.344	1.465
Argentina		*11 October 2001 - 3 March 2005*					
	Max.	15.925	13.382	5.072	4.903	8.429	6.039
	Min.	-32.553	-8.124	-3.986	-6.337	-10.751	-5.374
	St. dev.	3.012	2.327	1.131	1.342	2.040	1.314
U.S. Subprime		*26 July 2007 - 31 December 2007*					
	Max.	7.293	6.477	4.250	5.807	4.408	3.668
	Min.	-5.496	-7.548	-5.582	-5.183	-4.139	-3.842
	St. dev.	2.011	3.037	1.825	2.172	1.681	1.663
Non-crisis							
	Max.	11.282	9.839	5.151	7.464	16.426	3.967
	Min.	-9.385	-11.797	-8.565	-5.716	-21.788	-6.248
	St. dev.	1.906	2.132	1.218	1.663	2.952	1.022

Table 3:
Descriptive statistics of filtered excess bond returns for selected periods.

Period/Crisis	Statistic	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
Russia		*17 August 1998 - 31 December 1998*					
	Max.	9.240	15.375	3.135	9.398	42.382	1.808
	Min.	-16.797	-15.033	-4.644	-8.655	-115.147	-3.438
	St. dev.	3.360	5.524	1.100	2.396	19.214	0.576
LTCM		*23 September 1998 - 15 October 1998*					
	Max.	9.240	8.890	3.135	4.877	17.253	1.808
	Min.	-2.946	-13.982	-3.330	-3.643	-12.520	-1.295
	St. dev.	2.943	5.231	1.653	2.136	8.887	0.654
Brazil		*7 January 1999 - 25 February 1999*					
	Max.	9.876	16.824	1.571	7.866	30.430	0.571
	Min.	-11.254	-12.801	-2.708	-4.948	-58.979	-0.838
	St. dev.	3.066	5.672	0.845	2.242	13.885	0.302
Dot-com		*28 February 2000 - 7 June 2000*					
	Max.	7.152	2.972	1.744	1.676	19.387	0.591
	Min.	-3.702	-3.595	-2.062	-2.240	-15.039	-0.738
	St. dev.	1.369	1.221	0.721	0.775	3.866	0.256
Argentina		*11 October 2001 - 3 March 2005*					
	Max.	29.180	17.258	2.808	2.665	11.596	2.233
	Min.	-40.621	-38.084	-1.790	-2.699	-4.745	-1.426
	St. dev.	6.385	2.603	0.643	0.600	1.257	0.349
U.S. Subprime		*26 July 2007 - 31 December 2007*					
	Max.	20.031	3.778	2.150	1.857	3.233	0.800
	Min.	-14.573	-2.595	-2.585	-1.980	-1.837	-1.366
	St. dev.	3.631	1.092	0.884	0.682	0.941	0.363
Non-crisis							
	Max.	33.360	10.577	2.889	5.059	55.570	1.851
	Min.	-33.700	-5.690	-2.960	-4.257	-44.350	-1.352
	St. dev.	3.418	1.202	0.577	0.650	4.358	0.258

Table 4:

Overidentification tests for common factors based on the J-statistic. Unrestricted model given by the column headed "Three common factors". The restrictions for "Two common factors" are based on $\pi_i^j = 0$. The restrictions for "One common factor" are based on $\pi_i^j = 0, \beta_i^j = 0$. The restrictions for "No common factors" are based on $\pi_i^j = 0, \beta_i^j = 0, \lambda_i^j = 0$. The last set of restrictions amounts to restricting the matrices A_w and B_w in (16) and (17) respectively, as null matrices.

Crisis	Statistic	Number of Common Factors			
		Three	Two	One	None
Russia/ LTCM	J-statistic	25.631	42.819	71.993	339.739
	dof	22	27	39	51
	p-value	0.268	0.027	0.001	0.000
Brazil	J-statistic	22.498	35.641	67.939	334.123
	dof	34	39	51	63
	p-value	0.934	0.624	0.056	0.000
Dot-com	J-statistic	49.388	66.460	98.373	363.581
	dof	34	39	51	63
	p-value	0.043	0.004	0.000	0.000
Argentina	J-statistic	50.826	54.878	143.806	369.569
	dof	34	39	51	63
	p-value	0.032	0.047	0.000	0.000
U.S. Subprime	J-statistic	20.858	35.758	67.557	333.514
	dof	34	39	51	63
	p-value	0.962	0.619	0.060	0.000

Table 5:

Contribution of contagion to stock and bond market volatility during financial crises: percentage of total volatility. The percentage contribution of the non-contagion component to volatility is obtained by subtracting the reported contagion contribution from 100. For comparison the variance of actual returns for stock and bonds for each country are also reported.

Crisis	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
				Stock Markets			
Russia/ LTCM	Contagion (%)	43.98	98.63	41.46	35.65	25.88	63.74
	Variance	9.79	15.78	2.83	11.18	140.12	2.09
Brazil	Contagion (%)	62.26	7.04	14.92	20.47	27.20	55.9
	Variance	7.45	25.52	1.33	5.78	17.84	1.62
Dot-com	Contagion (%)	92.47	39.63	2.97	88.50	0.46	2.12
	Variance	2.62	3.69	2.92	7.09	11.18	2.15
Argentina	Contagion (%)	4.59	61.93	7.04	1.91	0.02	6.90
	Variance	9.07	5.42	1.28	1.80	4.16	1.73
U.S. Subprime	Contagion (%)	28.20	42.64	44.97	44.49	3.86	13.62
	Variance	4.05	9.22	3.33	4.72	2.83	2.77
				Bond Markets			
Russia/ LTCM	Contagion (%)	31.01	89.33	45.92	85.67	4.55	31.38
	Variance	11.29	30.52	1.21	5.74	369.17	0.33
Brazil	Contagion (%)	14.73	4.73	12.28	82.48	65.09	7.58
	Variance	9.40	32.17	0.72	5.03	192.80	0.09
Dot-com	Contagion (%)	0.12	94.06	1.17	1.97	0.27	1.08
	Variance	1.88	1.49	0.52	0.60	14.95	0.07
Argentina	Contagion (%)	3.97	2.20	16.52	11.63	0.11	34.59
	Variance	40.77	6.77	0.41	0.36	1.58	0.12
U.S. Subprime	Contagion (%)	94.31	14.16	24.71	21.14	30.17	92.19
	Variance	13.18	1.19	0.78	0.47	0.89	0.13

Table 6:

Breakdown of the contribution of contagion channels to overall contagion in stock markets during financial crises: percentage of total volatility. A "n.a." represents not applicable.

Crisis	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
Russia/ LTCM	Market (bond)	1.16	37.65	11.48	9.16	18.82	0.32
	Country (Rus.)	38.05	2.57	6.92	13.48	n.a.	40.97
	Idio. (Rus. bond)	4.35	51.95	1.49	2.36	6.32	0.90
	Idio. (U.S. bond)	0.42	6.46	21.57	10.65	0.74	21.57
	Total contagion	43.98	98.63	41.46	35.65	25.88	63.74
	Variance	9.79	15.78	2.83	11.18	140.12	2.09
Brazil	Market (bond)	0.73	0.07	5.61	6.16	22.48	21.21
	Country (Brz.)	51.51	n.a.	1.43	10.50	0.13	2.46
	Idio. (Brz. bond)	10.02	6.97	7.88	3.81	4.59	32.23
	Total contagion	62.26	7.04	14.92	20.47	27.2	55.9
	Variance	7.45	25.52	1.33	5.78	17.84	1.62
Dot-com	Market (bond)	0.10	13.64	0.97	76.35	0.19	2.12
	Country (U.S.)	85.40	5.63	0.27	1.96	0.02	n.a.
	Idio. (U.S. stock)	6.93	20.36	1.72	10.20	0.25	n.a.
	Total contagion	92.47	39.63	2.97	88.50	0.46	2.12
	Variance	2.62	3.69	2.92	7.09	11.18	2.15
Argentina	Market (bond)	4.58	18.70	0.98	0.28	0.00	0.65
	Country (Arg.)	n.a.	0.00	4.30	1.55	0.01	6.14
	Idio. (Arg. bond)	0.01	43.23	1.76	0.08	0.01	0.11
	Total contagion	4.59	61.93	7.04	1.91	0.02	6.9
	Variance	9.07	5.42	1.28	1.80	4.16	1.73
U.S. Subprime	Market (bond)	10.14	15.77	17.34	17.33	0.67	7.94
	Idio. (U.S. stock)	5.31	7.74	8.11	7.28	1.18	n.a.
	Idio. (U.S. bond)	12.75	19.13	19.52	19.88	2.01	5.68
	Total contagion	28.20	42.64	44.97	44.49	3.86	13.62
	Variance	4.05	9.22	3.33	4.72	2.83	2.77

Table 7:

Breakdown of the contribution of contagion channels to overall contagion in bond markets during financial crises: percentage of total volatility. A "n.a." represents not applicable.

Crisis	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
Russia/ LTCM	Market (stock)	12.11	26.68	4.92	27.57	4.50	5.85
	Country (Rus.)	0.44	26.90	1.00	16.24	n.a.	22.88
	Idio. (Rus. bond)	13.62	15.67	8.36	17.01	n.a.	2.65
	Idio. (U.S. bond)	4.85	20.09	31.64	24.85	0.05	n.a.
	Total contagion	31.01	89.33	45.92	85.67	4.55	31.38
	Variance	11.29	30.52	1.21	5.74	369.17	0.33
Brazil	Market (stock)	0.06	4.73	0.41	2.39	25.37	0.31
	Country (Brz.)	14.57	n.a.	7.12	77.52	5.10	4.27
	Idio. (Brz bond)	0.10	n.a.	4.75	2.57	34.62	3.00
	Total contagion	14.73	4.73	12.28	82.48	65.09	7.58
	Variance	9.40	32.17	0.72	5.03	192.80	0.09
Dot-com	Market (stock)	0.09	42.91	0.58	1.55	0.00	0.47
	Country (U.S.)	0.03	0.33	0.02	0.32	0.00	n.a.
	Idio. (U.S. stock)	0.00	50.82	0.57	0.09	0.27	0.61
	Total contagion	0.12	94.06	1.17	1.97	0.27	1.08
	Variance	1.88	1.49	0.52	0.60	14.95	0.07
Argentina	Market (stock)	3.97	0.53	5.12	5.14	0.01	13.43
	Country (Arg.)	n.a.	0.04	2.74	2.82	0.10	17.59
	Idio. (Arg. bond)	n.a.	1.63	8.66	3.67	0.00	3.57
	Total contagion	3.97	2.2	16.52	11.63	0.11	34.59
	Variance	40.77	6.77	0.41	0.36	1.58	0.12
U.S. Subprime	Market (stock)	4.64	9.94	5.96	14.40	0.03	87.98
	Idio. (U.S. stock)	84.90	1.75	3.56	2.72	0.03	4.21
	Idio. (U.S. bond)	4.77	2.47	15.19	4.02	30.11	n.a.
	Total contagion	94.31	14.16	24.71	21.14	30.17	92.19
	Variance	13.18	1.19	0.78	0.47	0.89	0.13

Table 8:

Wald tests of contagion channels: p-values in brackets.

Test	DOF	Crisis				
		Russia /LTCM	Brazil	Dot-com	Argentina	U.S. Subprime
Market (stock)	6	43.203 (0.000)	1457611.981 (0.000)	3391.138 (0.000)	2884.244 (0.000)	122980.105 (0.000)
Market (bond)	6	40.062 (0.000)	174942.085 (0.000)	252266.248 (0.000)	294191.709 (0.000)	305.378 (0.000)
Country	10	179.529 (0.000)	316208.574 (0.000)	254690.275 (0.000)	5055.812 (0.000)	
Idiosyncratic (Rus. bond)	11	167.973 (0.000)				
Idiosyncratic (U.S. bond)	11	96.716 (0.000)				2254131.292 (0.000)
Idiosyncratic (Bra. bond)	11		2026223.758 (0.000)			
Idiosyncratic (U.S. stock)	11			65483.898 (0.000)		137316.057 (0.000)
Idiosyncratic (Arg. bond)	11				672290.298 (0.000)	
Joint	$44^{(a)}$ $33^{(b)}$	762.078 (0.000)	3977390.807 (0.000)	724307.180 (0.000)	1002437.128 (0.000)	2540997.373 (0.000)

(a) Degrees of freedom for the Russian/LTCM crisis.

(b) Degrees of freedom for the Brazilian, dot-com, Argentinian and U.S. subprime crises.

Table 9:

Sample sensitivity of Argentine crisis dates: stock and bond markets.

Market	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
Stocks	*October 11, 2001 to October 10, 2002*						
	Market (bond)	19.84	25.74	1.47	2.30	0.00	1.44
	Country (Arg.)	n.a.	2.96	2.34	0.13	3.69	5.68
	Idio. (Arg. bond)	0.17	3.59	25.71	5.87	10.09	48.04
	October 11, 2001 to October 10, 2003						
	Market (bond)	3.27	25.75	2.22	3.14	0.28	2.35
	Country (Arg.)	n.a.	2.96	5.75	1.76	1.25	9.37
	Idio. (Arg. bond)	0.49	3.60	23.53	0.56	2.37	37.77
	October 11, 2001 to October 10, 2004						
	Market (bond)	15.40	25.78	0.76	1.23	0.01	0.74
	Country (Arg.)	n.a.	2.97	3.17	0.07	2.16	12.52
	Idio. (Arg. Bond)	0.51	3.60	22.32	6.02	6.02	55.24
	October 11, 2001 to June 3, 2005						
	Market (bond)	4.58	18.70	0.98	0.28	0.00	0.65
	Country (Arg.)	n.a.	0.00	4.30	1.55	0.01	6.14
	Idio. (Arg. bond)	0.01	43.23	1.76	0.08	0.01	0.11
Bonds	*October 11, 2001 to October 10, 2002*						
	Market (stock)	3.25	0.06	0.01	0.00	0.01	27.76
	Country (Arg.)	n.a.	1.96	2.40	0.62	0.28	30.98
	Idio. (Arg. bond)	n.a.	19.31	2.79	3.57	0.75	8.49
	October 11, 2001 to October 10, 2003						
	Market (stock)	2.12	5.42	1.35	1.91	0.07	6.46
	Country (Arg.)	n.a.	35.95	4.17	8.83	0.02	1.95
	Idio. (Arg. bond)	n.a.	4.45	0.54	8.51	0.74	12.49
	October 11, 2001 to October 10, 2004						
	Market (stock)	3.45	0.03	0.03	0.03	0.00	27.91
	Country (Arg.)	n.a.	0.16	0.00	0.02	0.02	28.83
	Idio. (Arg. bond)	n.a.	0.08	1.48	6.22	0.32	10.66
	October 11, 2001 to June 3, 2005						
	Market (stock)	3.97	0.53	5.12	5.14	0.01	13.43
	Country (Arg.)	n.a.	0.04	2.74	2.82	0.10	17.59
	Idio. (Arg. bond)	n.a.	1.63	8.66	3.67	0.00	3.57

Table 10:

Extension of the model to all for additional countries during the U.S. subprime crisis. Percentage contribution of contagion to total variance.

Arg.	Brz.	Can.	Mex.	Rus.	U.S.	Aust.	Germ.	Jap.	U.K.
					Stocks				
35.41	66.21	54.72	58.51	22.95	47.62	70.47	52.46	15.22	71.93
					Bonds				
19.56	43.79	50.75	40.53	20.48	43.29	30.72	16.75	25.47	19.11

Table 11:

Conditional moment tests of the standardized VAR residuals (z_t) for selected periods: p-values. AR(1) based on testing $E\left[z_t z_{t-1} - 0\right]$, ARCH(1) based on testing $E\left[\left(z_t^2 - 1\right)\left(z_{t-1}^2 - 1\right) - 0\right]$.

Crisis	Statistic	Asset	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
Russia/LTCM	AR(1)	Stocks	0.312	0.813	0.183	0.900	0.426	0.175
	AR(1)	Bonds	0.099	0.886	0.616	0.591	0.409	0.865
	ARCH(1)	Stocks	0.473	0.190	0.386	0.442	0.273	0.179
	ARCH(1)	Bonds	0.325	0.600	0.463	0.109	0.761	0.215
Brazil	AR(1)	Stocks	0.848	0.435	0.376	0.305	0.207	0.439
	AR(1)	Bonds	0.132	0.265	0.998	0.036	0.184	0.365
	ARCH(1)	Stocks	0.474	0.331	0.831	0.536	0.314	0.299
	ARCH(1)	Bonds	0.229	0.929	0.220	0.652	0.979	0.505
Dot-com	AR(1)	Stocks	0.071	0.594	0.992	0.943	0.646	0.928
	AR(1)	Bonds	0.234	0.263	0.353	0.875	0.524	0.478
	ARCH(1)	Stocks	0.675	0.038	0.604	0.415	0.016	0.675
	ARCH(1)	Bonds	0.200	0.391	0.220	0.468	0.050	0.595
Argentina	AR(1)	Stocks	0.353	0.047	0.756	0.283	0.036	0.411
	AR(1)	Bonds	0.097	0.681	0.185	0.002	0.280	0.383
	ARCH(1)	Stocks	0.274	0.080	0.076	0.002	0.052	0.031
	ARCH(1)	Bonds	0.004	0.042	0.269	0.039	0.069	0.001
U.S. Subprime	AR(1)	Stocks	0.098	0.006	0.054	0.059	0.002	0.023
	AR(1)	Bonds	0.578	0.215	0.166	0.425	0.021	0.400
	ARCH(1)	Stocks	0.155	0.727	0.809	0.861	0.280	0.873
	ARCH(1)	Bonds	0.096	0.885	0.997	0.291	0.139	0.112

Table 12:

Wald tests of structural breaks: p-values in brackets.

Test	Degrees of freedom	Crisis				
		Russia /LTCM	Brazil	Dot-com	Argentina	U.S. Subprime
Market (stock)	6	93.382 (0.000)	246344.014 (0.000)	2968.468 (0.000)	116950.886 (0.000)	64.527 (0.000)
Market (bond)	6	38.170 (0.000)	996631.190 (0.000)	23.538 (0.001)	7199.044 (0.000)	2488.965 (0.000)
Country	2	13.874 (0.000)	34066.684 (0.000)		8120.438 (0.000)	
Idiosyncratic (Rus. bond)	1	13.285 (0.000)				
Idiosyncratic (U.S. bond)	1	27.856 (0.000)				96.124 (0.000)
Idiosyncratic (Bra. bond)	1		131.086 (0.000)			
Idiosyncratic (U.S. stock)	1					11.869 (0.001)
Idiosyncratic (Arg. bond)	1				1271.660 (0.000)	
Joint	$16^{(a)}$, $15^{(b)}$, $12^{(c)}$, $14^{(d)}$	435.214 (0.000)	1278002.867 (0.000)	3456.122 (0.000)	223229.604 (0.000)	2849.671 (0.000)

(a) Degrees of freedom for the Russian/LTCM crisis.

(b) Degrees of freedom for the Brazilian and Argentinian crises.

(c) Degrees of freedom for the dot-com crisis.

(d) Degrees of freedom for the U.S. subprime crisis.

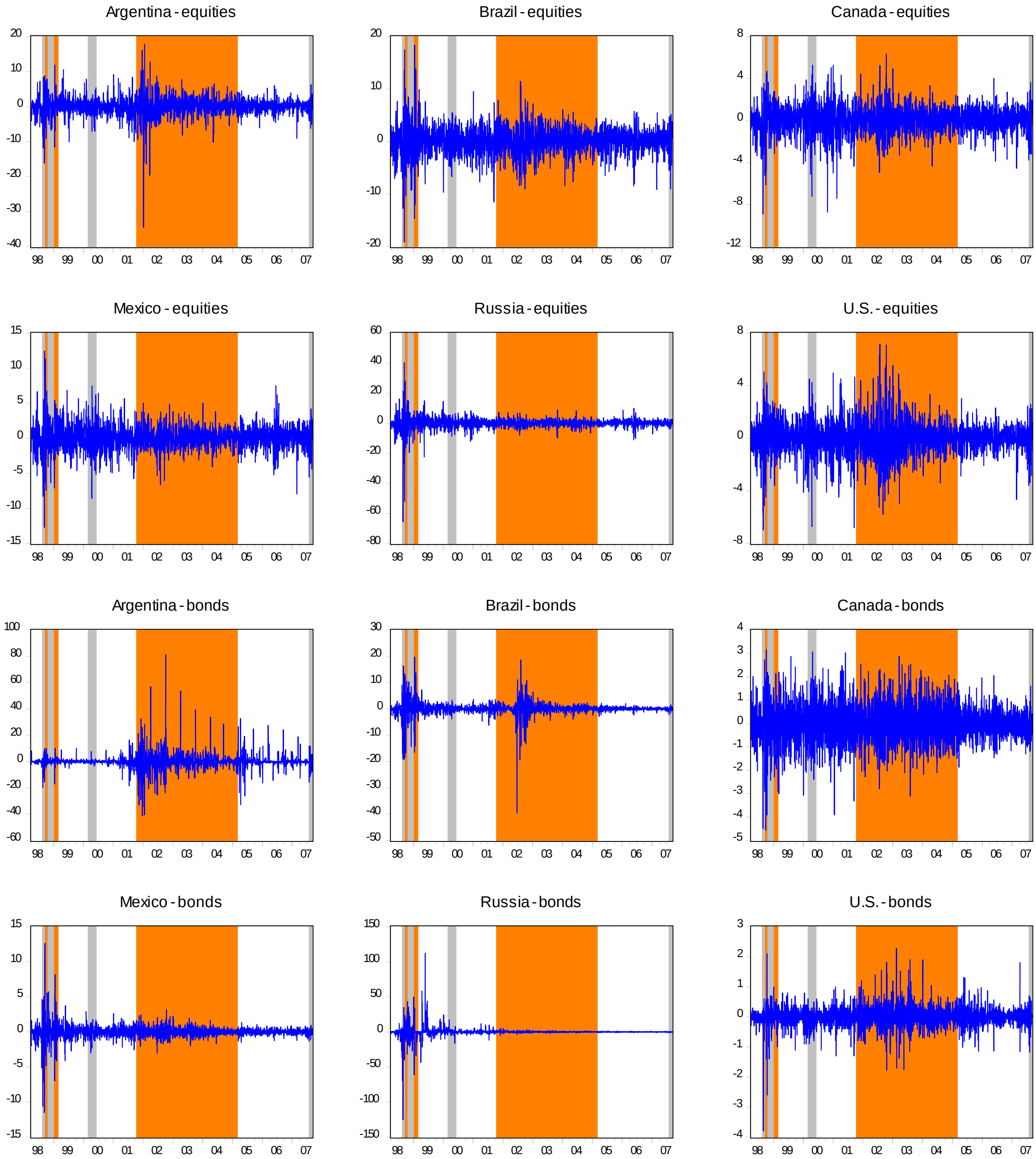

Figure 1: Daily stock and bond percentage excess returns, expressed in U.S. dollars, 31st of March 1998 to 31st of December 2007. Data are unfiltered. The shaded regions correspond to the crisis periods in the following order: Russia/LTCM, Brazil, dot-com, Argentina, U.S. subprime.

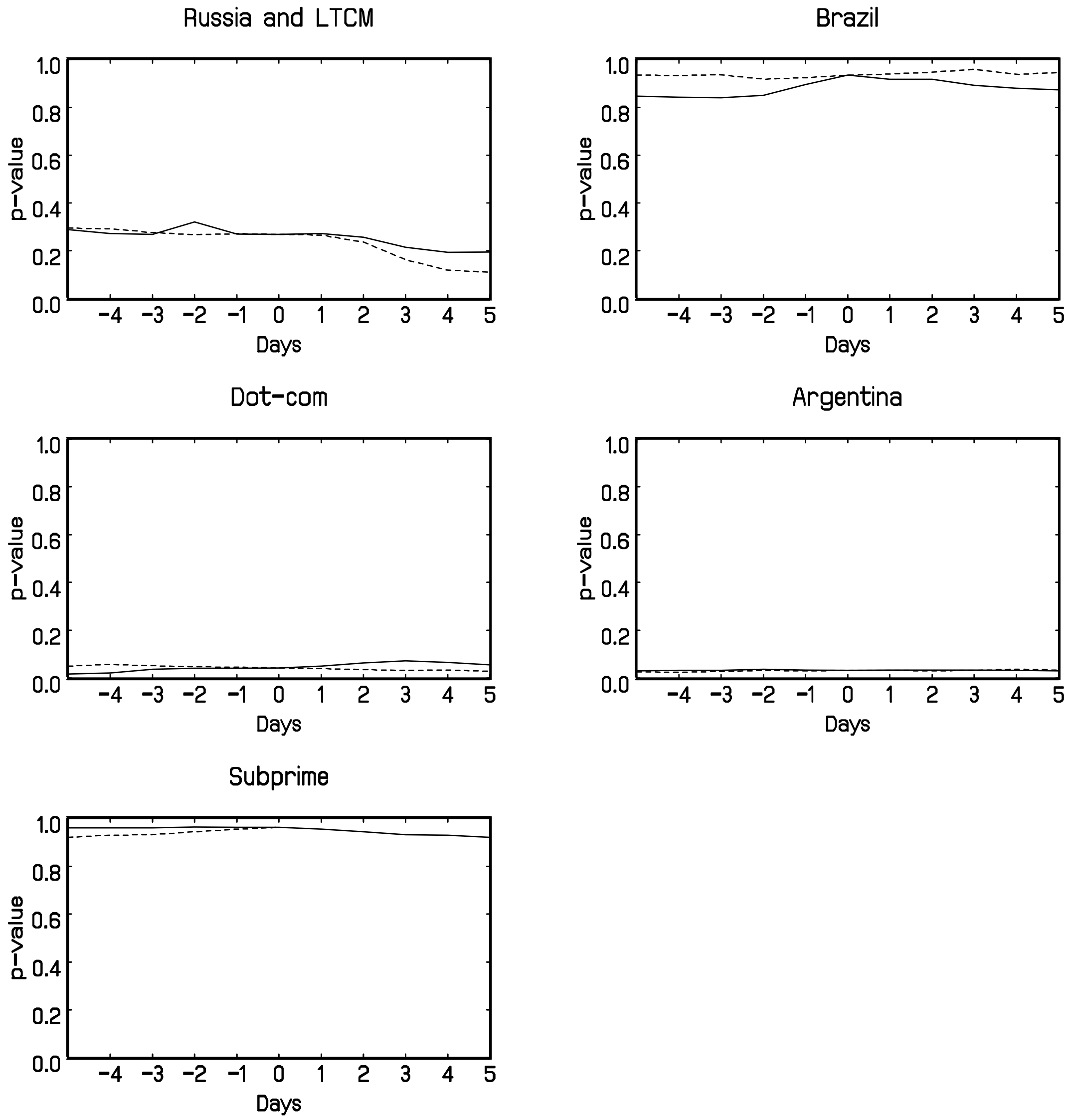

Figure 2: Model over-identification test p-values for sensitivity to crisis date selection: -5,4,...0,...+4,+5 days. Continuous (dashed) line represents the start (end) of the crisis period. The p-values at zero correspond to the values reported in Table 4 where the number of common factors is three.

A Model Derivations

A.1 Optimal Portfolio Weights

For a normally distributed random variable x, $E[\exp x] = \exp\left(E[x] + \frac{1}{2}Var[x]\right)$. Defining $y \equiv \exp x$, then $\ln E[y] = E[\ln y] + \frac{1}{2}Var[\ln y]$. Assuming that period 2 wealth W_2 is lognormally distributed, the objective function in (2) is reexpressed as

$$\max_{\alpha_k} \left\{ (1-\gamma) E[\ln W_2|\Omega_k] + \frac{1}{2}(1-\gamma)^2 Var[\ln W_2|\Omega_k] \right\},$$

or

$$\max_{\alpha_k} \{(1-\gamma)[E[\ln(1+R_p)|\Omega_k] + \ln W_1] + \frac{1}{2}(1-\gamma)^2 Var[\ln(1+R_p)|\Omega_k] \Big\}, \quad (22)$$

by substituting out W_2 in the objective function using the budget constraint in (3), and where $E[\ln W_1|\Omega_k] = \ln W_1$ and $Var[\ln W_1|\Omega_k] = 0$, as W_1 is known at time 1.

Using the definition of the portfolio return in (4) and some algebraic manipulation, the $\ln[1+R_p]$ term in the objective function in (22) is expressed as

$$\begin{aligned} \ln[1+R_p] &= \ln[1+\alpha_k' R + (1-\alpha_k' \imath) R_f] \\ &= \ln\left[1+\alpha_k'\left(\exp\ln\left((1+R_f)^{-1}(1+R)\right)-1\right)\right] + \ln[1+R_f], \end{aligned}$$

or, in terms of log excess returns

$$r_p - r_f = \ln[1+\alpha_k'(\exp(r-r_f)-1)],$$

where $r_p \equiv \ln(1+R_p)$; $r \equiv \ln(1+R)$; $r_f \equiv \ln(1+R_f)$, represent the respective logarithm of returns. The excess portfolio return is approximated by taking a Taylor series expansion around zero excess return $(r - r_f = 0)$

$$r_p - r_f \simeq \alpha_k'(r-r_f) + \frac{1}{2}\alpha_k'(r-r_f)(r-r_f)'(1-\alpha_k'\imath),$$

where the third and higher order terms are assumed to be small.

Taking expectations of the excess portfolio return conditional on the information set of the k^{th} investor, and rearranging gives

$$\begin{aligned} E[(r_p-r_f)|\Omega_k] &\simeq \alpha_k' E[(r-r_f)|\Omega_k] + \frac{1}{2}\alpha_k' E\left[(r-r_f)(r-r_f)'|\Omega_k\right](1-\alpha_k'\imath) \\ E[r_p|\Omega_k] - r_f &\simeq \alpha_k'(E[r|\Omega_k]-r_f) + \frac{1}{2}\alpha_k' Var[(r-r_f)|\Omega_k](1-\alpha_k'\imath) \\ E[r_p|\Omega_k] &\simeq \alpha_k'(E[r|\Omega_k]-r_f) + \frac{1}{2}\alpha_k' Var[r|\Omega_k](1-\alpha_k'\imath) + r_f, \end{aligned} \quad (23)$$

and

$$\begin{aligned} Var\left[\left(r_p - r_f\right)|\Omega_k\right] &\simeq Var\left[\left(\alpha_k'\left(r - r_f\right)\right)|\Omega_k\right] \\ Var\left[r_p|\Omega_k\right] &\simeq \alpha_k' Var\left[r|\Omega_k\right]\alpha_k. \end{aligned} \tag{24}$$

Upon substituting (23) and (24) into (22), together with the definition of log portfolio returns $r_p \equiv \ln(1 + R_p)$, the objective function is rewritten as

$$\max_{\alpha_k}\left\{(1-\gamma)\left[\alpha_k'\left(E\left[r|\Omega_k\right] - r_f\right) + \frac{1}{2}\alpha_k' Var\left[r|\Omega_k\right]\left(1 - \alpha_k'\imath\right) + r_f + \ln W_1\right] \right. \tag{25}$$
$$\left. + \frac{1}{2}(1-\gamma)^2 \alpha_k' Var\left[r|\Omega_k\right]\alpha_k\right\}.$$

Differentiating (25) with respect to α_k yields the optimal solution to the portfolio problem of the informed and the uninformed investors given in (9)

$$\alpha_k^* = \frac{1}{\gamma}\left[E\left[r|\Omega_k\right] - r_f + \frac{1}{2}Covar\left[r|\Omega_k\right]\right]Covar\left[r|\Omega_k\right]^{-1}. \tag{26}$$

A.2 Informed Investor Conditional Expectations

Using $r \equiv \ln(1 + R)$ combined with the definition of $R = (v - P)/P$ in (5) and the liquidation value definition in (6), gives

$$r = \ln\theta + \ln u - \ln P. \tag{27}$$

Now taking conditional expectations based on the information set Ω_I in (10), yields the following conditional expectations of the informed investor

$$E\left[r|\Omega_I\right] = \ln\theta + E\left[\ln u|\Omega_I\right] - \ln P = \ln\theta + \beta\ln f_t - \ln P, \tag{28}$$

and

$$Var\left[r|\Omega_I\right] = Var\left[\ln u|\Omega_I\right] = \beta\beta' + \Sigma_\eta, \tag{29}$$

where

$$E\left[\ln u|\Omega_I\right] = \beta E\left[\ln f_{t+1}|\Omega_I\right] + E\left[\ln\eta_{t+1}\left|\Omega_I\right|\right] = \beta\ln f_t,$$

$$Var\left[\ln u|\Omega_I\right] = \beta Var\left[\ln f_{t+1}|\Omega_I\right]\beta' + Var\left[\ln\eta_{t+1}\left|\Omega_I\right|\right] = \beta\beta' + I_N.$$

Substituting (28) and (29) into the optimal solution of the informed investor's portfolio problem in (9) with $k = I$, gives

$$\alpha_I^* = \frac{\ln\theta + \beta\ln f - \ln P - r_f + \frac{1}{2}\left(\beta\beta' + \Sigma_\eta\right)}{\gamma\left(\beta\beta' + \Sigma_\eta\right)}.$$

A.3 Uninformed Investor Conditional Expectations

The conditional expectations of (27) based on the information set Ω_U in (12), are

$$E[r|\Omega_U] = E[\ln v|\Omega_U] - \ln P,$$

and

$$Var[r|\Omega_U] = Var[\ln v|\Omega_U].$$

The solution to the uninformed investor's optimization problem given in (9) with $k = U$, is reexpressed using the expressions for the conditional expectations given above

$$\alpha_U^* = \frac{(E[\ln v|\Omega_U] - \ln P) - r_f + \frac{1}{2}Var[\ln v|\Omega_U]}{\gamma Var[\ln v|\Omega_U]}.$$

Unlike the conditional expectations of the informed investor, calculation of the uninformed investor's conditional expectations are more involved as it is now necessary to form expectations of θ, as well as ϵ. To achieve this, consider the market equilibrium condition where the supply of the risky asset (X_T) equals demand by the market participants

$$X_T = \mu_I \alpha_I^* W_1 + \mu_U \alpha_U^* W_1 + \ln \epsilon,$$

where μ_I and μ_U are respectively the number of informed and uninformed investors. Using the expressions of α_I^* and α_U^* derived above

$$\begin{aligned} X_T &= \mu_I \frac{\ln\theta + \beta \ln f - \ln P - r_f + \frac{1}{2}(\beta\beta' + \Sigma_\eta)}{\gamma(\beta\beta' + \Sigma_\eta)} W_1 \\ &\quad + \mu_U \frac{E[\ln v|\Omega_U] - \ln P - r_f + \frac{1}{2}Var[\ln v|\Omega_U]}{\gamma Var[\ln v|\Omega_U]} W_1 + \ln\epsilon. \end{aligned} \tag{30}$$

Rearranging this equation in terms of those variables not contained in the information set of the uninformed investor as a function of $\ln P$, gives

$$\begin{aligned} S(\ln P) &= \ln\theta + \frac{\gamma(\beta\beta' + \Sigma_\eta)}{\mu_I W_1} \ln\epsilon \\ &= \frac{\gamma(\beta\beta' + \Sigma_\eta)}{\mu_I W_1} \Bigg[X_T - \mu_U \frac{E[\ln v|\Omega_U] - \ln P - r_f + \frac{1}{2}Var[\ln v|\Omega_U]}{\gamma Var[\ln v|\Omega_U]} W_1 \\ &\qquad + \mu_I \frac{-\beta \ln f + \ln P + r_f - \frac{1}{2}(\beta\beta' + \Sigma_\eta)}{\gamma(\beta\beta' + \Sigma_\eta)} W_1 \Bigg]. \end{aligned}$$

To ensure that uninformed investor's expectations conditional on equilibrium prices are consistent with that conditional on the information revealed by $S(P)$, the following "belief consistency" conditions are imposed

$$
\begin{aligned}
E\left[\ln v|\Omega_U\right] &= E\left[\ln v|S\left(\ln P\right)\right] \\
&= E\left[\ln v\right] + Cov\left[\ln v, S\left(\ln P\right)\right]\left(Var\left[S\left(\ln P\right)\right]\right)^{-1} \\
&\quad \times\left(S\left(\ln P\right) - E\left[S\left(\ln P\right)\right]\right) \\
&= \overline{\theta} + \Sigma_\theta\left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1}\right)^2\left(\beta\beta' + \Sigma_\eta\right)\Sigma_\epsilon\left(\beta\beta' + \Sigma_\eta\right)'\right]^{-1} \\
&\quad \times\left[\ln\theta + \frac{\gamma\left(\beta\beta' + \Sigma_\eta\right)}{\mu_I W_1}\ln\epsilon - \overline{\theta}\right],
\end{aligned}
\tag{31}
$$

$$
\begin{aligned}
Var\left[\ln v|\Omega_U\right] &= Var\left[\ln v|S\left(\ln P\right)\right] \\
&= Var\left[\ln v\right] - Cov\left[\ln v, S\left(\ln P\right)\right]\left(Var\left[S\left(\ln P\right)\right]\right)^{-1} \\
&\quad \times\left(Cov\left[\ln v, S\left(\ln P\right)\right]\right)' \\
&= \left[\Sigma_\theta + \Sigma_u\right] \\
&\quad -\Sigma_\theta\left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1}\right)^2\left(\beta\beta' + \Sigma_\eta\right)\Sigma_\epsilon\left(\beta\beta' + \Sigma_\eta\right)'\right]^{-1}\Sigma'_\theta,
\end{aligned}
$$

which represent the required conditional expectations of the uninformed investor.

A.4 Excess Returns Equation

The derivations of the model given above are based on the return on the asset R, which is unknown as it is a function of the asset's liquidation value v, which by definition is unknown. To derive an expression of the observed or realized excess return on the asset, the following steps are adopted. Substitute the conditional expectations in (31) into the market-clearing condition in (30), and rearrange to generate an expression of the current price in terms of the factors

$$
\ln P = \varphi + \xi\ln\theta + \chi\ln\epsilon + \delta\ln f, \tag{32}
$$

where

$$\begin{aligned}
\varphi &= M_0 + M_1 \left[I - \Sigma_\theta \left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1} \right)^2 (\beta\beta' + \Sigma_\eta) \Sigma_\epsilon (\beta\beta' + \Sigma_\eta)' \right]^{-1} \right] \overline{\theta}, \\
\xi &= \left[M_1 \Sigma_\theta \left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1} \right)^2 (\beta\beta' + \Sigma_\eta) \Sigma_\epsilon (\beta\beta' + \Sigma_\eta)' \right]^{-1} + M_2 \right], \\
\chi &= \left[M_1 \Sigma_\theta \left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1} \right)^2 (\beta\beta' + \Sigma_\eta) \Sigma_\epsilon (\beta\beta' + \Sigma_\eta)' \right]^{-1} \frac{\gamma (\beta\beta' + \Sigma_\eta)}{\mu_I W_1} + M_3 \right], \\
\delta &= M_4.
\end{aligned}$$

and

$$\begin{aligned}
M_0 &= -\Psi^{-1} \left[X_T + \frac{\mu_U}{\gamma} W_1 \left(r_f Var [\ln v | \ln P]^{-1} - \frac{1}{2} \right) \right. \\
&\quad \left. + \frac{\mu_I}{\gamma} W_1 \left(r_f (\beta\beta' + \Sigma_\eta)^{-1} - \frac{1}{2} \right) \right], \\
M_1 &= \Psi^{-1} \frac{\mu_U}{\gamma} W_1 Var [\ln v | \ln P]^{-1}, \\
M_2 &= \Psi^{-1} \frac{\mu_I}{\gamma} W_1 (\beta\beta' + \Sigma_\eta)^{-1}, \\
M_3 &= \Psi^{-1}, \\
M_4 &= \Psi^{-1} \frac{\mu_I}{\gamma} W_1 (\beta\beta' + \Sigma_\eta)^{-1} \beta, \\
\Psi &= \frac{\mu_I}{\gamma} W_1 (\beta\beta' + \Sigma_\eta)^{-1} + \frac{\mu_U}{\gamma} W_1 Var [\ln v | \ln P]^{-1}.
\end{aligned}$$

Now let P_{+1} be the realized price in the next period, formally the realization from the distribution of v, be given by

$$\ln P_{+1} = E [\ln v | \Omega_U] + \ln \zeta,$$

where $\ln \zeta$ is the expectations error which under the assumption of rational expectations is assumed to be *iid*. Then the realized return is

$$\begin{aligned}
\ln P_2 - \ln P &= E [\ln v | \Omega_U] + \ln \zeta - \ln P \\
&= \overline{\theta} + \Sigma_\theta \left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1} \right)^2 (\beta\beta' + \Sigma_\eta) \Sigma_\epsilon (\beta\beta' + \Sigma_\eta)' \right]^{-1} \\
&\quad \times \left[\ln \theta + \frac{\gamma (\beta\beta' + \Sigma_\eta)}{\mu_I W_1} \ln \epsilon - \overline{\theta} \right] + \ln \zeta - \varphi - \xi \ln \theta - \chi \ln \epsilon - \delta \ln f,
\end{aligned}$$

where the last step is based on using the expression for $E [\ln v | \Omega_U]$ in (31) and the expression for $\ln P$ in (32). Or, in terms of excess returns, $\ln P_{+1} - \ln P - r_f$, the factor equation becomes

$$y = C_0 + C_1 \ln \theta + C_2 \ln \epsilon + C_3 \ln f + C_4 \ln \zeta,$$

where

$$\begin{aligned}
C_0 &= \left\{ I - \Sigma_\theta \left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1} \right)^2 (\beta\beta' + \Sigma_\eta) \Sigma_\epsilon (\beta\beta' + \Sigma_\eta)' \right]^{-1} \right\} \overline{\theta} - \varphi - r_f \\
C_1 &= \Sigma_\theta \left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1} \right)^2 (\beta\beta' + \Sigma_\eta) \Sigma_\epsilon (\beta\beta' + \Sigma_\eta)' \right]^{-1} - \xi \\
C_2 &= \Sigma_\theta \left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1} \right)^2 (\beta\beta' + \Sigma_\eta) \Sigma_\epsilon (\beta\beta' + \Sigma_\eta)' \right]^{-1} \frac{\gamma (\beta\beta' + \Sigma_\eta)}{\mu_I W_1} - \gamma \\
C_3 &= -\delta \\
C_4 &= I_N.
\end{aligned}$$

This is the most general factor representation of excess returns during financial crises as it includes both "normal" and contagious transmission mechanisms. In a non-crisis period where there is no contagion, this is represented by $\beta\beta'$ and Σ_η being diagonal matrices.

B Data Sources and Definitions

Table B1: Data mnemonics, definitions and sources.

Country	Asset	Description	Code[1]
Argentina	Stocks	MERVAL Index	ARGMERV(PI) (D)
	Bonds	1. 11% coupon (issued in USD) Issued October 9, 1996. Matures October 9, 2006	007022140 (B)
		2. 11.375% coupon (issued in USD) Issued March 15, 2000. Matures March 15, 2010	010909899 (B)
	Currency	Argentinian peso per USD	ARGPES$ (D)
Brazil	Stock	BOVESPA Index	BRBOVES(PI) (D)
	Bond	1. 9.375% coupon (issued in USD) Issued March 31, 1998. Matures April 7, 2008	105756AG5 (B)
		2. 10.25% coupon (issued in USD) Issued June 17, 2003. Matures June 17, 2013	017062875 (B)
	Currency	Brazilian real per USD	BRACRU$ (D)
Canada	Stock	S&P/TSX Index	TTOCOMP(PI) (D)
	Bond	Corporate BBB (issued in Canadian dollars)	C28810Y (B)
	Currency	Canadian dollar per USD	CNDOLL$ (D)
Mexico	Stock	BOLSA Index	MXIPC35(PI) (D)
	Bond	1. 8.625% coupon (issued in USD) Issued March 5, 1998. Matures March 12, 2008	8534713 (B)
		2. 6.375% coupon (issued in USD) Issued January 16, 2003. Matures January 16, 2013	016113468 (B)
	Currency	Mexican peso per USD	MEXPES$ (D)

[1]. (B) denotes Bloomberg, (D) denotes Datastream.

Table B1 continued: Data mnemonics, definitions and sources.

Country	Asset	Description	Code[1]
Russia	Stocks	RSF EE MT Index	RSMTIND(PI) (D)
	Bonds	1. 3% coupon (issued in USD) Issued May 14, 1993. Matures May 14 2008.	TT3182314 (B)
		2. 3% coupon (issued in USD) Issued May 14, 1996. Matures May 14, 2011	008170363 (B)
	Currency	Russian rouble per USD	CISRUB$ (D)
U.S.	Stocks	Dow Jones Index	DJINDUS(PI) (D)
	Bonds	Corporate BBB bond rate	C00910Y (B)
Australia	Stocks	Australian All Ordinaries Index	AS30 Index (B)
	Bonds	Corporate BBB bond rate (issued in AUD)	AC40 Index (B)
	Currency	Australian dollar per USD	USDAUSP (D)
Germany	Stocks	German HDAX Index	HDAX Index (B)
	Bonds	Corporate BBB bond rate (issued in Euro)	ER46 Index (B)
	Currency	Euro per USD	EURO.US (D)
Japan	Stocks	TOPIX Index	TPX Index (B)
	Bonds	Corpoate BBB bond rate (issued in yen)	JC40 Index (B)
	Currency	Japanese yen per USD	JPYN1UD (D)
U.K.	Stocks	UK FTSE ALL Share Index	ASX Index (B)
	Bonds	Corporate BBB bond rate (issued in pounds)	UR47 Index (B)
	Currency	British pound per USD	BRITPUS (D)

1. (B) denotes Bloomberg, (D) denotes Datastream.

C Additional Variance Decompositions

Table C1: Variance decompositions, Russian/LTCM crisis: percentage of total. Also see footnote 8 for an explanation of the n.a. in the results for the U.S.

Market	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
				Stock Markets			
Noncontagion	Common 1	1.12	0.20	0.03	1.02	0.18	13.79
	Common 2	10.91	0.36	13.76	5.57	0.15	15.27
	Emerging	1.24	0.27	n.a.	n.a.	0.19	n.a.
	Market (stock)	16.03	0.23	5.12	10.60	52.75	7.21
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country	2.37	0.05	15.23	0.43	19.92	n.a.
	Idio.	24.34	0.26	24.40	46.75	0.93	n.a.
Contagion	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	1.16	37.65	11.48	9.16	18.82	0.32
	Country (Russia)	38.05	2.57	6.92	13.48	n.a.	40.97
	Idio. (Rus. bond)	4.35	51.95	1.49	2.36	6.32	0.90
	Idio. (U.S. bond)	0.42	6.46	21.57	10.65	0.74	21.57
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		9.79	15.78	2.83	11.18	140.12	2.09
				Bond Markets			
Noncontagion	Common 1	0.00	0.02	0.27	0.02	0.48	0.22
	Common 2	3.79	5.14	5.81	7.12	3.10	5.55
	Emerging	0.34	n.a.	n.a.	n.a.	0.78	n.a.
	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	6.66	2.86	24.24	4.12	23.82	29.06
	Country	1.29	1.26	12.84	2.22	47.14	n.a.
	Idio.	56.91	1.38	10.92	0.86	20.13	33.79
Contagion	Market (stock)	12.11	26.68	4.92	27.57	4.50	5.85
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country (Russia)	0.44	26.90	1.00	16.24	n.a.	22.88
	Idio. (Rus. bond)	13.62	15.67	8.36	17.01	n.a.	2.65
	Idio. (U.S. bond)	4.85	20.09	31.64	24.85	0.05	n.a.
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		11.29	30.52	1.21	5.74	369.17	0.33

Table C2: Variance decompositions, Brazilian crisis: percentage of total. Also see footnote 8 for an explanation of the n.a. in the results for the U.S.

Market	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
				Stock Markets			
Noncontagion	Common 1	4.00	0.82	13.54	2.46	0.01	40.02
	Common 2	7.26	8.20	7.95	8.01	0.52	0.54
	Emerging	1.19	4.27	n.a.	n.a.	0.22	n.a.
	Market (stock)	1.23	1.49	0.13	2.40	70.40	3.54
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country	4.74	74.46	19.77	14.09	0.89	n.a.
	Idio.	19.32	3.73	43.70	52.58	0.77	n.a.
Contagion	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	0.73	0.07	5.61	6.16	22.48	21.21
	Country (Brazil)	51.51	n.a.	1.43	10.50	0.13	2.46
	Idio. (Brz. bond)	10.02	6.97	7.88	3.81	4.59	32.23
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		7.45	25.52	1.33	5.78	17.84	1.62
				Bond Markets			
Noncontagion	Common 1	3.78	2.17	8.46	7.55	0.02	0.95
	Common 2	1.35	0.97	7.37	3.19	0.04	0.08
	Emerging	0.46	n.a.	n.a.	n.a.	0.01	n.a.
	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	0.48	13.74	4.12	2.26	34.23	3.24
	Country	1.01	77.54	42.44	0.14	0.00	0.00
	Idio.	78.18	0.85	25.34	4.38	0.62	88.15
Contagion	Market (stock)	0.06	4.73	0.41	2.39	25.37	0.31
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country (Brazil)	14.57	n.a.	7.12	77.52	5.10	4.27
	Idio. (Brz. bond)	0.10	n.a.	4.75	2.57	34.62	3.00
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		9.40	32.17	0.72	5.03	192.80	0.09

Table C3: Variance decompositions, dot-com crisis: percentage of total. Also see footnote 8 for an explanation of the n.a. in the results for the U.S.

Market	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
				Stock Markets			
Noncontagion	Common 1	0.01	17.60	0.31	0.01	30.89	25.67
	Common 2	1.11	39.86	36.55	0.28	18.21	69.87
	Emerging	0.03	17.73	n.a.	n.a.	48.69	n.a.
	Market (stock)	4.81	6.59	1.57	10.32	0.39	0.71
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country	0.00	1.42	14.78	0.02	0.10	0.04
	Idio.	1.42	0.25	46.02	1.21	1.47	3.66
Contagion	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	0.07	4.30	0.02	75.71	0.03	0.05
	Country (U.S.)	86.06	1.06	0.03	2.05	0.17	n.a.
	Idio. (U.S. stock)	6.50	11.19	0.72	10.40	0.04	n.a.
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		2.62	3.69	2.92	7.09	11.18	2.15
				Bond Markets			
Noncontagion	Common 1	0.01	0.02	0.43	0.31	0.53	0.00
	Common 2	3.41	4.42	8.37	40.09	2.92	0.04
	Emerging	0.08	n.a.	n.a.	n.a.	0.60	n.a.
	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	0.63	0.88	0.19	9.13	0.22	0.05
	Country	93.64	5.15	60.89	13.84	0.05	0.02
	Idio.	0.58	0.01	29.31	7.42	95.47	98.91
Contagion	Market (stock)	1.04	35.66	0.30	17.03	0.13	0.35
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country (U.S.)	0.27	0.77	0.45	4.23	0.01	n.a.
	Idio. (U.S. stock)	0.35	53.08	0.07	7.96	0.07	0.64
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		1.88	1.49	0.52	0.60	14.95	0.07

Table C4: Variance decompositions, Argentinian crisis: percentage of total. Also see footnote 8 for an explanation of the n.a. in the results for the U.S.

Market	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
				Stock Markets			
Noncontagion	Common 1	0.55	0.00	1.02	0.05	0.13	19.05
	Common 2	23.59	0.24	36.36	13.68	10.36	73.16
	Emerging	1.83	0.12	n.a.	n.a.	12.01	n.a.
	Market (stock)	1.49	37.58	0.48	0.01	0.01	0.90
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country	29.27	0.04	11.64	0.69	11.35	n.a.
	Idio.	38.68	0.10	43.47	83.67	66.11	n.a.
Contagion	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	4.58	18.70	0.98	0.28	0.00	0.65
	Country (Arg.)	n.a.	0.00	4.30	1.55	0.01	6.14
	Idio. (Arg. bond)	0.01	43.23	1.76	0.08	0.01	0.11
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		9.07	5.42	1.28	1.80	4.16	1.73
				Bond Markets			
Noncontagion	Common 1	5.64	18.63	7.08	13.94	1.52	0.00
	Common 2	15.87	47.43	11.14	45.42	3.14	0.00
	Emerging	1.95	n.a.	n.a.	n.a.	0.00	n.a.
	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	10.57	0.01	1.52	0.05	0.01	64.79
	Country	62.00	10.16	63.16	10.88	1.52	n.a.
	Idio.	0.00	21.58	0.60	18.08	93.69	0.62
Contagion	Market (stock)	3.97	0.53	5.12	5.14	0.01	13.43
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country (Arg.)	n.a.	0.04	2.74	2.82	0.10	17.59
	Idio. (Arg. bond)	n.a.	1.63	8.66	3.67	0.00	3.57
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		40.77	6.77	0.41	0.36	1.58	0.12

Table C5: Variance decompositions, U.S. subprime crisis: percentage of total. Also see footnote 8 for an explanation of the n.a. in the results for the U.S.

Market	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
				Stock Markets			
Noncontagion	Common 1	3.10	9.25	0.20	1.57	12.62	4.08
	Common 2	15.58	10.54	7.88	4.05	6.65	8.05
	Emerging	1.95	9.34	n.a.	n.a.	7.59	n.a.
	Market (stock)	11.43	19.64	23.13	14.70	8.59	65.69
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country	4.53	0.89	9.52	0.23	0.06	n.a.
	Idio.	35.20	7.72	14.31	34.96	60.63	8.57
Contagion	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	10.14	15.77	17.34	17.33	0.67	7.94
	Idio. (U.S. stock)	5.31	7.74	8.11	7.28	1.18	n.a.
	Idio. (U.S. bond)	12.75	19.13	19.52	19.88	2.01	5.68
Total		100	100	100	100	100	100
Variance		4.05	9.22	3.33	4.72	2.83	2.77
				Bond Markets			
Noncontagion	Common 1	0.00	0.19	0.60	0.12	0.35	0.34
	Common 2	0.06	56.19	11.28	53.81	1.79	4.96
	Emerging	0.01	n.a.	n.a.	n.a.	0.49	n.a.
	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	4.62	0.89	11.04	2.39	42.32	0.16
	Country	0.02	25.06	25.28	22.31	12.32	n.a.
	Idio.	0.97	3.50	27.11	0.22	12.57	2.34
Contagion	Market (stock)	4.64	9.94	5.96	14.40	0.03	87.98
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Idio. (U.S. stock)	84.90	1.75	3.56	2.72	0.03	4.21
	Idio. (U.S. bond)	4.77	2.47	15.19	4.02	30.11	n.a.
Total		100	100	100	100	100	100
Variance		13.18	1.19	0.78	0.47	0.89	0.13

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