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PROEFSCHRIFT

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To my precious family Carey, Alexei, and Kristen;
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Brenda González-Hermosillo

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Chapter 1: Introduction [1]

1 MOTIVATION

Market participants, policymakers, and academics often point to the role of contagion in recent financial crises—witness terminology such as the "Asian flu." Typically, however, most references to contagion are made rather loosely, often failing to distinguish between normal asset-market linkages and the extreme co-movements that may exist only during periods of stress. In the empirical literature, existing research focuses primarily on the presence of contagion, while measuring the extent of contagion has received little attention. Furthermore, most studies focus on a single asset class across countries—often via some form of correlation analysis—despite our expectation that different asset markets, domestic or otherwise, are linked by a pool of global investors.

The policy interest in this area is clear as contagion can play a key role in spreading globally what would otherwise be idiosyncratic episodes of financial stress, potentially leading to systemic financial crises. This is particularly the case as financial markets across the globe are increasingly becoming more integrated, as they have become rapidly more intermingled in complex ways. Indeed, potentially systemic financial crises can be so costly that policy makers often intervene by bailing-out key financial institutions or relaxing monetary policy when there is a fear that contagion may spread financial crises.

This thesis will examine the role of contagion in transmitting shocks across markets. The thesis begins by reviewing the empirical literature on contagion. Contagion is then examined in individual asset classes, such as bonds and equities, and jointly. In particular, recent crises events thought to have been highly contagious are examined, and a methodology to address the current gaps in the literature is proposed. The thesis analyzes a number of financial crises during the past decade, encompassing daily financial data for a representative set of developing countries and mature economies. In contrast to a large part

[1] The views presented in this thesis are those of the author and do not necessarily represent those of the IMF or IMF policy.

of the earlier empirical literature on contagion that has traditionally seen developing countries as the key, and often the only, source of contagion, here emerging markets and mature economies are modeled jointly. In an increasingly integrated global financial system, and against the torrid pace of innovation in financial markets as well as the rapid introduction of financial sector reforms in most developing countries, examining separately financial markets in emerging and mature economies no longer makes sense. One possible conduit for contagion that will be also examined is shifts in international investors' risk appetite.

There has been a number of episodes of financial crises during the past decade. However, the period between the start of the Argentinean crisis in 2001 and the U.S. subprime and liquidity crisis in mid-2007 was characterized by fairly infrequent episodes of financial stress which were largely contained within national boundaries. Some bouts of instability were evident during the spring and summer of 2006, when Iceland and Turkey faced financial stress, and in late-February 2007 when China's Shanghai stock exchange experienced a significant correction. However, these recent episodes are generally viewed as seemingly idiosyncratic and relatively innocuous from the perspective of contagion in global financial markets. The vast academic literature that was sparked by the key episodes of financial crises in Latin America in 1994-1995, the Asian crisis in 1996, and the Russian crisis in 1998, had been fairly subdued in recent years as no major regional or global crisis has been evident in recent years. That is, until mid-2007 when a financial crises of global proportions re-appeared, for the first time since late-1998. This latest financial crisis was sparked by the decline in the U.S. housing market, which led to a certain segment of the U.S. mortgage market deemed to be particularly risky because of the characteristics of the borrowers (e.g., self-employed, with limited income verification, etc.), the "subprime" mortgages, defaulting in large numbers. What started as a seemingly idiosyncratic and market-specific crisis driven by problems in the subprime mortgage market in the United States during the spring and early summer of 2007, quickly led to defaults of financial institutions in other countries such as Germany, Canada, and the United Kingdom. A number of systemically important financial institutions became unsound and had to be recapitalized by sovereign wealth funds and even rescued by governments, including in the

United States. The stress in financial markets was also felt in various measures of volatility and illiquidity in a number of global financial markets. At the time of writing this thesis, this crisis was far from over.

These recent events bring a renewed urgency for the need to understand the financial crises of the past, so that we can anticipate the crises of the future and perhaps be able to act pre-emptively to avoid the recurrence of systemic shocks sparked by contagion. In the past, these type of events have often been associated with bail-out policies or liquidity injections which have introduced moral hazard in the system (e.g., "too-large to fail", excess monetary liquidity, etc.). Possibly, these reactive policies have themselves introduced the seeds for future crises. It is in this setting that the research agenda in this thesis is carried out.

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). These examples include 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, where there now exist three broad classes of models. The first generation models emphasize the role of macroeconomic variables in causing currency crises when countries adopted fixed exchange rates (Flood and Marion (1999)); the second generation models focus on the role of speculative attacks; while the third generation of models focus on institutional imbalances and information asymmetries (Allen and Gale (2000), Kaminsky and Reinhart (2003); Kodres and Pritsker (2002), Yuan (2005), and Pavlova and Rigobon (2007)).

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 various financial markets. These links are emphasized in third generation crisis models, where channels over and above the market fundamental mechanisms that link countries and asset markets during noncrisis periods appear during a crisis. These additional linkages are broadly known as contagion (see Dornbusch, Park and Claessens (2000); Pericoli and Sbracia (2003), and Dungey, Fry, González-Hermosillo and Martin (2005b), for surveys of this literature).

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. Some previous attempts are by van Rijikghem and Weder (2001) who focus on banking channels; Glick and Rose (1999) who look at regional linkages; and Boyer, Kumagai and Yuan (2006) who emphasize 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.

The strategy to be followed in this thesis is to adopt a broader approach and focus on the factor structures of the transmission mechanisms linking international asset markets. In a series of papers, the thesis develops an empirical methodology to examine financial market spillovers and quantifying the contribution of contagion during various critical episodes. As well, the role of international investors' risk appetite as a propagating mechanism for contagion is examined explicitly. Some of the key questions to be addressed include the following: What are the channels through which recent crises episodes have (or not) been transmitted across markets and across borders? Why have some episodes been systemic and contagious, while others have not?

The thesis is organized in five separate chapters that analyze different aspects of this issue, and are discussed in more detail below. The first three chapters of the thesis constitute work recently published in refereed journals or academic books.[2] This research agenda is also reviewed in González-Hermosillo (2007a).

2 OVERVIEW OF THE CHAPTERS

Chapter 2 begins by providing a critical review of the various approaches in the current empirical literature on contagion, aiming to reconcile seemingly unrelated approaches which have been hereto proposed to examine financial contagion (Dungey, Fry, González-Hermosillo and Martin (2005b)). Chapter 3 proposes a methodology based on latent factor models to analyze contagion and applies it to international bond markets across emerging markets and mature economies (Dungey, Fry, González-Hermosillo and Martin (2005a), (2006)). It finds that contagion in global bond markets was evident during the fall of 1998, when the Russian crisis and the hedge fund Long-Term Capital Management (LTCM) nearly collapsed.

In Chapter 4, a similar exercise is undertaken for international equity markets. The key result of this chapter is that contagion is also significant and widespread to a variety of international equity markets during the LTCM crisis, with the effects of contagion being strongest on the industrial markets and the geographically close Latin American markets. The contagion transmission mechanisms emanating from the Russian equity market tended to be more selective during the Russian crisis, but nonetheless still impacted upon both emerging and industrial equity markets. Moreover, rather than the Russian crisis being seen as an emerging market phenomenon, as suggested by the Committee on the Global Financial System (1999, pp.7-8), contagion from Russia was found to be more statistically significant in industrial countries than in emerging markets.

The results from Chapters 3 and 4 suggest that it would be informative to construct a more general model of asset markets, combining both bonds and equities to test the importance of contagious transmission mechanisms between markets and across

[2] Versions of Chapters 2, 3 and 4 have been recently published in refereed Economics journals or books; see Dungey, M., R. Fry, B. González-Hermosillo and V.L. Martin (2005a, 2005b, 2006, 2007a). Chapters 2, 3, 4 and 5 have been partly joint work with Mardi Dungey (Cambridge University), Renee Fry (Canberra University), Vance Martin and T. Tang (Melbourne University).

international borders. Thus, Chapter 5 focuses on further refining the sources of contagion in a multi-country and multi-asset model and applying the model to recent crises. In this chapter, the sample is extended to include the 2007 U.S. subprime mortgage crisis. The approach is to examine daily data from early in 1998 through mid-2007 in bond *and* equity markets in a sample of emerging markets *and* mature economies jointly. A richer set of linkages allows identification of three channels of contagion, dubbed the market channel (where the shock originates throughout the world in a specific class of asset markets), the country channel (where the shock originates in a particular country which transmits it to the asset markets of other countries), and the idiosyncratic channel (where the shock originates in a specific asset market of a single country). Each of these channels played a significant role in recent crises during the period 1998-2007. Based on the estimated amount of contagion to international bond and equity markets, the Russian/LTCM crisis in 1998 was the most systemic episode. Of the subsequent crises examined in this chapter, the role of contagion was smaller in the Brazilian crisis in early 1999, the so-called dot-com crisis in 2000, and the Argentinean crisis in 2001-04. The results suggest that the 2007 crisis was also characterized by rampant global contagion, and that the transmission of contagion generally runs from credit markets to equity markets. Both episodes of contagious effects (the fall of 1998 and the summer of 2007) occurred largely through bond markets and both of them involved stress in the financial markets of a mature economy. This observation raises the possibility that the risk appetite of international investors, who are key players in major global financial centers, may play a role in the transmission of shocks across markets and countries.

Indeed, there may be several mechanisms for contagion whereby channels are established only during periods of stress that are over and above the market fundamental mechanisms, or spillovers, that link countries and asset markets during noncrisis periods. One such mechanism may be the presence of common international investors who react to a given shock by rebalancing their portfolios globally in assets and markets that would be otherwise seemingly unrelated. As investors become less willing to assume risk, they require a higher compensation for bearing such risk. This re-pricing of risk can effect the prices of other risky assets.

Observers often refer to this mechanism as investors' increased risk aversion or reduced risk appetite. However, these two concepts are conceptually different. Risk aversion measures the subjective attitude of investors with regard to uncertainty. Since the degree of investors' risk aversion reflects entrenched preferences, it is usually assumed to be constant in asset pricing models. In contrast, the notion of investors' risk appetite is broader as it encompasses the notion of risk aversion, but it is also influenced by the amount of uncertainty about the fundamental factors that drive asset prices. Thus, the risk premia embedded in asset prices are influenced by both risk aversion and the riskiness of the asset in question. One potential venue for shifts in investors' risk appetite is changes in global financial market conditions, a venue which is investigated empirically in this chapter. Gauging the degree of investors' risk appetite is relevant from a global financial stability perspective as past episodes of brisk changes in risk premia, variations in market liquidity, and sharp movements in asset prices have been often associated with changes in investors' risk appetite.

Chapter 6, therefore, quantifies the relative importance of the potential determinants of spreads for emerging markets' sovereign bonds and mature markets' corporate bonds from 1998 through 2007, encompassing several episodes of financial market distress. A structural vector autoregression model is developed to analyze the dynamics of bond spreads among a sample of mature and developing countries during periods of financial stress in the last decade. The model identifies and quantifies the contribution on bond spreads from global market conditions (including funding liquidity, market liquidity, as well as credit and volatility risks), contagion effects, and idiosyncratic factors. While idiosyncratic factors explain a large amount of the changes in bond spreads over the sample, global market risk factors are fundamental driving forces during periods of stress. It is found that the relative importance of the different risk factors changes substantially depending on the crisis episode. One key result is that contagion from emerging markets becomes small or non-existent when global financial market risks are explicitly taken into account.

Lastly, Chapter 7 concludes by drawing some inferences from the research of this thesis and suggesting areas of future research. The main results are as follows. First, there is evidence that contagion was significant during the Russian/LTCM crisis in the fall of

1998 and more recently in mid-2007 as a result of the U.S. subprime mortgage and liquidity squeeze. Second, international investors' risk appetite (conditioned by global financial market conditions) appear to be a significant factor in all the crisis episodes of the past decade. Third, once investors' risk appetite are explicitly considered, contagion from emerging markets is very small or essentially not existent. This result is at odds with some of the results in the empirical literature of contagion. The literature on contagion examines the connections that exist over and above the market fundamental mechanisms that link countries and asset markets during noncrisis periods, which only appear during a crisis. However, the empirical literature on contagion does not identify exactly how these additional channels are formed during periods of stress. One potential channel of contagion is that shocks in any given market may impact international investors' risk appetite through their rebalancing of portfolios or simply by a revised set of expectations. The results in Chapter 6 suggest that contagion essentially dissappears when identifying the actual channels of spillovers. Fourth, although emerging markets have been historically more volatile than mature economies, global financial market risk factors are important for all countries. Finally, this type of analysis should be helpful in elaborating a framework to assess global financial stability, an area for future research, as investors' risk appetite may play an important role in increasingly integrated global financial markets.

Chapter 2: Review of the Empirical Literature [1]

1 Introduction

There is now a reasonably large body of empirical work testing for the existence of contagion during financial crises. A range of different methodologies are in use, making it difficult to assess the evidence for and against contagion, and particularly its significance in transmitting crises between countries. The origins of current empirical studies of contagion stem from Sharpe (1964) and Grubel and Fadner (1971), and more recently from King and Wadhwani (1990), Engle, Ito and Lin (1990) and Bekaert and Hodrick (1992).[2]

The aim of the present chapter is to provide a unifying framework to highlight the key similarities and differences between the various approaches. For an overview of the literature see Pericoli and Sbracia (2003) and Dornbusch, Park and Claessens (2000). The proposed framework is based on a latent factor structure which forms the basis of the models of Dungey and Martin (2001), Corsetti, Pericoli and Sbracia (2001, 2003) and Bekaert, Harvey and Ng (2005). This framework is used to compare directly the correlation analysis approach popularised in this literature by Forbes and Rigobon (2002), the VAR approach of Favero and Giavazzi (2002), the probability model of Eichengreen, Rose and Wyplosz (1995, 1996) and the co-exceedance approach of Bae, Karolyi and Stulz (2003).

An important outcome of this chapter is that differences in the definitions used to test for contagion are minor and under certain conditions are even equivalent. In particular, all definitions are interpreted as working from the same model, with the differences stemming from the amount of information used in the data to detect contagion. Interpreting the approaches in this way provides a natural ordering of models across the information spectrum with some models representing full information methods and, as discussed below, others representing partial information methods.

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[1] This chapter is published in Dungey, M., R. Fry, B. González-Hermosillo and V. Martin (2005b), "Empirical Modeling of Contagion: A Review of the Methodologies", *Quantitative Finance*, Vol. 5, No. 1, February.

[2] As this paper focuses on empirical models of contagion it does not discuss the corresponding theoretical literature and more generally the literature on financial crises. For examples of theoretical models of contagion see Allen and Gale (2000), Calvo and Mendoza (2000), Kyle and Xiong (2001), Chue (2002), Kiyotaki and Moore (2002) and Kodres and Pritsker (2002). The literature on financial crises is overviewed in Flood and Marion (1998).

The chapter proceeds as follows. In Section 2 a framework is developed to model the interdependence between asset returns in a non-crisis environment. This framework is augmented in Section 3 to give a model which includes an avenue for contagion during a crisis. The relationship between this model and the bivariate correlation tests for contagion of Forbes and Rigobon is discussed in Section 4. This section also includes a number of extensions of the original Forbes and Rigobon approach, as well as its relationship with the approaches of Favero and Giavazzi (2002), Eichengreen, Rose and Wyplosz (1995,1996) and Bae, Karolyi and Stulz (2003). An empirical example comparing the various contagion tests is contained in Section 5. The results show that the Forbes and Rigobon adjusted correlation test is a conservative test, whereas the contagion test of Favero and Giavazzi tends to reject the null of no contagion too easily. The remaining tests investigated yield results falling within these two extremes. Concluding comments are given in Section 6 together with a number of suggestions for future research that encompass both theoretical and empirical issues.

2 A Model of Interdependence

Before developing a model of contagion, a model of interdependence of asset markets during non-crisis periods is specified as a latent factor model of asset returns. The model has its origins in the factor models in finance based on Arbitrage Pricing Theory, where asset returns are determined by a set of common factors representing non-diversifiable risk and a set of idiosyncratic factors representing diversifiable risk (Sharpe (1964), Solnik (1974)). Similar latent factor models of contagion are used by Corsetti et al.(2003,2001), Dungey and Martin (2001), Dungey, Fry, González-Hermosillo and Martin (2005a, 2006, 2007a, 2007b), Forbes and Rigobon (2002) and Bekaert, Harvey and Ng (2005).

To simplify the analysis, the number of assets considered is three. Extending the model to N assets or asset classes is straightforward. Let the returns of three assets during a non-crisis period be defined as

$$\{x_{1,t}, x_{2,t}, x_{3,t}\} . \tag{2.1}$$

All returns are assumed to have zero means. The returns could be on currencies, or national equity markets, or a combination of currency and equity returns in a particular country or across countries.[3] The following trivariate factor model is assumed to summarize the dynamics of the three processes during a period of tranquility

$$x_{i,t} = \lambda_i w_t + \delta_i u_{i,t}, \qquad i = 1, 2, 3. \tag{2.2}$$

The variable w_t represents common shocks that impact upon all asset returns with loadings λ_i. These shocks could represent financial shocks arising from changes to the risk aversion of international investors, or changes in world endowments (c.f. Mahieu and Schotman (1994), Rigobon (2003b), Cizeau, Potters, Bouchard (2001)). In general, w_t represents market fundamentals which determine the average level of asset returns across international markets during "normal", that is, tranquil, times. This variable is commonly referred to as a world factor, which may or may not be observed.[4] For expositional purposes, the world factor is assumed to be a latent stochastic process with zero mean and unit variance

$$w_t \sim (0, 1). \tag{2.3}$$

The properties of this factor are extended below to capture richer dynamics including both autocorrelation and time-varying volatility. The terms $u_{i,t}$ in equation (2.2) are idiosyncratic factors that are unique to a specific asset market. The contribution of idiosyncratic shocks to the volatility of asset returns is determined by the loadings $\delta_i > 0$. These factors are also assumed to be stochastic processes with zero mean and unit variance

$$u_{i,t} \sim (0, 1). \tag{2.4}$$

To complete the specification of the model, all factors are assumed to be independent

$$E[u_{i,t} u_{j,t}] = 0, \qquad \forall i \neq j \tag{2.5}$$

$$E[u_{i,t} w_t] = 0, \qquad \forall i. \tag{2.6}$$

To highlight the interrelationships amongst the three asset returns in (2.2) during a non-crisis period, the covariances are given by

$$E[x_{i,t} x_{j,t}] = \lambda_i \lambda_j, \qquad \forall i \neq j, \tag{2.7}$$

[3] See, for example, Hartmann, Stratemans and de Vries (2004), Bekaert, Harvey and Ng (2005) and Granger, Huang and Yang (2000), who model the interactions between asset classes.

[4] The model outlined here can be extended to allow for a richer set of factors, including observed fundamentals (Eichengreen, Rose and Wyplosz (1995,1996)), trade linkages (Glick and Rose (1999) and Pesaran and Pick (2003)), financial flows (Van Rijckeghem and Weder (2001)), geographical distance (Bayoumi, Fazio, Kumar and MacDonald (2003)) and Fama-French factors (Flood and Rose (2005)).

whilst the variances are

$$E\left[x_{i,t}^2\right] = \lambda_i^2 + \delta_i^2, \qquad \forall i. \tag{2.8}$$

Expression (2.7) shows that any dependence between asset returns is solely the result of the influence of common shocks arising from w_t, that simultaneously impact upon all markets. Setting

$$\lambda_1 = \lambda_2 = \lambda_3 = 0, \tag{2.9}$$

results in independent asset markets with all movements determined by the idiosyncratic shocks, $u_{i,t}$.[5] The identifying assumption used by Mahieu and Schotman (1994) in a similar problem is to set $\lambda_i \lambda_j$ to a constant value, L, for all $i \neq j$.

3 An Empirical Model of Contagion

In this chapter contagion is represented by the contemporaneous transmission of local shocks to another country or market after conditioning on common factors that exist over a non-crisis period, given by w_t in equation (2.2). This definition is consistent with that of Masson (1999a,b,c), who decomposes shocks to asset markets into common, spillovers that result from some identifiable channel, and contagion. As shown below this definition is also consistent with that of other approaches, such as Forbes and Rigobon (2002), where contagion is represented by an increase in correlation during periods of crisis.

The first model discussed is based on the factor structure developed by Dungey, Fry, González-Hermosillo and Martin (2005a, 2006, 2007a). Consider the case of contagion from country 1 to country 2. The factor model in (2.2) is now augmented as follows

$$\begin{aligned} y_{1,t} &= \lambda_1 w_t + \delta_1 u_{1,t} \\ y_{2,t} &= \lambda_2 w_t + \delta_2 u_{2,t} + \gamma u_{1,t} \\ y_{3,t} &= \lambda_3 w_t + \delta_3 u_{3,t} \end{aligned} \tag{2.10}$$

where the $x_{i,t}$ in (2.2) are replaced by $y_{i,t}$ to denote demeaned asset returns during the crisis period. The expression for $y_{2,t}$ now contains a contagious transmission channel as represented by local shocks from the asset market in country 1, with its impact mea-

[5] Of course, just two of the restrictions in (2.9) are sufficient for independence of asset markets.

sured by the parameter γ. The fundamental aim of all empirical models of contagion is to test the statistical significance of the parameter γ.[6]

3.1 Bivariate Testing

Bivariate tests of contagion focus on changes in the volatility of pairs of asset returns. From (2.10), the covariance between the asset returns of countries 1 and 2 during the crisis is

$$E\left[y_{1,t}y_{2,t}\right] = \lambda_1\lambda_2 + \gamma\delta_1. \tag{2.11}$$

Comparing this expression with the covariance for the non-crisis period in (2.7) shows that the change in the covariance between the two periods is

$$E\left[y_{1,t}y_{2,t}\right] - E\left[x_{1,t}x_{2,t}\right] = \gamma\delta_1. \tag{2.12}$$

If $\gamma > 0$, there is an increase in the covariance of asset returns during the crisis period as $\delta_1 > 0$ by assumption. This is usually the situation observed in crisis data. However, it is possible for $\gamma < 0$, in which case there is a reduction in the covariance. Both situations are valid as both represent evidence of contagion via the impact of shocks in (2.10). Hence a test of contagion is given by testing the restriction

$$\gamma = 0, \tag{2.13}$$

in the factor model in equation (2.10). This is the approach adopted Dungey, Fry, González-Hermosillo and Martin (2005a, 2006, 2007a, 2007b), which are also described in chapters 3, 4 and 5 of this thesis, and in Dungey and Martin (2004).[7]

An alternative way to construct a test of contagion is to use the volatility expression for $y_{2,t}$, which is given by

$$E\left[y_{2,t}^2\right] = \lambda_2^2 + \delta_2^2 + \gamma^2. \tag{2.14}$$

Comparing this expression with (2.8) shows that the change in volatility over the two periods is solely attributed to the presence of contagion

$$E\left[y_{2,t}^2\right] - E\left[x_{2,t}^2\right] = \gamma^2. \tag{2.15}$$

[6] An important assumption underlying (2.10) is that the common shock (w_t) and idiosyncratic shocks ($u_{i,t}$) have the same impact during the crisis period as they have during the non-crisis period. This assumption of no structural break is discussed in Section 3.3.

[7] Most concern seems to centre on the case where $\gamma > 0$, that is, where contagion is associated with a rise in volatility. The existing tests can be characterized as testing the null hypothesis of $\gamma = 0$ against either a two-sided alternative or a one-sided alternative.

Thus, the contagion test based on (2.15) can be interpreted as a test of whether there is an increase in volatility. Expression (2.14) suggests that a useful description of the volatility of $y_{2,t}$ is to decompose the effects of shocks into common, idiosyncratic and contagion respectively as follows

$$\frac{\lambda_2^2}{\lambda_2^2+\delta_2^2+\gamma^2}, \frac{\delta_2^2}{\lambda_2^2+\delta_2^2+\gamma^2}, \frac{\gamma^2}{\lambda_2^2+\delta_2^2+\gamma^2}. \tag{2.16}$$

This decomposition provides a descriptive measure of the relative strength of contagion in contributing to the volatility of returns during a crisis period. As before, the strength of contagion is determined by the parameter γ, which can be tested formally.

3.2 Multivariate Testing

The test for contagion presented so far is a test for contagion from country 1 to country 2. However, it is possible to test for contagion in many directions provided that there are sufficient moment conditions to identify the unknown parameters. For example, (2.10) can be extended as

$$\begin{aligned} y_{1,t} &= \lambda_1 w_t + \delta_1 u_{1,t} + \gamma_{1,2} u_{2,t} + \gamma_{1,3} u_{3,t} \\ y_{2,t} &= \lambda_2 w_t + \delta_2 u_{2,t} + \gamma_{2,1} u_{1,t} + \gamma_{2,3} u_{3,t} \\ y_{3,t} &= \lambda_3 w_t + \delta_3 u_{3,t} + \gamma_{3,1} u_{1,t} + \gamma_{3,2} u_{2,t}, \end{aligned} \tag{2.17}$$

or more succinctly

$$y_{i,t} = \lambda_i w_t + \delta_i u_{i,t} + \sum_{j=1,j\neq i}^{3} \gamma_{i,j} u_{j,t}, \qquad i = 1, 2, 3. \tag{2.18}$$

The theoretical variances and covariances are an extension of the expressions given in (2.14) and (2.11) respectively. For example, the variance of the returns of country 1 is

$$E\left[y_{1,t}^2\right] = \lambda_1^2 + \delta_1^2 + \gamma_{1,2}^2 + \gamma_{1,3}^2, \tag{2.19}$$

whereas the covariance of asset returns between countries 1 and 2 is

$$E\left[y_{1,t} y_{2,t}\right] = \lambda_1 \lambda_2 + \delta_1 \gamma_{2,1} + \delta_2 \gamma_{1,2} + \gamma_{1,3} \gamma_{2,3} \tag{2.20}$$

In this case there are 6 parameters, $\gamma_{i,j}$, controlling the strength of contagion across all asset markets. This model, by itself, is unidentified as there are 12 unknown parameters. However, by combining the empirical moments of the variance-covariance matrix during the crisis period, 6 moments, with the empirical moments from the variance-covariance matrix of the non-crisis period, another 6 moments, gives 12 empirical moments in total which can be used to estimate the 12 unknown parameters by Generalised Method of Moments (GMM).

A joint test of contagion using the factor models in (2.2) and (2.17), can be achieved by comparing the objective function from the unconstrained model, q_u, with the value obtained from estimating the constrained model, q_c, where the contagion parameters are set to zero. As the unconstrained model is just identified in this case, $q_u = 0$, the test is simply a test that under the null hypothesis of no contagion

$$H_0 : q_c = 0, \tag{2.21}$$

which is distributed asymptotically as χ^2 with 6 degrees of freedom under the null. As before, the test of contagion can be interpreted as testing for changes in both variances and covariances.

3.3 Structural Breaks

The model given by equations (2.2) and (2.18) is based on the assumption that the increase in volatility during the crisis period is solely generated by contagion, that is, $\gamma_{i,j} \neq 0, \forall i, j$. However, another scenario is that there is a general increase in volatility without any contagion; denoted as increased interdependence by Forbes and Rigobon (2002). This would arise if either the world loadings (λ_i) change, or idiosyncratic loadings (δ_i) change, or a combination of the two. The former would be representative of a general increase in volatility across all asset markets brought about, for example, by an increase in the risk aversion of international investors. The latter would arise from increases in the shocks of (some) individual asset markets which are entirely specific to those markets and thus independent of other asset markets.

To allow for structural breaks in the underlying relationships, the number of contagious linkages that can be entertained needs to be restricted. In the case where changes in the idiosyncratic shocks are allowed across the sample periods in all $N = 3$ asset markets, equation (2.18) becomes

$$y_{i,t} = \lambda_i w_t + \delta_{y,i} u_{i,t} + \sum_{j=1, j\neq i}^{3} \gamma_{i,j} u_{j,t}, \tag{2.22}$$

where $\delta_{y,i} \neq \delta_i$, are the idiosyncratic parameters during the crisis period. Bekaert, Harvey and Ng (2005) adopt a different strategy for modeling structural breaks by specifying time varying factor loadings.

The number of world and idiosyncratic parameters now increases to $3N$. Because the model is still block-recursive, there are just $N(N+1)/2$ empirical moments from the crisis period available to identify the contagion parameters $(\gamma_{i,j})$ and the structural break parameters $(\delta_{y,i})$. This means that there are $N(N+1)/2 - N = N(N-1)/2$, excess moments to identify contagion channels.

Extending the model to allow for structural breaks in both common and idiosyncratic factors in all N asset markets, increases the number of world and idiosyncratic parameters to $4N$, now yielding $N(N+1)/2 - 2N = N(N-3)/2$, excess moments to identify contagion channels in the crisis period. For a trivariate model $(N = 3)$ that allows for all potential structural breaks in common and idiosyncratic factors, no contagion channels can be tested as the model is just identified. Extending the model to $N = 4$ assets, allows for $N(N-3)/2 = 2$ potential contagion channels. Further extending the model to $N = 6$ assets, means that the number of contagion channels that can be tested increases to $N(N-3)/2 = 9$.

3.4 Using Just Crisis Data

Identification of the unknown parameters in the factor model framework discussed above is based on using information from both non-crisis and crisis periods. For certain asset markets it may be problematic to use non-crisis data to obtain empirical moments to identify unknown parameters. An example being the move from fixed to floating exchange rate regimes during the East Asian currency crisis. However, it is nonetheless possible to identify the model using just crisis period data, provided that the number of asset returns exceeds 3 and a limited number of contagious links are entertained. For example, for $N = 4$ asset returns, there are 10 unique empirical moments from the variance-covariance matrix using crisis data. Specifying the factor model in (2.2) for $N = 4$ assets, means that there are 4 world parameters and 4 idiosyncratic parameters. This implies that 2 contagious links can be specified and identified.

3.5 Autoregressive and Heteroskedastic Dynamics

Given that an important feature of financial returns during crises is that they exhibit high volatility, models which do not incorporate this feature are potentially misspecified. This suggests that the framework developed so far be extended to allow for a range of dynamics.[8] Four broad avenues are possible. The first consists of including lagged values of the returns in the system. When the number of assets being studied is large, this approach can give rise to a large number of unknown parameters, thereby making estimation difficult. The second approach is to capture the dynamics through lags in the common factor, w_t. This provides a more parsimonious representation of the system's dynamics as a result of a set of cross equation restrictions arising naturally from the factor structure. A third approach is to specify autoregressive representations for the idiosyncratic factors, $u_{i,t}$. The specification of dynamics on all of the factors yields a state-space representation which can be estimated using a Kalman filter, see for example Mody and Taylor (2003).

A fourth approach for specifying dynamics, which is potentially more important for models of asset returns than dynamics in the mean, is the specification of dynamics in the variance. This is especially true in models of contagion as increases in volatility are symptomatic of crises.[9] A common way to capture this phenomenon is to include a generalized autoregressive conditional heteroskedastic structure ($GARCH$) on the factors. This approach is adopted by Bekaert, Harvey and Ng (2005), Dungey and Martin (2004) and in Dungey, Fry, González-Hermosillo and Martin (2005a, 2006, 2007a).[10] In the case where there is a single factor a suitable specification is

$$w_t = e_t, \tag{2.23}$$

where

$$e_t \sim (0, h_t), \tag{2.24}$$

with conditional volatility h_t, given by the following $GARCH$ factor structure (Diebold

[8] This implies that methods based on principal components, such as Kaminsky and Reinhart (2001), which assume constant covariance matrices are inappropriate to model financial crises.

[9] A further approach is by Jeanne and Masson (2000) who allow for a Markovian switching structure to incorporate the multiple equilibria features of theoretical contagion models.

[10] See also Chernov, Gallant, Ghysels and Tauchen (2003) for a recent investigation of the dynamics of asset markets.

and Nerlove (1989), and Dungey, Martin and Pagan (2000))

$$h_t = (1 - \alpha - \beta) + \alpha e_{t-1}^2 + \beta h_{t-1}. \tag{2.25}$$

The choice of the normalisation $(1 - \alpha - \beta)$, constrains the unconditional volatility to equal unity and is adopted for identification.

Using (2.10) augmented by (2.23) to (2.25), gives the total (conditional) volatility of $y_{2,t}$, the asset return in the crisis period, as

$$\begin{aligned} E_{t-1}\left[y_{2,t}^2\right] &= E_{t-1}\left[\left(\lambda_2 w_t + \delta_2 u_{2,t} + \gamma u_{1,t}\right)^2\right] \\ &= \lambda_2^2 h_t + \delta_2^2 + \gamma^2, \end{aligned}$$

where the assumption of independent factors in (2.5) and (2.6) is utilised. The conditional covariance between $y_{1,t}$ and $y_{2,t}$ during the crisis period for example, is

$$\begin{aligned} E_{t-1}\left[y_{1,t}y_{2,t}\right] &= E_{t-1}\left[\left(\lambda_1 w_t + \delta_1 u_{1,t}\right)\left(\lambda_2 w_t + \delta_2 u_{2,t} + \gamma u_{1,t}\right)\right] \\ &= \lambda_1\lambda_2 h_t + \gamma\delta_1. \end{aligned}$$

Both the conditional variance and covariance during the crisis period are affected by the presence of contagion $(\gamma \neq 0)$. In particular, contagion has the effect of causing a structural shift during the crisis period in the conditional covariance by $\gamma\delta_1$, and the conditional variance by γ^2.

An important advantage of adopting a $GARCH$ factor model of asset returns is that it provides a parsimonious multivariate $GARCH$ model. This model, when combined with a model of contagion, can capture changes in the variance and covariance structures of asset returns during financial crises.[11] The parsimony of the factor $GARCH$ model specification contrasts with multivariate $GARCH$ models based on the $BEKK$ specification (Engle and Kroner (1995)) which require a large number of parameters for even moderate size models.[12]

[11] Further extensions to allow for asymmetric shocks are by Dungey, Fry and Martin (2003) and asymmetric volatility by Bekaert, Harvey and Ng (2005).

[12] The *BEEK* specification, based on univariate estimation of multivariate $GARCH$ models with simultaneous equations systems, is named after the contibution from Baba, Y., R.F. Engle, D.F. Kraft and K.F. Kroner described in Engle and Kroner (1995). Problems in estimating multivariate $GARCH$ models are noted by Malliaroupulos (1997), although research on this problem proceeds apace.

4 Correlation and Covariance Analysis

Forbes and Rigobon (2002) define contagion as the increase in correlation between two variables during a crisis period. In performing their test, the correlation between the two asset returns during the crisis period is adjusted to overcome the problem that correlations are a positive function of volatility. As crisis periods are typically characterised by an increase in volatility, a test based on the (conditional) correlation is biased upwards resulting in evidence of spurious contagion (Forbes and Rigobon (2002), Boyer, Gibson and Loretan (1999), Loretan and English (2000), Corsetti, Pericoli and Sbracia (2003)).[13]

4.1 Bivariate Testing

To demonstrate the Forbes and Rigobon (2002) approach, consider testing for contagion from country 1 to country 2 where the returns volatilities are $\sigma^2_{x,i}$ and $\sigma^2_{y,i}$ in the non-crisis and crisis periods respectively. The correlation between the two asset returns is ρ_y during the crisis period (high volatility period) and ρ_x in the non-crisis (low volatility period).[14] If there is an increase in the volatility of the asset return of country 1, $\sigma^2_{y,1} > \sigma^2_{x,1}$, without there being any change to the fundamental relationship between the asset returns in the two markets, then $\rho_y > \rho_x$ giving the false appearance of contagion. To adjust for this bias, Forbes and Rigobon show that the adjusted (unconditional) correlation is given by; see also Boyer, Gibson and Loretan (1999), Loretan and English (2000) and Corsetti, Pericoli and Sbracia (2001,2003)[15],

$$\nu_y = \frac{\rho_y}{\sqrt{1 + \left(\frac{\sigma^2_{y,1} - \sigma^2_{x,1}}{\sigma^2_{x,1}}\right)\left(1 - \rho^2_y\right)}}. \tag{2.26}$$

This is the unconditional correlation (ν_y) which is the conditional correlation (ρ_y) scaled by a nonlinear function of the percentage change in volatility in the asset return of the source country $\left(\left(\sigma^2_{y,1} - \sigma^2_{x,1}\right)/\sigma^2_{x,1}\right)$, country 1 in this case, over the high and

[13] Butler and Joaquin (2002) conduct the same test across bull and bear markets, although they do not specifically use the terminology of contagion.

[14] Forbes and Rigobon (2002) in their empirical application, compare the crisis period correlation with the correlation calculated over the total sample period (low volatility period). That is, x is replaced by $z = (x; y)$. This alternative formulation is also discussed below.

[15] Other approaches using correlation analysis are Karolyi and Stulz (1996) and Longin and Solnik (1995).

low volatility periods. If there is no fundamental change in the relationship between the two asset markets then $\nu_y = \rho_x$.

To test that there is a significant increase in correlation in the crisis period, the null hypothesis is for no contagion,

$$H_0 : \nu_y = \rho_x, \tag{2.27}$$

against the alternative hypothesis of

$$H_1 : \nu_y > \rho_x. \tag{2.28}$$

A t-statistic for testing this hypothesis is given by

$$FR_1 = \frac{\widehat{\nu}_y - \widehat{\rho}_x}{\sqrt{\frac{1}{T_y} + \frac{1}{T_x}}}, \tag{2.29}$$

where the ˆ signifies the sample estimator, and T_y and T_x are the respective sample sizes of the high volatility and low volatility periods. The standard error in (2.29) derives from assuming that the two samples are drawn from independent normal distributions. That is,

$$\begin{aligned} Var(\widehat{\nu}_y - \widehat{\rho}_x) &= Var(\widehat{\nu}_y) + Var(\widehat{\rho}_x) - 2Cov(\widehat{\nu}_y, \widehat{\rho}_x) \\ &= Var(\widehat{\nu}_y) + Var(\widehat{\rho}_x) \\ &\simeq \frac{1}{T_y} + \frac{1}{T_x}, \end{aligned} \tag{2.30}$$

where the second step follows from the independence assumption, and the last step follows from the assumption of normality and the use of an asymptotic approximation (Kendall and Stuart (1973, p.307)). To improve the finite sample properties of the test statistic, Forbes and Rigobon (2002) suggest using the Fisher transformation[16]

$$FR_2 = \frac{\frac{1}{2}\ln\left(\frac{1+\widehat{\nu}_y}{1-\widehat{\nu}_y}\right) - \frac{1}{2}\ln\left(\frac{1+\widehat{\rho}_x}{1-\widehat{\rho}_x}\right)}{\sqrt{\frac{1}{T_y-3} + \frac{1}{T_x-3}}}. \tag{2.31}$$

In the adjusted correlation test adopted by Forbes and Rigobon (2002) in their empirical work, the non-crisis period is defined as the total sample period. For this

[16] This tranformation is valid for small values of the correlation coefficients, ρ_x and v_y. Further refinements are discussed in Kendall and Stuart (1969, p.391). For the case of independence, $\rho_x = \nu_y = 0$, an exact expression for the variance of the transformed correlation coefficient is available. An illustration of these problems for the Forbes and Rigobon method is given in Dungey and Zhumabekova (2001).

case, the test statistic in equation (2.29) becomes

$$FR_3 = \frac{\widehat{\nu}'_y - \widehat{\rho}_z}{\sqrt{\frac{1}{T_y} + \frac{1}{T_z}}}, \tag{2.32}$$

where x is replaced by z and

$$\widehat{\nu}'_y = \frac{\rho_y}{\sqrt{1 + \left(\frac{\sigma^2_{y,1} - \sigma^2_{z,1}}{\sigma^2_{z,1}}\right)\left(1 - \rho^2_y\right)}}, \tag{2.33}$$

which is (2.26) with $\sigma^2_{x,1}$ replaced by $\sigma^2_{z,1}$. From (2.31), the Fisher adjusted version of the test statistic is

$$FR_4 = \frac{\frac{1}{2}\ln\left(\frac{1+\widehat{\nu}_y}{1-\widehat{\nu}_y}\right) - \frac{1}{2}\ln\left(\frac{1+\widehat{\rho}_z}{1-\widehat{\rho}_z}\right)}{\sqrt{\frac{1}{T_y-3} + \frac{1}{T_z-3}}}. \tag{2.34}$$

Underlying (2.32) and (2.34), is the assumption that the variances of $\widehat{\nu}'_y$ and $\widehat{\rho}_z$ are independent. Clearly this cannot be correct in the case of overlapping data. One implication of this result is that the standard error in (2.30) is too large as it neglects the (negative) covariance term arising from the use of overlapping data. This biases the t-statistic to zero resulting in a failure to reject the null of contagion.

4.2 Alternative Formulation

In implementing the correlation test in (2.29) or (2.31), equation (2.26) shows that the conditional correlation needs to be scaled initially by a nonlinear function of the change in volatility in the asset return of the source country, 1 in this case, over the pertinent sample periods. Another way to implement the Forbes and Rigobon test of contagion is to scale the asset returns and perform the contagion test within a regression framework.[17] Continuing with the example of testing for contagion from the asset market of country 1 to the asset market of country 2, consider scaling the asset returns during the non-crisis period by their respective standard deviations. First, define the following regression equation during the non-crisis period where the returns are scaled by their respective standard errors

$$\left(\frac{x_{2,t}}{\sigma_{x,2}}\right) = \alpha_0 + \alpha_1\left(\frac{x_{1,t}}{\sigma_{x,1}}\right) + \eta_{x,t}, \tag{2.35}$$

[17] Corsetti, Pericoli and Sbracia (2001) extend the Forbes and Rigobon framework to a model equivalent to the factor structure given in (2.10). Their approach requires evaluating quantities given by the ratio of the contribution of idiosyncratic and common factors to volatility, δ^2_i/λ^2_i for example. These quantities can be estimated directly using GMM as discussed in Section 3.2.

where $\eta_{x,t}$ is a disturbance term and α_0 and α_1 are regression parameters. The non-crisis slope regression parameter equals the non-crisis correlation coefficient, $\alpha_1 = \rho_x$. Second, for the crisis returns the regression equation is given as follows, where the scaling of asset returns is still by the respective standard deviations from the non-crisis periods

$$\left(\frac{y_{2,t}}{\sigma_{x,2}}\right) = \beta_0 + \beta_1 \left(\frac{y_{1,t}}{\sigma_{x,1}}\right) + \eta_{y,t}, \tag{2.36}$$

where $\eta_{y,t}$ is a disturbance term and β_0 and β_1 are regression parameters. The crisis regression slope parameter $\beta_1 = \nu_y$, which is the Forbes-Rigobon adjusted correlation coefficient given in (2.26).

This alternative formulation suggests that another way to implement the Forbes-Rigobon adjusted correlation is to estimate (2.35) and (2.36) by OLS and test the equality of the regression slope parameters. This test is equivalent to a Chow test for a structural break of the regression slope. Implementation of the test can be based on the following pooled regression equation over the entire sample

$$\left(\frac{z_{2,t}}{\sigma_{x,2}}\right) = \gamma_0 + \gamma_1 d_t + \gamma_2 \left(\frac{z_{1,t}}{\sigma_{x,1}}\right) + \gamma_3 \left(\frac{z_{1,t}}{\sigma_{x,1}}\right) d_t + \eta_t, \tag{2.37}$$

where

$$z_i = \left(x_{i,1}, x_{i,2}, ..., x_{i,T_x}, y_{i,1}, y_{i,2}, ..., y_{i,T_y}\right)', \qquad i = 1, 2, \tag{2.38}$$

represents the $(T_x + T_y) \times 1$ pooled data set by stacking the non-crisis and crisis data and η_t is a disturbance term. The slope dummy, d_t, is defined as

$$d_t = \begin{cases} 1: & t > T_x \\ 0: & \text{otherwise} \end{cases}. \tag{2.39}$$

The parameter $\gamma_3 = \beta_1 - \alpha_1$ in (2.37) captures the effect of contagion. It represents the additional contribution of information on asset returns in country 2 to the non-crisis regression: if there is no change in the relationship the dummy variable provides no new additional information during the crisis period, resulting in $\gamma_3 = 0$. Thus the Forbes and Rigobon contagion test can be implemented by estimating (2.37) by OLS and performing a one-sided t-test of

$$H_0 : \gamma_3 = 0, \tag{2.40}$$

in (2.37), which is equivalent to testing

$$H_0 : \alpha_1 = \beta_1, \tag{2.41}$$

in (2.35) and (2.36).[18] Of course, the test statistic to perform the contagion test is invariant to scaling transformations of the regressors, such as the use of $\sigma_{x,1}$ and $\sigma_{x,2}$ to standardise z_t. This suggests that an even more direct way to test for contagion is to implement a standard test of parameter constancy in a regression framework simply based on z_t, the unscaled data.[19]

There is one difference between the regression approach to correlation testing for contagion based on (2.37) and the approach implemented by Forbes and Rigobon, and that is the standard errors used in the test statistics are different in small samples. The latter approach is based on the asymptotic adjustment given in (2.31) or (2.34), whilst the former are based in general, on the usual least squares standard errors or some robust estimator.

4.3 Multivariate Testing

The regression framework developed above for implementing the Forbes and Rigobon test suggests that a multivariate analogue can be easily constructed as follows. Given that there is no need to scale the data to perform the contagion test, in the case of three asset returns the non-crisis period equations are

$$\begin{aligned} x_{1,t} &= \alpha_{1,2}x_{2,t} + \alpha_{1,3}x_{3,t} + \eta_{x,1,t} \\ x_{2,t} &= \alpha_{2,1}x_{1,t} + \alpha_{2,3}x_{3,t} + \eta_{x,2,t} \\ x_{3,t} &= \alpha_{3,1}x_{1,t} + \alpha_{3,2}x_{2,t} + \eta_{x,3,t} \end{aligned} \tag{2.42}$$

whilst the crisis equations are specified as

$$\begin{aligned} y_{1,t} &= \beta_{1,2}y_{2,t} + \beta_{1,3}y_{3,t} + \eta_{y,1,t} \\ y_{2,t} &= \beta_{2,1}y_{1,t} + \beta_{2,3}y_{3,t} + \eta_{y,2,t} \\ y_{3,t} &= \beta_{3,1}y_{1,t} + \beta_{3,2}y_{2,t} + \eta_{y,3,t} \end{aligned} \tag{2.43}$$

[18] Interestingly, Caporale, Cipollini and Spagnolo (2002), conduct a test of contagion based on a slope dummy, but do not identify the connection of the test with the Forbes and Rigobon (2002) correlation approach.

[19] To implement the form of the Forbes and Rigobon (2002) version of the correlation test within the regression framework in (2.37), the pre-crisis data is now replaced by the total sample data. That is, the low volatility period is defined as the total sample period and not the pre-crisis period. This requires redefining the pertinent variables as $z = (x, y, y)$ and the slope dummy as $d = \left(0_{T_x}, 0_{T_y}, 1_{T_y}\right)$, and scaling the variables using the total sample period.

where $\eta_{x,i,t}$ and $\eta_{y,i,t}$ are error terms. A joint test of contagion is given by

$$\alpha_{i,j} = \beta_{i,j}, \qquad \forall i \neq j, \tag{2.44}$$

which represents 6 restrictions. A convenient way to implement the multivariate version of the Forbes and Rigobon test is to adopt the strategy of (2.37) and write the model as a 3 equation system augmented by a set of slope dummy variables to capture the impact of contagion on asset returns

$$\begin{aligned} z_{1,t} &= \alpha_{1,2} z_{2,t} + \alpha_{1,3} z_{3,t} + \gamma_{1,2} z_{2,t} d_t + \gamma_{1,3} z_{3,t} d_t + \eta_{1,t} \\ z_{2,t} &= \alpha_{2,1} z_{1,t} + \alpha_{2,3} z_{3,t} + \gamma_{2,1} z_{1,t} d_t + \gamma_{2,3} z_{3,t} d_t + \eta_{2,t} \\ z_{3,t} &= \alpha_{3,1} z_{1,t} + \alpha_{3,2} z_{2,t} + \gamma_{3,1} z_{1,t} d_t + \gamma_{3,2} z_{2,t} d_t + \eta_{3,t} \end{aligned} \tag{2.45}$$

where the $z_{i,t}$ pooled asset returns are as defined in (2.38), $\eta_{i,t}$ are disturbance terms, d_t is the dummy variable defined in (2.39), and $\gamma_{i,j} = \beta_{i,j} - \alpha_{i,j}$, are the parameters which control the strength of contagion.

The multivariate contagion test is based on testing the null hypothesis

$$H_0 : \gamma_{i,j} = 0, \qquad \forall i \neq j. \tag{2.46}$$

Implementation of the test can be performed by using standard multivariate test statistics, including likelihood ratio, Wald and Lagrange multiplier statistics.

Rigobon (2003b) suggests an alternative multivariate test of contagion. This test is referred to as the determinant of the change in the covariance matrix (DCC) as it is based on comparing the covariance matrices across two samples (non-crisis and crisis) and taking the determinant to express the statistic as a scalar. The DCC statistic is formally defined as

$$DCC = \frac{\left| \widehat{\Omega}_y - \widehat{\Omega}_x \right|}{\widehat{\sigma}_{DCC}}, \tag{2.47}$$

where $\widehat{\Omega}_y$ and $\widehat{\Omega}_x$ are the estimated covariance matrices of asset returns in the crisis and non-crisis periods, respectively, and $\widehat{\sigma}_{DCC}$ is an estimate of the pertinent standard error of the statistic. Under the null hypothesis there is no change in the covariance structure of asset returns across sample periods, resulting in a value of $DCC = 0$. If contagion increases volatility during the crisis period, then $DCC > 0$, resulting in a rejection of the null hypothesis of no contagion.

The DCC test represents a test of parameter stability and thus provides an alternative test to a Chow test. However, given the relationship between Chow and contagion tests discussed above, this implies that potentially the DCC test is also a test of contagion. To highlight this point, consider the following bivariate factor model based on the first two equations in (2.2) and (2.10). The non-crisis and crisis covariance matrices are respectively

$$\Omega_x = \begin{bmatrix} \lambda_1^2 + \delta_1^2 & \lambda_1\lambda_2 \\ \lambda_1\lambda_2 & \lambda_2^2 + \delta_2^2 \end{bmatrix}, \Omega_y = \begin{bmatrix} \lambda_1^2 + \delta_1^2 & \lambda_1\lambda_2 + \gamma\delta_1 \\ \lambda_1\lambda_2 + \gamma\delta_1 & \lambda_2^2 + \delta_2^2 + \gamma^2 \end{bmatrix}.$$

The numerator of the DCC statistic is this case is

$$\left|\widehat{\Omega}_y - \widehat{\Omega}_x\right| = \begin{vmatrix} 0 & \widehat{\gamma}\widehat{\delta}_1 \\ \widehat{\gamma}\widehat{\delta}_1 & \widehat{\gamma}^2 \end{vmatrix} = -\widehat{\gamma}^2\widehat{\delta}_1^2,$$

where the ˆ signifies a parameter estimator. Under the null hypothesis $DCC = 0$, which is achieved when $\gamma = 0$, a result that is equivalent to the tests of contagion already discussed.

In implementing the DCC test, the covariance matrices employed tend to be conditional covariance matrices if dynamics arising from lagged variables and other exogenous variables are controlled for. One approach is to estimate a VAR for the total period, $T_x + T_y$, and base the covariances on the vector autoregression (VAR) residuals. This is the approach adopted in the empirical application of Rigobon (2003b). The advantage of working with VAR residuals, as compared to structural residuals, is that the VAR represents an unconstrained reduced form, thereby circumventing problems of simultaneity bias. Endogeneity issues are now discussed.

4.4 Endogeneity Issues

The potential simultaneity biases arising from the presence of endogenous variables are more evident when the Forbes and Rigobon test is cast in a linear regression framework. Forbes and Rigobon perform the correlation test on pairs of countries under the assumption that contagion spreads from one country to another with the source country being exogenous. The test can then be performed in the reverse direction with the implicit assumption of exogeneity on the two asset returns reversed. Performing the two tests in this way is inappropriate as it clearly ignores the simultaneity bias problem.[20]

Forbes and Rigobon (2002) show using a Monte Carlo analysis that the size of the simultaneity bias is unlikely to be severe if the correlations between asset returns are relatively small. Interestingly, Rigobon (2003b) notes that the volatility adjustment in performing the test in (2.26) is incorrect in the presence of simultaneity bias. However, as noted above, the Forbes and Rigobon adjustment acts as a scaling parameter which has no affect on the properties of the test statistic in a linear regression framework. The problem of simultaneity bias is the same irrespective of whether the endogenous explanatory variables are scaled or not.

To perform the Forbes and Rigobon contagion test while correcting for simultaneity bias, equations (2.42) and (2.43) need to be estimated initially using a simultaneous equations estimator and the tests of contagion based on the simultaneous equation estimates of $\gamma_{i,j}$ in (2.45). To demonstrate some of the issues, the bivariate model is expanded to allow for structural breaks in the idiosyncratic loadings. The bivariate versions of the model without intercepts during the non-crisis and crisis periods are respectively

$$\begin{aligned} x_{1,t} &= \alpha_1 x_{2,t} + \eta_{x,1,t} \\ x_{2,t} &= \alpha_2 x_{1,t} + \eta_{x,2,t} \end{aligned} \tag{2.48}$$

where $\eta_{x,i,t}$ are iid with zero means and variances $E\left[\eta_{x,i}^2\right] = \omega_{x,i}^2$, and

$$\begin{aligned} y_{1,t} &= \beta_1 y_{2,t} + \eta_{y,1,t} \\ y_{2,t} &= \beta_2 y_{1,t} + \eta_{y,2,t} \end{aligned} \tag{2.49}$$

where $\eta_{y,i,t}$ are independently and identically distributed (iid) with zero means and variances $E\left[\eta_{y,i}^2\right] = \omega_{y,i}^2$. The respective reduced forms are

$$\begin{aligned} x_{1,t} &= \frac{1}{1-\alpha_1\alpha_2}\left(\eta_{x,1,t} + \alpha_1 \eta_{x,2,t}\right) \\ x_{2,t} &= \frac{1}{1-\alpha_1\alpha_2}\left(\eta_{x,2,t} + \alpha_2 \eta_{x,1,t}\right) \end{aligned} \tag{2.50}$$

[20] Forbes and Rigobon recognise this problem and do not test for contagion in both directions being very clear about their exogeneity assumptions.

for the non-crisis period and

$$\begin{aligned} y_{1,t} &= \frac{1}{1-\beta_1\beta_2}\left(\eta_{y,1,t}+\beta_1\eta_{y,2,t}\right) \\ y_{2,t} &= \frac{1}{1-\beta_1\beta_2}\left(\eta_{y,2,t}+\beta_2\eta_{y,1,t}\right) \end{aligned} \tag{2.51}$$

for the crisis period. For the two sub-periods the variance-covariance matrices are, respectively

$$\Omega_x = \frac{1}{\left(1-\alpha_1\alpha_2\right)^2}\begin{bmatrix} \omega_{x,1}^2+\alpha_1^2\omega_{x,2}^2 & \alpha_1^2\omega_{x,2}^2 \\ \alpha_1\omega_{x,2}^2 & \omega_{x,2}^2+\alpha_2^2\omega_{x,1}^2 \end{bmatrix} \tag{2.52}$$

$$\Omega_y = \frac{1}{\left(1-\beta_1\beta_2\right)^2}\begin{bmatrix} \omega_{y,1}^2+\beta_1^2\omega_{y,2}^2 & \beta_1\omega_{y,2}^2 \\ \beta_1\omega_{y,2}^2 & \omega_{y,2}^2+\beta_2^2\omega_{y,1}^2 \end{bmatrix}. \tag{2.53}$$

The model at present is underidentified as there is a total of just 6 unique moments across the two samples, to identify the 8 unknown parameters

$$\left\{\alpha_1,\alpha_2,\beta_1,\beta_2,\omega_{x,1}^2,\omega_{x,2}^2,\omega_{y,1}^2,\omega_{y,2}^2\right\}.$$

In a study of the relationship between Mexican and Argentinian bonds, Rigobon (2003a) identifies the model by setting $\alpha_1=\beta_1$ and $\alpha_2=\beta_2$. However, from (2.41), this implies that there is no contagion, just a structural break in the idiosyncratic variances. An alternative approach to identification, which is more informative in the context of testing for contagion, is not to allow for a structural break and set $\omega_{x,1}^2=\omega_{y,1}^2$, and $\omega_{x,2}^2=\omega_{y,2}^2$. Now there are 6 equations to identify the 6 unknowns. A test of contagion is given by a test of the over-identifying restrictions under the null hypothesis of no contagion. The observational equivalence between the two identification strategies has already been noted above in the discussion of the factor model. However, if the idiosyncratic variances are changing over the sample, the contagion test is under-sized (Toyoda and Ohtani (1986)). Another alternative solution is to expand the number of asset markets investigated. For example, increasing the number of assets to $N=3$ results in a just identified model as there are 12 unknown parameters,

$$\left\{\alpha_1,\alpha_2,\alpha_3,\beta_1,\beta_2,\beta_3,\omega_{x,1}^2,\omega_{x,2}^2,\omega_{x,3}^2,\omega_{y,1}^2,\omega_{y,2}^2,\omega_{y,3}^2\right\},$$

and 12 moments (as there are 6 unique moments from each of the variance-covariance matrices from the two sub-periods).

Rigobon (2002) also suggests using instrumental variables to obtain consistent parameter estimates with the instruments defined as

$$s_i = \left(\begin{array}{cc} -x_{i,1}, -x_{i,2}, ..., -x_{i,T_x} & y_{i,1}, y_{i,2}, ..., y_{i,T_y} \end{array} \right)', \qquad i = 1, 2.$$

This choice of instruments is an extension of the early suggestions of Wald (1940) and Durbin (1954). For example, Wald defined the instrument set as a dummy variable with a 1 signifying observations above the median and a -1 for observations below the median. In the case of contagion and modelling financial crises, observations above (below) the median can be expected to correspond to crisis (non-crisis) observations. This suggests that the Rigobon instrument is likely to be more efficient than the instrument chosen by Wald as it uses more information. Rigobon then proceeds to estimate pooled equations as in (2.45), but with $\gamma_{i,j} = 0$. But this is not a test of contagion as $\alpha_i = \beta_i$ is imposed and not tested. Not surprisingly, the IV estimator of the structural parameters in this case, is equivalent to the matching moment estimator using (2.52) and (2.53), subject to the restrictions $\alpha_1 = \beta_1$, and $\alpha_2 = \beta_2$.

4.5 Relationship with Other Models

Interpreting the Forbes and Rigobon contagion test as a Chow test provides an important link connecting this approach with the contagion modelling framework of Dungey, Fry, González-Hermosillo and Martin (2005b). To highlight this link, let the dynamics of the processes be represented by the first two expressions of the contagion model in (2.10)

$$y_{1,t} = \lambda_1 w_t + \delta_1 u_{1,t} \tag{2.54}$$

$$y_{2,t} = \lambda_2 w_t + \delta_2 u_{2,t} + \gamma u_{1,t}, \tag{2.55}$$

where as before, contagion from the asset market in country 1 to country 2 is controlled by the parameter γ. Combining these expressions to substitute out $u_{1,t}$ from the equation for $y_{2,t}$ gives

$$y_{2,t} = \left(\frac{\lambda_2 \delta_1 - \lambda_1 \gamma}{\delta_1} \right) w_t + \frac{\gamma}{\delta_1} y_{1,t} + \delta_2 u_{2,t}. \tag{2.56}$$

The corresponding asset equation in the non-crisis period is given by setting $\gamma = 0$, and changing $y_{i,t}$ to $x_{i,t}$,

$$x_{2,t} = \left(\frac{\lambda_2 \delta_1 - \lambda_1 \gamma}{\delta_1} \right) w_t + \delta_2 u_{2,t}. \tag{2.57}$$

Stacking equations(2.56) and (2.57) yields an equation of the same form as (2.37) provided that the common factor is taken as $w_t = z_{1,t}$, the stacked vector of asset returns in country 1 across non-crisis and crisis periods. In this scenario the Forbes and Rigobon and Dungey, Fry, González-Hermosillo and Martin approaches are equivalent with the test of contagion still being based on $\gamma = 0$. This amounts to testing the additional explanatory power of the asset returns in country 1 to explain movements in the asset returns in country 2 over and above the factors that govern movements in asset markets during non-crisis periods.

In practice, Forbes and Rigobon (2002) identify the common factor w_t using a number of observed variables including US interest rates. These variables are initially extracted from the asset returns data by regressing the returns on the chosen set of common factors and using the residuals from these regressions in the contagion tests given in (2.26) to (2.31). In conducting the contagion tests, the analysis is performed in pairs with the source country changing depending on the hypothesis being tested. This testing strategy is highlighted in (2.56) and (2.57) where the source country is country 1.

Testing for contagion based on the dummy variable version of the Forbes and Rigobon contagion test in equation (2.37) also introduces the links to a range of other tests for contagion. For example, the approach of Favero and Giavazzi (2002) consists of defining the dummy variable in (2.39) as

$$d_{i,t} = \begin{cases} 1: & |u_{i,t}| > 3\delta_i \\ 0: & \text{otherwise} \end{cases}, \qquad (2.58)$$

where δ_i is computed as the standard deviation of the residuals in a VAR(p) associated with the variable $y_{i,t}$.[21] A structural model is then specified where each return is expressed as a function of all other returns, own lagged returns and the full set of dummy variables. The system of equations is estimated by full information maximum likelihood (FIML) and the contagion test is based on a joint test of the parameters on the dummy variables of the other returns. The test will identify contagion if extreme returns in the dependent variable are matched with extreme returns in the other vari-

[21] In a related approach, Pesaran and Pick (2003) also identify outliers by constructing dummy variables which are used in a structural model to test for contagion. One important difference is that Pesaran and Pick do not define the dummy variables for each outlier, but combine the outliers associated with each dummy variable.

ables. The dummy variables define the period of the crisis. This contrasts with the approach of Forbes and Rigobon and Dungey, Fry, González-Hermosillo and Martin (2005a, 2006, 2007a), where the crisis period is determined a priori. One implication of the Favero and Giavazzi test is that the results can potentially be driven by a small number of observations thereby making the test rather fragile. A further implication of this approach concerns the use of lagged variables to identify the simultaneous equations model. In the case where it is asset returns that are being modelled, the autocorrelation structure of asset returns is expected to be low.[22] This results in a weak instrument problem where the bias of a simultaneous estimator can exceed the bias of the OLS estimator which, in turn, can yield spurious results (Nelson and Startz (1990), andStock, Wright and Yogo (2002)).

Eichengreen, Rose and Wyplosz (1995,1996) choose dummy variables for both $y_{1,t}$ and $y_{2,t}$ respectively as

$$\begin{aligned} d_{1,t} &= \begin{cases} 1: & y_{1,t} > f(EMP_{1,t}) \\ 0: & \text{otherwise} \end{cases} \\ d_{2,t} &= \begin{cases} 1: & y_{2,t} > f(EMP_{2,t}) \\ 0: & \text{otherwise} \end{cases} , \end{aligned} \tag{2.59}$$

where $EMP_{i,t}$ is the exchange market pressure index.[23] As a result of the binary dependent variable the model is estimated as a probit model. Bae, Karolyi and Stulz (2003) extend this model to provide for polychotomous variables, where the dummy variables, $d_{i,t}$, are defined as exceedances

[22]This is less of a problem in the application considered by Favero and Giavazzi (2002) who used interest rates which have strong autocorrelation structures.

[23]The threshold indicator $EMP_{i,t}$ represents the Exchange Market Pressure Index corresponding to the i^{th} asset return at time t, which is computed as a linear combination of the change in exchange rates, interest differentials and changes in levels of reserve assets for country i with respect to some numeraire country, 0,

$$EMP_{i,t} = a\Delta e_{i,t} + b(r_{i,t} - r_{0,t}) + c(\Delta R_{i,t} - \Delta R_{0,t}), \tag{2.60}$$

where e_i is the logarithm of the bilateral exchange rate, r_i is the short-term interest rate and R_i is the stock of reserve assets. The weights, a, b and c, are given by the inverse of the standard deviation of the individual component series over the sample period. Kaminsky and Reinhart (2000) adopt a different weighting scheme whereby the weight on interest rates is zero.

$$d_{1,t} = \begin{cases} 1: & |y_{1,t}| > THRESH \\ 0: & \text{otherwise} \end{cases}$$
$$d_{2,t} = \begin{cases} 1: & |y_{2,t}| > THRESH \\ 0: & \text{otherwise} \end{cases} . \qquad (2.61)$$

In their application $THRESH$ is chosen to identify the 5% of extreme observations in the sample. A co-exceedance occurs when $d_{1,t} = d_{2,t} = 1$. The number of exceedances and co-exceedances at time t yields a polychotomous variable which is then used in a multinominal logit model to test for contagion.[24]

An important part of the Eichengreen et al. (1995, 1996) approach is that it requires choosing the threshold value of the EMP index for classifying asset returns into crisis and non-crisis periods. As with the threshold values adopted by Favero and Giavazzi (2002) and Bae, Karolyi and Stulz (2003), the empirical results are contingent on the choice of the threshold value. In each of these approaches, this choice is based on sample estimates of the data, resulting in potentially non-unique classifications of the data for different sample periods.[25]

The construction of binary dummies in (2.58) to (2.61) in general amounts to a loss of sample information resulting in inefficient parameter estimates and a loss of power in testing for contagion. A more direct approach which does not result in any loss of sample information is to estimate (2.56) by least squares and perform a test of contagion by undertaking a t-test of γ. In fact, the probit model delivers consistent estimates of the same unknown parameters given in (2.56), but these estimates suffer a loss of efficiency as a result of the loss of sample information in constructing the dummy variables.[26]

[24] In the application of Bae, Karolyi and Stulz (2003) the cases of negative and positive returns are considered separately. They also combined all exceedances into a single category. However, by separating the exceedances of each variable it is possible to test for contagion from the host country to the remaining countries separately, see Dungey, Fry, González-Hermosillo and Martin (2005a). This is done in the application in Section 5.

[25] Both Eichengreen et al. (1995, 1996) and Kaminsky and Reinhart (2000) use some matching of their crisis index constructed using these thresholds to market events to validate the threshold choice.

[26] The dummy variable framework can be extended further by allowing for asymmetric shocks (Dungey, Fry, and Martin (2003), Butler and Joaquin (2002), Baig and Goldfajn (2000), Ellis and Lewis (2000) and Kaminsky and Schmukler (1999)).

5 Empirical Application: Equity Markets in 1997-1998

To illustrate the application of the alternative empirical methodologies discussed above, this section explores the turmoil in equity markets resulting from the speculative attack on the Hong Kong currency in October 1997.[27] This attack was successfully defended by the Hong Kong Monetary Authority, but resulted in a substantial decline in Hong Kong equity markets. A number of Asian markets were also affected. This application considers the potential contagion from this crisis to the equity markets of Korea and Malaysia, with the US equity markets used as a control for common shocks, as per Forbes and Rigobon (2002).

The non-crisis period covers January 1, 1997 to October 17, 1997. The Hong Kong equity markets declined rapidly beginning October 20-23, 1997. The Hang Seng Index fell by almost a quarter and was associated with large falls in indices in other international markets including Japan, the US and other Asian markets. The crisis period here covers from October 20, 1997 to August 31, 1998, a period often associated with the end of the Asian financial crisis, marked by the repegging of the Malaysian ringgitt.

The example presented here is not intended as a definitive analysis of this crisis, but serves rather as an example of the application of the contagion testing procedures outlined in the first part of the chapter. Further analysis of this particular data set and crisis are presented in Dungey, Fry, González-Hermosillo and Martin (2005a) and other analyses of the Asian crisis episode include Forbes and Rigobon (2002), Bae, Karolyi and Stulz (2003) and Dungey, Fry and Martin (2003b).

5.1 Stylized Facts

Table 1 contains some descriptive statistics as well as variance-covariances of equity returns during the non-crisis and crisis sample periods for the three countries. The increase in volatility experienced during the crisis period is evident by the large increase in the variances in each country. In the case of Hong Kong the variance in equities rises over three fold, while for both Korea and Malaysia there is more than a five-fold increase. All countries experience a fall in their average returns during the crisis period.

[27] This application is based on Dungey, Fry, González-Hermosillo and Martin (2005a).

Table 1:

Descriptive statistics and variance-covariances of daily percentage equity returns for selected sample periods: Non-crisis period (January 1, 1997 to October 17, 1997), Crisis period (October 20, 1997 to August 31, 1998).

	Non-crisis Period			*Crisis Period*		
	Hong Kong	Korea	Malaysia	Hong Kong	Korea	Malaysia
Descriptive Statistics						
Mean	0.004	-0.056	-0.209	-0.300	-0.300	-0.468
Max	6.883	4.019	1.666	17.247	10.024	20.817
Min	-5.150	-4.306	-5.817	-14.735	-11.601	-11.744
Covariance Matrix						
Hong Kong	2.238			10.794		
Korea	0.260	2.045		1.611	13.114	
Malaysia	0.631	0.063	2.782	4.716	3.348	10.291

In addition, for each country the extreme minimum and maximum daily return occurs during the crisis period.

5.2 Implementation Issues

There are a number of practical issues in implementing the contagion tests outlined in the previous sections. These include identifying the crisis period from the non-crisis period, the use of proxy variables to identify common factors, choice of frequency of data and the treatment of missing observations and time zones. Each of these issues is dealt with in more detail in Dungey, Fry, González-Hermosillo and Martin (2005a), but are briefly outlined in what follows.

There are two broad approaches to identifying the timing of crises. The first approach is based on ex post observation of events in the existing literature as in Forbes and Rigobon (2002) (the FR test) and Dungey, Fry, González-Hermosillo and Martin (2005a, 2006, 2007a) (the DFGM test). The second approach is based on the identification of some threshold value, such as in Favero and Giavazzi (2002) (the FG test), Bae, Karolyi and Stulz (2003) (the BKS test) and Eichengreen, Rose and Wyplosz (1996).

The choice of proxy variables for the common factors is often related to the choice of data frequency. One group of researchers recognises contagion in its effects on relatively low frequency data where appropriate macroeconomic controls can be taken into account, for example Eichengreen, Rose and Wyplosz (1995,1996). Then there are those who would presumably prefer to test at higher frequency, but are constrained by the availability of control data, such as Glick and Rose (1999) who consider trade flows. And finally the majority of studies consider contagion in relatively high frequency data, at either daily or weekly frequency, where contagion is viewed as a relatively short-lived phenomenon. This is the case with all of the correlation analysis studies, most of the extreme value studies, threshold models and the latent factor models. Some studies also utilise observed high frequency data as common variable controls, such as in Forbes and Rigobon (2002) who use US interest rates. This is the approach adopted in the empirical application whereby a VAR containing one lag and US returns is estimated, with the residuals representing the filtered returns. This pre-filtering of the data is used in the calculations of the DFGM, FR and BKS tests, but not the FG test so as to be commensurate with their methodology.

To allow for differences in the time zones between the US and the three Asian equity markets, the US interest rates are dated at time $t-1$. In general, time zone alignment problems arise because markets may be open on nominally the same date, but there may be no actual trading time overlap. Kaminsky and Reinhart (2003) find significant time zone effects in equity markets. One approach to this problem is to control for differences in time zones by using moving averages of returns (Forbes and Rigobon (2002), Ellis and Lewis (2000)). However, this may mask movements in asset prices and hence introduce biases into the tests of contagion. Bae, Karolyi and Stulz (2003) choose different lags depending on the time zone under investigation, which works because two distinct time zones are involved. Dungey, Fry, González-Hermosillo and Martin (2007a) suggest using simulation methods by treating time zones problems as a missing observation issue.

Finally, missing observations cause problems in tracking volatility across markets in a single period, and are usually dealt with by either replacing the missing observation with the previous market observation or removing that data point from the investigation. In practice, most researchers seem to use a strategy of excluding days corresponding to missing observations, which is the approach adopted below.

5.3 Contagion Testing

To gain some insight into the relative size of contagion amongst equity markets during the crisis, Table 2 provides the DFGM factor decompositions of the variances and the covariances given in Table 1. As the model is just identified these decompositions provide a breakdown of these moments in terms of the underlying factors, including contagion.

The variance decompositions in Table 2 show that asset return volatility during the crisis is dominated by contagion with much smaller contributions from the world and idiosyncratic factors. The dominant contagion channels are from Hong Kong to both Korea (7.972) and Malaysia (5.972), which are over 50% of the total volatility of the returns in these two countries (13.114 and 10.291 respectively). There are also important reverse contagion channels from Korea and Malaysia to Hong Kong (3.705 and 4.858), and from Malaysia to Korea (3.181).

The covariance decompositions in Table 2 reveal that contagion from Hong Kong had positive impacts on the covariances between all asset returns. In contrast, contagion from Korea and Malaysia tended to have a negative impact on several of the covariances.

The volatility decompositions discussed above provide a description of the relative magnitude of contagion linking the three equity markets. To examine the strength of these linkages more formally, Table 3 presents the results of 7 contagion tests. The first column gives the country from which contagion is assumed to emanate (labelled Host). The second column gives the recipient country. The remaining 7 columns give the results of the contagion tests based on the DFGM test, the FR test with overlapping data (FR-0) and with non-overlapping data (FR-N), the multivariate version of the FR test (FRM), the FG test with an endogeneity correction (FG-E) and a non-endogeneity corrected version (FG-N), and the BKS test. The row headed 'Both' in each panel of the table gives the results of a joint test of contagion from the host country to the two recipient countries. The last panel of the table gives the results of the joint test of no contagion amongst all three countries.

The results in Table 3 show that the Forbes and Rigobon test (FR-O) finds no evidence of contagion in any of the channels tested. This lack of any rejection of the null hypothesis is consistent with the discussion in Section 4 where it was concluded that this is a conservative test as it is biased towards zero as a result of the variance of the test statistic being incorrect when the non-crisis period is defined as the total sample period.

To examine the issue concerning the downward bias in the Forbes and Rigobon test further, the results of the Forbes and Rigobon test (FR-N) where the non-crisis period is based on non overlapping data, are also presented in Table 3. The results show that 4 of the 6 bivariate contagion tests do indeed lead to lower p-values. However, at the 5% level, this test still seems to be conservative as it does not identify any significant contagion linkages. Further confirmation of the bias in the Forbes and Rigobon test FR-O, arising from overlapping data, is given by the multivariate version of the Forbes and Rigobon test (FRM). Here the results point to uniformly stronger contagious linkages, that is lower p-values, with significant evidence of contagion detected from Malaysia to both Hong Kong and Korea.

In complete contrast to the FR test results in Table 3, the FG test (FG-E) finds evidence of contagion in all cases.[28] To control for potential weak instrument problems, the Favero and Giavazzi test is recomputed with no endogeneity correction (FG-N) by simply estimating the pertinent structural model by OLS. The results show a very different story with now just half of the bivariate contagion tests showing significant evidence of contagion at the 5% level. The strong evidence of contagion based on FG-E appear to be spurious and arise from the presence of weak instruments.[29] Comparing the results of the FG-N test and DFGM tests shows that the two methods produce similar qualitative results in 4 of the 6 bivariate cases at the 10% level. The two differences are the test of contagion from Hong Kong to Korea where the DFGM test finds evidence of contagion, and the test of contagion from Malaysia to Korea where the FG-N test finds evidence of contagion. The transmission channel from Hong Kong to Korea identified by the DFGM test is consistent with the strong level of contagion identified in the variance decomposition given in Table 2. In addition, the lack of significant evidence of contagion from Malaysia to Korea identified by the DFGM test is also consistent with the moderate level of contagion identified in the variance decomposition in Table 2 as well.

The last test results reported in Table 3 are for the Bae, Karolyi and Stultz (BKS) test.[30] Comparing the bivariate DFGM and BKS results shows that the two testing procedures give opposite results where Hong Kong and Korea are the hosts, but the same results where Malaysia is the host. Part of the explanation underlying these results could be the dating of the crisis period which is determined a priori in the case of the DFGM test, whereas for the BKS test is determined endogenously. An additional issue surrounding the BKS test is that it discards information in constructing the dummy dependent and independent variables, which may in turn lead to a loss of efficiency in the parameter estimates.

In general, these results in Table 3 provide evidence of the difficulties in obtaining consistent information on the existence of contagion from the different tests. This is

[28] The Favero and Giavazzi test based on the dummy variable in (2.58) identifies 19 outliers: 1 common outlier, 5 outliers in Hong Kong, 6 in Korea and 7 in Malaysia.

[29] Performing the weak instrument test based on the F-test of the regressors in the three reduced form equations yields values of $12.893, 7.618, 15.369$. Using the critical values reported in Stock, Wright and Yogo (2000: Table 1), shows that the null of a weak instrument is not rejected.

[30] The BKS test is based on 22 exceedances, 4 co-exceedances between Hong Kong and Korea, 5 co-exceedances between Hong Kong and Malaysia and 4 co-exceedances between Korea and Malaysia.

not unique to this example, similar outcomes emerge in other applied examples for the 1994 Mexican crisis and the 2001 Argentine crisis provided in Dungey, Fry, González-Hermosillo and Martin (2005a). Some of these problems are shown by Dungey, Fry, González-Hermosillo and Martin (2004) to be due to low power and poor size properties of these various tests of contagion.

6 Conclusions

This chapter has overviewed a number of important tests for the presence and characteristics of contagion in financial markets adopted in the current literature. Using a framework of a latent factor model similar to that proposed in the finance literature, the different testing methodologies are shown to be related. In essence, each method is shown to be a test on a common parameter regarding the transmission of a shock from one country or market to another.

An important result of this chapter is that the main distinguishing feature of alternative empirical models of contagion is the way in which the information is used to identify contagion. Dungey, Fry, González-Hermosillo and Martin (2006) and Forbes and Rigobon (2002) use the information on all of the shocks in the crisis period to test for contagion. Under certain conditions these two models are the same. Favero and Giavazzi (2002) utilize shift dummies at selected crisis points to represent potentially contagious transmissions. Eichengreen, Rose and Wyplosz (1995,1996) also use dummy variables to identify contagion, however they transform both the dependent and independent indicators into binary variables, which results in a further reduction of the information used in estimation. Bae, Karolyi and Stulz (2003) provide an extension of the Eichengreen, Rose and Wyplosz approach by allowing for a polychotomous dependent variable, based on the number of co-exceedances in their crisis indicator.

Some of the properties and relationships of the various contagion tests were demonstrated in an empirical application of the Asian crisis of 1997-1998. A number of empirical issues concerning missing observations, time zones, dating of crises and data frequency were also discussed. The results showed that the Forbes and Rigobon contagion test was a conservative test as it failed to find evidence of contagion in any of the linkages tested. The Favero and Giavazzi test was at the other extreme, finding evidence of contagion in all cases investigated. Much of this evidence of linkages was

Table 2:

Unconditional volatility decompositions of Asian equity markets during the crisis period, expressed in squared returns: based on equations (2.19) and (2.20).

Components	Country		
	Variance Decomposition		
	Hong Kong	Korea	Malaysia
World factor	0.057	1.755	0.017
Idiosyncratic factor	2.174	0.279	2.760
Contagion from:			
Hong Kong	-	7.972	5.792
Korea	3.705	-	1.723
Malaysia	4.858	3.181	-
Sub-total	8.563	11.153	7.515
Total	10.794	13.114	10.291
	Covariance Decomposition		
	Hong Kong/Korea	Hong Kong/Malaysia	Korea/Malaysia
World factor	0.317	0.032	0.175
Idiosyncratic factor	0.000	0.000	0.000
Contagion from:			
Hong Kong	4.163	3.549	6.795
Korea	1.017	-2.526	-0.693
Malaysia	-3.886	3.662	-2.929
Sub-total	1.294	4.685	3.173
Total	1.611	4.716	3.348

Table 3:

Contagion tests of Asian equity markets Hong Kong (HK), Korea (K) and Malaysia (M): p-values in parentheses. A * denotes statistically significant at the 5% level.

Host	Recipient	DFGM[(a)]	FR-O[(b)]	FR-N[(b)]	FRM[(c)]	FG-E[(d)]	FG-N[(d)]	BKS[(e)]
HK to:	K	158.17*	-0.295	-1.002	1.175	117.582*	7.589	2.210
		(0.000)	(0.616)	(0.842)	(0.278)	(0.000)	(0.180)	(0.137)
	M	1.574	-0.507	-0.263	1.162	137.669*	8.881	6.015*
		(0.210)	(0.694)	(0.604)	(0.281)	(0.000)	(0.114)	(0.014)
	Both	182.063*	-		1.968	217.451*	17.850	10.019*
		(0.000)			(0.374)	(0.000)	(0.058)	(0.002)
K to:	HK	45.651*	-0.315	-1.062	1.518	304.902*	11.077	2.146
		(0.000)	(0.624)	(0.856)	(0.218)	(0.000)	(0.086)	(0.143)
	M	12.085*	-0.256	0.209	1.031	356.649*	17.549*	2.369
		(0.001)	(0.601)	(0.417)	(0.310)	(0.000)	(0.007)	(0.124)
	Both	439.764*	-		1.872	65.402*	33.911*	8.517*
		(0.000)			(0.392)	(0.000)	0.001	(0.004)
M to:	HK	53.578*	-0.348	0.189	6.582*	146.704*	23.251*	6.862*
		(0.000)	(0.636)	(0.425)	(0.010)	(0.000)	(0.002)	(0.009)
	K	0.773	-0.105	0.650	4.963*	73.385*	24.636*	2.181
		(0.379)	(0.542)	(0.258)	(0.026)	(0.000)	(0.001)	(0.140)
	Both	70.005*	-	-	10.765*	202.745*	51.439*	11.145*
		(0.000)			(0.005)	(0.000)	(0.000)	(0.001)
Joint		772.474*	-	-	14.357*	1085.284*	101.973*	-
		(0.000)			(0.026)	(0.000)	(0.000)	

(a) Dungey, Fry, González-Hermosillo and Martin test: A Wald test using the GMM parameter estimates of $\gamma_{i,j}$ in (2.17).

(b) Forbes and Rigobon tests: FR-O is based on overlapping data using (2.34) and FR-N is based on non-overlapping data using (2.31).

(c) Multivariate Forbes and Rigobon tests: Based on a Wald test using the least squares parameter estimates of $\gamma_{i,j}$ in (2.45).

(d) Favero and Giavazzi tests: FG-E and FG-N are the IV (endogeneity corrected) and OLS (non-endogeneity corrected) Favero and Giavazzi tests respectively. Tests based on likelihood ratio tests on the parameters of the dummy variables defined in (2.58), a trivariate structural system where each return is expressed as a function of the remaining contemporaneous asset returns, own lagged returns and the set of dummy variables.

(e) Bae, Karolyi and Stultz test: based on defining the dummy variables as in (2.61) and using Wald tests applied to the maximum likelihood estimates of a multinomial logit model.

found to be spurious, being the result of weak instruments. Correcting the Favero and Giavazzi test for weak instruments yielded contagion channels similar to the channels identified by the DFGM test. The BKS test results tended to be inconsistent with the results of these last two tests. In general, the empirical results of the tests highlighted the need for investigating the sampling properties of the various tests with an extensive Monte Carlo design that looks at issues such as the dating of crises, the modelling of dynamics, the information effects of filtering. Some of these issues have been tackled in Dungey, Fry, González-Hermosillo and Martin (2004) who use a number of Monte Carlo experiments to demonstrate the size and power properties of many of these tests.

Chapter 3: Contagion in International Bond Markets [1]

1 INTRODUCTION

International financial markets have experienced several episodes of financial crisis since the mid-1990s. A major concern of financial market participants, central banks and governments during these periods is that a crisis in one country can spread to other markets to create extreme volatility elsewhere in the world. This is the case for the period corresponding to the Russian bond default in August of 1998, followed by the announcement of a recapitalization package for the hedge fund Long Term Capital Management (LTCM) in September, where bond markets in emerging and industrial countries exhibited widespread volatility. The Bank of International Settelements survey of market participants characterized this period as “the worst crisis” in recent times (BIS, 1999, p.40). A special feature of this crisis was that the duration was extremely short, possibly as a result of the aggressive easing of monetary policy by the U.S. Federal Reserve in the period following the recapitalization announcement.

This chapter identifies the transmission mechanisms of shocks from both the Russian bond default and the LTCM recapitalization announcement, to bond markets in emerging and industrial countries. Most analyses of recent financial crises tend to focus on either currency, banking or equity markets. In contrast, there is little empirical literature on the spread of crises through international bond markets. This is partly because a consistent and comprehensive historical time series database on bonds for many emerging economies is difficult to obtain. It is also partly the result of bond markets being relatively more stable during other financial crises such as the 1997-1998 Asian crisis, where it was equity and currency markets that exhibited relatively greater volatility; see for example Forbes and Rigobon (2002), Bae, Karolyi and Stulz (2003) and Granger, Huang and Yang (2000).

[1] This chapter is published in Dungey, M., Fry, R., González-Hermosillo B. and Martin V. (2006), “Contagion in International Bond Markets during the Russian and LTCM Crises,” *Journal of Financial Stability*, Vol. 2, March.

The empirical analysis is conducted on a panel of daily bond spreads for a broad range of emerging and industrial countries over 1998. The spreads of the emerging economies are the long-term sovereign bonds issued in international markets relative to a comparable risk-free benchmark, whilst the spreads of the industrial countries are the long-term corporate bonds issued in the domestic economy relative to a comparable risk-free benchmark.[1] One advantage of working with bond spreads is that they reflect the risk premium that investors assign to prospective borrowers. These risks include the perceived creditworthiness of borrowers, the willingness of lenders to take on risk, and the liquidity in the market, all of which are entangled during crisis episodes.[2]

The identification of the transmission mechanisms linking international bond markets is based on specifying a latent factor model of bond spreads. Four types of factors are considered. The first three types of factors include a common factor which impacts upon all bond markets, a set of regional factors, which are common to countries within a geographical area, and country-specific factors which are idiosyncratic to a specific bond market. The fourth type of factor investigated represents the effects of contemporaneous movements across markets having conditioned on the common, regional and idiosyncratic factors. This transmission channel is referred to as contagion as it represents an additional linkage during crisis periods in excess of movements in bond spreads that arise during non crisis periods; see, for example, Sachs, Tornell and Velasco (1996), Masson (1999a,b,c), Dornbusch, Park and Claessens (2000) and Pericoli and Sbracia (2003). An important feature of this modelling strategy is that it is possible to decompose the observed volatility in bond spreads into various components and thereby identify the contribution of contagion to total volatility in each country's bond market.[3]

[1] During most of the period of consideration, sovereign bonds in emerging markets were largely below investment grade or just investment grade. Therefore, for comparison, investment grade corporate bonds in mature economies are examined.

[2] This interpretation is consistent with the widening of the liquidity premium on otherwise similar assets (e.g. on-the-run 30-year versus off-the-run 29-year U.S. Treasury bonds) following the LTCM recapitalization announcement. The credit risk view of the Russian shock is also consistent with a cash-out of liquid markets with increased credit risks as investors' rebalanced their portfolios.

[3] Another advantage of the latent factor model is that it circumvents the need to use proxy variables to measure market fundamentals, as they are identified by extracting the common movements in bond spreads.

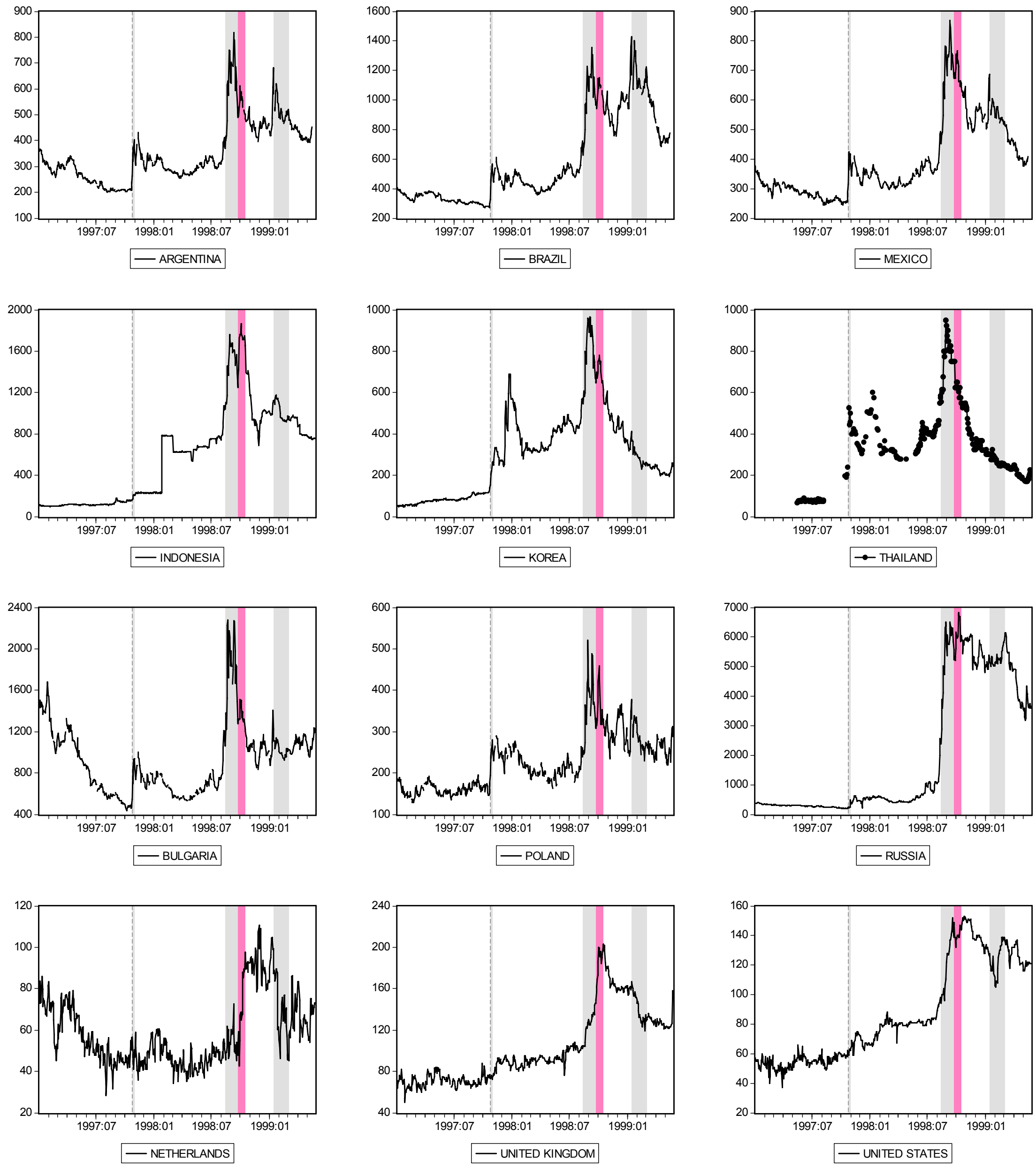
(continued)

The empirical analysis leads to four important findings. First, there is substantial contagion evident emerging from the Russian shock but relatively little from the LTCM shock. The contribution of contagion to total observed volatility in the change in bond spreads ranged from under one percent (to the US) to around 17 percent (to the Netherlands and Brazil). The second result points to the importance of financial exposures to the crisis countries in transmitting the crisis, the countries most affected by contagion from Russia had substantial banking exposures to Russia. The third result provides some evidence supporting the literature that contagion effects are regional in nature, contagion is consistently present in the Eastern European countries of the sample. The final important result is that contagion effects are not necessarily more apparent in developing financial markets than developed markets. Although the level of volatility experienced in developing markets is generally higher than developed markets the proportionate effect of contagion does not systematically differ between them.

The remainder of this paper is organized as follows. Section 2 reviews the background of events and puts forward a set of four propositions about the transmission of the crises. This is followed by a discussion of the empirical characterics of the data in Section 3. A model of contagion is described in Section 4, which is related to the existing literature on contagion in Section 5. The estimation method is discussed in Section 6 followed by the empirical results in Section 7. Section 8 concludes.

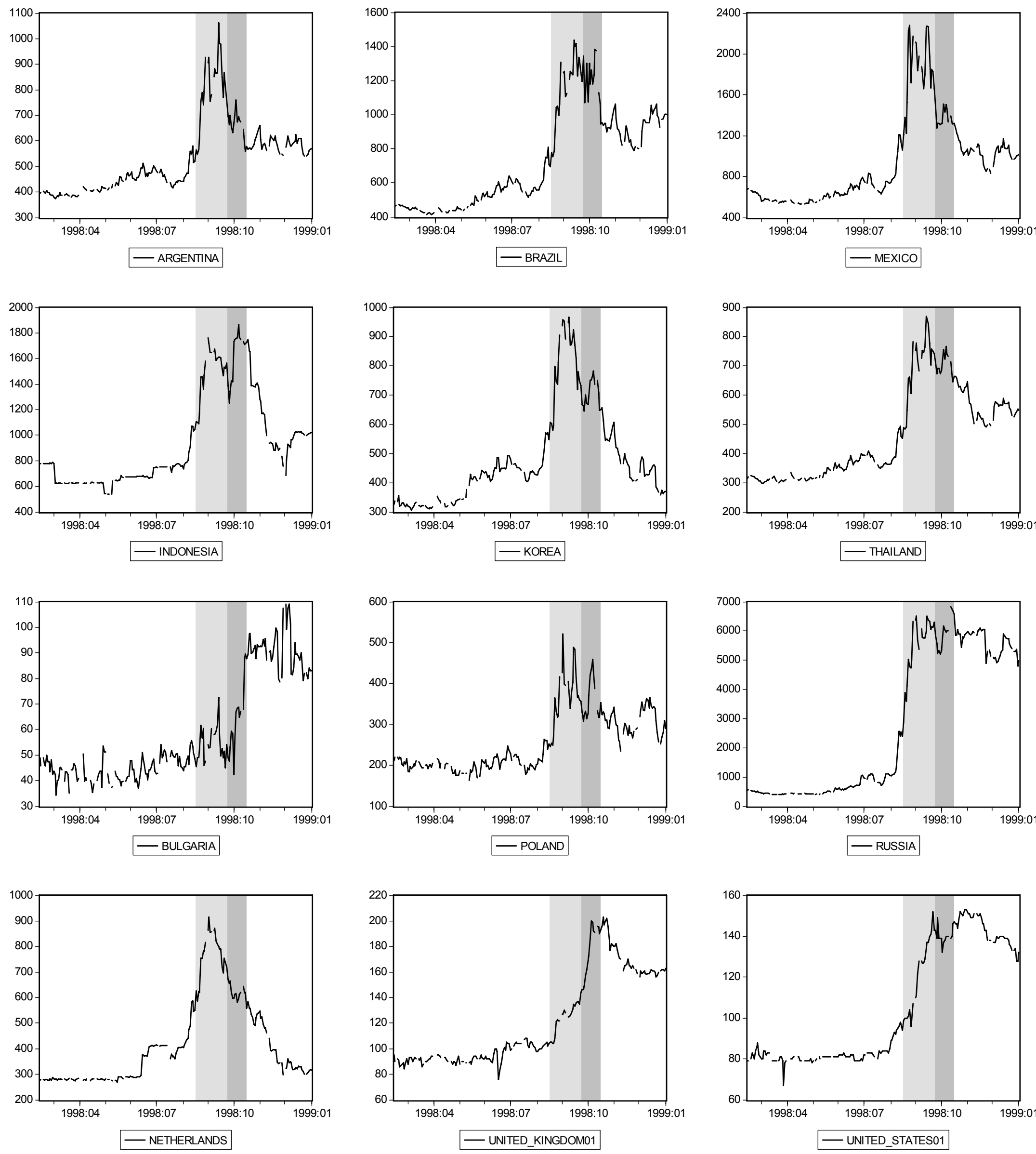
Examples of using proxy variables to measure market fundamentals include Eichengreen, Rose and Wyplosz (1996), Glick and Rose (1999) and Forbes and Rigobon (2002).

Figure 1: Bond Spreads, January 1997-May 1999 [4] (basis points)



[4] The shaded areas refer to episodes of crisis in international bond markets: the Hong Kong speculative attack on October 27, 1997; the Russian bond default on August 17, 1998; the LTCM recapitalization announcement on September 23, 1998; the inter-FOMC Fed interest rate cut on October 15, 1998; and the Brazilian effective devaluation on January 13, 1999 followed by several weeks of internal turmoil at the central bank. Data Sources: U.S. Federal Reserve, Bloomberg, Scotia Capital and Credit Swiss First Boston.

Figure 2: Bond Spreads, January 1998-December 1998 [5] (basis points)



[5] The shaded areas refer to episodes of crisis in international bond markets during this period: the Russian bond default on August 17, 1998; the LTCM recapitalization announcement on September 23, 1998; and the inter-FOMC Fed interest rate cut on October 15, 1998. Data Sources: U.S. Federal Reserve, Bloomberg, Scotia Capital and Credit Swiss First Boston.

2 BACKGROUND OF EVENTS AND PROPOSITIONS

2.1 Stylized Facts

During the Asian crisis, the turmoil which began with the devaluation of the Thai baht in July 1997, quickly precipitated declines in currencies and equities in the region and in other emerging markets (Granger, Huang and Yang (2000)). This contrasts with debt markets during this period where the effects on the risk premia of international bonds issued by emerging countries were rather limited. Apart from the relatively short period of turmoil in global financial markets resulting from the speculative attack on Hong Kong on October 27, 1997, bond spreads remained relatively stable in non-Asian countries during the second half of 1997 (see Figure 1).

Figures 1 and 2 also show that the stability experienced in international bond markets in the second half of 1997, continued into the first part of 1998. However, on August 17, 1998, when Russia widened the trading band of the ruble, imposed a 90-day moratorium on the repayment of private external debt and announced its plan to restructure official debt obligations due to the end of 1999, financial turmoil ensued.[6] Following the Russian default, spreads in other bond markets jumped, particularly in emerging markets, as markets reassessed global credit risks, see Figures 1-2.

In a matter of weeks after the Russian crisis, on September 23, 1998, financial markets learned of the plan to rescue LTCM, a large U.S. hedge fund which was in danger of collapse. LTCM operated by placing highly leveraged positions on the expectation of falling yield spreads based on historical evidence. Many historical correlations were overturned following the Russian crisis with LTCM losing enormous amounts of money on these positions; see Jorion (2000) who documents the evolution of LTCM's problems. The situation became serious quickly, to the extent that the New York Federal Reserve acted to facilitate a meeting between major banks which eventually co-operated to provide a bailout package to the troubled hedge fund.

During this period the U.S. Federal Reserve cut interest rates in three steps, on 29 September, 15 October and 17 November, partly due to concerns that the dramatic rises in

[6] See Kharas, Pinto and Ulatov (2001) for a discussion of the Russian crisis.

bond spreads, particularly for corporate debt, were indicative of a liquidity crisis. The October 15 interest rate cut was considered a surprise, as it occured between FOMC meetings. This cut was also interpreted as signalling a return to confidence in the markets, according to market participants surveyed in BIS (1999: pp. 9,39,45).[7]

Informal examination of the data for the second half of 1998 (Figure 2) suggests that the Russian crisis had a discernible impact on bond markets in both developed economies and emerging markets. The LTCM recapitalization announcement also appears to have had an impact on all the countries, with a relatively smaller hump experienced by most emerging countries relative to the effect of the Russian shock. The data suggest that the Russian and the LTCM recapitalization announcement shocks were reinforcing in their effects on other financial markets as practically all markets experienced two jumps in their spreads: one following the Russian default (the first band in Figure 2) and another one following the announcement of the LTCM financial problems (the second band in Figure 2).

Unlike other recent financial crises, the shocks that occurred during August and September 1998, seem to have been transmitted across countries with little in common. This includes countries that do not fit traditional explanations of contagion based on trade links, competitive devaluation or regional effects as suggested in the taxonomies of contagion by Lowell, Neu and Tong (1998) and Goldstein (1998). These crises affected countries as diverse as the United Kindgom and Brazil, and spanned emerging and developed markets. Disentangling the crises of 1998 is particularly complex because of its relative brevity and the fact that two distinct shocks occurred within weeks of each other.

2.2 Propositions

The discussion above suggests that a number of propositions can be formulated around the transmission of contagion across national borders. Four broad propositions are

[7] The exact timing of the LTCM crisis is necessarily approximate as pressures began building before the announcement of the recapitalization package for LTCM. Here we date the crisis as beginning with the recapitalization announcement on September 23, 1998 and ending with inter-FOMC Fed interest rate cut on October 15, 1998 which signaled the beginning of the "end" of the LTCM crisis. This otherwise arbitrary "end" to the crisis of 1998, is supported by the findings of Kumar and Persaud (2001).

formulated. The first is based on the existence of contagion, whereas the other three propositions are concerned with the conditions that control the strength of contagious transmisssion mechanisms.

Proposition A: Transmission of the crises through contagion

The empirical evidence for contagion effects is mixed. Some papers find little evidence of contagion while others find significant contagion; see for example Forbes and Rigobon (2002), Bae, Karolyi and Stulz (2003) and Favero and Giavazzi (2002). Most approaches test the statistical significance of the contagion. Here we consider whether contagion effects exist and measure their relative contribution to volatility in the bond spreads during the crisis. If contagion is not important, then the transmission mechanisms solely arise from trade and other macroeconomic linkages which occur during non-crisis periods as well.

Proposition B: Exposure through the banking system

Countries whose financial institutions have relatively larger exposures to Russia are expected to experience greater contagion. The implications of financial and institutional linkages between countries as a channel of contagion have been investigated by Kaminsky and Reinhart (2000), Van Rijkeghem and Weder (2001, 2003) and Pritsker (2001). Table 1 provides information on the relative size of offshore banking exposure for the industrial economies of the United States, the United Kingdom and the Netherlands. These figures show that as a proportion of the total economy, total offshore banking exposure is 23.4% for the Netherlands in 1998, which is nearly twice that of the United States and more than 10 times that of the United Kingdom In terms of exposure to Russia, the proportion is nearly 10 times more than both the United States and the United Kingdom These figures suggest that the Netherlands is potentially more vulnerable to contagion arising from the Russian bond default than either the United States or the United Kingdom.

Table 1: Industrial Country Offshore Banking Exposure, June 1998 (nominal US$ terms)

Country	Size of Economy (GNI, US$ bil)	Offshore Banking Exposure (US$ million)		Total banking exposure to size of economy (percent)	Russian exposure to total (percent)
	(1)	Total (2)	Russia (3)	(2) to (1)	(3) to (2)
U.S.	8447	160784	7781	1.9	0.1
U.K.	1327	165815	1834	12.5	0.1
Netherlands	403	94394	3979	23.4	1.0

Sources: Column (1) is drawn from World Bank World Tables; Columns (2) and (3) are sourced from the historical data from Table 9C in the *BIS Quarterly Review.*

Proposition C: Regional effects

If contagion impacts within regions, it is expected that the Russian bond default should particularly impact upon the Eastern European countries, Poland and Bulgaria. The importance of testing the regional effects of contagion is emphasized by Eichengreen, Rose and Wypolz (1996), Glick and Rose (1999) and Kaminsky and Reinhart (2000).

Proposition D: Fundamentals – Vulnerabilities

Countries with strong market fundamentals are less susceptible to the effects of contagion (Mody and Taylor, 2003, Sachs, Tornell and Velasco, 1996). This suggests that the emerging market economies investigated here are more likely to be prone to contagion than the developed economies; namely the U.S., U.K. and the Netherlands. In a similar vein, the Committee for Global Financial System (1999: pp7-8) claims that the Russian crisis affected emerging markets, while the LTCM recapitalization announcement affected developed markets. In equity markets, Kaminsky and Reinhart (2002) find that developed markets act as a conduit for financial crises between emerging markets, while Bae, Karolyi and Stulz (2003) find greater impact of crises on emerging equity markets.

3 The Data and Sample

The dataset comprises daily data for 12 countries collected for February to December 1998 (Argentina, Brazil, Mexico, Indonesia, Korea, Thailand, Bulgaria, Poland, Russia, the Netherlands, the United Kingdom and the United States). The countries were chosen to represent the key regions in global financial markets, for which long-term data series of liquid bonds could be constructed. This sample period allows our estimation to incorporate a clear 'pre-crisis' period and the two crisis events of the Russian bond default and the LTCM recapitalization announcement. The choice of daily data, over lower frequency data, is made in order to disentangle the effects of the Russian shock and the LTCM recapitalization announcement which occurred in close proximity to each other.

The data represent the spread of long-term debt over the appropriate risk-free yield for each country (see Appendix A for source descriptions, definitions and details). We label this spread as the 'premium' while recognizing that it does in fact reflect a myriad of factors, including the liquidity premium and the term structure of the yield curve. The choice of the risk-free rate is specific to each long-term bond. In the case of emerging countries, sovereign bonds are issued in U.S. dollars and hence the spread is calculated against the comparable maturity-matched U.S. Treasury bond rate. Where possible, the bonds selected for emerging markets are sovereign issues to reflect the true cost of new foreign capital – the exceptions are Poland and Bulgaria which are represented by Brady bonds. In the case of the developed bond markets, which are able to issue international bonds in domestic currency, BBB investment grade corporate bonds are compared to the corresponding risk-free Treasury bond in each country.[8]

The data for the United States are obtained directly from the Federal Reserve, and not from published sources. The source of the data for countries other than the United States is the authorities of each country. This data set was originally collated for the Committee on the Global Financial System to examine the events surrounding the market stresses in the third quarter of 1998 and is summarized in BIS (1999). In those cases where

[8] Below-investment grade corporate issues experienced even bigger jumps in their spreads and in their volatility. However, data limitations restricted the study to investment grade bonds.

there are missing observations, the data are obtained from either Bloomberg database or Credit Swiss First Boston directly (see Appendix A for more details).

A potential problem with using just price data is that prices may be biased due to lack of active market makers during the crisis periods. This is especially true during the LTCM recapitalization announcement period which was a crisis of liquidity. To circumvent this problem would require data on trade quantities. However, quantity data are not available at high frequency for the range of countries considered. Using lower frequency data would have the disadvantage of yielding insufficient information to characterize the Russian and LTCM recapitalization announcement crises, which are of a relatively short duration. For this reason, attention is focused on using daily price data.

The statistical characteristics of the data are summarised in Appendix B. The rise in spreads over the period is approximated by a unit root, as the corresponding risk free rates remained relatively constant during 1998. Both larger means and absolute movements are evident in the premia of developing markets compared with the industrialized countries. The data display non-normality, and fitting univariate integrated GARCH(1,1) models to the changes in the premia suggests that there is a common time-varying volatility structure underlying the data. This feature of the structure is exploited in the model described in the following section.

4 A Factor Model of Bond Spreads

Volatility in the premia of each country is hypothesized to be influenced by events that are country-specific and events that are common to all economies. However, it is difficult to ascertain both the timing and nature of these events. In the existing literature, contagion is tested by conditioning on events chosen by the researcher after the observed financial crises, for example the work of Eichengreen, Rose and Wyplosz (1995, 1996), Sachs, Tornell and Velasco (1996), and Glick and Rose (1999) follows this approach. The economic indicators chosen in this way are often statistically insignificant, and it is difficult to know whether they are the ‘correct’ choice even ex-post. A desirable alternative, noted by authors such as Dooley (2000) and Edwards (2000), is to use a modelling specification which does not require the choice of specific indicators with which to associate the crises, that is to use latent factors.

Latent factor models have been specified for a number of markets. The majority of the existing empirical work has focused on currency and equity markets, such as represented in Diebold and Nerlove (1989), Ng, Engle and Rothschild (1992), Mahieu and Schotman (1994), and King, Sentana and Wadhwani (1994). Empirical work on interest rates is rather less extensive. Gregory and Watts (1995) explore long bond yields across countries, while Dungey, Martin and Pagan (2000) apply a latent factor model to the spreads between individual country bonds and the US bond.[9]

The basic model of the bond market adopted in this paper is similar to that specified by Forbes and Rigobon (2002) and King, Sentana and Wadhwani (1994) for equity markets. Letting $r_{i,t}$ be the interest rate on the bond in country *i*, the interest rate is determined by a risk-free rate of interest, $rf_{i,t}$, a world factor, W_t and a time-varying country-specific factor $f_{i,t}$,

$$r_{i,t} = rf_{i,t} + \lambda_i W_t + \phi_i f_{i,t}, \qquad i = 1...n, \tag{3.1}$$

where n is the number of bond markets. The loadings on these world and country-specific factors are given by the parameters λ_i and ϕ_i respectively. The common factor, W_t, affects the premia in all countries, but with a differing parameter in each case.

Regional effects have been posited to be important in the spread of crises, for example in the work of Kaminsky and Reinhart (2002) and Glick and Rose (1999). To incorporate these effects, equation (3.1) is extended as follows:

$$r_{i,t} = rf_{i,t} + \lambda_i W_t + \phi_i f_{i,t} + \gamma_i R_{k,t}, \quad i = 1,...,n, k = Lat, As, Eur, \tag{3.2}$$

where $R_{k,t}$ is a time-varying regional factor and K=3 is the number of regions. The first regional factor is common to Latin American countries (Argentina, Brazil and Mexico) and is denoted $R_{Lat,t}$. The second is a regional factor common to the Asian economies (Indonesia, Korea and Thailand), denoted $R_{As,t}$ whilst the third regional factor of Eastern Europe (Bulgaria, Poland and Russia) is denoted $R_{Eur,t}$. No regional factor is included for

[9] A similar class of models is adopted by Kose, Otrok and Whiteman (2003) in studying business cycles.

the industrialized countries comprising the U.S., the U.K. and the Netherlands. Defining the premium to be $P_{i,t} = r_{i,t} - rf_{i,t}$, the model without contagion is specified as

$$\begin{bmatrix} P_{1,t} \\ P_{2,t} \\ : \\ : \\ : \\ : \\ : \\ : \\ : \\ : \\ : \\ P_{12,t} \end{bmatrix} = \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ : \\ : \\ : \\ : \\ : \\ : \\ : \\ : \\ : \\ \lambda_{12} \end{bmatrix} W_t + \begin{bmatrix} \gamma_{1,Lat} & 0 & 0 \\ \gamma_{2,Lat} & 0 & 0 \\ \gamma_{3,Lat} & 0 & 0 \\ 0 & \gamma_{4,As} & 0 \\ 0 & \gamma_{5,As} & 0 \\ 0 & \gamma_{6,As} & 0 \\ 0 & 0 & \gamma_{7,Eur} \\ 0 & 0 & \gamma_{8,Eur} \\ 0 & 0 & \gamma_{9,Eur} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} R_{Lat,t} \\ R_{As,t} \\ R_{Eur,t} \end{bmatrix} + \begin{bmatrix} \phi_1 & & 0 \\ & \phi_1 & \\ & .. & \\ 0 & & \phi_{12} \end{bmatrix} \begin{bmatrix} f_{1,t} \\ f_{2,t} \\ .. \\ f_{12,t} \end{bmatrix}, \quad (3.3)$$

where the order of the countries is: Argentina, Brazil, Mexico, Indonesia, Korea, Thailand, Bulgaria, Poland, Russia, Netherlands, UK and the U.S..

To incorporate the large movements in the premia over the sample period identified in Section 2, the common factor is specified as integrated of order one

$$W_t = W_{t-1} + \eta_t, \quad (3.4)$$

where η_t is a stationary disturbance term. The regional factors in (3.3) are also specified as integrated processes of order one

$$R_{k,t} = R_{k,t-1} + v_{k,t}, \ \ where \ \ k = Lat, As, Eur, \quad (3.5)$$

where $v_{k,t}$ are stationary disturbance terms. In addition, equation (3.3) shows that each premium has a unique idiosyncratic error, or country-specific factor, $f_{i,t}$. To complete the specification of the non-contagion model, the disturbance processes are assumed to be distributed as

$$\eta_t, v_{Lat,t}, v_{As,t}, v_{Eur,t}, f_{1,t}, f_{2,t}, ..., f_{12,t} \sim N(0, H_t), \quad (3.6)$$

where in general H_t is a 16-variate system of independent GARCH processes normalized to have unit unconditional variances. Whilst the factors are assumed to be independent, the model nonetheless is able to capture the comovements in bond spreads in the mean, as well as in the variance. An important advantage of adopting a factor structure is that it provides a parsimonious representation of the data, thereby circumventing the need to estimate highly parameterized multivariate GARCH models. Here we restrict the GARCH to the world factor, following the preliminary GARCH results reported in Appendix B, Table B.4, which showed a high degree of commonality amongst the conditional variance structure of the premia.[10]

To allow for the effects of contagion, equation (3.3) is augmented to include the idiosyncratic shocks from Russia ($f_{9,t}$) and the U.S. ($f_{12,t}$). This definition of contagion is consistent with those of Sachs, Tornell and Velasco (1996) and Masson (1999a,b,c) as it reflects the additional contemporaneous linkages across markets during crisis periods having conditioned on the factors in equation (3.3). The full factor model is represented by;

$$\begin{bmatrix} P_{1,t} \\ P_{2,t} \\ : \\ : \\ : \\ : \\ : \\ : \\ : \\ : \\ : \\ P_{12,t} \end{bmatrix} = \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ : \\ : \\ : \\ : \\ : \\ : \\ : \\ : \\ : \\ \lambda_{12} \end{bmatrix} W_t + \begin{bmatrix} \gamma_{1,Lat} & 0 & 0 \\ \gamma_{2,Lat} & 0 & 0 \\ \gamma_{3,Lat} & 0 & 0 \\ 0 & \gamma_{4,As} & 0 \\ 0 & \gamma_{5,As} & 0 \\ 0 & \gamma_{6,As} & 0 \\ 0 & 0 & \gamma_{7,Eur} \\ 0 & 0 & \gamma_{8,Eur} \\ 0 & 0 & \gamma_{9,Eur} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} R_{Lat,t} \\ R_{As,t} \\ R_{Eur,t} \end{bmatrix} + \begin{bmatrix} \phi_1 & & & 0 \\ & \phi_1 & & \\ & & .. & \\ 0 & & & \phi_{12} \end{bmatrix} \begin{bmatrix} f_{1,t} \\ f_{2,t} \\ .. \\ f_{12,t} \end{bmatrix} + \begin{bmatrix} \delta_{1,Rus} & \delta_{1,US} \\ \delta_{2,Rus} & \delta_{2,US} \\ \delta_{3,Rus} & \delta_{3,US} \\ \delta_{4,Rus} & \delta_{4,US} \\ \delta_{5,Rus} & \delta_{5,US} \\ \delta_{6,Rus} & \delta_{6,US} \\ \delta_{7,Rus} & \delta_{7,US} \\ \delta_{8,Rus} & \delta_{8,US} \\ 0 & \delta_{9,US} \\ \delta_{10,Rus} & \delta_{10,US} \\ \delta_{11,Rus} & \delta_{11,US} \\ \delta_{12,Rus} & 0 \end{bmatrix} \begin{bmatrix} f_{9,t} \\ I_t f_{12,t} \end{bmatrix}, \tag{3.7}$$

[10] The three regional factors were initially assumed to exhibit GARCH processes, but were found to be statistically insignificant.

where the strength of contagion from both Russia and LTCM are controlled by the parameters $\delta_{i,Rus}$ and $\delta_{i,US}$, whilst the other parameters are as defined in equation (3.3). For identification reasons there are no own effects, that is $\delta_{9,Rus} = \delta_{12,US} = 0$.

Given the global dominance of U.S. financial markets it is desirable to isolate the LTCM shock from other US based news. To achieve this, the contagion effects of LTCM ($f_{12,t}$) in equation (3.7) is multiplied by the indicator variable I_t. This takes the value of 1 for the period of the LTCM recapitalization announcement shock, the 23rd of September 1998 to the 15th of October 1998, and 0 for the non-LTCM crisis period.[11] This choice of dates is consistent with the BIS Committee on the Global Financial System (1999: pp. 8-9). It begins with the recapitalization package announced on 23rd September, and ends with the inter-Federal Open Market Commission (FOMC) rate cut by the Federal Reserve on October 15th, a date supported by Kumar and Persaud (2001). Whilst it is apparent that there were signals that LTCM was in difficulty pre-September 1998, reports suggest that the true size of the problem became clearer around the time of the meetings co-ordinated by the Federal Reserve; see, for example, Shirreff (1998). As the clearest signal to the market of LTCM's difficulties was the recapitalization announcement, this is used as the starting date.

A useful way of examining the results from estimating a model such as (3.7) is to consider the contribution that each factor makes to total volatility in the movement of the premium of each country. As the factors are independent, the total variance of the change in the premia for each economy can be conveniently decomposed as [12]

$$Var\left(\Delta P_{i,t}\right) = \lambda_i^2 + \gamma_i^2 + 2\delta_{i,Rus}^2 + 2\delta_{i,US}^2 + 2\phi_i^2. \tag{3.8}$$

The results of interest are then given as the proportion of the total volatility in the changes in the premium for country i due to the:

(i) contribution of the world factor $\dfrac{\lambda_i^2}{Var(\Delta P_i)}$

[11] In Dungey, Fry, González-Hermosillo and Martin (2002b), the indicator variable, I_t, was omitted – the influence of the US economy in global markets means that the impact of the LTCM shock was somewhat overstated. We thank Charles Goodhart for his suggestions on the structure of the dummy variable.

[12] The expression in equation (3.8) is based on rewriting equation (3.7) as an error correction model; for details see Dungey, Fry, Gonzalez-Hermosillo and Martin (2002b) equations (3.10) - (3.16).

(ii) contribution of the regional factor $\frac{\gamma_i^2}{Var(\Delta P_i)}$

(iii) contribution of the country-specific factor $\frac{2\phi_i^2}{Var(\Delta P_i)}$

(iv) contribution of contagion from Russia $\frac{2\delta_{i,Rus}^2}{Var(\Delta P_i)}$

(v) contribution of contagion from the U.S. $\frac{2\delta_{i,US}^2}{Var(\Delta P_i)}$.

5 Relationship with Existing Literature

The concept of contagion from both a theoretical and empirical viewpoint is controversial in the literature. Recent overviews of the issues are provided by Dornbusch, Park and Claessens (2000) and Pericoli and Sbracia (2003). The definition of contagion adopted in this paper is that contagion represents the effects of contemporaneous movements across countries having conditioned on a range of factors including common, regional and idiosyncratic factors. This definition of contagion is related to the approach of Favero and Giavazzi (2002) and Forbes and Rigobon (2001, 2002) and under certain scenarios is also equivalent to Eichengreen, Rose and Wyplosz (1996) and Bae, Karolyi and Stulz (2003); see Dungey, Fry, González-Hermosillo and Martin (2005b).

Contagion is viewed here as a residual, which is a common theme in the literature, for example the work of Sachs, Tornell and Velasco (1996) and Masson (1999a,b,c). Masson decomposes exchange rate changes into four components. These are "monsoonal shocks", or global shocks affecting all countries simultaneously, (W_t in (3.7)); linkages which occur through normal trade and economic relationships, (a combination of W_t and $R_{k,t}$ in (3.7)); country-specific shocks, ($f_{i,t}$ in (3.7)), and a residual, which is the component unexplained by these systematic relationships. It is this last concept that both this chapter and Masson (1999a,b,c) denote as contagion. For the model specified here this residual is a combination of the effects from $f_{9,t}$ and $f_{12,t}$ which are the shocks from Russia and the U.S..

Masson (1999a,b,c) attributes part of the residual process to multiple equilibria, or sunspots, where there is a role for self-fulfilling expectations leading to contagion if opinions are coordinated across countries, an approach also taken by Loisel and Martin (2001). Multiple equilibria models are also consistent with other channels for contagion, such as wake-up calls due to Goldstein (1998) or heightened awareness due to Lowell, Neu and Tong (1998). In these cases a reappraisal of one country's fundamentals leads to a reappraisal of the fundamentals in other countries, thereby resulting in the transmission of crises. Kyle and Xiong (2001) explain contagion in the LTCM and Russian crises as a wealth effect, as traders operating in risky markets encounter shocks and liquidate their portfolios. Thus, a shock in one market can reverberate in seemingly unconnected markets. Both the wake-up call, wealth effect model and Masson's definition of contagion are consistent with the model presented in Section 4.

The transmission of expectations in both the multiple equilibrium and wake-up call models can lead to herd behavior as in work by Kaminsky and Schmukler (1999) and Calvo and Mendoza (2000). Herd behavior leads to a concept distinguished as unwarranted contagion by Kruger, Osakwe and Page (1998), which occurs when a crisis spreads to another country that otherwise would not have experienced a speculative attack. This also corresponds with contagion defined as a residual. A further potential channel of contagion is through asset bubbles created by self-fulfilling expectations, moral hazard, or government guarantees, either implied or explicit. Krugman (1998) shows how herd behaviour may burst these bubbles.

Existing empirical work which also uses definitions of contagion fitting into the current framework, include Forbes and Rigobon (2002) who test for changes in the correlation structure between asset returns, and Favero and Giavazzi (2002) who concentrate on testing for the transmission of large shocks across markets. The effect of 'news' announcements in transmitting crises is investigated by Baig and Goldfajn (1999) and Ellis and Lewis (2000) for a range of countries. Kaminsky and Schmukler (1999) also analyze the effects of news, where contagion is defined as the spread of investors' moods across national borders. Their key result is that some of the largest swings in the stock market occurred on days of no news. However, Baig and Goldfajn (1999) and Kaminsky and Schmukler (1999) make no distinction between anticipated or unanticipated shocks.

Alternative definitions of contagion which lie outside the framework adopted in this paper are based on market fundamental linkages. In the framework of Section 4, these channels are captured by the global and regional factors of the model. For example, Reside and Gochoco-Bautista (1999) define contagion as the spillover effects of domestic disturbances on nearby or related economies, using lagged changes in the exchange rates as their contagion variable. Goldstein, Kaminsky and Reinhart (2000) construct a contagion vulnerability index based on correlations between stock markets, trade linkages, presence of common markets and inter-linkages between banking systems. Van Rijckeghem and Weder (2001) construct a subjective binary variable to examine contagion effects due to financial and trade linkages. Eichengreen, Rose and Wyplosz (1996), Wirjanto (1999), and Kruger, Osakwe and Page (1998) condition their models on the existence of a crisis elsewhere.

6 Estimation Method

Gourieroux and Monfort (1994) have shown that direct estimation of the factor model in Section 4 by likelihood methods based on existing deterministic numerical procedures is infeasible as a result of the nonlinear structure arising from the GARCH conditional variance structure. Estimation procedures based on the Kalman filter or GMM only produce an approximation to the likelihood and thereby yield inconsistent parameter estimates. To circumvent problems of parameter inconsistency we adopt the indirect estimation techniques of Gourieroux, Monfort and Renault (1993) and Gourieroux and Monfort (1994) to estimate the models specified in Section 4. A recent alternative numerical simulation approach focusing on the direct likelihood is Fiorentini, Sentana and Shephard (2004).

Indirect estimation belongs to a class of techniques whereby the parameters are estimated by matching the characteristics of the sample data, with those of data simulated from the hypothesized model. The key to this technique is that while the model is analytically complex to evaluate directly, it is relatively straightforward to simulate. Other forms of this technique are known as Simulated Method of Moments (SMM) and Efficient Method of Moments (EMM). SMM is associated with the work of Duffie and Singleton (1993) and EMM with Gallant and Tauchen (1996). The differences between the three methods lie in the way in which the matching of moments between actual and simulated data proceeds.

In indirect estimation, the matching of moments is accomplished via specifying an auxiliary model which acts as an approximation to the true likelihood function. The auxiliary model is chosen to capture the key empirical characteristics of the data which are needed to identify the unknown parameters. The first set of conditions is based on a VAR(1) of the levels of the premia, where the moments are given by the product of the residuals and the lagged values of all premia in the VAR, P_{t-1}. That is,

$$k_t^0 = \{u_{1t}P_{t-1}^{'}, u_{2t}P_{t-1}^{'}, u_{3t}P_{t-1}^{'}, ..., u_{12t}P_{t-1}^{'}\}. \tag{3.9}$$

This is of dimension (1x144). The second set of moment conditions corresponds to the variance of the level of the premia. Formally,

$$k_t^1 = P_{i,t}^2, \quad i \geq 1, 2, ..., 12. \tag{3.10}$$

The third set of moment conditions captures the AR(1) structure of the changes in the premia,

$$k_t^2 = (\Delta P_{i,t} - \Delta \overline{P}_{i,t})(\Delta P_{i,t-1} - \Delta \overline{P}_{i,t-1}), \qquad i = 1, 2, ...12\,. \tag{3.11}$$

The fourth and fifth set of moment conditions capture conditional volatility in the premia arising from the GARCH characteristics of the data discussed in Section II. It comprises AR(1) and AR(2) loadings for the squared changes in the premia. In a similar manner to Diebold and Nerlove (1989), the number of overidentifying conditions is controlled by including only the 'own' squared autocorrelations of the change in the premium. These additional expressions contain a total of 12 elements each

$$k_t^3 = (\Delta P_{i,t}^2 - \Delta \overline{P}_{i,t}^2)(\Delta P_{i,t-1}^2 - \Delta \overline{P}_{i,t-1}^2), \quad i = 1, 2, ..., 12\,, \tag{3.12}$$

$$k_t^4 = (\Delta P_{i,t}^2 - \Delta \overline{P}_{i,t}^2)(\Delta P_{i,t-2}^2 - \Delta \overline{P}_{i,t-2}^2), \quad i = 1, 2, ..., 12\,. \tag{3.13}$$

Collecting all (144+12+12+12+12) time series from (3.9) to (3.13) into a (1x192) vector

$$g_t = \{k_t^0, k_t^1, k_t^2, k_t^3, k_t^4\}, \tag{3.14}$$

and taking the sample average of g_t defines all of the moment conditions that summarize the auxiliary model at time *t*.

Analogous to the moment conditions based on the sample data, a set of moment conditions based on the simulated data is given by taking the sample averages of,

$$v_h = \{k_h^0, k_h^1, k_h^2, k_h^3, k_h^4\}, \tag{3.15}$$

where $k_h^0, k_h^1, k_h^2, k_h^3$ and k_h^4 are the analogs of equations (3.9) to (3.13) with the actual data replaced by the simulated data for the h^{th} simulation of the premia, $P_{i,h}$.

Letting θ be the set of unknown parameters of the latent factor model, the indirect estimator, $\hat{\theta}$, is the solution of:

$$\hat{\theta} = \arg\min_{\theta} \left[\overline{g} - \frac{1}{H}\sum_{h=1}^{H} \overline{v}_h \right]' \Omega^{-1} \left[\overline{g} - \frac{1}{H}\sum_{h=1}^{H} \overline{v}_h \right], \tag{3.16}$$

where $\overline{g}$ and $\overline{v}_h$ are respectively the sample means of equations (3.14) and (3.15). The matrix Ω is a weighting matrix computed as follows, see Gourieroux, Monfort and Renault (1993),

$$\Omega = \frac{1}{T} g_t{}' g_t + \frac{1}{T} \sum_{l}^{L} \omega_l (g_t{}' g_{t-l} + g_{t-l}{}' g_t) \tag{3.17}$$

where

$$\omega_l = 1 - \frac{l}{L+l}, \tag{3.18}$$

are the Newey-West weights. In constructing this weighting matrix, the blocks are assumed to be independent.

The indirect estimator in equation (3.16) is solved using the gradient algorithms in OPTMUM, GAUSS version 3.2, where the gradients are computed numerically. The simulations are based on normal random numbers using the GAUSS procedure RNDN. [13]

7 Empirical Results

To examine the differences between the transmission of contagion from the Russian crisis and the LTCM recapitalization announcement, the unconditional variance decomposition estimates using equation (3.8), are presented in Table 2, and summarized in

[13] All results are based on H=500 simulation paths in (3.16) with a convergence tolerance of 0.001 and a lag window of L=5 in equation (3.17).

Figure 3.[14] Total volatility is decomposed into the contribution due to the world factor, regional factors, country-specific factors and the contagion effects from Russia and the LTCM recapitalization announcement shocks.

The results in Table 2 indicate that the dominant factor in the volatility decomposition of the change in the bond premia is the world factor, pointing strongly towards commonality in the movements in premia experienced over the sample period (Figures 1 and 2). This result is consistent with the view that increasing financial market integration has led to high (and expected) co-movements in asset prices. The world factor accounts for between 82 percent (Netherlands) and 99.7 percent (U.K. and Mexico) of total volatility. A corollary of this is that the regional factors have little influence on volatility, with all accounting for less than one percentage point of total volatility. Country-specific factors are relatively important for the U.S. (11.8 percent) and Argentina (12.7 percent), with the contribution to all the other countries being relatively small at less than 6 percent of total volatility.

The contagion effects recorded in Table 2 are consistent with Proposition A in Section 2.2, that contagious links exist during the crisis period. Most of the contagion effects in the results are sourced from Russia. The empirical results also show that contagion affects a wide range of countries across the regions investigated. Of the industrial nations, the Netherlands experiences almost 17 percent of its total volatility from contagion originating in Russia. The other developed markets experience less than 4 percent. These results provide support for Proposition B in Section 2.2, that financial exposure to the Russian markets made economies vulnerable to contagion. The U.S. financial exposure to Russia is also partly evident in the results, with contagion representing 3 percent of total U.S. volatility.

[14] Experiments extending this class of models to allow for contagion from the Latin American and Asian regions in conjunction with contagion from the U.S. and Russia, were undertaken to allow for the most general specification. However, this line of research was not pursued due to an undesirable amount of parameter instability inherent in estimating the larger models. The present model is an extension of the model investigated in Dungey, Fry, González-Hermosillo and Martin (2002b) which allowed for contagion effects just from Russia.

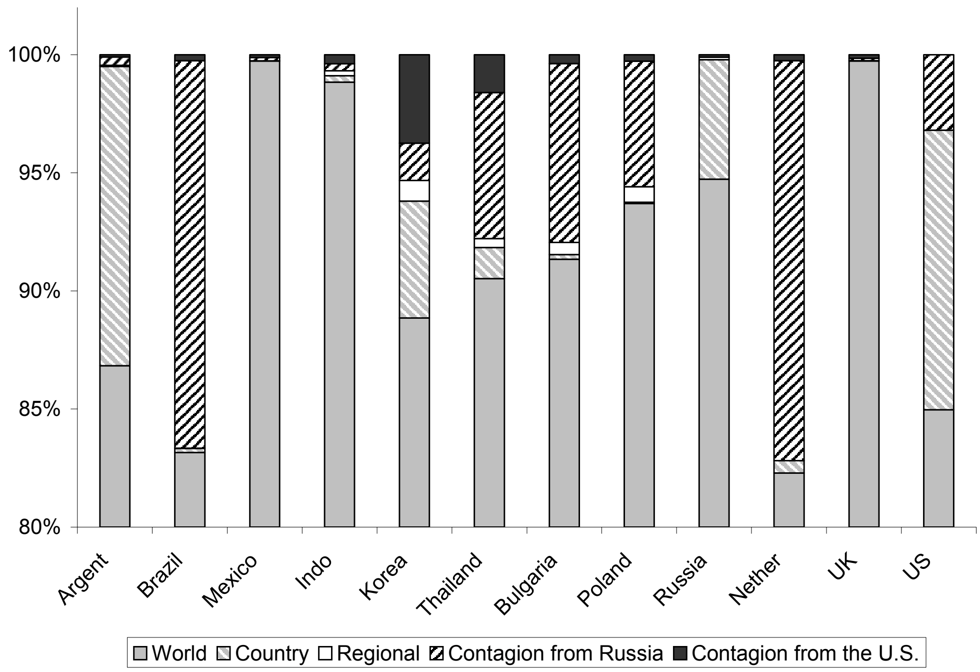
The Russian crisis results provide some support for the regional proposition, Proposition C in Section 2.2. Contagion from the Russian crisis was most consistently present in Eastern Europe, where it represents 5 and 7 percent of volatility for Poland and Bulgaria.

In contrast, contagion from the LTCM recapitalization announcement shock is very small as a proportion of total volatility, although its effects are nonetheless widespread across countries and regions. The largest contagion effect from the LTCM recapitalization announcement shock is under 4 percent of total volatility, experienced by Korea. It is possible that the relatively small LTCM recapitalization announcement effects are the result of the coordinated action of the U.S. Fed to halt its spread.

Table 2: Volatility Decomposition of Changes in the Premia
(contribution to total volatility, in percent)

	World	Country	Regional	Contagion		
				From Russia	From U.S.	Total Contagion
Latin America						
Argentina	86.828	12.676	0.045	0.352	0.099	0.451
Brazil	83.153	0.184	0.004	16.410	0.249	16.659
Mexico	99.736	0.001	0.006	0.148	0.109	0.257
Asia						
Indonesia	98.847	0.269	0.205	0.299	0.381	0.679
Korea	88.853	4.950	0.880	1.571	3.746	5.317
Thailand	90.521	1.318	0.376	6.181	1.603	7.784
Eastern Europe						
Bulgaria	91.334	0.204	0.516	7.573	0.374	7.946
Poland	93.708	0.046	0.659	5.314	0.273	5.587
Russia	94.733	5.058	0.107	-	0.102	0.102
Industrial						
Netherlands	82.289	0.520	-	16.941	0.251	17.191
U.K.	99.735	0.013	-	0.099	0.153	0.252
U.S.	84.972	11.833	-	3.196	-	3.196

Figure 3: Volatility Decomposition of Changes in the Premia
(contribution to total volatility, in percent)



The results for Indonesia, Brazil, and Argentina are worthy of further examination. Indonesia drew comment as the hardest hit by contagion effects in currency markets during the 1997 Asian crisis; see for example discussions by Radelet and Sachs (1998) and Goldstein, Kaminsky and Reinhart (2000). However, the contagion effects in Indonesian bond markets during 1998, as measured here, are relatively small. Contagion may still have been transmitted to Indonesia through asset markets other than the bond market, possibly due to illiquidity in the sovereign bond market during the political turmoil prevailing in Indonesia. An alternative interpretation is that Indonesia became extremely sensitive to global financial events in this period, consistent with a large value of λ_i in equation (3.7), compared with the East Asian crisis.

The Brazilian results show a relatively large proportionate effect of contagion, predominantly sourced from Russia, consistent with the view developed by Baig and Goldfajn (2000) that the withdrawal of foreign capital from Brazil during the Russian crisis precipitated the Brazilian crisis of January 1999. The relatively large contagion effect to Brazil may be a reflection of the vulnerability of Brazilian fundamentals, consistent with Proposition D in Section 2.2. Brazil at the time had recently managed to reenter global markets as a sovereign issuer and let domestic interest rates fall to stimulate the economy. In response to the Russian shock it experienced sharp capital outflows as foreign investors withdrew, which eventually promoted higher domestic interest rates and a tighter fiscal stance. However, the relief was short-lived as these reforms came to be viewed as unsustainable in the light of the depreciation of the Brazilian real (International Monetary Fund (2001)).

Argentina experienced relatively small contagion effects in 1998. Krueger (2002), notes that Argentina appeared in relatively good economic condition at that time, which is consistent with the fundamentals proposition. The International Monetary Fund (2001: p.9) pointed out that Argentina had not had access to financial markets to meet its current financing commitments during the crisis period. It was only later that the combination of policy settings was revealed to be unsustainable. In light of this it is noteworthy that the factors determining total volatility in the sample period for Argentina are more like those determining the U.S. than the other countries examined. In particular, the contributions to total volatility coming from the country-specific factors in Argentina and the U.S. are the largest of the countries examined. This may reflect the fact that Argentina was the only emerging economy in our sample with a currency board regime that appeared to be credible during this time.

The results provide little evidence to support the proposition that contagion emanating from Russia is confined to developing nations, or that contagion emanating from the LTCM recapitalization announcement was confined to developed markets, as suggested by the Committee on the Global Financial System (1999: p.7-8). However, it is difficult to derive any stylized facts to support or refute the contention that emerging markets are more affected by contagion than developed markets. The evidence presented here suggests that both types of markets can be affected by contagion to varying degrees. For example, countries where the effect of contagion from Russia is less than one percentage point include the Argentina, Mexico, Indonesia and the United Kingdom.

To address these issues further, we transform the results in Table 2 into their squared basis point equivalent by multiplying the values in Table 2 by the variance in the changes in the premia for each country (i.e. the square of the standard deviations which are reported in Table B.2 in Appendix B). The estimated variance decompositions in squared basis points are reported in Table 3.

Table 3: Volatility Decomposition of Changes in the Premia
(contribution to total volatility, in squared basis points)

	World	Country	Regional	Total Contagion
Latin America				
Argentina	984.339	143.707	0.505	5.118
Brazil	2923.097	6.472	0.138	585.600
Mexico	525.311	0.006	0.034	1.352
Asia				
Indonesia	3085.454	8.385	6.408	21.210
Korea	728.813	40.602	7.219	43.616
Thailand	452.579	6.591	1.882	38.918
Eastern Europe				
Bulgaria	9138.896	20.378	51.620	795.107
Poland	494.421	0.245	3.479	29.476
Russia	55685.890	2973.197	62.971	59.942
Industrial				
Netherlands	23.907	0.151	-	4.994
U.K.	13.876	0.002	-	0.035
U.S.	6.380	0.888	-	0.240

Comparing the results in Tables 2 and 3 highlights the differences between emerging and developed markets. Consider the Netherlands. In proportionate terms in Table 2, contagion contributes 17 percent to volatility in the Netherlands. However, in Table 3, this corresponds to 5 squared basis points[15], only greater than the other developed markets and Mexico. On the other hand, Brazil, which had the second greatest proportionate contribution from contagion, also has the second greatest squared basis point contribution, at around 590 squared basis points. The largest squared basis point contribution from contagion was experienced by Bulgaria. Bulgaria had a proportionate

[15] This result may also reflect the choice of the corporate bond used for the Netherlands, it would be interesting to expand the empirical analysis to a wider set of corporates.

contribution from contagion of almost 8 percent, similar to that for Thailand, but contagion contributed 795 squared basis points in Bulgaria, compared with 39 squared basis points in Thailand. The bond markets of emerging countries experienced a greater squared basis point contribution from contagion than the developed countries due to their absolute higher levels of volatility.

8 Conclusion

The international spillover effects stemming from the Russian debt default and the LTCM recapitalization announcement in 1998 seemed to be different from those of other financial crises in the 1990s. In 1998, bond markets in both developed and emerging economies experienced a significant widening of spreads between long-term bonds and their corresponding risk-free rate of return. In other episodes of financial crisis during the 1990s, the impact of crises seemed to be limited to emerging markets, or even a regional subset of them.

This paper examined the crises associated with the Russian bond default in August 1998, and the LTCM recapitalization announcement in September 1998. Using a latent factor model, the change in the premia of twelve bond markets was decomposed into components associated with a common world factor, country-specific factors, regional factors and contagion effects. Contagion was defined as the contemporaneous effect of idiosyncratic shocks transmitting across country borders. This definition of contagion is consistent with those offered in a substantial portion of the literature on this topic, including Masson (1999 a,b,c), Favero and Giavazzi (2002) and Forbes and Rigobon (2001, 2002). The contribution of this paper is both in the application to bond markets and that we provide numerical estimates of the contribution of contagion to volatility in those markets.

The results show clear evidence of contagion effects from Russia, to both emerging and developed countries, while the global contagion effects from the LTCM recapitalization announcement tended to be smaller. In proportionate terms, contagion effects from Russia were particularly substantial for the Netherlands, Brazil, Bulgaria and Thailand, ranging from 8 percent to about 17 percent of total volatility. The results showed that the strength of market fundamentals and the extent of offshore exposures of countries to Russia were important factors in determining the strength of contagion across national borders. Further, there is also strong evidence that contagion operated within regions, with the Russian bond default affecting the bonds markets of Poland and Bulgaria.

The absence of substantial contagion from the LTCM recapitalization announcement, as a global liquidity shock, is somewhat surprising given the anecdotal evidence offered by traders surveyed by the Committee on the Global Financial System (1999: chapter 3). However, these results may reflect the short duration of the LTCM recapitalization announcement period (spanning about three weeks) as the Fed acted to contain a potential credit crunch by easing monetary policy aggressively. The evidence also suggests that while the U.S. experienced some contagion from Russia, contagion from the LTCM recapitalization announcement crisis to Russia was very small.

The proportion of volatility in the premia attributed to contagion did not provide clear evidence as to whether the crises had a greater effect on emerging or developed markets. When the results were transformed to squared basis point effects, the evidence generally supported the contention that contagion was greater in emerging markets, due to the overall higher degree of volatility typically experienced in those markets. While most of the literature on contagion generally espouses the notion that contagion is only a concern for emerging countries, the results in this paper suggest that contagion can also be meaningful for developed economies, at least in the bond market.

The results also give support to the view that Brazil was affected by contagion prior to its currency crisis in January 1999. The relatively large contagion effects from Russia to Brazil, may be a reflection of the vulnerability of this country. That the contagion to Brazil is evident in the data prior to its own crisis provides scope for interesting future work in establishing at what point pre-crisis jitters are evident in financial markets.

A Data Definitions and Sources

Argentina: Republic of Argentina bond spread over U.S. Treasury.
Source: U.S. Federal Reserve.

Brazil: Republic of Brazil bond spread over U.S. Treasury.
Source: U.S. Federal Reserve.

Mexico: JP Morgan Eurobond Index Mexico Sovereign spread over U.S. Treasury. Source: U.S. Federal Reserve.

Indonesia: Indonesian Yankee Bond Spread over U.S. Treasury.
Source: U.S. Federal Reserve.

Korea: Government of Korea 8 7/8% 4/2008 over U.S. Treasury.
Source: Bloomberg (50064FAB0)

Thailand: Kingdom of Thailand Yankee Bond Spread over U.S. Treasury.
Source: U.S. Federal Reserve. (The longer series used in Figure 1, 7.75% 15/04/07, comes from Credit Swiss First Boston).

Bulgaria: Bulgarian Discount Stripped Brady Bond Yield Spread over U.S. Treasury. Source: U.S. Federal Reserve.

Poland: Poland Par Stripped Brady Bond Yield Spread over U.S. Treasury.
Source: U.S. Federal Reserve.

Russia: Government of Russia 9.25% 11/2001 over U.S. Treasury.
Source: Bloomberg (007149662).

Netherlands: Akzo Nobel NV 8% 12/2002 yield spread over NETHER 8.25% 6/2002. Source: U.S. Federal Reserve.

U.K.: U.K. Industrial BBB Corporate 5-year Bond Spread over Gilt. Source: Bloomberg (UKBF3B05)

U.S.: U.S. Industrial BBB1 Corporate 10-year Bond Spread over U.S. Treasury. Source: Bloomberg (IN10Y3B1)

The data obtained from the U.S. Federal Reserve was for the Bank for International Settlements, Committee on Global Financial System to aid in their enquiry into the turmoil of 1998 (Bank for International Settlements, Committee on the Global Financial System (1999)). The data will not necessarily represent trades enacted. The estimation is based on daily data on spreads from February 12 to January 1, 1999. The bond spreads, or "risk premia," are constructed by taking a representative long-term sovereign bond issued in U.S. dollars by an emerging country and subtracting from it a U.S. Treasury bond of comparable maturity. For developed economies, the risk premia are constructed by taking a representative long-term corporate bond in domestic currency and subtracting from it a Government Treasury bond of comparable maturity.

Missing observations were dealt with by removing all contemporaneous observations for that date across countries. The original sample of 231 observations was reduced to 209 observations after accounting for missing observations. The exact details of the missing observations are contained in Dungey, Fry, González-Hermosillo and Martin (2002b).

B Descriptive Statistics

Table B1: Descriptive Statistics of Premia (in levels)

	Latin America			**Asia**		
Statistics	Argentina	Brazil	Mexico	Indonesia	Korea	Thailand
Mean	534.70	744.07	469.70	959.67	486.26	423.17
Maximum	1061.00	1438.00	868.33	1865.80	965.88	916.30
Minimum	374.00	415.00	297.66	537.10	306.70	270.20
Std. Dev.	140.62	291.13	155.61	369.50	163.88	167.48
AR(1)	0.97	0.98	0.99	0.99	0.98	0.99
AR(2)	0.94	0.96	0.97	0.97	0.96	0.98
Skewness	1.26	0.61	0.66	0.97	1.26	1.16
Kurtosis	4.38	2.12	2.16	2.58	3.84	3.32
Jarque-Bera	71.84	19.71	21.10	34.05	61.44	47.79
(p value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Eastern Europe			**Industrial**		
	Bulgaria	Poland	Russia	Netherlands	U.K.	U.S.
Mean	951.72	261.21	2871.81	58.59	122.92	106.06
Maximum	2279.00	521.00	6825.78	109.10	203.00	153.00
Minimum	535.00	162.00	392.35	34.20	76.00	67.00
Std. Dev.	431.92	75.73	2512.65	20.38	36.26	28.85
AR(1)	0.97	0.95	0.99	0.96	0.99	0.99
AR(2)	0.94	0.90	0.98	0.93	0.98	0.98
Skewness	1.35	0.95	0.28	0.95	0.72	0.44
Kurtosis	4.26	3.17	1.20	2.42	2.03	1.38
Jarque-Bera	77.52	31.53	30.96	34.24	26.11	29.51
(p value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table B2: Standard Deviations of the Change in the Premia

Latin America		**Asia**	
Argentina	33.67	Indonesia	55.87
Brazil	59.29	Korea	28.64
Mexico	22.95	Thailand	22.36
Eastern Europe		**Industrial**	
Bulgaria	100.03	Netherlands	5.39
Poland	22.97	U.K.	3.73
Russia	242.45	U.S.	2.74

Table B3: Augmented Dickey Fuller (ADF) and
Phillips Perron (PP) Unit Root Tests of the Premia

	Latin America			**Asia**		
Statistic	Argentina	Brazil	Mexico	Indonesia	Korea	Thailand
ADF Test	-1.700	-1.138	-1.183	-1.219	-1.302	-1.129
PP Test	-1.818	-1.283	-1.273	-1.216	-1.433	-1.081
	Eastern Europe			**Industrial**		
	Bulgaria	Poland	Russia	Netherlands	U.K.	U.S.
ADF Test	-1.379	-2.287	-0.727	-1.256	-0.605	-0.602
PP Test	-1.685	-2.299	-0.741	-1.540	-0.577	-0.641

MacKinnon critical values for rejection of the hypothesis of a unit root for the ADF test are:
1% critical value -3.4634 (* represents rejection at the 1% level of significance)
5% critical value -2.8756 (** represents rejection at the 5% level of significance)
MacKinnon critical values for rejection of the hypothesis of a unit root for the PP test are:
1% critical value -3.4631 (* represents rejection at the 1% level of significance)
5% critical value -2.8755 (** represents rejection at the 5% level of significance)

Table B.4 presents the results from estimating an integrated GARCH(1,1) model for changes in each of the premium series. The changes are examined in order to highlight the properties of the short-term adjustment process in the data.

$$\begin{aligned} \Delta P_{i,t} &= \rho_0 + e_{i,t} \\ e_{i,t} &= \sqrt{h_{i,t}}\,u_{i,t} \\ h_{i,t} &= \alpha_0 + \alpha_1 e^2_{i,t-1} + (1-\alpha_1)h_{i,t-1} \\ u_{i,t} &\sim N(0,1), \end{aligned} \tag{1}$$

where $\Delta P_{i,t}$ is the change in the premium for country i recorded at time t.

Table B4: Univariate Integrated GARCH (1,1) Parameter Estimates
(QMLE standard errors in brackets)

Country	Parameter ρ_0	α_0	α_1	ln L
Latin America				
Argentina	0.324	12.602	0.288	-916.035
	(0.897)	(6.989)	(0.065)	
Brazil	1.015	26.714	0.242	-1023.260
	(1.524)	(18.608)	(0.055)	
Mexico	0.145	11.528	0.338	-854.152
	(0.649)	(6.980)	(0.098)	
Asia				
Indonesia	–1.216	251.212	0.413	-1088.470
	(2.553)	(212.662)	(0.164)	
Korea	–0.535	20.813	0.203	-947.494
	(1.212)	(11.063)	(0.044)	
Thailand	–0.700	32.425	0.250	-906.889
	(0.862)	(30.407)	(0.138)	
Eastern Europe				
Bulgaria	0.150	59.091	0.317	-1088.000
	(2.152)	(37.833)	(0.070)	
Poland	–0.209	22.949	0.325	-896.909
	(0.902)	(30.524)	(0.254)	
Russia	–0.022	1.584	0.213	-636.669
	(0.374)	(1.609)	(0.145)	
Industrial				
Netherlands	–0.022	1.583	0.213	-626.669
	(0.322)	(1.602)	(0.144)	
U.K.	0.070	1.627	0.409	-553.957
	(0.233)	(0.776)	(0.113)	
U.S.	0.061	1.059	0.595	–467.876
	(0.124)	(1.320)	(0.446)	

Chapter 4: Contagion in Global Equity Markts [1]

1 Introduction

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

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

The empirical results also show that the most influential source of contagion effects differs across the two asset types during this period: the majority of the contagion effects in equity markets are sourced through the US equity market, while in bond markets contagion is primarily associated with events in Russia, as discussed in chapter 3 of this thesis. The importance of the US market in distributing equity market shocks supports the hypothesis of Kaminsky and Reinhart (2002) that large markets act as centres in distributing shocks to the periphery markets.

The empirical results of this paper contribute to the existing literature that focuses on the role of equity markets in acting as a conduit during the Russian bond crisis and the LTCM's near collapse, by adopting a more general model that looks at a range of

[1] This chapter is published in Dungey, M., R. Fry, B. Gonzalez-Hermosillo, and V. Martin (2007a), "Unanticipated Shocks and Systemic Influences: the Impact of Contagion in Global Equity Markets in 1998," *American Journal of Finance and Economics*, Vol. 18, Issue 2, August.

factors linking both industrial and emerging equity markets during the financial crises of 1998. The earlier work of the BIS Committee on the Global Financial System (1999) focuses on industrial countries, whereas Rigobon (2003) and Hernández and Valdés (2001) concentrate on emerging markets. More recently, Kaminsky and Reinhart (2003) look at the interrelationships between industrial and emerging markets, while Baig and Goldfajn (2001) specifically focus on the transmissions to Brazil. The effects of the Russian and LTCM shocks on international bond markets are studied by Dungey, Fry, González-Hermosillo and Martin (2006), Jorion (2000) and the Committee on the Global Financial System (1999).

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

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

2 A Model of Financial Turmoil in Equity Markets During 1998

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

Let $s_{i,t}$ represent the equity returns of country i at time t. A total of 10 equity markets is used in the empirical analysis including 6 emerging equity markets (Argentina (AR), Brazil (BR), Hong Kong SAR (HK), Thailand (TH), Poland (PO) and Russia (RU)) and 4 industrial equity markets (Germany (GE), Japan (JA), United Kingdom (UK) and the United States (US)).[2] Defining s_t as a (10×1) vector of all equity returns, the dynamics of equity markets are assumed to be represented by the following vector autoregression (VAR)

$$s_t = \mu + A_1 s_{t-1} + A_2 s_{t-2} + \cdots + A_p s_{t-p} + u_t, \tag{4.1}$$

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

The disturbance term u_t in (4.1) represents shocks to equity markets which are assumed to be derived from a set of factors. In specifying the factor structure, the model distinguishes between a benchmark period where the factors represent the market fundamentals which link international equity markets, and a crisis period where the benchmark factor structure is augmented with additional linkages that capture contagion caused by shocks which increase the comovements of international equity markets. These factor structures are formally specified below.

2.1 A Benchmark Model

The factor structure of u_t in (4.1) during the benchmark period is specified as

$$u_t = \left[\begin{array}{ccc} A & \vdots & \Phi_1 \end{array} \right] f_t = \Gamma_1 f_t, \tag{4.2}$$

[2] The countries examined in this chapter are slightly different from those in chapter 3 because of an interest in examining countries known to have experienced a sharp correction in their equity markets during the period of study, which appear to have been inmune to contagion in bond markets (for example, Hong Kong). However, both chapters examine representative countries from emerging markets in Asia, Latin America and Europe, as well as mature economies. Furthermore, a robustness check is undertaken at the end of the chapter to examine differences between the data sets used in chapters 3 and 4.

where f_t represents the full set of factors

$$f_t = [w_t, e_t, d_t, r_t, v_{AR,t}, v_{BR,t}, \cdots, v_{US,t}], \tag{4.3}$$

and

$$A = \begin{bmatrix} \lambda_{AR} & \gamma_{AR} & 0 & \psi_{AR} \\ \lambda_{BR} & \gamma_{BR} & 0 & \psi_{BR} \\ \lambda_{HK} & \gamma_{HK} & 0 & 0 \\ \lambda_{TH} & \gamma_{TH} & 0 & 0 \\ \lambda_{PO} & \gamma_{PO} & 0 & 0 \\ \lambda_{RU} & \gamma_{RU} & 0 & 0 \\ \lambda_{GE} & 0 & \delta_{GE} & 0 \\ \lambda_{JA} & 0 & \delta_{JA} & 0 \\ \lambda_{UK} & 0 & \delta_{UK} & 0 \\ \lambda_{US} & 0 & \delta_{US} & \psi_{US} \end{bmatrix}, \quad \Phi_1 = diag \begin{bmatrix} \phi_{AR} \\ \phi_{BR} \\ \phi_{HK} \\ \phi_{TH} \\ \phi_{PO} \\ \phi_{RU} \\ \phi_{GE} \\ \phi_{JA} \\ \phi_{UK} \\ \phi_{US} \end{bmatrix}. \tag{4.4}$$

The factor w_t in (4.3) represents shocks that simultaneously impact upon all equity markets with the size of the impact determined by the loading parameter λ_i. For this reason this factor is referred to as a world factor. Typical examples of world factors would be the global effects of changes in US monetary policy on world equity markets (Forbes and Rigobon, 2002), or the simultaneous impact on international equity markets of an oil price shock. One important difference between these choices of factors is that w_t in (4.3) is not assumed to be observable, but is treated as a latent factor.

The model in (4.3) contains two factors to distinguish emerging and developed markets, which are represented by e_t and d_t respectively (see also Kaminsky and Reinhart (2002), and the Committee on the Global Financial System (1999). The factor e_t, captures those shocks which specifically affect the six emerging markets where the size of the impact is governed by the parameter γ_i. The factor d_t captures those shocks which just affect the four industrial equity markets, with the size of the impact controlled by the parameter δ_i.

To allow for shocks which solely capture a common regional interest, such as proposed by Glick and Rose (1999), the factor r_t impacts only upon Argentina (AR), Brazil (BR) and the US, with loading parameters given by ψ_i. There are insufficient countries in any other common regional grouping to warrant the inclusion of further regional factors in the set of equity markets used in the empirical application.

The last set of factors in (4.3) are given by $v_{i,t}$, which represent shocks that are specific to each of the 10 equity markets with loading parameters given by ϕ_i. The full set of factors can be classified into two broad groups, with the first four factors (w_t, e_t, d_t, r_t) representing systematic factors whose risks are not diversifiable, whilst the country specific factors $(v_{i,t})$ represent idiosyncratic factors whose risks are diversifiable (Solnik, 1974).[3]

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

$$f_t \sim (0, 1) . \tag{4.5}$$

In this specification, the variance of the series is assumed to be homoskedastic. This choice of the normalization of the factors provides a convenient decomposition of equity volatility into the contributions of each of the underlying factors during the benchmark period

$$Var\,(u_{i,t}) = \lambda_i^2 + \gamma_i^2 + \delta_i^2 + \psi_i^2 + \phi_i^2. \tag{4.6}$$

2.2 A Model Incorporating Contagion

The crisis model of equity shocks is characterized by the inclusion of additional transmission mechanisms linking global equity markets during periods of crisis, over and above the mechanisms identified by the benchmark model in (4.2). The approach to modelling these additional linkages is to include the Russian $(v_{RU,t})$ and US $(v_{US,t})$ idiosyncratic shocks defined in (4.2), into the factor structure of the remaining countries during periods in which crises are present. Following Masson (1999), Forbes and Rigobon (2002), Pericoli and Sbracia (2003) and Dungey, Fry, González-Hermosillo, and Martin (2006), these linkages are referred to as contagion as they represent additional shocks over and above the shocks that occur during the benchmark period linking

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

equity markets, which contribute to the volatility of asset markets during periods of crisis.

2.2.1 Incorporating Contagion from Russia

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

$$u_t = \left[\begin{array}{ccc} A & \vdots & \Phi_2 \end{array} \right] f_t = \Gamma_2 f_t, \tag{4.7}$$

where A and f_t are respectively given in (4.4) and (4.3), and Φ_2 is specified as

$$\Phi_2 = \begin{bmatrix} \phi_{AR} & & & & & \alpha_{AR} & & & & \\ & \phi_{BR} & & & & \alpha_{BR} & & & & \\ & & \phi_{HK} & & & \alpha_{HK} & & & & \\ & & & \phi_{TH} & & \alpha_{TH} & & & & \\ & & & & \phi_{PO} & \alpha_{PO} & & & & \\ & & & & & \alpha_{RU} & & & & \\ & & & & & \alpha_{GE} & \phi_{GE} & & & \\ & & & & & \alpha_{JA} & & \phi_{JA} & & \\ & & & & & \alpha_{UK} & & & \phi_{UK} & \\ & & & & & \alpha_{US} & & & & \phi_{US} \end{bmatrix}, \tag{4.8}$$

where blank cells represent zeros. The strength of contagion from Russia to international equity markets is controlled by the parameter α_i. Equation (4.7) also allows for the effect of Russian idiosyncratic shocks to differ across regimes by allowing the parameter ϕ_{RU} in (4.4) to differ from α_{RU} in (4.8). Dungey, Fry, González-Hermosillo and Martin (2005) interpret this as an idiosyncratic structural break.

Following the benchmark decomposition of the variance in (4.6), equity market volatility with contagion from Russia is decomposed as

$$Var\left(u_{i,t}\right) = \lambda_i^2 + \gamma_i^2 + \delta_i^2 + \psi_i^2 + \phi_i^2 + \alpha_i^2. \tag{4.9}$$

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

$$\Delta Var\left(u_{i,t}\right) = \alpha_i^2. \tag{4.10}$$

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

$$H_0 : \alpha_i = 0, \qquad \forall i \neq RU. \tag{4.11}$$

The specification in (4.8) allows for an exogenous change in the volatility of idiosyncratic shocks in Russia between the benchmark and Russian crisis period. This constitutes a structural break in the Russian idiosyncratic factor which can be tested via the restriction

$$H_0 : \phi_{RU} = \alpha_{RU}. \tag{4.12}$$

2.2.2 Incorporating Contagion from LTCM

An important feature of the LTCM crisis is that it occurs in conjunction with the Russian crisis, but is of shorter duration. The LTCM liquidity crisis is viewed to have ended at the time of the surprise inter-FOMC meeting to cut interest rates on October 15th (see Committee on the Global Financial System, 1999). The implication of this characteristic of the twin-crisis periods, is that the contagious channel used to model the transmission of shocks from Russia, is still active during the LTCM crisis period. This feature of the problem imposes additional structure on the factors across the regimes.

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

$$u_t = \left[\begin{array}{ccc} A & \vdots & \Phi_3 \end{array}\right] f_t = \Gamma_3 f_t. \tag{4.13}$$

where A and f_t are respectively given in (4.4) and (4.3), and Φ_3 is specified as

$$\Phi_3 = \begin{bmatrix} \phi_{AR} & & & & & \alpha_{AR} & & & & \beta_{AR} \\ & \phi_{BR} & & & & \alpha_{BR} & & & & \beta_{BR} \\ & & \phi_{HK} & & & \alpha_{HK} & & & & \beta_{HK} \\ & & & \phi_{TH} & & \alpha_{TH} & & & & \beta_{TH} \\ & & & & \phi_{PO} & \alpha_{PO} & & & & \beta_{PO} \\ & & & & & \alpha_{RU} & & & & \beta_{RU} \\ & & & & & \alpha_{GE} & \phi_{GE} & & & \beta_{GE} \\ & & & & & \alpha_{JA} & & \phi_{JA} & & \beta_{JA} \\ & & & & & \alpha_{UK} & & & \phi_{UK} & \beta_{UK} \\ & & & & & \alpha_{US} & & & & \beta_{US} \end{bmatrix}, \tag{4.14}$$

where blank cells represent zeros. The strength of contagion from LTCM to international equity markets is controlled by the parameter β_i. As in the case of the model including contagion from Russia, the specification of the LTCM crisis model allows for a structural break in the idiosyncratic shock of the US, with the parameter β_{US} in (4.14) being allowed to differ from the parameter ϕ_{US} in (4.4). As the LTCM crisis coincides with potential contagion from the Russian crisis, the Russian idiosyncratic shock $v_{RU,t}$, is also included in the factor specification of the other equity markets to reflect the twin nature of the crises during the time of the LTCM crisis. A comparison of (4.7) and (4.13) shows that the parameters measuring the strength of contagion from Russia (α_i) to equity markets are the same across the two regimes.

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

$$Var\,(v_{i,t}) = \lambda_i^2 + \gamma_i^2 + \delta_i^2 + \psi_i^2 + \phi_i^2 + \alpha_i^2 + \beta_i^2. \tag{4.15}$$

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

$$\Delta Var\,(v_{i,t}) = \alpha_i^2 + \beta_i^2, \tag{4.16}$$

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

$$H_0 : \beta_i = 0, \qquad \forall i \neq US. \tag{4.17}$$

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

$$H_0 : \alpha_i = 0; \beta_j = 0, \qquad \forall i \neq RU, \quad j \neq \forall US. \tag{4.18}$$

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

$$H_0 : \phi_{US} = \beta_{US}. \tag{4.19}$$

3 Empirical Issues

3.1 Data

The sample consists of daily share prices $(P_{i,t})$ on 10 countries, beginning January 2, 1998 and ending December 31, 1998, a total of $T = 260$ observations. Local equity market data are used which are sourced from Bloomberg.[4] Extending the sample period either before or after 1998 would complicate estimating the model as it would involve including additional regimes to capture the East Asian currency crisis and the Brazilian crisis of 1999 respectively.

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

$$s_{i,t} = 100 \left(\ln \left(P_{i,t} \right) - \ln \left(P_{i,t-1} \right) \right). \tag{4.20}$$

Missing observations are treated by using the lagged price.[5] To capture differences in time zones of equity markets, a 2-day moving average is chosen following the approach of Forbes and Rigobon (2002), with the first observation of the moving average set equal to the realized returns on January 5th.[6] Thus, the effective sample of returns data begins January 5, 1998 and ends December 31, 1998, a total of $T = 259$ observations.

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

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

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

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

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

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

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

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

3.2 GMM Estimator

The model is estimated using generalized method of moments (GMM); see also Rigobon and Sack (2004) for a recent application, and Sentana and Fiorentini (2001) for identification conditions. This has the advantage of not having to specify the distribution of the factors in (4.5). Let the sample periods for the three regimes be respectively T_1 (benchmark), T_2 (Russian crisis) and T_3 (LTCM crisis). Associated with each regime is the empirical variance-covariance matrix

$$\Omega_1 = \frac{1}{T_1}\sum_{t=1}^{T_1} u_t u_t', \qquad \Omega_2 = \frac{1}{T_2}\sum_{t=1}^{T_2} u_t u_t', \qquad \Omega_3 = \frac{1}{T_3}\sum_{t=1}^{T_3} u_t u_t', \tag{4.21}$$

where u_t is the (10×1) vector of shocks from the VAR in (4.1).

The factor model is compactly written as

$$u_t = \Gamma_k f_t, \qquad k = 1, 2, 3, \tag{4.22}$$

where Γ_1, Γ_2 and Γ_3 are defined in equations (4.2), (4.7) and (4.13) respectively and f_t is the set of all factors defined in equation (4.3). Using the property that the factors are independent with zero means and unit variances, as in equation (4.5), the theoretical variance-covariance matrices for the three regimes are conveniently given by

$$E\left[u_t u_t'\right] = \Gamma_k \Gamma_k', \qquad k = 1, 2, 3. \tag{4.23}$$

The total number of unknown parameters in Γ_1, Γ_2 and Γ_3 is 53. The GMM estimator is obtained by choosing the parameters of the factor model in Γ_1, Γ_2 and Γ_3, and matching the empirical moments in (4.21) with the theoretical moments in (4.23). Associated with each empirical variance-covariance matrix are $10 \times 11/2 = 55$ unique moments. In total there are $3 \times 55 = 165$ moments across all three regimes. As the LTCM crisis period is relatively short, it is necessary to control the number of moments used in the GMM procedure. The strategy is to choose for the LTCM crisis period the 10 variances, the 9 covariances between the US and the remaining countries, and the 8 covariances between Russia and the remaining countries, excluding the US. This means that there are $2 \times 55 + 27 = 137$ empirical moments used to identify the 53 unknown parameters, a total of 84 excess moment conditions.

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

$$\begin{aligned} M_1 &= vech\,(\Omega_1) - vech\,(\Gamma_1\Gamma_1') \\ M_2 &= diag\,(\Omega_2) - diag\,(\Gamma_2\Gamma_2') \\ M_3 &= diag\,(\Omega_3) - diag\,(\Gamma_3\Gamma_3') \end{aligned} \tag{4.24}$$

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

$$Q = M_1'W_1^{-1}M_1 + M_2'W_2^{-1}M_2 + M_3'W_3^{-1}M_3, \tag{4.25}$$

where W_1, W_2 and W_3 represent the optimal weighting matrices corresponding to the respective regimes (Hamilton, 1994) which correct the standard errors for heteroskedasticity in each regime. Equation (4.25) is minimized with u_t in (4.21) replaced by the residuals of the estimated VAR in (4.1) where the lag structure is set at $p = 1$ lags.S [8]

4 Empirical Results

4.1 Parameter Estimates

The GMM point estimates of the factor model in (4.2), (4.7) and (4.13) are given in Table 3 with robust standard errors reported in parentheses. An overall test of the model is given by testing the 84 over-identifying restrictions. Under the null hypothesis that the restrictions are satisfied, the value of the objective function in (4.25) is asymptotically distributed as χ^2 with 84 degrees of freedom. The reported value of the test statistic is 97.785. This yields a p-value of 0.144, showing that the restrictions are not rejected at conventional significance levels. A test of the factor specification of the benchmark model is given by testing the $55 - 33 = 22$ over-identifying restrictions in the non-crisis period. The test statistic is given by the first term in (4.25) which has a value of 29.177. The p-value is 0.140, showing that the benchmark factor structure is not rejected at the 5% level.

The parameter estimates associated with the common factors highlight the factor structure underlying international equity returns during the benchmark period. The parameter estimates of the common factor (λ_i) show that all equity markets react in

[8] The computations are performed using the BFGS algorithm in GAUSS Version 7, with a convergence criterion of 0.00001.

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

A comparison of the contagion parameter estimates stemming from Russia (α_i), shows that the effects of contagion on international equity markets during the Russian crisis is selective, although it does affect both emerging and industrial equity markets. The largest (absolute) impact is felt by Germany (0.686) and the UK (0.459), which are both statistically significant at conventional significance levels. This result picks up the fact that most international lenders to Russia were European-based. Van Rijckeghem and Weder (2003) document that German banks had a heavy exposure of loans to Russia. Performing a joint test of no contagion from Russia to all 4 industrial equity markets in Table 4, shows that these restrictions are rejected at the 5% level.

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

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

4.2 Volatility Decompositions

An alternative way of identifying the relative importance of contagion is by computing the variance decompositions in (4.6) for the benchmark period, and (4.9) and (4.15) in the Russian and LTCM crisis periods respectively. The results of the volatility decomposition in the benchmark period are given in Table 5, where the decompositions are expressed as a percentage of the total. This table shows the importance of idiosyncratic shocks in explaining equity market volatility in many of the countries investigated, with Russia (73.45%) followed by Poland (64.45%) exhibiting the highest proportions.

The volatility decompositions during the Russian crisis reported in Table 6 support the previous results showing that equity markets in Germany (57.18%) and the UK (48.67%) are the most affected of all equity markets by contagion from Russia. The maximum affect of contagion from Russia on the emerging markets during this period is felt by Argentina (10.38%). In contrast, US equity markets (3.05%) appear to be hardly affected by contagion from Russia.

The volatility decompositions during the LTCM crisis reported in Table 7 further highlight the relative importance and widespread effects of contagion from the US during this period. Of the emerging markets, Argentina (71.74%) and Brazil (82.16%) are particularly affected by contagion from the US, as is Poland (55.76%). Hong Kong (24.90%) and Thailand (14.86%) are proportionately less affected by contagion from the US, suggesting that an important component of their volatilities are the result of idiosyncratic factors. This is particularly true for Thailand where the contribution of the idiosyncratic shock is 45.22% during the LTCM crisis. Russian equities (0.44%) show no effect of contagion from the US, which are still dominated by their own idiosyncratic shocks (88.64%). Of the industrials, Japanese (74.59%) equity markets are the most affected by contagion from the US, followed by Germany (37.39%) and the UK (32.66%).

4.3 Structural Break Tests

Table 4 also gives the results of two structural break tests. The first is a test of a structural break in the Russian idiosyncratic parameter. The increase in volatility caused by the Russian crisis is highlighted in Table 3 where the idiosyncratic parameter estimate nearly doubles in magnitude from ($\phi_{RU} = 1.322$) in the benchmark period to

($\alpha_{RU} = 2.265$) in the Russian crisis period. The p-value of this structural break test is 0.008 showing evidence of a significant structural break. The second structural break test reported in Table 3 is for the U.S. idiosyncratic parameter. Finally, the test yields a p-value of 0.179 showing that the null of no structural break is not rejected at conventional significance levels.

4.4 Robustness Checks

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

The first robustness check consists of extending the factor structure to allow for an additional common factor in the benchmark model. The results of the variance decompositions show no qualitative change to the results reported above. The biggest contribution to the variance decomposition in the second common factor is for Russia where the weight is 6.937 percent.

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

4.5 Comparison with Bond Market Transmissions

Chapter 3 of this thesis measures the effects of contagion on international bond markets using a similar framework to the approach adopted in this chapter, though the choice of countries is slightly different. In addition, the LTCM sample period in the bond market chapter is slightly shorter than in the current chapter, where the start of the LTCM crisis period is defined to coincide with the public recapitalization announcement on 23 September. To enable a comparison of the results for the two markets, the model in chapter 3 is reestimated using the same definition of the LTCM crisis period used in this chapter.[9] The results are given in Table 8 which gives the contribution of contagion as a proportion of total volatility during the Russian and LTCM crisis periods for the

[9] Consistent with the original paper, the bond market model in this paper is estimated using Gauss v.3.2.

bond market, together with the equity market results which are taken from Table 7. Dashes indicate countries not included in a particular study.

Inspection of Table 8 shows that contagion from both Russia and the United States dominates the observed volatility in equity market returns of most countries, while the effects in bond markets are smaller, but still not insubstantial. In the case of Argentina, Brazil, Poland, Germany, Japan and the United Kingdom, the contribution of contagion to total volatility in equities is over 50%. The largest contributions of contagion to bond market volatility are in Argentina, Poland and Russia, where the total contribution is just under 50%.

The main source of contagion in most equity markets is from the United States. In the case of Germany and the United Kingdom, the contributions of contagion from Russia and the US are similar at between 32% and 37%. A similar result occurs in bond markets where the main contributor to bond market volatility is contagion from the US. Two exceptions are Brazil where the contribution from Russia is 23.64% compared to 1.31% from the United States, and to a lesser extend, the Netherlands where the contribution from Russia is 11.04% compared to 4.6% from the United States.

A comparison of the equity market and bond market results shows that Brazil is a recipient of contagion from the United States in equity markets, and from Russia in bonds. This suggests that in the case of Brazil at least, crises may be propagated differently through different asset markets, across the same geographical borders. This also implies that the influences of trade and other regional considerations such as suggested in Glick and Rose (1999) and Van Rijckeghem and Weder (2001), where transmission is based on trade or financial linkages, cannot constitute the entire story. The evidence presented suggests that the nature of particular assets or asset markets may hold important information on the transmission of shocks.

5 Conclusions

This chapter has provided a framework for modelling the transmission of contagion in international equity markets during the complex period of the Russian bond default and the LTCM crisis in 1998. The model was based on extending the existing class of latent factor models commonly adopted in finance by allowing for additional transmission mechanisms between global equity markets during periods of financial crises arising from contagion. Contagion was identified as the impact of shocks from either Russia or the United States on global equity markets, having conditioned on both world and regional factors, as well as country specific shocks in equity markets. A property of the model was that the volatility of equity returns could be decomposed in terms of the underlying factors, thereby providing a measure of the relative strength of contagion. A number of hypothesis tests of contagion and structural breaks were also carried out. The model was applied to 10 equity markets consisting of four developed markets, and six emerging markets from three regions (Latin America, Asia, and Eastern Europe), using daily equity returns over 1998. A GMM estimator, which matched the theoretical moments of the factor model with the empirical moments of the data across regimes, was presented.

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

In related work on contagion during the Russian and LTCM crises, chapter 3 of this thesis found that contagion in bond markets also affected a wide variety of economies. The combination of the results suggest that it would be informative to construct a more general model of asset markets, combining both bonds and equities to test jointly the importance of contagious transmission mechanisms between markets across international borders. A step in this direction, for different case studies, has been recently undertaken in Ehrmann, Fratzscher and Rigobon (2005), while Granger, Huang and Yang (2000) and Hartmann, Straetmans and de Vries (2004) focused on bivariate relationships between asset markets during financial crises.

An important feature of the proposed model is the specification of a multiple regime model to allow for multiple crises. This suggests that the framework could be applied to model several crises simultaneously by extending the sample period adopted in the current application. Although still ongoing at the time of writing, extending the framework to encompass the current U.S. subprime and liquidity crisis, and contrasting this event to previous crises, should give some insights as to how financial crises are alike or not. This issues are examined in chapter 5 below.

Table 1:
Descriptive statistics of daily percentage equity returns in 1998 for selected sample periods.[(a)]: the sample mean (Mean), the standard deviation (SD), the maximum (Max) and the minimum (Min).

Statistic	Country									
	AR	BR	HK	TH	PO	RU	GE	JA	UK	US
Benchmark Period: Jan. 5 to Jul. 31										
Mean	-0.005	0.045	-0.259	-0.200	0.018	-0.562	0.252	0.011	0.130	0.090
SD	1.120	1.284	1.549	1.779	1.224	2.553	0.709	0.828	0.599	0.511
Max	3.304	2.638	4.320	8.756	3.040	10.548	1.998	2.558	1.664	1.254
Min	-4.359	-4.909	-6.462	-4.108	-3.687	-8.476	-2.485	-2.119	-1.467	-1.814
Russian Crisis Period: Aug. 3 to Dec. 31										
Mean	-0.408	-0.345	0.465	0.025	-0.214	-0.950	0.072	-0.097	0.045	0.061
SD	1.858	2.506	1.852	1.715	2.596	3.100	1.253	1.088	0.904	0.769
Max	3.104	6.210	6.891	4.653	7.496	6.469	2.497	2.500	1.899	1.789
Min	-6.442	-6.547	-2.874	-3.979	-6.922	-12.828	-3.324	-2.734	-2.156	-2.333
LTCM Crisis Period: Aug. 31 to Oct. 15										
Mean	0.512	-0.200	0.505	0.772	-0.450	-0.764	-0.473	-0.131	-0.276	-0.205
SD	2.994	4.129	1.956	1.825	2.053	3.475	1.782	1.217	1.255	1.173
Max	5.344	10.653	4.872	5.422	3.219	9.496	2.841	2.785	2.515	2.174
Min	-8.522	-10.844	-3.783	-2.090	-5.352	-7.478	-5.003	-2.720	-2.517	-4.225

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

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

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

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

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

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

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

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

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

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

Table 6:
Variance decomposition of equity returns in proportions (%): Russian crisis period. Row totals sum to 100%. Based on (4.9).

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

Table 7:
Variance decomposition of equity returns in proportions (%): LTCM crisis period. Row totals sum to 100%. Based on (4.15).

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

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

Country		Equity Markets			Bond Markets		
	Contagion from:	Russia	US	Total	Russia	US	Total
Argentina		2.93	71.74	74.67	0.03	45.37	45.40
Brazil		0.11	82.16	82.27	23.64	1.31	24.95
Mexico		-	-	-	0.01	2.74	2.75
Hong Kong		0.51	24.90	25.41	-	-	-
Indonesia		-	-	-	0.08	0.01	0.09
Korea		-	-	-	0.36	2.10	2.46
Thailand		4.80	14.86	19.66	1.41	27.78	29.19
Bulgaria		-	-	-	8.32	1.22	9.54
Poland		0.37	55.76	56.13	0.05	46.18	46.23
Russia		-	0.44	0.44	-	42.00	42.00
Netherlands		-	-	-	11.04	4.60	15.64
Germany		35.80	37.39	73.19	-	-	-
Japan		0.96	74.59	75.55	-	-	-
UK		32.78	32.66	65.44	0.22	6.67	6.89
US		3.71	-	3.71	1.65	-	1.65

(a) The bond market results are based on reestimating the model in chapter 3 of this thesis, by extending the LTCM period from 23 September 1998 to 15 October 1998, and from 31 August 1998 to 15 October 1998. Some of the bond market results reported in this table differ from those in chapter 3. Given the robustness properties of the equity markets presented above, this suggests that the bond markets are more sensitive to changes in crisis dates. The equity market results are based on Table 7.

Chapter 5: Contagion Across Bond and Equity Markets, and Across National Borders [1]

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).[2] These examples include 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, where there now exist three broad classes of models. The first generation models emphasize the role of macroeconomic variables in causing currency crises when countries adopted fixed exchange rates (Flood and Marion (1999)); the second generation models focus on the role of speculative attacks; while the third generation of models focus on institutional imbalances and information asymmetries (Allen and Gale (2000), Kaminsky and Reinhart (2003), Kodres and Pritsker (2002), Pavlova and Rigobon (2007) and Yuan (2005)).

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. These links are emphasized in third generation crisis models, where channels over and above the market fundamental mechanisms that link countries and asset markets during noncrisis periods appear during a crisis. These additional linkages are broadly known as contagion (see Dornbusch, Park and Claessens

[1] Joint work with Dungey, M., R. Fry, B. González-Hermosillo, V. Martin, and C. Tang (2007b), mimeograph, International Monetary Fund.

[2] Further analysis of these crises are given in Lowenstein (2001); Jorion (2000); Baig and Goldfajn (2000); and del Torre, Levy, Yeyati and Schmulker (2003).

(2000); Pericoli and Sbracia (2003) and Dungey, Fry, González-Hermosillo and Martin (2005), for surveys of this literature).

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

[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 crises.

crisis investigated, this suggests that the financial crises of the past decade are similar. However, crises are not the same in terms of the relative contribution of each channel to the volatility of returns in asset markets which varies across crises.. 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.

The rest of the chapter proceeds as follows. The theoretical model is specified in Section 2 where asset returns are specified in term of a set of latent factors. The form of these factors are discussed in Section 3. The factors are expressed (rotated) in terms of 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. 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 heterogeneous 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 optimising behaviour, 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

$$X_T = \mu_I \alpha_I^* W_1 + \mu_U \alpha_U^* W_1 + \ln \epsilon, \tag{5.1}$$

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 risk assets of uninformed agents, and $\ln \epsilon$ is the total demand of risk 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 V from wealth in period two (W_2)

$$\max_{\alpha_k} E[V(W_2)|\Omega_k] = \max_{\alpha_k} \left\{ \ln E\left[W_2^{(1-\gamma)} \middle| \Omega_k \right] \right\}, \qquad k = I, U, \tag{5.2}$$

subject to the wealth constraint

$$W_2 = (1 + R_p) W_1, \tag{5.3}$$

where γ is the relative risk aversion parameter, W_1 is period 1 wealth, and

$$R_p = \alpha_k' R + (1 - \alpha_k' \imath) R_f, \tag{5.4}$$

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)

$$R_i = \frac{v_i - P_i}{P_i}, \qquad i = 1, 2, \cdots, N. \tag{5.5}$$

The liquidation values of the asset are determined by two factors, θ and u, according to

$$\ln v = \ln \theta + \ln u. \tag{5.6}$$

The factor θ represents an information factor with the following distribution

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

while u is driven by a set of K macroeconomic ($\ln f$) and N idiosyncratic ($\ln \eta$) factors

$$\ln u_{t+1} = \beta \ln f_{t+1} + \ln \eta_{t+1}, \tag{5.7}$$

with loadings β, and

$$\begin{aligned} \ln f_{t+1} &= \ln f_t + \ln \delta_{t+1} \\ \ln \eta_{t+1} &\sim N\left(0, \Sigma_{\eta}\right) \\ \ln \delta_{t+1} &\sim N\left(0, I_N\right), \end{aligned} \tag{5.8}$$

show that the macroeconomic factors are integrated processes of order one.

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

$$\alpha_k^* = \frac{1}{\gamma}\left[E\left[r|\Omega_k\right] - r_f + \frac{1}{2}Covar\left[r|\Omega_k\right]\right] Covar\left[r|\Omega_k\right]^{-1}, \qquad k = I, U, \tag{5.9}$$

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

$$\Omega_I = \{\ln \theta, \ln P\}, \tag{5.10}$$

in which case the conditional moments in (5.9) are given by (see Appendix A2)

$$\begin{aligned} E\left[r|\Omega_I\right] &= \ln \theta + \beta \ln f - \ln P \\ Var\left[r|\Omega_I\right] &= \beta\beta' + \Sigma_{\eta}. \end{aligned} \tag{5.11}$$

The information set of the uninformed investor is defined as

$$\Omega_U = \{\ln P\}, \tag{5.12}$$

in which case the conditional moments in (5.9) are given by (see Appendix A3)

$$\begin{aligned} E\left[r|\Omega_U\right] &= \ln P + \overline{\theta} + \Sigma_\theta \left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1}\right)^2 \left(\beta\beta' + \Sigma_\eta\right)\Sigma_\epsilon \left(\beta\beta' + \Sigma_\eta\right)'\right]^{-1} \\ &\quad \times \left[\ln\theta + \frac{\gamma\left(\beta\beta' + \Sigma_\eta\right)}{\mu_I W_1}\ln\epsilon - \overline{\theta}\right], \\ Var\left[r|\Omega_U\right] &= \left[\Sigma_\theta + \Sigma_u\right] - \Sigma_\theta \left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1}\right)^2 \right. \\ &\quad \left. \left(\beta\beta' + \Sigma_\eta\right)\Sigma_\epsilon \left(\beta\beta' + \Sigma_\eta\right)' \quad \right]^{-1} \Sigma_\theta'. \end{aligned} \tag{5.13}$$

To complete the specification of the demand for risky assets in (5.1), 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 asset returns, let

$$y = \ln P_2 - \ln P_1 - r_f,$$

represent the vector of N realized excess returns, where P_1 and P_2 are the price vectors in periods 1 and 2 respectively. 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 $\{\ln\theta, \ln\epsilon, \ln f, \ln\zeta\}$

$$y = C_0 + C_1 \ln\theta + C_2 \ln\epsilon + C_3 \ln f + C_4 \ln\zeta, \tag{5.14}$$

where $\ln\zeta = \ln P_2 - E\left[\ln v|_U\right]$ 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 (5.11) and (5.13) (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 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 (5.7) and (5.8) 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).

3 Empirical Factor Specification

The empirical factors are identified using the approach of Dungey and Martin (2007) which involves expressing the N excess returns (y_t) by rotating the factors in (5.14) into global (w_t), market (m_t), country (c_t) and idiosyncratic (v_t) components. 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 (Ŭ), 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)).

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 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 4.2 below.

3.1 Noncrisis Specification

The factor specification during the noncrisis period is

$$
\begin{bmatrix} s_{A,t} \\ s_{B,t} \\ s_{C,t} \\ s_{M,t} \\ s_{R,t} \\ s_{\breve{U},t} \\ \cdots \\ b_{A,t} \\ b_{B,t} \\ b_{C,t} \\ b_{M,t} \\ b_{R,t} \\ b_{\breve{U},t} \end{bmatrix}
= \underbrace{\begin{bmatrix} \lambda^s_A & \beta^s_A & \pi^s_A \\ \lambda^s_B & \beta^s_B & \pi^s_B \\ \lambda^s_C & \beta^s_C & \\ \lambda^s_M & \beta^s_M & \\ \lambda^s_R & \beta^s_R & \pi^s_R \\ \lambda^s_{\breve{U}} & \beta^s_{\breve{U}} & \\ \lambda^b_A & \beta^b_A & \pi^b_A \\ \lambda^b_B & \beta^b_B & \pi^b_B \\ \lambda^b_C & \beta^b_C & \\ \lambda^b_M & \beta^b_M & \\ \lambda^b_R & \beta^b_R & \pi^b_R \\ \lambda^b_{\breve{U}} & \beta^b_{\breve{U}} & \end{bmatrix} \begin{bmatrix} w^1_t \\ w^2_t \\ w^3_t \end{bmatrix}}_{\text{Common}}
+ \underbrace{\begin{bmatrix} \gamma^s_A & \\ \gamma^s_B & \\ \gamma^s_C & \\ \gamma^s_M & \\ \gamma^s_R & \\ \gamma^s_{\breve{U}} & \\ & \gamma^b_A \\ & \gamma^b_B \\ & \gamma^b_C \\ & \gamma^b_M \\ & \gamma^b_R \\ & \gamma^b_{\breve{U}} \end{bmatrix} \begin{bmatrix} m^s_t \\ m^b_t \end{bmatrix}}_{\text{Market}}
$$

$$
+ \underbrace{\begin{bmatrix} \kappa^s_A & & & & & \\ & \kappa^s_B & & & & \\ & & \kappa^s_C & & & \\ & & & \kappa^s_M & & \\ & & & & \kappa^s_R & \\ & & & & & \kappa^s_{\breve{U}} \\ \kappa^b_A & & & & & \\ & \kappa^b_B & & & & \\ & & \kappa^b_C & & & \\ & & & \kappa^b_M & & \\ & & & & \kappa^b_R & \\ & & & & & \kappa^b_{\breve{U}} \end{bmatrix} \begin{bmatrix} c_{A,t} \\ c_{B,t} \\ c_{C,t} \\ c_{M,t} \\ c_{R,t} \\ c_{\breve{U},t} \end{bmatrix}}_{\text{Country}}
+ \underbrace{diag \begin{pmatrix} \phi^s_A \\ \phi^s_B \\ \phi^s_C \\ \phi^s_M \\ \phi^s_R \\ \phi^s_{\breve{U}} \\ \phi^b_A \\ \phi^b_B \\ \phi^b_C \\ \phi^b_M \\ \phi^b_R \\ \phi^b_{\breve{U}} \end{pmatrix} \begin{bmatrix} \upsilon^s_{A,t} \\ \upsilon^s_{B,t} \\ \upsilon^s_{C,t} \\ \upsilon^s_{M,t} \\ \upsilon^s_{R,t} \\ \upsilon^s_{\breve{U},t} \\ \upsilon^b_{A,t} \\ \upsilon^b_{B,t} \\ \upsilon^b_{C,t} \\ \upsilon^b_{M,t} \\ \upsilon^b_{R,t} \\ \upsilon^b_{\breve{U},t} \end{bmatrix}}_{\text{Idiosyncratic}} . \tag{5.15}
$$

All variables on the right hand-side of (5.15) are classified into the four sets of factors. The first set of factors are referred to as the common factors. The first two factors within this set (w^1_t, w^2_t) impact upon all asset markets, across all countries with loadings given by $\left(\lambda^j_i, \beta^j_i\right)$ for asset market $j = s, b$, in country i. The third factor in the common set of factors (w^3_t) represents the set of emerging markets where crises originated during the sample period: Argentina, Brazil and Russia, with loadings $\left(\pi^j_i\right)$. The second set of factors is the market factor, which captures respectively shocks to stock markets (m^s_t) and bond markets $\left(m^b_t\right)$ with loadings (γ^s_i) and $\left(\gamma^b_i\right)$. The set of country factors are given by $c_{A,t}, c_{B,t}, c_{C,t}, c_{M,t}, c_{R,t}, c_{\breve{U},t}$, 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 are given by the $\upsilon_{i,t}^j$ 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 (5.15) is conveniently expressed as

$$y_t = A_w w_t + A_m m_t + A_c c_t + A_v v_t, \tag{5.16}$$

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 (5.15).

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 the asset market and country contagion channels. The 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 diluted by using a longer sample period than is necessary.

The Russian/LTCM crisis model is specified as

$$y_t = B_w w_t + B_m m_t + B_c c_t + B_v v_t, \tag{5.17}$$

where the parameter matrices are defined as

$$B_w = \begin{bmatrix} \lambda_A^s & \beta_A^s & \pi_A^s \\ \lambda_B^s & \beta_B^s & \pi_B^s \\ \lambda_C^s & \beta_C^s & \\ \lambda_M^s & \beta_M^s & \\ \lambda_R^s & \beta_R^s & \pi_R^s \\ \lambda_{\breve{U}}^s & \beta_{\breve{U}}^s & \\ \cdots & \cdots & \cdots \\ \lambda_A^b & \beta_A^b & \pi_A^b \\ \lambda_B^b & \beta_B^b & \pi_B^b \\ \lambda_C^b & \beta_C^b & \\ \lambda_M^b & \beta_M^b & \\ \lambda_R^b & \beta_R^b & \pi_R^b \\ \lambda_{\breve{U}}^b & \beta_{\breve{U}}^b & \end{bmatrix}, \qquad B_m = \begin{bmatrix} \gamma_A^s + \tilde{\theta}_A^s & \delta_{A,b}^s \\ \gamma_B^s + \tilde{\theta}_B^s & \delta_{B,b}^s \\ \gamma_C^s + \tilde{\theta}_C^s & \delta_{C,b}^s \\ \gamma_M^s + \tilde{\theta}_M^s & \delta_{M,b}^s \\ \gamma_R^s + \tilde{\theta}_R^s & \delta_{R,b}^s \\ \gamma_{\breve{U}}^s + \tilde{\theta}_{\breve{U}}^s & \delta_{\breve{U},b}^s \\ \cdots & \cdots \\ \delta_{A,s}^b & \gamma_A^b + \tilde{\theta}_A^b \\ \delta_{B,s}^b & \gamma_B^b + \tilde{\theta}_B^b \\ \delta_{C,s}^b & \gamma_C^b + \tilde{\theta}_C^b \\ \delta_{M,s}^b & \gamma_M^b + \tilde{\theta}_M^b \\ \delta_{R,s}^b & \gamma_R^b + \tilde{\theta}_R^b \\ \delta_{\breve{U},s}^b & \gamma_{\breve{U}}^b + \tilde{\theta}_{\breve{U}}^b \end{bmatrix},$$

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

[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.

and

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

The parameter matrices are specified by augmenting the noncrisis parameter matrices in (5.15) and (5.16) 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 $\delta^j_{i,Rb}$ $\left(\delta^j_{i,\breve{U}b}\right)$. All structural breaks in the factors during the crisis period are controlled by the parameter $\tilde{\theta}$. 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 $\tilde{\theta}^s_i$ and $\tilde{\theta}^b_i$. 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 (5.17), 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 the 2nd and 8th rows of the B_m matrix in (5.17). The country channel of contagion switches from the 5th column (Russian country factor) to the 2nd column (Brazilian country factor) of B_c. The idiosyncratic contagion channel arising from the Brazilian bond market shock is specified by switching column 11 in B_v in (5.17) to column 8 (Brazilian bond), and deleting the cells of 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 the 6th column of B_c (U.S. country factor), and the idiosyncratic contagion channel is specified in column 6 of the B_v matrix (U.S. stock) in (5.17).

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 the 1st column of B_c (Argentinian country factor), and the idiosyncratic contagion channel is specified in column 7 of the B_v matrix (Argentinian bond) in (5.17).

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 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 bond and stock idiosyncratic channels of contagion are allowed for in the subprime crisis specification.

4 Data

The data consist of daily excess returns on stocks and bonds, all expressed in U.S. dollars, beginning 31st of March 1998 and ending 3rd of September, 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

$$b_t = -n\left(r_{n,t} - r_{n-1,t-1}\right), \tag{5.18}$$

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 (5.18) 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 begining 1st of July, 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 11 September 2001 are replaced by the previously observed price. Stock returns are computed by taking the first difference of the natural logarithm of the

[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 (2007)).

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. There are five crises investigated, whose dates are discussed below.

4.1 Filters

Two filters are applied to the raw returns before estimating the model. First, all excess returns are adjusted for any dynamics by estimating a 12-variate VAR(1) consisting of all six stock and bond excess returns together with a constant. Higher order lags do not qualitatively change the empirical properties of the model. 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.

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 57.73% to 44.97%, arising from the change in the Russian Finance Minister on May 25th of 1999. Inspection of the excess returns of Argentinian bonds shows that there are five large spikes which occur during the Argentinian crisis: the dates are April 4th and October 4th in 2002, April 4th and October 6th in 2003, and April 6th 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 1st to June 30th in 2006, and the large movements in asset returns on February 27th and March 13th 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 comprises 2,458 observations across bond and stock markets for the six countries.

4.2 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 chapters 3 and 4 of this thesis 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 US$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, 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

[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.

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]

Turbulence in the U.S. subprime mortgage markets became severe by mid-2007. By late-Spring 2007, a broad range of markets worldwide began to experience a sharp decline in risk appetite and in liquidity. By August, credit spreads had widened substantially, stock markets had fallen significantly, and spreads in interbank markets rose sharply. The European Central Bank (ECB) injected extraordinary amounts of liquidity on August 10, 2007 and 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 and solvency concerns persisted. Indeed, what began as a fairly contained crisis in collateralized debt obligations (CDO) backed by U.S. subprime mortgages, quickly transformed into a liquidity crisis and even metastasized into credit concerns for a number of systematically important financial institutions. In this chapter, the U.S. subprime crisis period is assumed to begin on July 26, 2007. The end of the sample is September 3, 2007.[9]

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.

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

[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.

[9] There is considerable uncertainty as to when exactly the recent U.S. mortgage subprime and liquidity crisis began. The excesses that led to the crisis were evident from 2005 when the U.S. housing market reached a peak. However, it was not until June 15th, 2007 that news broke that two of Bear Stearns' hedge funds were facing financial difficulties. On July 9th, 2007, credit rating agencies began downgrading higher-rated assets. Markets were in a full-blown crisis by late July 2007. Various robustness checks were undertaken for sensitivity to the different potential starting dates, with no significant change in the results.

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.[10]

The objective function of the GMM estimator is specified as

$$q = M'WM, \tag{5.19}$$

where M is a vector containing the differences between the empirical and theoretical moments and W is the optimal weighting matrix.[11]

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

$$J = Tq, \tag{5.20}$$

where q is defined in (5.19) and T 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 5% level for all crises, and at even the 10% level for all crisis models with the exception of the Argentinian crisis model where the p-value of the overidentification test is 0.099.

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 (5.16) and (5.17) and testing if the restrictions are consistent with the data using the J-statistic in (5.20). Reducing the number of common factors from three to two, is satisfied for the Brazilian and U.S.

[10] In estimating the model the parameters

$$\pi_B^b, \kappa_{\breve{U}}^s, \kappa_{\breve{U}}^b, \phi_{\breve{U}}^s,$$

were found to be small, in which case they were restricted to be zero. The restriction $\kappa_{\breve{U}}^s = \kappa_{\breve{U}}^b = 0$, means that there is no U.S. country factor. Setting $\phi_{\breve{U}}^s = 0$ in (5.15) has the effect of making the U.S. equity market the common equity market factor.

[11] All calculations are undertaken using the library MAXLIK in GAUSS Version 7.0. The GMM estimates are computed by iterating over the parameters and optimal weighting matrix W, using the BFGS algorithm with the gradients computed numerically.

subprime crisis models at the 5% level where the p-values of the test are respectively 0.717 and 0.524, and at the 1% level for the Argentinian crisis models where the p-value is 0.027. This restriction is not satisfied for the Russian/LTCM and dot-com crisis models. Further restricting the number of common factors from two to one leads to a clear rejection of the null hypothesis for all crisis models with the exception of the Brazilian model where the p-value is 0.089 and the U.S. subprime crisis model where the P-value is 0.050. 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 chapter is to specify a model that is common for all crises, the number of common factors is chosen to be three for all crisis models in the rest of the chapter.

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 (5.17), as

$$E\left[y_t y_t'\right] = B_w B_w' + B_m B_m' + B_c B_c' + B_v B_v', \tag{5.21}$$

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 (5.21), expressed as a percentage of the total, with the parameter values replaced by their GMM parameter estimates. For example, from (5.17) the contribution of the bond market factor to the variance of stocks in Argentina during the Russian/LTCM crisis is

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

where

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

Complete variance decompositions which contain both noncrisis and crisis factor contributions for the five crisis periods, are given in Appendix C.

Table 5 gives the percentage contribution of contagion to total volatility in stock and bond markets for the five crisis periods. For comparative purposes, the table 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 asset markets, stocks and bonds. The stock markets hit hardest during this crisis are Brazil (96.93%) , the United States (67.64%) , Argentina (61.02%) , Mexico (46.97%) , Canada (39.94%) , with Russia (12.68%) being the least affected. The bond markets most affected during this crisis are Brazil (92.71%) , Mexico (88.57%) , Canada (45.47%) , Argentina (39.04%) and the United States (31.02%) . The low contribution of contagion to Russian bonds (13.30%) 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 (2006) who document the portfolio effects of the Russian crisis on Brazil.

Second, comparison of the relative importance of contagion during the financial crises between Russia/LTCM and the U.S. subprime crisis, shows that the strength of contagion tends to dissipate, 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, there are strong effects on Russian stock (89.80%) and bond (63.24%) markets, potentially reflecting an overhang of the Russian crisis. There are also important effects on the stock market in Argentina (62.70%) and the bond market in Mexico (81.01%). During the dot-com and Argentinian crises, the main effects are on stocks, with very little impact on bond markets. The South American stock markets are affected most during the dot-com crisis where the contributions of contagion to total volatility are Argentina (93.75%) , Mexico (88.36%) and Brazil (55.86%) . The Canadian stock market (22.18%) is also affected by dot-com, whereas Russia (1.36%) is not. 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, where now the largest impact occurs in U.S. stocks (52.03%) , followed by stock markets in Brazil (32.32%) and Canada (25.74%).

Third, and in stark contrast to the diminishing strength of contagion channels during the previous financial crises and the apparent immunity of bond markets to contagion during the dot-com and Argentinian financial crises, the effects of contagion during the U.S. subprime crisis are widespread with no country immune. The exception is Brazilian asset markets. Stock markets in the United States (80.62%) are hardest hit reflecting the origin of the crisis. Stock markets in general are severely affected by this crisis, with four of the six countries having contagion effects of greater than 67.00% percent of volatility. There is also strong evidence that contagion has flowed through to international bond markets with Argentina (96.87%) being affected the most. 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, albeit relatively less than other countries in terms of volatility. Approximately one quarter of volatility in Russian stocks (22.67%) and bonds (27.84%) is the result of contagion.[12]

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 United States (54.86%), Argentina (44.86%) and Mexico (30.70%) are hardest hit, whilst Brazilian stocks (54.47%) are affected by the direct link from Russian bonds. In the case of bond markets, Table 7 shows that all channels are operating, with U.S. bonds being the least affected by the crisis. The most affected country during the LTCM phase of the Russian/LTCM crisis is Brazil, where stocks (29.62%) and bonds (22.45%) are affected

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

directly by U.S. bonds. The Canadian (28.28%) and Mexican (18.79%) bond markets are also affected by the LTCM crisis through the idiosyncratic U.S. bond channel, but their stock markets are not.

The Russian asset markets are the most affected by the Brazilian crisis again reflecting the volatility in Russian asset markets following its own crisis in the previous year. There is an idiosyncratic channel and channels through the bond and stock market channels. Other asset markets affected by this crisis are the Argentinian stock market (51.04%) and the Mexican bond market (76.72%) , where it is the country channel that transmits contagion.

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 (88.03%) through the country channel, and Mexico (75.90%) through the bond market channel. The effects on Brazilian (27.58%) and Canadian (21.42%) stocks through the idiosyncratic channel from U.S. stocks, are relatively larger than they are for Argentina and Mexico. Russian stocks are immune to the dot-com crisis as are all international bond markets.

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 (25.77%) through the bond market channel, and the stock market in the United States (45.79%) and to a lesser extent Canada (18.88%) through the idiosyncratic channel from the Argentinian bond market, in operation. However, as the results in Table 7 show that bond markets are immune to the Argentinian crisis, suggesting that the market linkage transmitting contagion to the Brazilian stock market is dominated by shocks in Argentina's bond market, and thus also represents an idiosyncratic channel.

Table 6 shows that during the subprime crisis in the United States it is the bond market and idiosyncratic linkages that transmit the crisis to stock markets. The lack of any strong idiosyncratic channel from U.S. stocks strongly supports the classification of this crisis as a credit crisis. The results for the bond markets in Table 7 show that the effects of the subprime crisis are less widespread, with the main effects felt by Argentina (92.57%) through the idiosyncratic U.S. stock market channel, and Russia (27.78%) through the U.S. bond market idiosyncratic channel. The U.S. bond market (22.86%) is also affected through the U.S. idiosyncratic stock market channel, which represents a second-round effect of the credit market shock that occurred first in the

U.S. bond market.

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.[13] 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 (5.17). 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 (5.17). 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 (5.17). 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 $\delta^s_{i,\breve{U}b} = \delta^b_{i,\breve{U}b} = 0$. 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 Testing

In this section a number of additional robustness checks and diagnostic tests are performed on the factor model specification.

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

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, the P-values from performing the moment overidentification test based on the J-statistic in (5.20) are examined to determine possible 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 or the end of the crisis period 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 are qualitatively insensitive to changes in the dating of the five crises.[14]

6.2 Conditional Moment Tests

Conditional moment tests of autocorrelation and conditional volatility in the standardized residuals of the VAR, are given in Table 9. 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 0.05, showing that the null hypothesis of no autocorrelation or no conditional volatility can not be rejected at the 5% level.

6.3 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 10 using a Wald test. In the case of the Russian/LTCM crisis, from equation (5.17) the structural break tests are performed on the loadings of the stock market $\left(\tilde{\theta}_i^s\right)$ and the bond market $\left(\tilde{\theta}_i^b\right)$ factors where $i = A, B, C, M, R, \breve{U}$, the loadings of the Russian country factor $\left(\tilde{\theta}_{R,R}^s, \tilde{\theta}_{R,R}^b\right)$, and the loadings of the Russian and U.S. idiosyncratic bond factors $\left(\tilde{\theta}_{R,Rb}^b, \tilde{\theta}_{\breve{U},\breve{U}b}^b\right)$. Similar restrictions hold for the other three crisis models. All tests are calculated using a Wald test that the parameter $\tilde{\theta}$ is zero. Under the null hypothesis of no structural break, this

[14]The variance decompositions of the relative importance of the factors are computed for each of the P-values, but they 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.

amounts to the parameters associated with each factor being the same in the noncrisis and crisis periods.

The results in Table 10 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 structural break tests also show no evidence of a structural break in the idiosyncratic U.S. bond shock during the U.S. subprime crisis, whilst the P-value of the structural break test of the idiosyncratic stock market shock during the same crisis is just on the margin with a P-value of 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 (2005a)).

7 Conclusions

This paper investigated the possibility that financial crises were alike by considering whether a single modelling framework could fit multiple distinct crises. On this basis, financial crises during the past decade were all alike. The framework introduced three potential channels for contagion effects during a financial crisis, and the empricial 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 asset returns rather than prices. The empirical implementation was a latent factor representation of the equilibrium solution of that model.

The three potential channels for contagion effects were simultaneously identified and quantified. These 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 of stock and bond market returns over the period March 1998 to September 2007 for six countries; Argentina, Brazil, Canada, Mexico, Russia and the United States. 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. The Russian/LTCM crises had a widespread impact. All three contagion channels were active in this period, although the country channel dominated effects on stock markets. The Brazilian crisis had greater impact on emerging markets than developed markets, with the major effect on Russian asset markets, via all but the country channel. Russian stock markets, however, were immune to the dot-com crisis, which mainly effected stock markets. Although all three contagion channels operated during the dot-com crisis the effects on bond markets were limited. 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 most systemic 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.

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	3 September 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.	7.947	10.990	4.933	11.540	39.787	4.149
	Min.	-9.319	-9.539	-6.875	-11.852	-58.715	-3.561
	St. dev.	3.120	3.955	1.686	3.334	11.843	1.439
LTCM	*23 September 1998 - 15 October 1998*						
	Max.	6.835	5.351	4.933	6.265	10.056	3.726
	Min.	-6.327	-5.873	-5.263	-9.014	-12.082	-3.561
	St. dev.	3.417	3.459	2.489	3.877	6.806	1.684
Brazil	*7 January 1999 - 25 February 1999*						
	Max.	6.724	12.553	2.548	6.095	8.910	2.661
	Min.	-8.254	-11.623	-2.261	-6.169	-10.067	-4.154
	St. dev.	2.708	5.035	1.152	2.434	4.180	1.275
Dot-com	*28 February 2000 - 7 June 2000*						
	Max.	2.738	4.857	4.474	6.979	6.968	4.427
	Min.	-5.125	-5.802	-4.792	-8.503	-7.249	-4.222
	St. dev.	1.617	1.912	1.698	2.663	3.350	1.464
Argentina	*11 October 2001 - 3 March 2005*						
	Max.	15.791	13.375	5.053	4.916	8.295	6.040
	Min.	-32.503	-8.131	-3.835	-6.407	-10.833	-5.354
	St. dev.	3.011	2.325	1.130	1.341	2.051	1.307
U.S. subprime	*26 July 2007 - 3 September 2007*						
	Max.	7.377	6.580	4.383	4.982	4.680	3.220
	Min.	-5.534	-7.594	-3.692	-5.174	-4.215	-3.679
	St. dev.	2.981	3.610	2.012	2.636	2.005	1.864
Non-crisis							
	Max.	11.281	9.956	5.185	7.410	16.452	3.863
	Min.	-9.382	-12.028	-8.539	-5.852	-21.635	-6.005
	St. dev.	1.907	2.135	1.218	1.661	2.947	1.025

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.	9.038	15.656	4.003	9.273	42.465	1.796
	Min.	-16.599	-14.767	-4.245	-8.615	-115.655	-3.400
	St. dev.	3.345	5.505	1.213	2.383	19.264	0.570
LTCM			*23 September 1998 - 15 October 1998*				
	Max.	9.038	8.688	4.003	4.900	17.995	1.796
	Min.	-3.641	-13.611	-4.144	-3.508	-11.902	-1.253
	St. dev.	3.001	5.191	1.820	2.144	8.847	0.639
Brazil			*7 January 1999 - 25 February 1999*				
	Max.	9.813	16.825	1.595	7.853	30.260	0.547
	Min.	-11.181	-12.789	-2.393	-4.944	-58.994	-0.832
	St. dev.	3.033	5.674	0.886	2.234	13.902	0.299
Dot-com			*28 February 2000 - 7 June 2000*				
	Max.	7.063	3.056	2.294	1.682	19.067	0.585
	Min.	-3.367	-3.520	-2.325	-2.211	-14.952	-0.723
	St. dev.	1.362	1.239	0.920	0.777	3.796	0.254
Argentina			*11 October 2001 - 3 March 2005*				
	Max.	29.454	16.961	2.987	2.636	12.009	2.205
	Min.	-40.488	-37.978	-2.086	-2.676	-4.677	-1.445
	St. dev.	6.382	2.598	0.737	0.601	1.240	0.349
U.S. subprime			*26 July 2007 - 3 September 2007*				
	Max.	10.853	3.955	1.520	1.772	2.955	0.644
	Min.	-14.518	-1.655	-1.214	-0.812	-1.397	-0.894
	St. dev.	5.307	1.312	0.623	0.627	1.059	0.397
Non-crisis							
	Max.	33.484	10.623	2.618	5.069	55.995	1.847
	Min.	-33.666	-5.449	-3.701	-4.252	-44.637	-1.368
	St. dev.	3.417	1.208	0.661	0.653	4.366	0.259

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 (5.16) and (5.17) respectively, as null matrices.)

Crisis	Statistic	Number of Common Factors			
		Three	Two	One	None
Russia/ LTCM	J-statistic	29.358	47.758	68.367	329.202
	dof	22	27	39	51
	P-value	0.135	0.008	0.003	0.000
Brazil	J-statistic	22.449	33.525	65.046	326.526
	dof	34	39	51	63
	P-value	0.935	0.717	0.089	0.000
Dot-com	J-statistic	41.586	69.755	94.775	356.846
	dof	34	39	51	63
	P-value	0.174	0.002	0.000	0.000
Argentina	J-statistic	44.943	57.750	95.781	361.129
	dof	34	39	51	63
	P-value	0.099	0.027	0.000	0.000
U.S. subprime	J-statistic	20.680	37.82	68.627	330.203
	dof	34	39	51	63
	P-value	0.965	0.524	0.050	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/	Contagion (%)	61.02	96.93	39.94	46.97	12.68	67.64
LTCM	Variance	9.74	15.64	2.84	11.12	140.25	2.07
Brazil	Contagion (%)	62.70	9.56	6.93	13.48	89.80	18.28
	Variance	7.33	25.35	1.33	5.93	17.47	1.63
Dot-com	Contagion (%)	93.75	55.86	22.18	88.36	1.36	0.48
	Variance	2.61	3.66	2.88	7.09	11.22	2.14
Argentina	Contagion (%)	11.33	32.32	25.74	6.89	8.78	52.03
	Variance	9.06	5.40	1.28	1.80	4.20	1.71
U.S. subprime	Contagion (%)	67.03	16.10	73.73	68.08	22.67	80.62
	Variance	8.89	13.04	4.05	6.95	4.02	3.47
				Bond Markets			
Russia/	Contagion (%)	39.04	92.71	45.47	88.57	13.30	31.02
LTCM	Variance	11.19	30.30	1.47	5.68	371.11	0.32
Brazil	Contagion (%)	14.12	18.02	7.68	81.01	63.24	8.24
	Variance	9.20	32.20	0.78	4.99	193.26	0.09
Dot-com	Contagion (%)	0.04	7.60	18.41	0.15	11.60	11.27
	Variance	1.86	1.54	0.85	0.60	14.41	0.06
Argentina	Contagion (%)	5.80	0.13	7.23	8.86	0.81	7.00
	Variance	40.73	6.75	0.54	0.36	1.54	0.12
U.S. subprime	Contagion (%)	96.87	16.77	14.53	15.91	27.84	34.31
	Variance	28.17	1.72	0.39	0.39	1.12	0.16

Table 6:

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

Crisis	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
Russia/ LTCM	Market (bond)	0.90	12.14	6.65	9.00	0.09	5.99
	Country (Rus.)	44.86	0.71	21.81	30.70	n.a.	54.86
	Idio. (Rus. bond)	12.75	54.47	0.91	0.01	1.17	0.03
	Idio. (U.S. bond)	2.52	29.62	10.58	7.27	11.42	6.77
	Total contagion	61.02	96.93	39.94	46.97	12.68	67.64
	Variance	9.74	15.64	2.84	11.12	140.25	2.07
Brazil	Market (bond)	2.24	2.49	0.28	0.00	55.33	2.23
	Country (Brz.)	51.04	n.a.	1.53	12.40	n.a.	2.31
	Idio. (Brz bond)	9.42	7.07	5.12	1.08	34.47	13.75
	Total contagion	62.70	9.56	6.93	13.48	89.80	18.28
	Variance	7.33	25.35	1.33	5.93	17.47	1.63
Dot-com	Market (bond)	0.01	21.19	0.28	75.90	0.17	0.48
	Country (U.S.)	88.03	7.09	0.48	2.04	0.01	n.a.
	Idio. (U.S. stock)	5.71	27.58	21.42	10.42	1.18	n.a.
	Total contagion	93.75	55.86	22.18	88.36	1.36	0.48
	Variance	2.61	3.66	2.88	7.09	11.22	2.14
Argentina	Market (bond)	9.70	25.77	2.01	1.23	0.17	0.08
	Country (Arg.)	n.a.	2.96	4.85	0.58	1.69	6.16
	Idio. (Arg. Bond)	1.64	3.60	18.88	5.08	6.92	45.79
	Total contagion	11.33	32.32	25.74	6.89	8.78	52.03
	Variance	9.06	5.40	1.28	1.80	4.20	1.71
U.S. subprime	Market (bond)	28.33	5.06	30.88	28.59	8.33	36.05
	Idio. (U.S. stock)	2.93	3.74	2.48	2.30	0.75	n.a.
	Idio. (U.S. bond)	35.77	7.30	40.37	37.20	13.59	44.57
	Total contagion	67.03	16.10	73.73	68.08	22.67	80.62
	Variance	8.89	13.04	4.05	6.95	4.02	3.47

Table 7:

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

Crisis	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
Russia/ LTCM	Market (stock)	31.65	9.30	9.15	26.32	0.47	5.91
	Country (Rus.)	0.74	29.55	4.61	18.22	n.a.	7.47
	Idio. (Rus. bond)	5.77	31.42	3.43	25.23	n.a.	17.64
	Idio. (U.S. bond)	0.87	22.45	28.28	18.79	12.83	n.a.
	Total contagion	39.04	92.71	45.47	88.57	13.30	31.02
	Variance	11.19	30.30	1.47	5.68	371.11	0.32
Brazil	Market (stock)	0.16	18.02	0.80	1.87	28.63	3.25
	Country (Brz.)	13.92	n.a.	6.26	76.72	5.62	3.98
	Idio. (Brz bond)	0.04	n.a.	0.62	2.42	29.00	1.01
	Total contagion	14.12	18.02	7.68	81.01	63.24	8.24
	Variance	9.20	32.20	0.78	4.99	193.26	0.09
Dot-com	Market (stock)	0.01	4.13	9.62	0.06	4.20	7.18
	Country (U.S.)	0.01	0.21	0.49	0.02	0.06	n.a.
	Idio. (U.S. stock)	0.02	3.26	8.30	0.07	7.34	5.09
	Total contagion	0.04	7.60	18.41	0.15	11.60	11.27
	Variance	1.86	1.54	0.85	0.60	14.41	0.06
Argentina	Market (stock)	5.80	0.01	4.76	0.74	0.04	1.42
	Country (Arg.)	n.a.	0.08	2.33	1.33	0.03	0.28
	Idio. (Arg. Bond)	n.a.	0.04	0.14	6.79	0.74	5.29
	Total contagion	5.80	0.13	7.23	8.86	0.81	7.00
	Variance	40.73	6.75	0.54	0.36	1.54	0.12
U.S. subprime	Market (stock)	2.15	0.14	0.02	0.03	0.00	11.45
	Idio. (U.S. stock)	92.57	1.03	0.43	0.90	0.06	22.86
	Idio. (U.S. bond)	2.15	15.59	14.07	14.99	27.78	n.a.
	Total contagion	96.87	16.77	14.53	15.91	27.84	34.31
	Variance	28.17	1.72	0.39	0.39	1.12	0.16

Table 8:
Wald tests of contagion channels: P-values in brackets.

Test	Degrees of freedom	Crisis				
		Russia /LTCM	Brazil	Dot-com	Argentina	U.S. subprime
Market (stock)	6	5475.53 (0.000)	1795103.28 (0.000)	30.05 (0.000)	37.60 (0.000)	3.85 (0.697)
Market (bonds)	6	49180.17 (0.001)	494665.10 (0.000)	90158.10 (0.000)	120.46 (0.000)	424.23 (0.000)
Country	10	2789.53 (0.000)	370838.88 (0.000)	112956.68 (0.000)	167.87 (0.000)	
Idiosyncratic (Rus. bonds)	11	154327.77 (0.000)				
Idiosyncratic (U.S. bonds)	11	104016.36 (0.000)				660.29 (0.000)
Idiosyncratic (Bra. bonds)	11		2122141.10 (0.000)			
Idiosyncratic (U.S. stock)	11			20842.49 (0.000)		292.75 (0.000)
Idiosyncratic (Arg. bonds)	11				247.82 (0.000)	
Joint	$44^{(a)}$, $33^{(b)}$	455321.86 (0.000)	4779749.06 (0.000)	646829.77 (0.000)	609.72 (0.000)	1354.27 (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:
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	AR(1)	Stocks	0.352	0.899	0.175	0.761	0.477	0.182
	AR(1)	Bonds	0.118	0.795	0.237	0.669	0.380	0.790
	ARCH(1)	Stocks	0.485	0.215	0.489	0.419	0.285	0.207
	ARCH(1)	Bonds	0.372	0.686	0.499	0.190	0.748	0.195
LTCM	AR(1)	Stocks	0.362	0.288	0.073	0.913	0.801	0.667
	AR(1)	Bonds	0.322	0.083	0.108	0.470	0.643	0.435
	ARCH(1)	Stocks	0.973	0.673	0.924	0.429	0.898	0.112
	ARCH(1)	Bonds	0.415	0.319	0.236	0.022	0.601	0.559
Brazil	AR(1)	Stocks	0.752	0.571	0.429	0.216	0.205	0.470
	AR(1)	Bonds	0.145	0.331	0.827	0.048	0.165	0.457
	ARCH(1)	Stocks	0.599	0.426	0.768	0.472	0.223	0.412
	ARCH(1)	Bonds	0.190	0.981	0.073	0.538	0.921	0.609
Dot-com	AR(1)	Stocks	0.080	0.472	0.959	0.968	0.687	0.936
	AR(1)	Bonds	0.203	0.301	0.385	0.895	0.557	0.459
	ARCH(1)	Stocks	0.746	0.074	0.598	0.528	0.014	0.685
	ARCH(1)	Bonds	0.252	0.525	0.393	0.405	0.041	0.746
Argentina	AR(1)	Stocks	0.360	0.067	0.986	0.394	0.024	0.607
	AR(1)	Bonds	0.116	0.678	0.027	0.002	0.394	0.328
	ARCH(1)	Stocks	0.243	0.097	0.072	0.004	0.061	0.039
	ARCH(1)	Bonds	0.006	0.048	0.263	0.027	0.067	0.001
U.S. subprime	AR(1)	Stocks	0.660	0.551	0.132	0.433	0.375	0.096
	AR(1)	Bonds	0.438	0.860	0.443	0.888	0.358	0.549
	ARCH(1)	Stocks	0.688	0.206	0.980	0.237	0.260	0.823
	ARCH(1)	Bonds	0.461	0.295	0.558	0.325	0.462	0.678

Table 10:

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	918.92 (0.000)	27992.76 (0.000)	1689.69 (0.000)	159.16 (0.000)	44.64 (0.000)
Market (bonds)	6	13677.70 (0.000)	1117223.14 (0.000)	46.55 (0.000)	44.99 (0.000)	15.46 (0.017)
Country	2	372.25 (0.000)	36550.06 (0.000)		11.41 (0.003)	
Idiosyncratic (Rus. bonds)	1	97.53 (0.000)				
Idiosyncratic (U.S. bonds)	1	8.62 (0.003)				0.05 (0.832)
Idiosyncratic (Bra. bonds)	1		154.71 (0.000)			
Idiosyncratic (U.S. stock)	1					17.518 (0.000)
Idiosyncratic (Arg. bonds)	1				29.56 (0.000)	
Joint	$16^{(a)}$, $15^{(b)}$, $12^{(c)}$, $14^{(d)}$	34398.96 (0.000)	1188511.63 (0.000)	1783.28 (0.000)	449.79 (0.000)	77.98 (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.

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 (5.2) is re-writte 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

$$\max_{\alpha_k}\left\{(1-\gamma)[E[\ln(1+R_p)|\Omega_k] + \ln W_1] + \frac{1}{2}(1-\gamma)^2 Var[\ln(1+R_p)|\Omega_k]\right\}, \quad (5.22)$$

by substituting out W_2 in the objective function using the budget constraint in (5.3), 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 (5.4) and some algebraic manipulation, the $\ln[1+R_p]$ term in the objective function in (5.22) 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

$$\begin{aligned}E[(r_p-r_f)|\Omega_k] &\simeq \alpha_k' E[(r-r_f)|\Omega_k] + \frac{1}{2}\alpha_k' E\left[(r-r_f)(r-r_f)'|\Omega_k\right](1-\alpha_k'\imath) \\ E[r_p|\Omega_k] - r_f &\simeq \alpha_k'(E[r|\Omega_k]-r_f) + \frac{1}{2}\alpha_k' Var[(r-r_f)|\Omega_k](1-\alpha_k'\imath) \\ E[r_p|\Omega_k] &\simeq \alpha_k'(E[r|\Omega_k]-r_f) + \frac{1}{2}\alpha_k' Var[r|\Omega_k](1-\alpha_k'\imath) + r_f, \quad (5.23)\end{aligned}$$

and

$$\begin{aligned} Var\left[\left(r_p - r_f\right)|\Omega_k\right] &\simeq Var\left[\left(\alpha_k'\left(r - r_f\right)\right)|\Omega_k\right] \\ Var\left[r_p|\Omega_k\right] &\simeq \alpha_k' Var\left[r|\Omega_k\right]\alpha_k. \end{aligned} \tag{5.24}$$

Upon substituting (5.23) and (5.24) into (5.22), together with the definition of log portfolio returns $r_p \equiv \ln(1+R_p)$, the objective function is rewritten as

$$\max_{\alpha_k}\left\{(1-\gamma)\left[\alpha_k'\left(E\left[r|\Omega_k\right]-r_f\right)+\frac{1}{2}\alpha_k' Var\left[r|\Omega_k\right]\left(1-\alpha_k'\imath\right)+r_f+\ln W_1\right]\right. \tag{5.25}$$
$$\left.+\frac{1}{2}(1-\gamma)^2\alpha_k' Var\left[r|\Omega_k\right]\alpha_k\right\}.$$

Differentiating (5.25) with respect to α_k yields the optimal solution to the portfolio problem of the informed and the uninformed investors given in (5.9)

$$\alpha_k^* = \frac{1}{\gamma}\left[E\left[r|\Omega_k\right] - r_f + \frac{1}{2}Covar\left[r|\Omega_k\right]\right]Covar\left[r|\Omega_k\right]^{-1}. \tag{5.26}$$

A.2 Informed Conditional Expectations

Using $r \equiv \ln(1+R)$ combined with the definition of $R = \frac{v-P}{P}$ in (5.5) and the liquidation value definition in (5.6), gives

$$r = \ln\theta + \ln u - \ln P. \tag{5.27}$$

Now taking conditional expectations based on the information set Ω_I in (5.10), yields the following conditional expectations of the informed investor

$$E\left[r|\Omega_I\right] = \ln\theta + E\left[\ln u|\Omega_I\right] - \ln P = \ln\theta + \beta\ln f_t - \ln P, \tag{5.28}$$

and

$$Var\left[r|\Omega_I\right] = Var\left[\ln u|\Omega_I\right] = \beta\beta' + \Sigma_\eta, \tag{5.29}$$

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 (5.28) and (5.29) into the optimal solution of the informed investor's portfolio problem in (5.9) 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 Conditional Expectations

The conditional expectations of (5.27) based on the information set Ω_U in (5.12), are

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

and

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

The solution to the uninformed investor's optimization problem given in (5.9) with $k = U$, is re-written using the expressions for the conditional expectations given above

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

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

$$\begin{aligned} X_T &= \mu_I \frac{\ln \theta + \beta \ln f - \ln P - r_f + \frac{1}{2}\left(\beta\beta' + \Sigma_\eta\right)}{\gamma\left(\beta\beta' + \Sigma_\eta\right)} W_1 \\ &\quad + \mu_U \frac{E\left[\ln v|\Omega_U\right] - \ln P - r_f + \frac{1}{2}Var\left[\ln v|\Omega_U\right]}{\gamma Var\left[\ln v|\Omega_U\right]} W_1 + \ln \epsilon. \end{aligned} \tag{5.30}$$

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

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

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

$$\begin{aligned}
E[\ln v|\Omega_U] &= E[\ln v|S(\ln P)] \\
&= E[\ln v] + Cov[\ln v, S(\ln P)](Var[S(\ln P)])^{-1} \\
&\quad \times (S(\ln P) - E[S(\ln P)]) \\
&= \overline{\theta} + \Sigma_\theta \left[\Sigma_\theta + \left(\frac{\gamma}{\mu_I W_1}\right)^2 (\beta\beta' + \Sigma_\eta)\Sigma_\epsilon(\beta\beta' + \Sigma_\eta)'\right]^{-1} \\
&\quad \times \left[\ln\theta + \frac{\gamma(\beta\beta' + \Sigma_\eta)}{\mu_I W_1}\ln\epsilon - \overline{\theta}\right],
\end{aligned} \tag{5.31}$$

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

which represent the required conditional expectations of the uninformed investor.

A.4 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 return on the asset, the following steps are adopted. Substitute the conditional expectations in (5.31) into the market-clearing condition in (5.30), and rearrange to generate an expression of the current price in terms of the factors

$$\ln P = \varphi + \xi\ln\theta + \chi\ln\epsilon + \delta\ln f, \tag{5.32}$$

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_2 be the realized price in the next period, formally the realization from the distribution of v, be given by

$$
\ln P_2 = E [\ln v | \Omega_U] + \ln \zeta,
$$

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 (5.31) and the expression for $\ln P$ in (5.32). Or, in terms of excess returns, $\ln P_2 - \ln P - r_f$, 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 sources and definitions.

Country	Bonds (issued in U.S. dollars)	Stocks (local currency)	Exchange rates (against USD)
Argentina	11% coupon: Issued October 9, 1996 Matures October 9, 2006 Bloomberg 007022140	MERVAL Index ARGMERV(PI)	 ARGPES$
	11.375% coupon: Issued March 15, 2000 Matures March 15, 2010 Bloomberg 010909899		
Brazil	9 3/8% coupon: Issued March 31, 1998 Matures April 7, 2008 Bloomberg 105756AG5	BOVESPA Index BRBOVES(PI)	 BRACRU$
	10.25% coupon: Issued June 17, 2003 Matures June 17, 2013 Bloomberg 017062875		
Canada	Corporate BBB Bloomberg C28810Y	S&P/TSX Index TTOCOMP(PI)	 CNDOLL$
Mexico	8 5/8% coupon Issued March 5, 1998 Matures March 12, 2008 Bloomberg 8534713	BOLSA Index MXIPC35(PI)	 MEXPES$
	6.375% coupon Issued January 16, 2003 Matures January 16, 2013 Bloomberg 016113468		
Sources:	Bloomberg	Datastream	Datastream

Table B1 (continued): Data sources and definitions.

Country	Bonds (issued in U.S. dollars)	Stocks (local currency)	Exchange rates (against USD)
Russia	3% coupon: Issued May 14, 1993 Matures May 14 2008 Bloomberg TT3182314	RSF EE MT Index RSMTIND(PI)	 CISRUB$
	3% coupon: Issued May 14, 1996 Matures May 14, 2011 Bloomberg 008170363		
U.S.	Corporate BBB bond rate Bloomberg C00910Y	Dow Jones Index DJINDUS(PI)	
Risk free	Yields on the U.S. Treasury 10 year bond Federal Reserve Board of Governors: Table 15 tcm10y		
Sources:	Bloomberg	Datastream	Datastream

C Additional Variance Decompositions

Table C1: Variance decompositions, Russian/LTCM crisis: percentage of total.

Market	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
				Stock Markets			
Noncontagion	Common 1	1.07	0.34	0.05	0.95	7.52	14.64
	Common 2	9.83	0.58	14.96	4.79	5.07	16.81
	Emerging	1.18	0.43	n.a.	n.a.	9.00	n.a.
	Market (stock)	2.31	1.19	1.12	4.16	16.85	0.91
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country	2.14	0.15	18.44	1.21	10.68	n.a.
	Idio.	22.45	0.39	25.49	41.92	38.19	n.a.
Contagion	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	0.90	12.14	6.65	9.00	0.09	5.99
	Country (Russia)	44.86	0.71	21.81	30.70	n.a.	54.86
	Idio. (Rus. bond)	12.75	54.47	0.91	0.01	1.17	0.03
	Idio. (U.S. bond)	2.52	29.62	10.58	7.27	11.42	6.77
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		9.74	15.64	2.84	11.12	140.25	2.07
				Bond Markets			
Noncontagion	Common 1	0.01	0.03	0.33	0.04	1.68	0.00
	Common 2	3.76	4.84	4.79	8.00	9.50	0.00
	Emerging	0.35	n.a.	n.a.	n.a.	2.62	n.a.
	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	0.52	0.02	8.55	0.01	0.12	68.80
	Country	1.22	0.77	15.04	0.94	52.36	n.a.
	Idio.	55.10	1.63	25.83	2.45	20.41	0.18
Contagion	Market (stock)	31.65	9.30	9.15	26.32	0.47	5.91
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country (Russia)	0.74	29.55	4.61	18.22	n.a.	7.47
	Idio. (Rus. bond)	5.77	31.42	3.43	25.23	n.a.	17.64
	Idio. (U.S. bond)	0.87	22.45	28.28	18.79	12.83	n.a.
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		11.19	30.30	1.47	5.68	371.11	0.32

Table C2: Variance decompositions, Brazilian crisis: percentage of total.

Market	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
				Stock Markets			
Noncontagion	Common 1	8.64	4.12	20.87	6.51	0.11	31.99
	Common 2	2.33	4.58	0.44	2.98	0.31	14.53
	Emerging	1.17	3.84	n.a.	n.a.	0.24	n.a.
	Market (stock)	1.23	0.25	7.09	10.71	8.23	35.20
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country	6.29	76.86	41.53	0.84	0.02	n.a.
	Idio.	17.64	0.80	23.14	65.49	1.31	n.a.
Contagion	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	2.24	2.49	0.28	0.00	55.33	2.23
	Country (Brazil)	51.04	n.a.	1.53	12.40	0.00	2.31
	Idio. (Brz. bond)	9.42	7.07	5.12	1.08	34.47	13.75
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		7.33	25.35	1.33	5.93	17.47	1.63
				Bond Markets			
Noncontagion	Common 1	5.18	3.10	8.78	10.85	0.04	0.66
	Common 2	0.09	0.08	1.15	0.27	0.01	0.01
	Emerging	0.48	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)	0.47	1.58	0.02	3.28	36.14	0.04
	Country	0.51	76.95	19.46	2.71	0.11	n.a.
	Idio.	79.15	0.27	62.91	1.88	0.45	91.07
Contagion	Market (stock)	0.16	18.02	0.80	1.87	28.63	3.25
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country (Brazil)	13.92	n.a.	6.26	76.72	5.62	3.98
	Idio. (Brz. bond)	0.04	n.a.	0.62	2.42	29.00	1.01
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		9.20	32.20	0.78	4.99	193.26	0.09

Table C3: Variance decompositions, dot-com crisis: percentage of total.

Market	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
				Stock Markets			
Noncontagion	Common 1	0.05	0.86	0.01	0.03	11.59	41.15
	Common 2	0.65	1.81	16.42	0.16	10.71	42.18
	Emerging	0.08	1.45	n.a.	n.a.	8.32	n.a.
	Market (stock)	3.94	38.83	11.63	10.23	0.88	2.25
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country	0.01	1.11	11.28	0.01	67.10	0.79
	Idio.	1.54	0.08	38.48	1.21	0.03	13.15
Contagion	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	0.01	21.19	0.28	75.90	0.17	0.48
	Country (U.S.)	88.03	7.09	0.48	2.04	0.01	n.a.
	Idio. (U.S. stock)	5.71	27.58	21.42	10.42	1.18	n.a.
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		2.61	3.66	2.88	7.09	11.22	2.14
				Bond Markets			
Noncontagion	Common 1	0.07	0.29	0.14	0.39	0.69	0.03
	Common 2	5.52	60.63	8.44	71.11	6.26	0.62
	Emerging	0.46	n.a.	n.a.	n.a.	1.34	n.a.
	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	0.01	0.10	0.02	0.10	0.01	0.02
	Country	93.36	3.70	48.64	22.95	0.02	0.21
	Idio.	0.56	27.69	24.36	5.30	80.09	86.85
Contagion	Market (stock)	0.01	4.13	9.62	0.06	4.20	7.18
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country (U.S.)	0.01	0.21	0.49	0.02	0.06	n.a.
	Idio. (U.S. stock)	0.02	3.26	8.30	0.07	7.34	5.09
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		1.86	1.54	0.85	0.60	14.41	0.06

Table C4: Variance decompositions, Argentinian crisis: percentage of total.

Market	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
				Stock Markets			
Noncontagion	Common 1	1.26	0.01	0.42	0.59	3.58	19.39
	Common 2	15.42	0.03	20.00	8.35	4.21	28.06
	Emerging	1.67	0.03	n.a.	n.a.	9.18	n.a.
	Market (stock)	0.20	67.57	0.17	0.12	0.27	0.52
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country	32.05	0.01	22.49	0.40	68.73	n.a.
	Idio.	38.08	0.03	31.18	83.65	5.27	n.a.
Contagion	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	9.70	25.77	2.01	1.23	0.17	0.08
	Country (Arg.)	n.a.	2.96	4.85	0.58	1.69	6.16
	Idio. (Arg. bond)	1.64	3.60	18.88	5.08	6.92	45.79
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		9.06	5.40	1.28	1.80	4.20	1.71
				Bond Markets			
Noncontagion	Common 1	0.80	4.78	1.08	3.71	1.37	0.01
	Common 2	12.17	61.60	7.32	60.63	3.54	0.54
	Emerging	1.26	n.a.	n.a.	n.a.	0.26	n.a.
	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	43.58	0.40	10.01	0.00	0.01	0.78
	Country	30.66	14.32	29.05	24.25	0.02	n.a.
	Idio.	5.73	18.78	45.32	2.56	94.00	91.67
Contagion	Market (stock)	5.80	0.01	4.76	0.74	0.04	1.42
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country (Arg.)	n.a.	0.08	2.33	1.33	0.03	0.28
	Idio. (Arg. bond)	n.a.	0.04	0.14	6.79	0.74	5.29
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		40.73	6.75	0.54	0.36	1.54	0.12

Table C5: Variance decompositions,U.S. subprime mortgage crisis: percentage of total.

Market	Factor	Arg.	Brz.	Can.	Mex.	Rus.	U.S.
				Stock Markets			
Noncontagion	Common 1	2.80	2.49	0.35	1.55	13.10	3.49
	Common 2	7.07	1.60	5.95	2.33	3.36	11.33
	Emerging	1.05	1.81	n.a.	n.a.	8.80	n.a.
	Market (stock)	0.57	75.93	0.74	1.23	0.28	1.21
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Country	2.08	0.21	7.37	0.20	0.23	n.a.
	Idio.	19.40	1.86	11.86	26.60	51.56	3.34
Contagion	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	28.33	5.06	30.88	28.59	8.33	36.05
	Idio. (U.S. stock)	2.93	3.74	2.48	2.30	0.75	n.a.
	Idio. (U.S. bond)	35.77	7.30	40.37	37.20	13.59	44.57
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		8.89	13.04	4.05	6.95	4.02	3.47
				Bond Markets			
Noncontagion	Common 1	0.00	2.57	1.34	2.73	0.70	0.01
	Common 2	0.05	46.54	6.73	51.47	1.63	15.17
	Emerging	0.01	n.a.	n.a.	n.a.	0.59	n.a.
	Market (stock)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Market (bond)	2.25	10.03	8.79	7.70	44.53	26.61
	Country	0.01	22.71	27.00	22.12	12.34	n.a.
	Idio.	0.81	1.38	41.61	0.07	12.37	23.90
Contagion	Market (stock)	2.15	0.14	0.02	0.03	0.00	11.45
	Market (bond)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Idio. (U.S. stock)	92.57	1.03	0.43	0.90	0.06	22.86
	Idio. (U.S. bond)	2.15	15.59	14.07	14.99	27.78	n.a.
Total		100.00	100.00	100.00	100.00	100.00	100.00
Variance		28.17	1.72	0.39	0.39	1.12	0.16

Chapter 6: Investors’ Risk Appetite and Global Financial Market Conditions [1]

> “When U.S. stocks are volatile, EMBI spreads widen. They narrow again when U.S. stocks calm down. That suggests that emerging market debt is not being driven by judgments of governments’ creditworthiness.”
>
> *Financial Times*, 10/26/07 (p. 15)

1 Introduction

The typical assumption is that spreads on sovereign bonds reflect the default risk of that country, which in turn are determined by its economic fundamentals. However, fundamentals do not change from one day to the other, unless new information is revealed periodically affecting the expectations about the underlying drivers of that particular economy. Yet spreads on sovereign bonds vary constantly, sometimes substantially over very short intervals of time. As quoted above by a leading international financial newspaper, observers have noticed that bond spreads generally tend to move with changes in global financial conditions, such as volatility in equity markets.

One observed regularity is that bond spreads tend to widen in a country facing financial stress, as investors price higher a risk in that country. But during periods of financial stress, spreads sometimes widen not only in the source country of the crisis, but also across other countries which appear to be unrelated. Indeed, shocks can transmit rapidly across global financial markets. One possible channel is that conditions in global financial markets affect international investors’ risk appetite, and changes in the latter may actually spread the original shock across global financial markets. Through this mechanism, seemingly unrelated asset markets across national boundaries may actually be affected by an otherwise unrelated shock.

As evidenced by the U.S. subprime mortgage and liquidity crisis that begun in mid-2007, financial crises are not simply events from the past—although it has been several years since global financial markets experienced such a pervasive shock—and are not confined to emerging markets. This recent crisis was characterized by a drying up of liquidity across financial markets which was sparked by difficulties in the U.S. subprime mortgage market (see International Monetary Fund

[1] The chapter is published in González-Hermosillo, B. (2007b), “The Role of International Investors’ Risk Appetite in Global Financial Crises: 1998-2007”, International Monetary Fund Working Paper WP/08/85.

(2007)). Empirical analyses of this recent episode of global financial crisis are still scant, particularly in the context of other historical crises. In chapter 5 of this thesis it is found that the most acute episodes of systemic contagion across markets and countries in the past decade have been the Russia/LTCM crisis in 1998 and the U.S. subprime and liquidity squeeze in mid-2007. In both of these cases, the channel of contagion is primarily from credit markets to equity markets. They also find that there was contagion from U.S. credit markets to Russian and Argentinean credit markets, both of which had their central banks inject emergency liquidity during the U.S. subprime and liquidity crisis.[2]

There is a rich literature on financial contagion which has tried to identify the channels through which shocks in one country transmit to financial markets in other countries (see Dornbusch, Park and Claessens (2000); Pericoli and Sbracia (2003) and Dungey, Fry, González-Hermosillo and Martin (2005b), for surveys of this literature). The theoretical determinants of contagion are discussed in Kodres and Pritsker (2002). While most of the empirical literature on contagion has focused on emerging markets, a few exceptions have analyzed emerging markets and mature economies jointly for clues as to how shocks transmit globally during periods of financial stress, usually across the same asset market class (Kaminsky and Reinhart (2003); and chapters 3 to 5 in this thesis). Analyses of spillover and contagion effects across emerging markets and mature economies, as well as across different asset market classes are even less common (one exception is Dungey, Fry, González-Hermosillo, Martin and Tang (2007b)).

There may be several mechanisms for contagion whereby channels are established only during periods of stress that are over and above the market fundamental mechanisms, or spillovers, that link countries and asset markets during noncrisis periods. One such mechanism may be the presence of common international investors who react to a given shock by rebalancing their portfolios globally in assets and markets that would be otherwise seemingly unrelated. As investors become less willing to assume risk, they require a higher compensation for bearing such risk. This re-pricing of risk can effect the prices of other risky assets (Kumar and Persaud (2002)).

Observers often refer to this mechanism as investors' increased risk aversion or reduced risk appetite. However, these two concepts are conceptually different.[3] Risk aversion measures the subjective attitude of investors with regard to uncertainty. Since the degree of investors' risk aversion reflects entrenched preferences, it is usually assumed to be constant in asset pricing

[2] *Financial Times* (9/26/07) and *Fitch Ratings* (10/18/07).

[3] In practice, it is clearly difficult to disentangle risk appetite from risk aversion. An increase in either one causes asset prices to decline and risk premia to increase. This issue is examined in Bliss and Panigirtzoglou (2004).

models. In contrast, the notion of investors' risk appetite is more broad as it is also influenced by the amount of uncertainty about the fundamental factors that drive asset prices. Thus, the risk premia embedded in asset prices are influenced by both risk aversion and the riskiness of the asset in question. One potential channel for shifts in investors' risk appetite is changes in global financial market conditions, a venue which is investigated empirically in this chapter. Gauging the degree of investors' risk appetite is relevant from a global financial stability perspective as past episodes of brisk changes in risk premia, variations in market liquidity, and sharp movements in asset prices have been often associated with changes in investors' risk appetite.

Work analyzing the role of risk appetite as a transmission channel of financial crises include Kumar and Persaud (2002), Gai and Vause (2005), Coudert and Gex (2007), and Dungey, Fry, González-Hermosillo and Martin (2003a). The first two papers analyze the relative importance of contagion due to shifts in risk appetite; the third paper analyzes the predictive power of several risk appetite indices; and the last one identifies the global market channels of financial crises.[4] There is also a wide literature on the determinants of emerging market spreads. For example, Kashiwase and Kodres (2005) estimate a panel data model in which emerging market spreads are a function of liquidity risk and fundamental factors.

This chapter quantifies the relative importance of potential determinants of spreads for emerging markets' sovereign bonds and mature markets' corporate bonds from 1998 through 2007, encompassing several episodes of financial market distress. A vector autoregression model is constructed to capture the dynamics of global bond spreads as a function of global market conditions, idiosyncratic factors and contagion effects. The identification of the factors is made through long-run restrictions which permit quantifying the contribution of the various factors to the bond spreads during various periods of financial stress.

In particular, four different global market risk factors are assumed to reflect the degree of risk appetite of international investors. The first risk factor is the *funding liquidity* premium,

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[4] The approach in this chapter is similar to Dungey, Fry, González-Hermosillo and Martin (2003a), with several important differences. First, the proxies for global market conditions in this paper are different and chosen to reflect, where possible, some of the newer instruments in financial markets. Second, the choice of countries is different and expanded, as they only examine emerging markets, while mature markets are also introduced here as part of a more global framework. As highlighted during the 2007 subprime mortgage meltdown and liquidity squeeze, global financial crises can also originate in mature markets. Third, this chapter covers a longer period January 1998 to August 2007, with a larger number of episodes of financial stress including the recent turbulence sparked by the U.S. subprime mortgage crisis. In contrast, in Dungey, Fry, González-Hermosillo and Martin (2003a) only nine emerging markets' sovereign spreads are examined during three crises episodes (the Russian default (1998), the LTCM bail-out (1998), and the Brazilian devaluation (1999)).

proxied by monetary conditions. The second risk factor is *default risk*. The third factor is *market liquidity risk*, as investors prefer liquid instruments which can be transformed into other assets without a significant loss of value during times of stress. Market liquidity may be an especially important systemic factor during financial crises if a liquidity squeeze forces a generalized sale of assets, depressing their prices and resulting in additional default risks which may feed back into even more illiquidity. The final aggregate risk factor considered reflects *volatility*, as measured in equity markets and in future interest rate contracts. The four aggregate global market risk factors are used to explain daily movements in the sovereign bond spreads for thirteen emerging markets and the spreads in BBB investment grade corporate bonds for four mature markets from January 2, 1998 through August 9, 2007 (one day before the European Central Bank began a round of liquidity injections into the financial system, which was followed a few days later by the easing of monetary policy in other central banks, including the U.S. Federal Reserve). In addition, idiosyncratic and contagion effects from emerging markets are also estimated in the model.

The results suggest that, while idiosyncratic factors explain a significant amount of the changes in bond spreads over time, global financial market conditions are fundamental driving forces at times of crisis. The relative importance of the various global risk factors depends on the crisis episode. An important result of this chapter is that, once global financial market factors are explicitly considered, contagion from emerging markets becomes very small or essentially not existent, suggesting that investors' risk appetite may be the key channel of transmission of shocks across national boundaries and market classes, especially in increasingly integrated global financial markets.

The chapter proceeds as follows. Section 6.2 discusses the conceptual basis of risk appetite. Section 6.3 surveys the variables which have been used in the empirical literature and by practitioners to proxy investors' risk appetite, and discusses the actual variables used in this paper. Section 6.4 discusses the identification and estimation strategy. Section 6.5 examines the unconditional variance decomposition. Section 6.6 discusses the spread decomposition and the empirical results. Section 6.7 concludes and offers suggestions for future research. Appendix A details the crises dates. Appendix B contains an explanation of the Data Sources as well as the Tables and Figures.

2 The Concept of Risk Appetite

The investors' degree of risk aversion reflects underlying preferences and, as such, it is expected to change infrequently over time. In contrast, risk appetite is likely to change more often as investors respond to changing levels of uncertainty in the macroeconomic environment. Thus, risk appetite depends on the subjective degree to which investors are willing to bear uncertainty *and* on the overall level of uncertainty about the fundamental factors which drive asset prices.

The standard treatment of asset pricing theory (e.g., Cochrane (2001) and also discussed in Gai and Vause (2005)) states that in an efficient market, with fully rational and informed investors, the current price of an asset, p_t, should equal the expected discounted value of its possible future payoffs, x_{t+1}. These payoffs comprise income (such as dividend payments) received over the long-run horizon, plus the ongoing value of the asset as implied by its future price. More formally,

$$p_t = E_t\left(m_{t+1} \cdot x_{t+1}\right), \tag{6.1}$$

where x_{t+1} denotes the payoff in period t+1, and m_{t+1} denotes the discount factor—the marginal rate at which the investor is willing to substitute consumption at time $t + 1$ for consumption at time t. Both x_{t+1} and m_{t+1} vary across states of the world. Indeed, m_{t+1} is usually referred to as the *stochastic* discount factor.

The basic asset pricing equation can also be expressed in terms of gross returns, R_{t+1}, by dividing equation (6.1) by current prices. Thus,

$$1 = E_t\left(m_{t+1} \cdot R_{t+1}\right). \tag{6.2}$$

Although, in general, different assets have different expected returns, all assets have the same expected *discounted* return in equilibrium (of unity). Since both the gross return and the stochastic discount factor are random variables, equation (6.2) can be written as

$$1 = \underbrace{E_t\left(m_{t+1}\right) \cdot E_t\left(R_{t+1}\right)}_{\text{risk-neutral component}} + \underbrace{cov_t\left(m_{t+1}, R_{t+1}\right)}_{\text{risk adjustment}}. \tag{6.3}$$

The first term on the right-hand side of equation (6.3) reflects the mean return required by investors to hold the asset *if* they were indifferent to risk, the risk-neutral component. The second term is a risk adjustment required by risk-averse investors. Given that the gross risk-free rate can be denoted as $R^f_{t+1} = 1/E_t m_{t+1}$, we can rearrange (6.3) to obtain the familiar expression

$$\underbrace{E_t\left(R_{t+1}\right) - R^f_{t+1}}_{\text{risk premium}} = -R^f_{t+1} cov_t\left(m_{t+1}, R_{t+1}\right). \tag{6.4}$$

Equation (6.4) states that the expected return of a risky asset in excess of that available on a risk-free asset is proportional to *minus* the covariance of its state-contingent rate of return and the stochastic discount factor.

The risk premium can, in turn, be decomposed into the quantity of risk, β_i, inherent in each asset and the unit price of risk that is common across assets, λ_t. In particular,

$$E_t\left(R_{t+1}\right)-R_{t+1}^f=\underbrace{\frac{-cov_t\left(m_{t+1},R_{t+1}\right)}{var\left(m_{t+1}\right)}}_{\beta_i}\cdot\underbrace{var\left(m_{t+1}\right)\cdot R_{t+1}^f}_{\lambda_t} \tag{6.5}$$

The price of risk, λ_t, is the expected excess return that, in equilibrium, investors require to hold each unit of risk. *Risk appetite*—the willingness of investors to bear risk—can therefore be defined as the inverse of the price of risk. So when an investor's risk appetite falls, they require larger expected excess returns to hold risky assets.

It is apparent from equation (6.5) that risk appetite reflects variation in the stochastic discount factor, $var(m_{t+1})$. Since the stochastic discount factor specifies the marginal rate at which the investor is willing to substitute uncertain future consumption for present consumption, risk appetite depends on the *degree* to which investors dislike uncertainty about their future consumption and on factors that determine the overall *level* of uncertainty surrounding consumption prospects. The degree to which investors dislike uncertainty corresponds to *risk aversion*. Accordingly, risk aversion reflects innate preferences over uncertain future consumption prospects—the curvature of individuals' utility functions—that are unlikely to vary significantly over time.

The factors underpinning risk appetite can also be examined by imposing some structure on the stochastic discount factor. For example, if consumption growth is log-normally distributed with variance, $\sigma_t^2\left(c_{t+1}\right)$, and investors have power utility functions, then the price of risk is

$$\lambda_t=\gamma\sigma_t^2\left(c_{t+1}\right) \tag{6.6}$$

where γ is the coefficient of absolute risk aversion.[5] So a rise in γ would mean a fall in risk appetite. But risk appetite will also fall if the uncertainty about future consumption growth (the expected volatility of future consumption) is amplified. The expected volatility of future consumption may depend on factors such as unemployment prospects, the stance of macroeconomic policy, global prospects and, more generally, global financial market conditions. In general, one would expect that

[5] This is a standard result in asset pricing. See Cochrane (2001) for a detailed exposition.

the periodic shifts in market sentiment witnessed over time are more likely to be driven by the macroeconomic environment rather than by changes in the risk aversion of investors.

3 Variables in the Empirical Model

Investors' risk appetite is, nevertheless, not directly observable. Yet, risk appetite is frequently cited as a factor explaining asset price movements and several indicators are typically used by market participants to measure it. These measures are often amalgamations of an array of different market-based indicators which are aggregated to produce a single index of "risk appetite." Box 1 details some of the key market-based indicators typically used to gauge investors' risk appetite.[6]

This plethora of market-based indicators are used routinely by market participants.[7] However, they are less than ideal for analytical purposes as they essentially add up all the potential risk factors into a mix that creates an index of risk appetite. In addition, they do not generally examine potential linkages among the different risk components.

Thus, for example, it is not clear how to examine analytically measures of risk appetite which throw into the mix sovereign bond spreads for emerging markets, movements in commodity prices, in equity prices, in fixed income markets, and in exchange rate markets, in addition to measures of volatility and liquidity and other market data. The approach adopted in this chapter is more fundamental, based on a few representative variables which are viewed to reflect the key risk factors in global financial markets. In particular, the model includes sovereign bond spreads in representative emerging markets and roughly comparable investment grade BBB corporate bonds in developed economies, several risk premia in global financial markets that are assumed to represent the compensation that international investors demand to accept risk, idiosyncratic factors proxying for "fundamentals", and any additional contagion effects from emerging markets.

[6] The group of indicators summarized in Box 1 include: CBOE's Volatility Index (VIX); JP Morgan's Risk Tolerance indices ─one global (JPM G-10 RTI) and another one for emerging markets (JPM EM RTI); UBS FX Risk Index (UBS FX); Westpac's Risk Appetite Index (WP); Bank of America's Risk Appetite Monitor (RAM); Merrill Lynch's Risk Aversion Indicator (ML RAI); Dresdner Kleinwort's Aggregate Risk Perception Index (ARPI); and Lehman Brothers' Market Risk Sentiment Index (MARS).

[7] In addition to market-based indicators, another strand of the literature has examined financial CAPM─type models in a single financial market. These include the Goldman Sachs Risk Aversion Index and the Credit Suisse Global Risk Appetite Index. They are not considered here because they tend to rely on macroeconomic data only available in monthly or quarterly data frequencies, whereas the approach in this paper is to focus on financial market high-frequency data. For a survey of these indicators, see European Central Bank (2007).

Box 1. Survey of Market-Based Indicators of Risk Appetite

Index	Components	Method
VIX	• Implied volatility of S&P500 Index	Based on a weighted average of the implied volatility from eight calls and puts on the index.
JPM G-10 RTI	• US swap spread (liquidity risk) • VIX (equity market risk) • EMBI+ (credit risk in emerging markets) • Trade-weighted Swiss franc (risk appetite in currency markets)	Constructed as an equally weighted average after having standardized the four components.
JPM EM RTI	• VIX • EMBI+	A weighted average after standardizing the two components (weights: 30% VIX, 70% EMBI+).
UBS FX	• US Treasury relative to the U.S. stocks • Three-month foreign exchange option implied volatility (USD/JPY and EUR/USD) • Gold in EUR and USD • VIX • EMBI+ • US Treasury spread • Differences in stock returns between the S&P financials and utilities • High-yield corporate spreads relative to the US Treasury	An arithmetic average of the normalized values of market variables.
WP	• An average of the three-month implied volatility for six major currencies • VIX index • US ten-year bond-swap spread • JP Morgan emerging markets bond spread • US BB1 industrial bond spread	A 60-day z-score[1)] of a base index calculated in three steps: the first step calculates the daily percentage change of each variable, then the figures obtained are averaged, and finally the index values are indexed to 100 on 1 January 1998.
RAM	• EMBI spread • Carry AUD/JPY • Corporate bond spread BB • Carry EUR/CHF • Spread MSCI EM Lccy	The correlation (over a rolling six-week period) among a large sample of emerging economies for each of the three asset classes, multiplying them by a market direction measure (in order to distinguish between bullish or bearish periods). Finally, the correlation coefficients are aggregated with an equally weighted average.
ML RAI	• US high-yield spreads (US higher yield spread over Treasuries, expressed as % yield) • VIX implied volatility • TED spreads (three-month euro-dollar deposits minus three-month T-bills) • US ten-year swap spreads, emerging market bond spreads (ML USD Emerging Markets Sovereign 'Plus' Index yield) • The trade-weighted Swiss franc, and emerging market equities (USD) • US small cap stock	For each item, this takes the standard deviations from 52-week moving averages. Then it sums the standard deviations of US high-yield spreads, VIX implied volatility, TED spreads, US ten-year swap spreads, emerging market bond spreads and the trade-weighted Swiss franc, while it subtracts those of EM equities and US small cap stock.
ARPI	Based on high-frequency data (mainly spreads and implied volatilities) from five asset classes: • Fixed income basket (global and political risk) • Equity basket (equity investment risk) • Liquidity basket (liquidity risk) • Commodity basket (energy risk) • Credit basket (credit risk)	Based on a two-step principal component analysis (PCA), firstly within the baskets, and secondly between the principal components of these baskets.
MARS	• Market volatility (one-year FX implied volatility and equity implied volatility) • EM event risk (EM CDS spreads and EM equities) • Market liquidity (G3 swap spread) • Risk appetite ratios (equity to bond returns, gold price to gold equity returns, and US equity P/E ratio).	Built on a four-step process: input transformation a rank transformation of each risk input relative to its past 20 day values), data aggregation (a simple equally weighted average), transformation of the average rank into a score between 0 and 1, and finally a computation of the two-day moving average of the aggregate index.

1) The X-day z-score is defined as the value of a base index, net of its X-day mean, and divided by its X-day standard deviation.

Source: European Central Bank (2007)

Given that the price and the quantity of risk that investors are willing to assume are not distinguishable from each other in the data, the observed risk premium demanded by investors is assumed to reflect their risk appetite. The overall risk premium in global financial markets, itself also not directly observable in one single indicator, is assumed to have several key components: a funding liquidity premium, a credit risk premium, a market liquidity premium and a market volatility premium.[8] In addition to these aggregate global factors, bond spreads can be also influenced by fundamental factors which are idiosyncratic and, potentially, by additional sources of contagion from emerging markets which are not already captured by the global financial market conditions that are assumed to condition investors' risk appetite.

Economic fundamentals are modeled rather simplistically in this chapter; essentially, as everything else that is not encompassed by the aggregate market factors or by the additional sources of contagion, discussed in more detail below, emanating from emerging markets. This trade-off is accepted because the objective is to analyze the role of changes in global market conditions based on high frequency data, whereas measures of economic fundamentals rely largely on monthly or quarterly data. Indeed, the objective of this chapter is to determine the relative importance of aggregate risk factors during periods of financial stress, rather than to provide a model that best fits bond spreads. Moreover, because bond spread across countries tend to be more strongly correlated during periods of stress (Dungey, Fry, González-Hermosillo, Martin (2005b)) than during tranquil periods, common factors are likely to be particularly important during periods of stress.[9]

Below follows a more detailed discussion of the data and the proxies used for the various components determining the risk premia required by global investors.

3.1 Bond Spreads

The data for bond spreads in emerging markets are based on JP Morgan's EMBI+ country-specific indices. These indices contain U.S. dollar-denominated Brady bonds, Eurobonds and other traded loans issued by sovereigns, rated Baa1/BBB+ or below, and which satisfy certain maturity

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[8] There is no theoretical model for the global transmission of shocks to guide the choice of the appropriate "global" variables for this paper. However, the actual selection of variables is based on the analysis of the financial position of a representative banking firm in González-Hermosillo and Li (2008, forthcoming) where market, liquidity and credit risks are viewed as fundamental. In addition, volatility risk is essential in equity and derivatives markets, while funding liquidity is related to credit conditions and the level of the risk-free interest rate.

[9] Of course, the interpretation that idiosyncratic factors represent what is not explained by common global factors or other sources of contagion requires caution since its appropriateness depends on the quality of the proxies used to measure those risk factors.

and liquidity conditions.[10] The spreads are calculated as the difference between the yield on the instruments and the yield on U.S. Treasury bonds of similar maturity. The sovereign spreads include Brazil, Bulgaria, Colombia, Ecuador, Mexico, Panama, Peru, Philippines, Russia, South Africa, Turkey, Ukraine, and Venezuela. For mature markets, the representative bond spread is constructed as the difference between the yields on 10-year BBB-rated corporate bond indices and government bond indices of similar maturity and currency.[11] The developed markets analyzed are the Canada, the Eurozone, Japan and the United States.

3.2 Global Financial Market Conditions

The choice of variables that reflect global financial markets is constrained by the need to have a parsimonious set of variables that is still able to reflect "global" market conditions. They are discussed below.

3.2.1 Funding Liquidity Premium

The first aggregate market risk factor considered is the funding liquidity premium or a proxy to measure the amount of credit availability in the global financial system. Finding proxies to measure the funding liquidity premium (denoted as FF) is particularly troublesome after 2004, as long-term interest rates have stayed relatively constant even as a number of central banks have increased short-term interest rates. In addition to traditional monetary aggregates like M1 and M2, more appropriate proxies for funding liquidity would need to also include measures of credit availability, fund flows, asset prices and leverage (Warsh (2007)). In addition to the fact that it would be extremely difficult to construct proxies for those broad liquidity conditions, most of them would not exist on the daily frequency needed in this model.[12]

In this paper, the *3-month-ahead federal funds futures rate* is used as a measure of global funding liquidity or monetary conditions.[13] The federal funds rate is the instrument used by the U.S. Federal Reserve to affect monetary conditions. This rate can affect risk spreads through two channels. A decline in the federal funds rate implies a lower cost of borrowing and therefore an

[10] In particular, the instruments must have a maturity greater than 2 1/2 years, meet certain liquidity conditions and have a minimum issue size of US$500 million.

[11] The corporate bond indices are computed by Bloomberg, whereas the government bond indices are computed by DataStream.

[12] It is difficult to get a satisfactory proxy for global liquidity funding conditions reflected in daily data, especially for recent years as financial innovation has led to extraordinary leverage in financial markets. Estimates based on monthly frequency of the data have included monetary aggregates plus foreign official reserve holdings (Rasmus and Stracca (2006)).

[13] Kashiwase and Kodres (2005) also choose this proxy for funding liquidity.

rising level of funding liquidity in the economy. In addition, it reduces the return from safer assets. Everything else constant, these two channels would be expected to result in international investors seeking higher returns in risky assets. In contrast, higher expected interest rates make borrowing more expensive and drains funding liquidity from the system, increasing the probability that creditors will face difficulties. In this chapter, funding liquidity conditions are proxied by the implied federal funds rate in futures markets, rather than the actual federal funds rate, because the former captures the effects of anticipated changes in monetary policy at the time when they are anticipated, rather than when they actually take place. Another advantage of focusing on the 3-month ahead federal funds futures rate is that it implicitly captures a segment of the yield curve that is longer than the spot overnight federal funds rate, while also exhibiting more daily variation than the actual federal funds policy rate.

3.2.2 Credit Risk Premium

Two different measures of aggregate credit or default risk are examined (denoted as DR and Def. in the tables). The most direct one, because it prices in the cost of buying insurance against default, is credit default swaps. In particular, the *10-year Itraxx Europe Crossover index* is examined in this chapter and it measures the cost of buying insurance against default by European firms whose ratings are between investment and speculative grade.[14] Because credit default swap indices only exist after 2004, we also need to rely on other proxies of credit risk that cover a longer period.

The proxy used to measure aggregate default risk over the longer sample is the *10-year USD swap spread* which is the difference between the 10-year swap rate and the 10-year U.S. Treasury bond ($s_{10,t} - i_{10,t}$).[15] [16] In a swap contract, one party agrees to pay a fixed interest rate in return for received an adjustable rate from another party. When an investor enters a swap agreement as a fixed receiver in a fixed-for-floating swap, the investor is promised to receive from the counterparty a series of semi-annual fixed payments in exchange for paying the counterparty a

[14] There are many Itraxx indices and derivatives on Itraxx. The Itraxx crossover Europe index was chosen because of its relative liquidity and the fact that the 35 companies on which it is based are closer substitutes to emerging market bonds than other higher-rated indices. A similar index exists for U.S. corporations (CDX), which moves similarly to Itraxx. Because most of the other "global" variables are largely U.S.-based, the choice of the Itraxx crossover Europe was thought to give the analysis a more global balance.

[15] Regarding the notation, the first subscript indicates the maturity of the instrument, while the second indicates the time period. Both the maturity and the period are denominated in years.

[16] A large universe of fixed-income securities, including corporate bonds and mortgage-backed securities, use interest rate swap spreads as a key benchmark for pricing and hedging.

series of semi-annual floating payments. While the fixed payments are determined at the outset of the swap agreement, the floating payments are to be determined at later dates, based on the relevant maturity of the LIBOR rates prevailing at the beginning of each payment period.[17] The swap rate is the fixed payment on the notional amount. The swap rate examined here is based on contracts in which the variable rate is the 3-month LIBOR rate ($l_{1/4,t}$), and payments are made semi-annually. Ignoring liquidity premiums, the swap rate must be the expected average of future default-risky LIBOR rates.

$$s_{10,t} = E_t\left[\frac{l_{1/4,t} + l_{1/4,t+1/4} + \ldots + l_{1/4,t+10}}{40}\right]. \tag{6.7}$$

Similarly, the 10-year US Treasury note must be the expected path of default-free 3-month Treasury bills.

$$i_{10,t} = E_t\left[\frac{i_{1/4,t} + i_{1/4,t+1/4} + \ldots + i_{1/4,t+10}}{40}\right]. \tag{6.8}$$

The difference between the yield on a Treasury note and the LIBOR rate is a short-term default-risk premium (DR). Thus the 10-year swap spread is the expected average of future short-term default premiums, reflecting not only current but also expected future default risk.

$$s_{10,t} - i_{10,t} = E_t\left[\frac{DR_{1/4,t} + DR_{1/4,t+1/4} + \ldots + DR_{1/4,t+10}}{40}\right]. \tag{6.9}$$

The empirical literature on swap spreads has found that they also contain a liquidity premium. However, the liquidity premium component of swap spreads appears to be much more persistent than the default premium component (Liu, Longstaff and Mandell (2006)), so most of the variation in swap spreads is expected to be caused by variations in default risk.[18] A proxy for movements in the market liquidity premium is discussed below.

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[17] The LIBOR rate is the rate at which banks lend to each other and it is recorded by the British Banking Association (BBA) each day at 11 a.m. London time. The composite rate is calculated based on quotes provided by a basket of reference banks selected by the BBA.

[18] It is worth noting that another potential candidate to measure credit risk could have been the so-called TED spread, or the difference between the 3-month U.S. dollar LIBOR and the yield on the 3-month U.S. Treasury bill. This spread behaves similarly to the 10-year USD swap spread discussed above, except that it captures only short-term movements and it is particularly difficult to separate the component originating from credit risk versus that related to market liquidity.

3.2.3 Market Liquidity Premium

The measure of market liquidity premium examined here is the *difference between the yield on the 20-year U.S. Treasury bond and the yield on the 10-year U.S. Treasury note* (denoted ML and Liq. in the tables). Since these two bonds are default-free, their yield is simply the expected average of future yields on Treasury bills plus a liquidity premium. Their difference must then be equal to:

$$i_{20,t} - i_{10,t} = E_t\left[\frac{i_{1,t+10} + \ldots + i_{1,t+20}}{10}\right] + LP_{20,t} - LP_{10,t}\ . \tag{6.10}$$

It is reasonable to assume that the first term of the RHS is fairly constant because of the long horizon of the interest rates at these maturities, given the current information (i.e., the expected U.S. Treasury bond rates for 10-year and 20-year maturities are approximately the same in practice). Thus, movements in this spread will be largely driven by movements in liquidity premiums (LP). In particular, 10-year U.S. Treasury notes are usually used as a benchmark in the pricing of other financial assets and therefore are more liquid than 20-year bonds. In fact, yields on 20-year U.S. Treasury bonds have sometimes been above those on 30-year U.S. Treasury bonds (which is also fairly liquid), which could be hardly explained if not by the relative illiquidity of 20-year bonds over other more liquid benchmark maturities.[19] [20]

3.2.4 Market Volatility Premium

The measure of market volatility used in this analysis is the *Chicago Board of Options Exchange (CBOE) Volatility Index*, known as VIX (denoted as MV and Vol. in the tables). It measures the implied volatility from option prices on the S&P 500 equity index.[21]

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[19] For example, during the LTCM crisis in the fall of 1998, spreads between the 30-year U.S. Treasury bond and the 29-year U.S. Treasury bond were unusually large, signaling market liquidity pressures (Committee on the Global Financial System (1999)). Yields on the 30-year U.S. Treasury bond are not used here because this maturity was discontinued for several years during the period examined.

[20] Another commonly used measure of liquidity is the difference between the yields of "on-the-run" and "off-the-run" U.S. Treasury bonds. However this measure has the disadvantage that it exhibits important variations caused directly by the timing of the auctions, and therefore it is not examined.

[21] This volatility index is largely U.S.-based, but it is widely used to measure global market volatility. One disadvantage of using this index is that it is based on an average of a few observations that are out-of-the-money (the so-called "volatility smile"), rather than using all of the possible volatility and out-of-the-money strike price combinations. The problem with the way in which this index is calculated is that it does not take into account changes in the shape of the volatility smile that lead to a different curvature or a shift in the curve. There are other volatility indices, including the VDAX for the German stock market and various

(continued)

Another measure examined that also captures volatility risk is the uncertainty about the future path of interest rates (denoted as IV and Int. in the tables). This is proxied by the *implied interest-rate volatility from swaptions* with maturities between one and six months.[22]

3.3 Contagion Effects

As discussed earlier, the empirical literature has identified contagious effects during some of the recent crises (surveyed in Dornbusch, Park and Claessens (2000); Pericoli and Sbracia (2003); and Dungey, Fry, González-Hermosillo and Martin (2005)). This literature identifies the transmission mechanisms that propagate shocks from the source country across national borders and across financial markets, where channels over and above the market fundamental mechanisms that link countries and asset markets during noncrisis periods appear only during a crisis. In particular, an increase in a country's spread can lead to extraordinary increases in the spreads of other countries. This transmission can happen through different channels. For example, a deterioration in the fundamentals of a particular country, or a certain shock (e.g., a terrorist attack, a natural disaster, etcetera), can cause a generalized reduction in investors' risk appetite, requiring higher spreads in markets all across the globe. This is an increase in the price of risk, and should be captured by the aggregate risk variables discussed earlier.

But spreads can also increase for other reasons. The discovery of bad news about one country may cause investors to revise their expectations about the fundamentals of other specific countries which share similar features (i.e., not a generalized effect across the globe, as in the case of a decline in risk appetite). This other channel works through an increase in the (perceived) quantity of idiosyncratic risk.

In order to measure the contagion effects from emerging markets to a particular country, it is not practical to include spreads in other countries or an aggregate index of emerging market spreads directly into the model because this would induce multicollinearity. Instead, as a proxy for this country-specific contagion effect, for each country we construct the *difference between the spread in the composite (aggregated) EMBI+ index for all emerging markets and the bond spread of the country in question*. This variable is meant to measure how a particular bond spread is affected by the *relative* performance of bonds spreads in other similar countries (denoted as EM).

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volatility indices for foreign exchange contracts. However, VIX was chosen because of its common use as representative of "global" volatility.

[22] A swaption is an option to enter into a swap contract.

4 Identification and Estimation

The variables in the model can be expressed as the following expression:

$$Z_{it} = \left\{ FF_t, DR_t, ML_t, MV_t, IV_t, \log\left(Spread_{EMBI+,t} / Spread_{it}\right), \log\left(Spread_{it,}\right)\right\} \quad (6.11)$$

where i indicates a particular bond spread, FF stands for the funding liquidity (or monetary conditions) proxy, DR stands for default risk, ML stands for market liquidity, MV stands for market volatility, and IV for interest-rate volatility.

The dynamics of each of the variables is captured by estimating a vector autoregression (VAR) model in which all seven variables are endogenous. This implies that there is immediate feedback among all variables in the short run. The structural innovations are identified by imposing restrictions on the long-run effects of the variables, as in Blanchard and Quah (1989). In particular, it is assumed that in the long run: (i) bond spreads have no permanent effect on funding liquidity or on any other aggregate global market risk factor; (ii) feedback effects among default risk, market liquidity risk, and market and interest rate volatility risks are temporary;[23] and (iii) the contagion effects from emerging markets are temporary.

The aggregate global market factors and bond spreads follow the following stationary process

$$\Delta Z_t = \chi + \sum_{j=0}^{\infty} C(j) e_{t-j} , \quad (6.12)$$

$$e \sim N\left(0, I\right),$$

where ΔZ_t is the vector of variables in first differences, e_t is the vector of structural innovations, and I is the identity matrix.

In order to estimate the innovations, the following reduced-form VAR(p) is first estimated:

$$\sum_{j=0}^{p} A(j) \Delta Z_{t-j} = \alpha + v_t , \quad (6.13)$$

$$A(0) = I ,$$

[23] The long-term feedback effects of funding liquidity risk are not restricted *a priori* to be zero over the long-term. The intuition is that funding liquidity effects may be more permanent than the other global factors.

$$v \sim N(0, \Omega).$$

We can invert (6.13) to obtain its moving-average representation

$$\Delta Z = \chi + \sum_{j=0}^{\infty} B(j) v_{t-j} , \tag{6.14}$$

where $\sum_{j=0}^{\infty} B(j) = \left(\sum_{j=0}^{p} A(j) \right)^{-1}$ and $\chi = \sum_{j=0}^{\infty} B(j)\alpha$. Since $A(0) = I$, $B(0) = I$, it follows that $v_t = C(0)e_t$. Therefore, identification of $C(0)$ allows us to recover the structural shocks from the residuals of the estimated VAR. In order to identify $C(0)$ we first notice that $Var(v) = C(0)Var(e)C(0)'$, which implies

$$\Omega = C(0)C(0)'. \tag{6.15}$$

Second, since $C(j) = B(j)C(0)$, it follows that

$$\sum_{j=0}^{\infty} C(j) = \left(\sum_{j=0}^{\infty} B(j) \right) C(0). \tag{6.16}$$

Several restrictions are imposed on the matrix of long-run multipliers, the LHS of (6.16), which is denoted by H . In particular, the identification restrictions discussed earlier imply that H must satisfy the following matrix:

$$H = \begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} & h_{15} & 0 & 0 \\ h_{21} & h_{22} & 0 & 0 & 0 & 0 & 0 \\ h_{31} & 0 & h_{33} & 0 & 0 & 0 & 0 \\ h_{41} & 0 & 0 & h_{44} & 0 & 0 & 0 \\ h_{51} & 0 & 0 & 0 & h_{55} & 0 & 0 \\ h_{61} & h_{62} & h_{63} & h_{64} & h_{65} & h_{66} & h_{67} \\ h_{71} & h_{72} & h_{73} & h_{74} & h_{75} & 0 & h_{77} \end{bmatrix}, \tag{6.17}$$

where h_{ik} is the long-run multiplier of an innovation to variable k on variable i . The order of the variables follows that in (6.11). Once we have $\hat{C}(0)$ we can construct estimates of e_t as $\hat{e}_t = \hat{C}(0)^{-1} \hat{v}_t$.

The reduced-form VAR in equation (6.13) is estimated by ordinary least squares. We use 5 lags, as suggested by the AIC criteria. Then the estimated coefficients $\hat{A}(j)$ and the residuals $\hat{v}_t$ are used to estimate $C(0)$ and H using the identifying restrictions (15) and (17). Since the model is over-identified, we estimate the parameters in $C(0)$ through maximum likelihood. The log-likelihood function is given by:

$$\ln L = -\sum_{t=1}^{T}\left(\frac{N}{2}\ln\left(2\pi\right)+\frac{1}{2}\ln\left|\Omega\right|+\frac{1}{2}v_t{}'\Omega^{-1}v_t\right). \tag{6.18}$$

The model is estimated using two different samples. The first sample covers the period between January 2nd, 1998 and August 9th, 2007.[24] The bond spreads analyzed are sovereign spreads from Brazil, Bulgaria, Ecuador, Mexico, Panama, Peru, Russia, and Venezuela, and the corporate spreads are from Canada and the United States. The proxy used for default risk is the 10-year USD swap spread.

The second sample starts in mid-September 2004. Here, we are able to use newer financial instruments which did not exist before (a credit default swap index) to gauge default risk directly. In addition, we are able to analyze a larger number of developing countries and mature markets. The additional sovereign bond spreads correspond to Colombia, the Philippines, South Africa, Turkey, Ukraine. The additional corporate bond spreads in mature markets correspond to Japan and the Eurozone.

5 Forecast-Error Variance Decomposition

The analysis proceeds by decomposing the unconditional variance of the bond spreads. The *h*-step ahead forecast error of ΔZ_t is

$$\Delta Z_{t+h} - E_t\left(\Delta Z_{t+h}\right) = \sum\nolimits_{j=0}^{h-1} C(j)e_{t+h-j} \ . \tag{6.19}$$

Given the independence of the innovations, the *h*-step ahead forecast error variance of ΔZ_t is

$$\mathrm{var}_t\left(\Delta Z_{t+h}\right) = \sum\nolimits_{0}^{h-1} C(j)C(j)' \ . \tag{6.20}$$

We can obtain the variance due to a particular innovation *k* as

$$\mathrm{var}_{k,t}\left(\Delta Z_{t+h}\right) = \sum\nolimits_{0}^{h-1} C(j)I_kC(j)' \ , \tag{6.21}$$

[24] The sample ends one day before the European Central Bank injected €95 billion into the financial system, marking the first policy intervention aimed at bringing to an end the U.S. subprime mortgage and liquidity crisis.

where I_k is a matrix with 1 in its (k,k) cell and zeros elsewhere. Taking the limit of these expressions we can compute the unconditional variance decomposition. The results are presented in Tables 2 and 14.

The results suggest that, overall, the aggregate global market factors account for a relatively small fraction of the total variance over the 1998-207 period (Table 2). The extent ranges from only 8 percent in the United States, up to a maximum of 27 percent in Mexico. Contagion from emerging markets is generally very small (accounting for a maximum of 12 percent in the case of Bulgaria).

For the 2004-2007 sample (Table 14), aggregate global market factors explain a more significant fraction of the variance for some of the emerging markets, accounting for around 50 percent for Brazil, Colombia, Mexico, and the Philippines. However, aggregate market factors during this period explain a smaller fraction for some of the other bond spreads, with the smallest contribution being in the case of mature markets (7 percent for Japan, and approximately 15 percent for the United States and the Eurozone). Contagion effects from emerging markets are very small (accounting for less than 4 percent of the variance).

These results suggest that idiosyncratic factors are generally the main drivers of bond spread changes over extended periods of time. We now turn to examining these trends, but for shorter periods known to have been distressful.

6 Spread Decomposition

For each period of financial stress (Appendix A details each period), the spreads are further decomposed into a benchmark spread, equal to the conditional expectation of the spreads during the period given information available before the start of the period, and the contributions of the structural innovations to the spreads during the period of stress. The purpose of this exercise is to examine how the different aggregate global market factors contribute to the bond spreads, relative to what they would have been if the crisis had not taken place.

Let T denote the first date of a crisis period. The change in the benchmark spread at date $T+h$, given the pre-crisis information is

$$E_{T-1}\left[\Delta Z_{T+h}\right] = \chi + \sum_{i=h+1}^{\infty} C(i) e_{T-2+h-i} \,. \tag{6.22}$$

We can then decompose the changes in spreads into their pre-crisis conditional expectation and their forecast error, which is given by

$$\Delta Z_{T+h} - E_{T-1}\left[\Delta Z_{T+h}\right] = \sum_{i=0}^{h} C(i) e_{T+h-i}. \tag{6.23}$$

The contribution of error k to the total forecast error is

$$\sum_{i=0}^{h} I_k C(i) e_{T+h-i}. \tag{6.24}$$

Because some crises are preceded by a period which may already show a certain degree of financial stress, in most cases we compute conditional expectations using information up to several days or weeks before the start of the crisis.

6.1 Empirical Results: Mean Spread Decomposition

The results are presented in the tables containing the mean spread decompositions (Tables 3-13 examine the 1998-2007 period, and Tables 15-18 the 2004-2007 period). The first three columns in these tables show the mean actual spread during the crisis episode, the mean benchmark spread during the same period,[25] and their difference or the mean forecast error. The columns that follow indicate the contribution of each factor innovation to the forecast error.[26] The cases examined comprise the main episodes of financial stress from 1998 to 2007. Some particular episodes were excluded from the empirical analysis if they had a relatively small impact on global financial markets, despite having an important repercussion domestically; some examples are Ecuador's currency collapse (1999-2000), Argentina's debt default (2001) and Iceland's financial crisis (2006). The episodes of financial stress examined include the Russian default and the subsequent near-collapse of Long-Term Capital Management (1998), the devaluation of the Brazilian currency (1999), the NASDAQ bubble burst (2000), the Turkish crisis (2001), the terrorist attacks on September 11th (2001), the Brazilian elections and the WorldCom accounting scandal (2002), the beginning of the tightening cycle of the Federal Funds rate (2004), the rating downgrades of Ford and General Motors (2005), the Turkish crisis (2006), the Chinese stock market correction (2007), and the U.S. subprime mortgages and liquidity crisis (2007). The specific dates used to define the episodes are described in Appendix A.

[25] Recall that benchmark spreads are computed as the conditional expectation, given pre-crisis information.

[26] Note that while actual and benchmark spreads are presented in basis points, the forecast error is $\log\left(Spread_{it}\right) - E_{T-1}\left[\log\left(Spread_{it}\right)\right]$, and thus the contributions to the forecast error are presented in terms of the differences in the logarithms of basis points, or percentage point contribution.

6.1.1 Russia's Default and the LTCM Crisis (1998)

In the first episode analyzed, the 1998 Russian default and the LTCM near-collapse are modeled jointly because of the proximity of the two events (Russia defaulted on August 17th, and the Fed-orchestrated rescue plan of LTCM was publicly disclosed on September 23rd). The results in Table 3 suggest that the main aggregate global financial market factors behind the increase in the spreads of all the countries considered in the sample, relative to their conditional expectations or benchmarks, are funding liquidity (proxied by U.S. monetary policy expectations), market volatility and default risk, which together account for almost 40 percent of the forecast error for some of the emerging markets and 23 percent for Canada. Among the three global financial market factors, volatility risk is the most important (accounting for up to 18 percent of the forecast error). The contribution of contagion from emerging markets is negligible for all countries, while the contribution of idiosyncratic factors (the residual in this specification) account for 58-85 percent of the forecast error.

Given that Brazil was the next country to experience a crisis in early January 1999, a few months after the Russian/LTCM crisis, it is interesting to examine the results during the August-October 1998 period but for the particular case of Brazil (Table 3). This is of special interest because several empirical studies have found evidence of contagion from the Russian/LTCM crises to Brazil (Baig and Godfajn (2001), and Dungey, Fry, González-Hermosillo and Martin (2006, 2007a)).[27] The results here suggest that global financial market conditions, proxying for investors' risk appetite, represent about 42 percent of the difference between the conditional expectation of Brazil's sovereign bond spread and its actual mean value. This difference represents 307 basis points, accounting for almost one-quarter of Brazil's 1,295 basis point actual mean spread against the equivalent U.S. Treasury bond during that period. The idiosyncratic component (the residual in this specification) accounted for another 431 basis points (58.5 percent of the forecast error). These results are consistent with the view that the contagion that was formerly found in previous studies may have been largely accounted for by the role of global investors' risk appetite. At the same time, it appears Brazil's fundamentals may have been reassessed, as captured by the significant size of the idiosyncratic component. Finally, contagion from emerging markets that is not already captured by global financial market conditions was negligible. However, it is somewhat puzzling that the

[27] In particular, Dungey, Fry, González-Hermosillo and Martin (2006) provide evidence that the Brazilian bond market was impacted by the Russian crisis, while the results in Dungey, Fry, González-Hermosillo and Martin (2007a) suggest that Brazil's equity markets were affected by the near-collapse of LTCM.

Brazilian results are not that different from other emerging markets, most of which did not have a full-blown crisis in the months that followed the Russian/LTCM crisis.

6.1.2 Brazil's Crisis (1999)

We now turn to examine the next crisis period marked by the devaluation of Brazil's Real on January 12, 1999 (Table 4). During this period, market volatility and funding liquidity are the main factors contributing to the forecast errors in emerging markets. Russia is unusual as the idiosyncratic contribution to the forecast error (the residual) is slightly negative, suggesting that the global market financial factors more than fully accounted for the forecast error. The effect from volatility risk, funding liquidity and default risk combined may have accounted for more than the 350 basis point forecast error in Russia. One interpretation is that the Russian and the Brazilian crises were so close in time that there were actually feedback effects from the latter to the former through a decline in investors' appetite for risk, reflected in the global financial market factors.

Another interesting observation during this period is that mature markets were essentially unaffected by global financial factors, as their benchmark spreads are close to the actual spreads. These results support the view that the Brazilian crisis did not importantly affect other markets, as the forecast errors are generally much smaller during this period, particularly in the case of mature economies. Once again, contagion from emerging markets (not already accounted for by the common global financial market factors) is negligible.

6.1.3 NASDAQ Bubble Burst (2000)

During the NASDAQ bubble burst in 2000, default and funding liquidity risks are the main factors explaining most of the forecast errors considered (Table 5). It is interesting that volatility risk became very small during this period, in contrast to the previous periods of stress considered. The forecast errors are generally small for all the countries considered, except for Ecuador which was still suffering from its own financial crisis.[28] Also noteworthy is the result pointing to a negative forecast error for Russia during this period, less than two years after facing its own crisis. The model suggests that the improvement in Russia's spreads during this period was not so much

[28] Ecuador's economy experienced a contraction in real GDP of 7 percent, an inflation rate of 60 percent and a 67 percent depreciation of the Sucre in 1999. Ecuador adopted the U.S. dollar as the legal tender in January 2000. Amid political and economic uncertainty, Ecuador's Finance Minister resigned in May 24, 2000.

due to improved fundamentals (recall that in this model, the residual is treated as "fundamentals") but largely resulting from an improved risk appetite for Russian assets (measured by the negative contributions to the forecast error coming from global market risk factors, despite some increased risk coming from interest volatility).

6.1.4 Turkey's Crisis (2001)

During Turkey's crisis in 2001 (Table 6), all of the forecast errors become smaller as the benchmark conditional expectations are close to the actual spreads for most countries. Volatility is again an important risk factor and, indeed, all global market risk factors take increased importance during this period. In contrast, idiosyncratic factors often have the opposite effect, acting to reduce the spreads. The only exceptions are Bulgaria, Peru and the United States.

6.1.5 September 11th (2001)

In the period following 9/11 in 2001, the U.S. Federal Reserve and other central banks injected substantial amounts of liquidity into the financial system in anticipation of potential disruptions in global markets following the closing on the New York stock exchange after the attacks. This is reflected in a negative contribution to the premia coming from funding liquidity (Table 7). That, plus a reduction in the default risk helped to largely offset the increases in spreads caused by higher premia coming from market liquidity, market volatility and interest-rate volatility risks. All forecast errors are relatively modest. It is noteworthy that market volatility risk, in particular, surged during this period and became the single most important source of risk premia for all emerging markets. However, in the case of mature economies, the largest contributor to the spreads is due to market liquidity risk.

6.1.6 WorldCom Scandal and Brazil's Elections (2002)

The next period of turbulence examined is the WorldCom accounting scandal, which roughly coincided with a period of uncertainty in the run-up to Brazil's elections, during June-October 2002 (Table 8). During this period, Brazil's forecast error is quite large, at around 1,200 basis points (the actual spread is 1,904 basis points and the conditional expectation is 709 basis points). The forecast error is explained mostly by a large contribution of idiosyncratic factors, which is consistent with the fact that investors were nervous about the likely election of a seemingly 'populist' Lula government.[29] The forecast errors during this period were also relatively large for other Latin American countries (especially Ecuador and Peru) which may have been influenced by the 'Lula-effect.' During this period, funding liquidity is the main contributor to the forecast errors, followed by volatility and market liquidity. This may reflect the expectation among market participants that the U.S. Federal Reserve was about to start a new tightening cycle, after an extended period of declines in policy interest rates since early-2000, and uncertainty as to exactly when the new cycle would begin. The results suggest that there were no other contagion effects coming from emerging markets that were not already captured through the international investors' risk appetite conduit.

6.1.7 U.S. Federal Reserve Begins Tightening Cycle (2004)

Indeed, the U.S. Federal Reserve began to tighten monetary conditions on June 30th, 2004 when it increased the federal funds policy rate by 25 basis points. However, the run-up to the tightening of monetary policy in the United States appeared to be a period of uncertainty amid jitters in global financial markets. This episode, marking expectations and uncertainty about the forthcoming tightening in U.S. monetary policy, is assumed to begin following the release of strong payroll data (for March) on April 2nd, 2004. Against increasing speculation and uncertainty as to when monetary conditions might be tightened, and in light of a scheduled FOMC meeting, emerging markets experienced a generalized sell-off on May 3rd, 2004. This spike in spreads was short-lived, however, as spreads resumed their overall downward trend (which had started in the early part of the 2000s) after June 30th, 2004 when the U.S. Federal Reserve actually increased its federal funds rate by 25 basis points for the first time in more than four years. This episode of uncertainty about the exact timing of the monetary policy tightening is, therefore, assumed to end on June 30th, 2004 when the U.S. Federal Reserve announced the change in its policy stance.

Table 9 decomposes the period during the run-up to the U.S. Federal Reserve switching to a tightening stance. This period is characterized by relatively small forecast errors as the benchmark conditional expectations are close to the actual spreads (less than 200 basis points for all countries). Most of the forecast errors are attributed to funding liquidity risk, though with a much smaller contribution than in the previous episode of stress in 2002 (Table 8). Default risk also plays a role,

[29] Lula was in fact elected on October 29th, 2002, but his presidency turned out to be quite pragmatic and less populist than had been anticipated by financial markets.

but market liquidity and volatility risks are generally very small or even negative (acting to offset the increase in spreads). Idiosyncratic factors are fairly large in most cases (the exceptions being Venezuela and Bulgaria). Interest-rate uncertainty does not seem to be a very important factor. This is somewhat surprising, but it may be explained by the funding liquidity risk already capturing some of this uncertainty. Other contagion channels from emerging markets are, again, minuscule.

6.1.8 Ford and General Motors Downgrades (2004)

The Ford and General Motors downgrades in the spring of 2004 coincided with a general moderate (and temporary) increase in bond spreads (Figures 1-3). During this period, the forecast errors are modest (less than 110 basis points for emerging economies and below 12 basis points for mature economies) for all the countries considered (Tables 10 for the 1998-2007 period and Table 15 for the 2004-2007 period). However, the funding liquidity and the default risk channels seem to be quite important. Interest rate risk is relatively small, but larger than in any other previous period. Other channels of contagion from emerging markets are, once again, tiny. Idiosyncratic factors vary.[30]

6.1.9 Turkey's Crisis (2006)

During Turkey's crisis in May-July of 2006, spreads in other emerging markets widened significantly, albeit resuming their downward trend by the second half of 2006 (Figures 1-3).[31] The forecast errors are relatively small (less than 62 percent for emerging markets, and less than 7 basis points for mature markets) for all countries other than Turkey. This episode is characterized by funding liquidity risks and, by a lesser amount, default risk and market volatility (Tables 11 and 16). Market liquidity and interest-rate risks are small or offsetting. The idiosyncratic components

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[30] Idiosyncratic factors move from positive during the 1998-2007 sample to negative in the shorter 2004-2007 sample based on the actual cost of default insurance. Since the idiosyncratic factors in the specification are essentially the residuals, negative contributions suggest that the contributions of other risks may be overestimated. However, the forecast errors are fairly small in most of the specifications where idiosyncratic factors contribute negatively to the difference between the actual spread and the benchmark, which reduces the importance of negative idiosyncratic factors.

[31] The crisis in Turkey surfaced a few months after the March 2006 crisis in Iceland. However, the Icelandic episode is not analyzed explicitly in this paper because it appears that it did not have significant spillovers to other markets. It is interesting that the two crises were very close in time, suggesting that there might have been some spillovers from Iceland into Turkey—though the trigger for the problems in Turkey appear to have been largely driven by political factors.

are important for all countries, except the United States. Other venues of contagion from emerging markets are minute or offsetting.

6.1.10 China's Shanghai Stock Exchange Correction (2007)

Although short-lived, China's Shanghai stock market went through a sizeable correction on February 27, 2007, dubbed in the international press as "black Tuesday". Emerging markets also experienced a (short-lived) melt-down. During this episode, the forecast errors are again fairly small: for emerging markets, less than 70 basis points in the 1998-2007 sample (Table 13) and less than 30 basis points in the 2004-2007 sample (Table 17). The forecast errors for mature economies are tiny (less than 3 basis points). In terms of the forecast error decomposition, the risks that explain the increase in risk spreads relatively to the benchmarks are: funding liquidity (which is especially large in the shorter sample), volatility, default risk and interest rate risk. Market liquidity risks are fairly small.[32]

6.1.11 U.S. Subprime Mortgage Crisis (2007)

The final episode of stress in global financial markets examined in this chapter is the U.S. subprime mortgage crisis and the subsequent liquidity squeeze in mid-2007. During this period, the forecast errors are relatively small (less than 70 basis points for emerging markets and less than 13 basis points for mature markets), but larger than in any previous episode of global financial stress since the Ford/GM downgrades in 2004 (Tables 13 and 18). All risk factors except market liquidity seem to have a significant contribution to the forecast errors. Contagion effects from emerging markets seem to have little effect on spreads during this period, which is not too surprising since this crisis originated in mature economies. Idiosyncratic factors tend to be important in explaining the difference between benchmark and actual spreads. However, in a number of cases, idiosyncratic factors explain little, or even contribute negatively by offsetting the increase in spreads caused by aggregate global market factors.

The result is that market liquidity was generally an unimportant contributor to explain the difference between the benchmark and the actual spreads is somewhat surprising since market illiquidity in certain segments of financial markets in mature economies was at the heart of the mid-

[32] Canada is an exception, but its forecast error is zero or slightly negative.

2007 financial crisis.[33] However, this puzzle may be explained by the possibility that market illiquidity was only characteristic of certain asset market classes, some of which are not considered in this chapter. The data in this study focus on bond spreads for sovereigns in the case of emerging markets and BBB corporates for mature economies (see Table 1 for details). The pervasive illiquidity observed in the early part of the subprime crisis was largely in short-term funding instruments (e.g., asset-backed commercial paper and interbank lending rates) as banks hoarded liquid assets to cover for potential losses incurred by their special investment vehicles (SVI) and other conduits. These bank-related SVIs (which are off-balance sheet vehicles) held mortgages which had been distributed after having been originated by banks. The SVIs and conduits funded themselves by issuing asset-backed commercial paper (ABCP), which investors decided not to roll-over when the subprime mortgage crisis was exposed.

Thus, it may have been the case that market illiquidity was not a generalized phenomena in all financial markets everywhere during this period. The second potential explanation is that the mean decomposition provides a limited snapshot to analyze factors that change over time. As discussed in the next Section 6.2 below, when looking at this from this perspective, market liquidity appeared to be more important during this last crisis episode. The third potential explanation for this puzzle is that the sample period in this study is simply not long enough to explain a crisis episode that was still unraveling, with several waves developing, at the time of writing.[34]

6.2 Empirical Results: Spread Decomposition Over Time

Figures 5-31 plot the spread decompositions over time, capturing the various crisis episodes discussed above by individual country. Figures 5-14 present the full period 1998-2007, while Figures 15-31 are based on the subsample 2004-2007 which rely on a larger number of countries and include credit default swaps.

For example, Figure 5 summarizes the decomposition of Brazil's sovereign bond spreads over time. The benchmark conditional expectation of Brazil's spreads (in basis points) are taken before the beginning of each of the periods of stress in financial markets discussed above, with information available prior to that event. The difference between the benchmark and the actual spreads are then explained proportionally by the various global financial market factors, as well as

[33] See International Monetary Fund (2007).

[34] However, extending the period after the policy interventions have been introduced (i.e. after the ECB injected substantial amount of funds on August 10th, 2007 and other central banks followed suit), also poses some challenges as this would have changed monetary liquidity conditions in itself.

by other potential contagion from emerging markets and the idiosyncratic element.[35] The charts suggest, for example, that contagion from emerging markets was essentially not existent, contributing to less than 2 percent of the forecast error at any time, even during the Russian/LTCM crisis in 1998. This result is at odds with other studies that have found evidence of contagion to Brazil from the Russian/LTCM crisis (Dungey, Fry, González-Hermosillo and Martin (2006, 2007); and Baig and Goldfajn (2001)). However, those studies focused on the unusual comovements among emerging markets during crises periods to explain contagion, rather than considering the potential indirect effects from international investors' changes in their risk appetite that may have resulted from the Russian/LTCM crisis. These results suggest that the spillovers observed to Brazil from the Russia/LTCM crisis may have indeed occurred through global financial market risk factors.

In contrast to the 1999 crisis in Brazil, the 2002 period of financial stress occurred despite the fact that global default risk and volatility interest rate risk were largely offsetting factors during this period, possibly reflecting the significant easing of monetary liquidity conditions during 2001-2002. As discussed earlier, this period was characterized by political uncertainty in Brazil (which is reflected in the idiosyncratic component). However, Brazil's problems also coincided with the WorldCom accounting scandal which led to a certain amount of stress in global financial markets−reflected, for example, in elevated market liquidity and volatility risks (see Figure 4) which together may have accounted for about 15 percent of the difference between Brazil's actual spreads and its conditional expectation (Figure 5). However, it appears that the increase in spreads in Brazil in 2002 was largely due to idiosyncratic factors.

The results from all countries throughout the key periods of financial stress during the past decade point to some stylized facts, discussed below. First, global financial market conditions appear to be significant in all the crisis episodes examined. These global market conditions are far from constant. The testing of exactly how these global risks interact with each other was not examined directly in this chapter, but it is clearly a fundamental question in need of further research. However, this chapter went beyond the *status quo* which assumes that investors' risk appetite can be neatly encapsulated in a given index by adding up all the potential risk factors.

[35] All the figures show a discontinuity during September 11-17, 2001, as several financial markets were temporarily closed after the terrorist attacks.

Second, once global financial market factors are explicitly considered, contagion from emerging markets is very small or essentially not existent.

Third, although emerging markets have largely been more volatile than mature economies, global financial market risk factors are important for all countries.

Fourth, some of the episodes of stress which were seemingly benign in that they were resolved relatively quickly may have actually altered investors' risk appetite importantly. For example, by examining the spread decomposition figures for the 2004-2007 period (Figures 15-31), it appears that the Turkey crisis in the spring of 2006 (which was preceded by a crisis in Iceland) increased default, as well market and interest rate volatility risks fundamentally by marking an upswing inflection point for all countries, including mature markets.

Similarly, the Shanghai stock market meltdown in February 2007 was short-lived and apparently innocuous when compared to the subsequent take off of that market in the subsequent months. However, in terms of global market factors, this event was associated with a significant increase in funding liquidity risks for all the countries considered. The connection is not straight forward, as funding liquidity is proxied here by monetary conditions in the United States and measured by the 3-month ahead Federal Funds futures rate. However, funding liquidity has been particularly difficult to gauge since 2004 when the Federal Reserve began its tightening cycle that ended in September 18th, 2007 in response to the subprime mortgage and liquidity crisis in the United States. During much of this period of tightening, long-term interest rates were largely unchanged even as short-term interest rates increased considerably in response to a number of hikes in the Federal Funds rate. This peculiar extended period of flat or inverted yield curves in the United States has been associated in part with the "excess savings" of emerging-market economies which found their way into U.S. financial markets (Warsh (2007)). China happens to be the chief investor in U.S. assets among emerging markets. It is possible, then, that the China meltdown in February 2007–which was too small to derail the subsequent bullish tendency of the Chinese markets–was sufficient to cause international investors to revalue their expectations about the potential for tighter funding liquidity conditions, perhaps as a result of China being likely to invest less heavily in U.S. dollar assets in response to less bullish Chinese market conditions or because of expectations of depreciation of the U.S. dollar as a means to narrow global trade imbalances. The Chinese episode was also associated with an important increase in market liquidity risks for most countries examined, with the exception of the United States, Canada, the Eurozone, Ukraine and Peru.

Fifth, the recent U.S. mortgage subprime crisis appeared to cause market liquidity strains in financial markets, particularly in mature economies. This effect is depicted most clearly in the

2004-2007 sub-period which is relies on new financial instruments as proxies (Figures 15-31). In particular, market liquidity risks increased in all the countries examined.[36] However, globally, default risk increased more sharply and accounted for a larger share of the difference between the actual spreads and their benchmark than market illiquidity. Thus, whereas a higher market liquidity risk accounted for up to about 8 percent of the innovations, increased default risk accounted for 20-30 percent of the innovations in emerging markets. A similar relationship is evident in most mature markets, except that default risk, although increasing sharply, accounted for much smaller amount than in the case of emerging markets.[37] In the United States, the contributions were roughly the same, as default risk and liquidity risk accounted for around 4 percent of the innovations each.

Increased funding liquidity risk as a result of the U.S. subprime mortgage problems is also evident in all countries.[38] Funding liquidity risks also increased for mature economies, contributing by about 4 percent of the innovations in the United States, less than 1 percent in Canada, and about 8 percent in the Eurozone.

Interestingly, Japan is the exception as global market risk factors did not appear to affect this country during the U.S. subprime mortgage crisis, at least not directly through the first round of effects.[39] This observation is consistent with the argument proposed earlier that Japan moved in an opposite direction during this recent period of stress in other markets because of the Yen being a carry-trade currency. Crises abroad would lead investors to sell their overseas investments and repay their low interest rate yen loans, resulting in capital inflows and increased funding liquidity conditions in Japan.

In sum, although the U.S. subprime mortgage crisis was experienced globally as a market liquidity shock , the contribution of default and funding liquidity risks were generally more important. While not exactly the same for all countries, default risk may have been slightly more important than funding liquidity risk (at least during the period prior to the injection of liquidity by several central banks). Japan is an exception in the sample examined. It may have been that what started as a market liquidity shock (as banks hoarded liquidity in response to the meltdown in the

[36] This time series snapshot appears to give a clearer picture during this period of the trends in market liquidity risks, than the mean spread decomposition analysis (Tables 13 and 18) discussed in Section VI.A above.

[37] For example, default risk in Canada accounted for around 6 percent of the innovations (compared to market liquidity amounting to less than 1 percent). In the case of the Eurozone, default risk accounted for close to 15 percent (versus market liquidity accounting for less than 1 percent).

[38] Contributing by about 15-30 percent of the innovations for most emerging markets, with the exception of Ecuador for which the contribution is smaller (around 6 percent).

[39] Of course, any potential weakness in the U.S. economy resulting from the subprime mortgage crisis would likely affect Japan's exports eventually.

ABCP market as subprime mortgages defaulted), quickly became a default and a funding liquidity crisis. This chapter is unspecific as to the exact mechanisms through which this may have occurred. However, these themes have been recently extended in Frank, González-Hermosillo and Hesse (2008) where these mechanisms are examined in more detail. In particular, interbank market rates are modeled as proxies for funding liquidity pressures during the U.S. subprime mortgage crisis, in addition to market volatility, market liquidity and default risks. They find that market and funding liquidity pressures increased sharply during the recent crisis, while bank solvency issues also became important.

One other interesting question is the issue of timing with regards to this latest period of financial stress. Why mid-2007, given that the U.S. housing prices and activity had been declining since mid-2005 when the housing market reached a peak, and it was common knowledge that this market was likely to suffer a correction? What triggered the U.S. mortgage crisis that began as a default shock, before it became a market liquidity shock when the ABCP market froze? Some of the available explanations for this are based on structural characteristics related to when different vintages of subprime mortgages were reset (see International Monetary Fund (2007)). However, based on the results of this paper, it is interesting that the correction in the Chinese stock market on February 27th, 2007 translated into a funding liquidity shock for all the countries considered (with the exception of Japan) of roughly the same magnitude, or bigger, than the U.S. shock. It appears that the Chinese correction, which was short-lived otherwise, contributed importantly to the shift in international investors' risk appetite. Future research may be able to determine whether this event was a contributing trigger.

For emerging markets, in particular, the U.S. subprime mortgage crisis largely represented a default risk and a funding liquidity shock, rather than a market liquidity shock, based on the relative contributions of the different risk factors. This is consistent with the fact that financial market development in emerging countries lags that in mature economies and therefore market liquidity shocks may be transmitted across borders, through this channel, less easily than across mature financial markets. Also, contrary to the common view that emerging markets were largely unaffected by the U.S. subprime mortgage crisis, the results in this chapter suggest that this was a global shock affecting all the countries examined. It is true, however, that the increase in spreads observed in emerging markets since mid-2007 still place them at historically low levels. But it is also evident from the results in this chapter that spreads have largely widened as a result of the U.S. subprime mortgage shock as investors have reduced their appetite for risky assets, with the main channels being an increase in the perceived risk of default and of tighter funding liquidity conditions.

Finally, the fact that idiosyncratic factors account for a relatively small proportion of the difference between the actual spreads and their benchmark for all the countries examined (at less than 20 percent of the innovations) further suggests that the global financial markets factors examined account for most of the innovations during the U.S. subprime mortgage crisis period. The only exception is Ukraine which was embroiled in uncertainty about its own presidential elections during mid-2007, showing a contribution from idiosyncratic factors amounting to close to 40 percent of the innovations.[40]

7 Conclusions

This chapter developed an empirical model for bond spreads which takes into account several variables associated with investors' risk appetite. The bond markets considered consist of a variety of sovereign bond spreads for emerging markets and corporate bond spreads for mature markets. The chapter examined the various key periods of financial stress during the past decade. A shorter subperiod 2004-2007 was also examined based on new financial instruments as the relevant proxies.

In contrast with much of the current approach to measure investors' risk appetite, which largely relies on ready-made composite indexes of different global risk proxies, this paper examines the relevant global components in a systematic fashion during the past decade. In particular, international investors' risk appetite is framed as being determined by funding liquidity risk, which is proxied monetary liquidity conditions and is measured by the 3-month ahead Federal Funds futures rate. Investors' risk appetite is also a function of default risk, proxied by the 10-year USD swap spread and the Itraxx 10-year Europe crossover credit default swap index for the shorter subperiod 2004-2007. As well, investors' risk appetite is assumed to be determined by market liquidity risk proxied by the spread between the 20-year and the 10-year U.S. Treasury bond (where the latter is a more liquid asset and both are equivalent in terms of default risk), market volatility risk (proxied by the VIX index) and interest volatility risk (proxied by the swaption-implied interest rate volatility). The model also allows for direct channels of contagion from emerging markets and idiosyncratic factors not captured by the model's specification.

The model is used to identify and analyze the contribution of several risk factors to the widening of spreads during periods of financial stress. The unexpected changes in the spreads

[40] In Ukraine, a presidential election took place on September 30th, 2008. In the run-up to the elections, there was significant uncertainty from the apparent dead heat contest between pro-Soviet and pro-Western European candidates.

during periods of financial stress are decomposed into changes caused by funding liquidity conditions, aggregate risk factors, contagion effects, and idiosyncratic factors. The aggregate risk factors are default risk, market liquidity, market volatility, and interest-rate volatility risk.

By using daily data, the model is able to capture short-lived episodes of crisis which would have appeared innocuous if based on their longevity alone. Some of them, like the financial crisis in Turkey during the Spring of 2006, appears to have fundamentally changed market volatility risk. Similarly, the meltdown of the Shanghai stock exchange in late February 2007, also seemingly innocuous if based on its duration alone, led to a significant increase in the perceived global funding liquidity risk—similar in size to the effect derived from the U.S. subprime mortgage debacle.

The role of the different global risk components is examined through the various periods of financial stress during the past decade by country and over time. The main results are summarized below.

First, global financial market conditions appear to be significant in all the crisis episodes examined. They themselves are far from constant. The testing of exactly how these global risks interact with each other was not examined directly in this chapter, but it is clearly a fundamental question in need of further research. However, this paper went beyond the *status quo* which assumes that investors' risk appetite can be neatly encapsulated in a given index by adding up all the potential risk factors.

Second, once global financial market factors are explicitly considered, contagion from emerging markets is very small or essentially not existent. This result is at odds with some of the results in the empirical literature of contagion. The literature on contagion examines the links that exist over and above the market fundamental mechanisms that link countries and asset markets during noncrisis periods, which only appear during a crisis. However, the empirical literature on contagion does not identify exactly how these additional channels are formed during periods of stress. One potential channel of contagion is that shocks in any given market may impact international investors' risk appetite through their rebalancing of portfolios or simply by a revised set of expectations. Often investors would first run from the most liquid markets where exiting is less costly. Almost a decade ago, Allan Greenspan noted that a rise in the default risk of a given country can impact upon the liquidity of other markets as a result of international investors offloading liquid assets, despite their relatively low default risk (Greenspan, 1999). The results in this chapter suggest that contagion essentially dissappears when identifying the actual channels of spillovers.[41]

Third, although emerging markets have been historically more volatile than mature economies, global financial market risk factors are important for all countries. An area of future research is to examine how global financial market risk are interconnected.

Fourth, although the U.S. subprime mortgage crisis was experienced globally as a market liquidity shock , the contribution of default and funding liquidity risks were generally more important. While not exactly the same for all countries, default risk may have been slightly more important than funding liquidity risk (at least during the period prior to the injection of liquidity by several central banks). It may have been that what started as a market liquidity shock (as banks hoarded liquidity in response to the meltdown in the ABCP market as subprime mortgages defaulted), quickly became a default and a funding liquidity crisis. This chapter is unspecific as to the exact mechanisms through which this may have occurred, and it should be a subject of future research. Interestingly, Japan behaved quite differently, likely as a result of the carry-trade as crises elsewhere are associated with larger capital inflows into Japan as low interest rate yen loans are repaid.

Finally, in general, the various crises are characterized differently by changes in the global market risk factors, and sometimes some risk factors work in different directions and partially offset each other. This type of analysis should be helpful in elaborating a framework to assess global financial stability, another area for future research, as investors' risk appetite may play an important role in increasingly integrated global financial markets.

[41] A similar result is found for a different class of variables and periods in Dungey et. al. (2003).

A Dates of Financial Distress

The Russian Default/LTCM crisis episode (1998) starts with Russia's announcement on August 17th of its intention to default on its international debt obligations and to devalue the Ruble. However, several events prior to this announcement had already created some distress in financial markets. Therefore, the benchmark spread is computed based on information prior to June 1st, 1998. On September 23rd, the U.S. Federal Reserve announced a rescue plan for the hedge fund Long-Term Capital Management (LTCM). The crisis period is assumed to end just before the second cut in the U.S. federal funds rate which occurred in a surprised fashion between FOMC meetings on October 15th, 1998. Given the proximity of the Russian crisis and the LTCM bail-out, these events are examined jointly during the period June 1st through October 14th,1998.

The Brazilian crisis (1999) starts on January 13th, with the effective devaluation of the Real. The benchmark spreads are computed with information up to one week before the devaluation and the episode is assumed to end on January 29th, 1999 when the Brazilian stock market rallied after the central bank further increased interest rates to support the currency. On that date it was also announced that an IMF team was in Brasilia to discuss an adjustment program with the authorities.

The NASDAQ Bubble Burst (2000) episode is assumed to begin on April 3rd, when Microsoft is ruled to have violated antitrust laws causing the NASDAQ Composite index to fall by 8 percent. The benchmark spreads are constructed with information up to March 10th, when NASDAQ reached an all-time high. The end of this episode of stress is assumed to be May 10th, 2000.

The Turkish crisis (2001) is assumed to start on February 19th, when the Turkish President and the Prime Minister had a confrontation that prompted a sell-off of Turkish assets, forcing the devaluation of the Lira three days later. The benchmark spreads are constructed with information available two weeks before the crisis began. The crisis is assumed to end on March 5th, 2001, coinciding with the appointment of a new Minister in charge of Treasury, State Planning Organization and Privatization.

The 9/11 (2001) episode is assumed to begin on September 17th, when the U.S. stock markets reopened a few days after the terrorist attacks in New York and the Pentagon. The end of this episode of stress is assumed to be November 6th, 2001, coinciding with one of the FOMC's interest rate cuts which appeared to calm global financial markets.[42]

The WorldCom Accounting Scandal/ Brazilian Elections (2002) episode of financial stress is assumed to start on June 19th, at the time when there was a generalized sell-off of risky assets. On June 25th, 2002 the accounting malpractices of WorldCom become public, leading to its bankruptcy on July 21st and to a period of in uncertainty about corporate integrity practices. The benchmark spreads are computed based on information up to April 23rd, coinciding with increasing concerns by investors regarding the anticipated Brazilian elections. This episode of financial stress is assumed to end on October 29th, 2002, the day after Lula's election when the head of the ruling party gave public assurances of fiscal responsibility and Brazil announced the successful rollover of its remaining foreign exchange swap contracts.

The run-up to the tightening of monetary policy in the United States (2004) was also a period of uncertainty and apparent stress in global financial markets. The episode marking expectations of an imminent monetary policy tightening in the United States is assumed to begin following the release of a strong payroll data (for March) on April 2nd, 2004. Against increasing speculation and uncertainty as to when monetary conditions might be tightened, and in light of a FOMC meeting, emerging markets experienced a generalized sell-off on May 3rd, 2004. The benchmark spreads are, therefore, computed based on information up to April 2nd, 2004. The end of this episode of uncertainty about the exact timing of the monetary policy tightening is assumed to be June 30th, 2004 at the time when the U.S. Federal Reserve actually increased its federal funds rate (by 25 basis points) for the first time in more than four years.

The Ford/General Motors downgrade episode (2005) is assumed to start on March 16th, at the time when Moody's announced its intention to review the credit ratings of General Motors (GM) for a possible downgrade. In the event, GM was assigned 'junk' status on May 5th, 2005. During this period, Ford's rating was also downgraded. The benchmark spreads are computed based on information up to February 14th, when it is disclosed that GM's outlook had become "negative". The end of this period of financial market stress is assumed to be May 19th, 2005 when bullish conditions appeared to have been reestablished in equity markets.

The Turkish crisis (2006) spans from May 11th to July 24th as a result of political instability in that country. This crisis came on the heels of financial difficulties in Iceland a couple of months

[42] Although foreign markets and U.S. bond markets were open before September 17th, there is incomplete data for some of the variables used in this paper until that date.

earlier.[43] During that period, there were several reports pointing to increased nervousness about the outlook for emerging markets and spreads generally increased.

The Chinese stock market correction (2007) episode started on February 27th ("black Tuesday") as a hefty sell-off in the Shanghai stock exchange spread around the world. This period of stress period lasted until March 19th when stock markets in emerging market rebounded.

The final episode of stress in global financial markets examined in this paper is the U.S. subprime mortgage crisis and the subsequent liquidity squeeze in mid-2007. The start of the U.S. subprime mortgages and liquidity crisis is assumed to start be June 15th, 2007, coinciding with the announcement that two Bear Stearns' hedge funds were having financial difficulties with their assets backed by mortgages in the United States. Although the troubles in the subprime mortgage market started earlier as defaults began to mount in late 2006, it took some time for the difficulties in this market to be clearly related to other financial markets. It was not until July 9th, 2007, when credit rating agencies began downgrading higher-rated assets, that the severity of the crisis was fully appreciated and global financial markets collapsed. Although at the time of writing this paper, the crisis is not clearly over, for purposes of this research the end of the crisis is assumed to be August 9th, 2007 which is also the end of the sample and it is just before the European Central Bank (ECB) began a round of liquidity injections, which was followed by several central banks across the world. Thus, on August 10th, 2007 the ECB injected €95 billion in an effort to avert the meltdown in global financial markets. Other central banks followed suit in countries such as Canada, the United Kingdom, Russia and Argentina. The U.S. Federal Reserve cut its federal funds policy rate by 50 basis points on August 17th, 2007 and by a further 25 basis points on October 30th, 2007.

[43] By the end-March 2006, Iceland's stock market had fallen 19.1 percent since reaching a peak on February 15, 2006; the Icelandic Krona had fallen 12 percent against the USD since end-2005; and the central bank raised interest rates by 75 basis points to 11.5 percent (more than doubled in the previous two years) in an attempt to head off a crisis of confidence (*Financial Times* 3/31/06).

B Tables and Figures

Figure 1: Bond Spreads (bps, log scale)

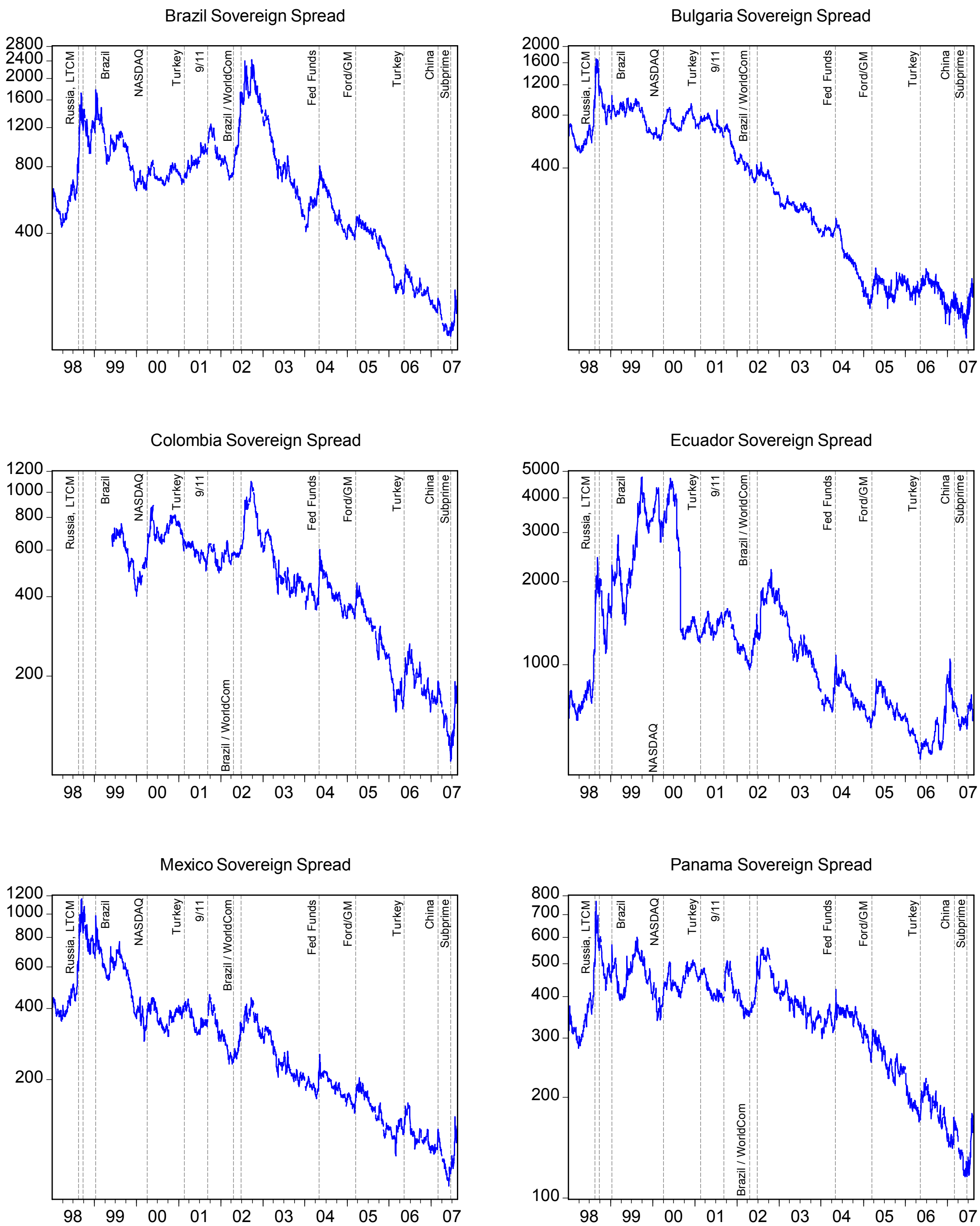


Figure 2: Bond Spreads (bps, log scale)

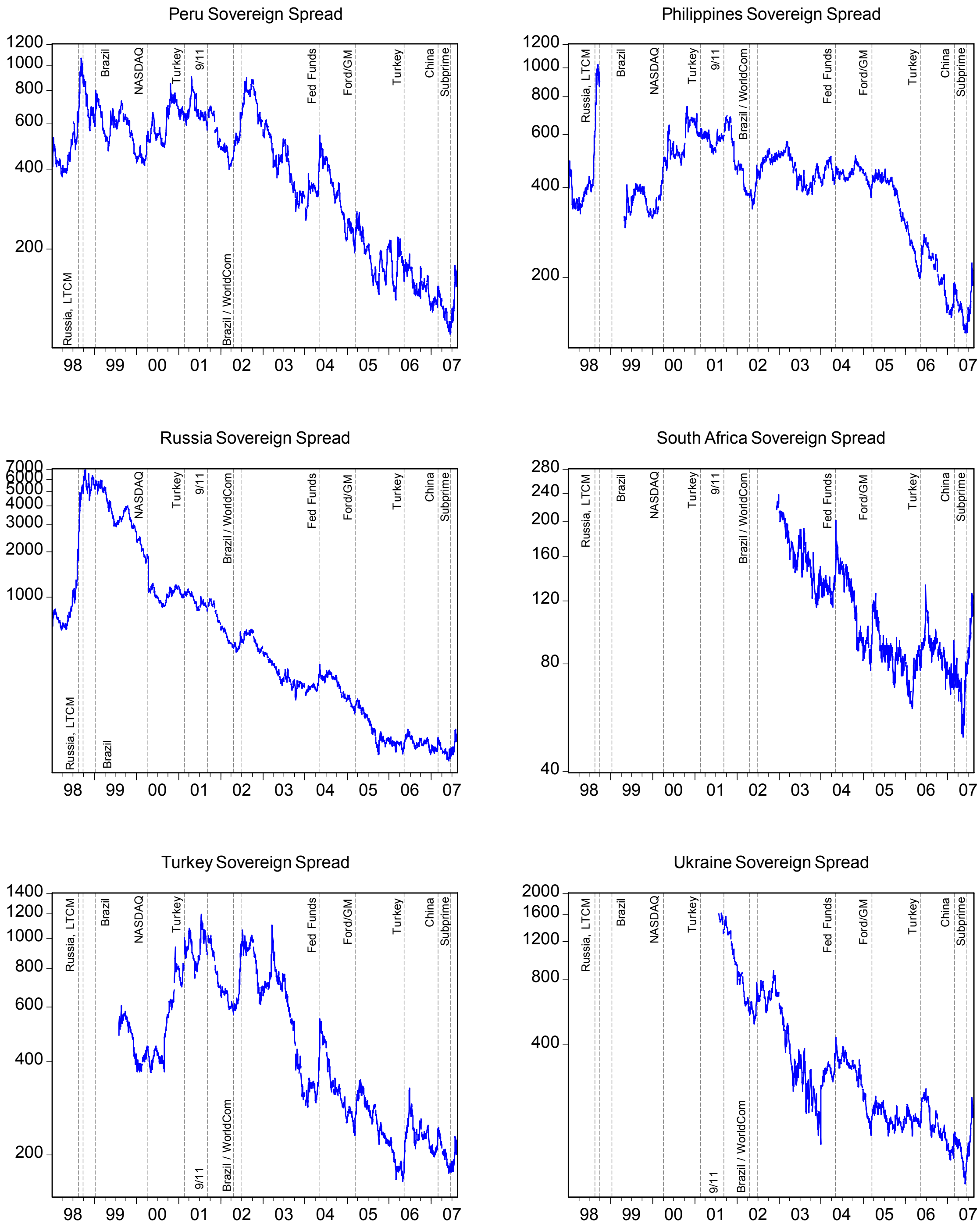


Figure 3: Bond Spreads (bps, log scale)

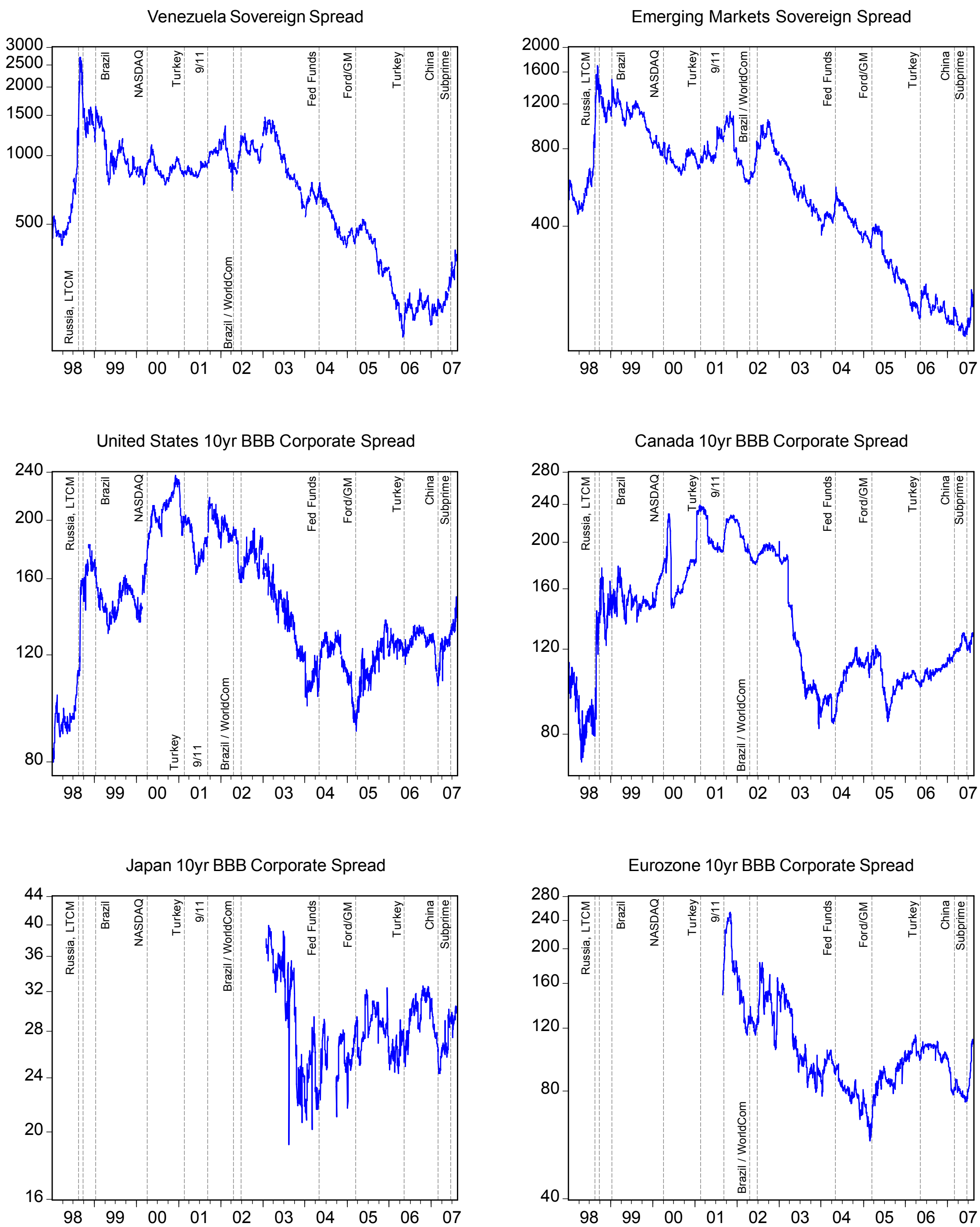


Figure 4: Monetary Policy and Risk Factors

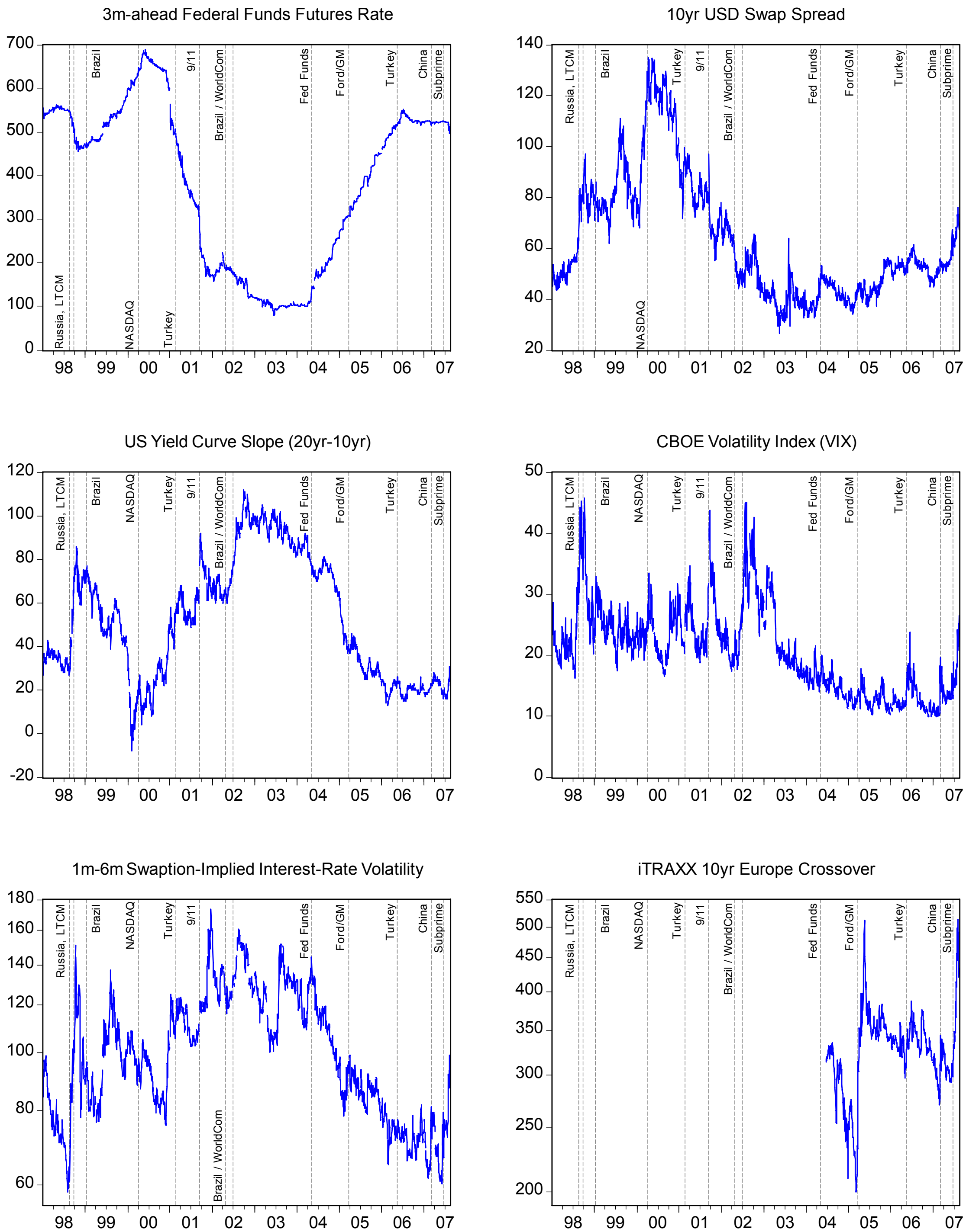


Table 1: Data Sources

Data Description	Source	Mnemonic
10yr Canada Benchmark DS Govt. Index (Redemption Yield)	Datastream	BMCN10Y(RY)
10yr Germany Benchmark DS Govt. Index (Redemption Yield)	Datastream	BMBD10Y(RY)
10yr Japan Benchmark DS Govt. Index (Redemption Yield)	Datastream	BMJP10Y(RY)
10yr USD Swap Rate (Semiannual fixed rate vs 3m LIBOR)	Bloomberg	USSW10 Index
30-day Fed Funds Futures - 3m ahead	Bloomberg	FF4 Comdty
BFV 10yr CAD Canada Corporate BBB Bond Yield	Bloomberg	C28810Y Index
BFV 10yr EUR Eurozone Industrial BBB Bond Yield	Bloomberg	C46810Y Index
BFV 10yr JPY Japan Industrial BBB Bond Yield	Bloomberg	C45410Y Index
BFV 10yr USD US Industrial BBB Bond Yield	Bloomberg	C00910Y Index
CBOE's SPX Volatility Index	Bloomberg	VIX Index
iTRAXX Europe Crossover 10yr, series 1	Bloomberg	ITRXEX01 Index
iTRAXX Europe Crossover 10yr, series 2	Bloomberg	ITRXEX02 Index
iTRAXX Europe Crossover 10yr, series 3	Bloomberg	ITRXEX03 Index
iTRAXX Europe Crossover 10yr, series 4	Bloomberg	ITRXEX04 Index
iTRAXX Europe Crossover 10yr, series 5	Bloomberg	ITRXEX05 Index
iTRAXX Europe Crossover 10yr, series 6	Bloomberg	ITRXEX06 Index
iTRAXX Europe Crossover 10yr, series 7	Bloomberg	ITRXEX07 Index
JP Morgan's EMBI Plus Brazil Sovereign Spread	Bloomberg	JPSSEMBR Index
JP Morgan's EMBI Plus Bulgaria Sovereign Spread	Bloomberg	JPSSEMBU Index
JP Morgan's EMBI Plus Colombia Sovereign Spread	Bloomberg	JPSSEMCO Index
JP Morgan's EMBI Plus Composite Sovereign Spread	Bloomberg	JPEMSOSD Index
JP Morgan's EMBI Plus Ecuador Sovereign Spread	Bloomberg	JPSSEMEC Index
JP Morgan's EMBI Plus Mexico Sovereign Spread	Bloomberg	JPSSEMME Index
JP Morgan's EMBI Plus Panama Sovereign Spread	Bloomberg	JPSSEMPA Index
JP Morgan's EMBI Plus Peru Sovereign Spread	Bloomberg	JPSSEMPE Index
JP Morgan's EMBI Plus Phillipinnes Sovereign Spread	Bloomberg	JPSSEMPH Index
JP Morgan's EMBI Plus Russia Sovereign Spread	Bloomberg	JPSSEMRU Index
JP Morgan's EMBI Plus South Africa Sovereign Spread	Bloomberg	JPSSEMSA Index
JP Morgan's EMBI Plus Turkey Sovereign Spread	Bloomberg	JPSSEMTU Index
JP Morgan's EMBI Plus Ukraine Sovereign Spread	Bloomberg	JPSSEMUK Index
JP Morgan's EMBI Plus Venezuela Sovereign Spread	Bloomberg	JPSSEMVE Index
Lehman Brothers Short Swaption Volatility Index (1m-6m)	Bloomberg	LBSPX Index
Yield on U.S. Treasury securities at 10-year, constant maturity	Bloomberg	H15T10Y Index
Yield on U.S. Treasury securities at 20-year, constant maturity	Bloomberg	H15T20Y Index

Table 2: Variance Decomposition, 1998-2007 (%)

	Federal Funds	Default Risk	Market Liquidity	Market Volatility	Int.-Rate Risk	Emerging Markets	Idiosyn.
Brazil	6.7	3.9	1.8	8.3	4.6	0.2	74.6
Bulgaria	2.0	1.7	0.5	2.9	1.7	12.3	79.0
Ecuador	3.6	2.4	0.5	3.6	2.4	0.8	86.8
Mexico	6.5	3.1	5.0	8.3	2.9	0.8	73.5
Panama	4.1	1.7	3.0	5.2	2.4	3.1	80.5
Peru	3.5	1.3	2.1	4.1	0.7	1.5	86.7
Russia	5.5	1.1	1.8	5.0	2.2	1.0	83.5
Venezuela	5.0	4.2	0.6	6.2	2.1	0.3	81.7
USA	0.9	11.1	1.2	2.2	0.2	4.1	80.2
Canada	0.5	1.0	2.1	0.8	0.6	2.8	92.1

Table 3: Mean Spread Decomposition (1998-2007) - Russian Default / LTCM Bailout (1998)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	Bench.	F. Err.	FF	Def	Liq	Vol	Int	EM	Idios
Brazil	1295	558	737	10.8	7.9	2.6	17.0	3.3	-0.1	58.5
Bulgaria	1291	539	752	9.1	9.7	-1.1	11.4	2.0	-0.4	69.3
Ecuador	1871	774	1097	9.9	9.0	0.1	11.0	2.9	0.0	67.1
Mexico	912	416	496	11.4	7.6	2.9	17.3	2.9	0.0	58.0
Panama	601	339	262	11.6	6.3	5.1	15.7	3.0	-0.3	58.5
Peru	869	434	435	10.5	8.2	2.8	18.1	2.2	-0.2	58.4
Russia	4664	758	3906	5.4	3.8	1.8	6.6	1.8	0.1	80.5
Venezuela	1881	526	1355	4.7	5.7	-0.6	9.9	0.8	0.1	79.3
USA	143	92	50	7.9	-0.2	4.4	3.1	-0.3	-0.2	85.3
Canada	126	84	42	7.8	10.1	4.9	4.9	1.7	-0.1	70.6

Table 4: Mean Spread Decomposition (1998-2007) - Brazil Devaluation (1999)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	Bench.	F. Err.	FF	Def	Liq	Vol	Int	EM	Idios
Brazil	1540	1140	401	9.8	5.2	-1.1	15.3	-1.7	0.0	72.5
Bulgaria	915	757	158	14.5	11.0	0.9	16.7	-1.9	-1.8	60.5
Ecuador	2066	1462	604	8.5	5.7	0.0	9.1	-0.7	0.0	77.5
Mexico	832	657	175	12.9	6.1	-1.6	18.5	-1.8	0.2	65.6
Panama	501	440	61	17.4	6.4	-4.0	21.8	-2.2	-0.9	61.5
Peru	739	573	165	9.8	5.4	-1.1	15.2	-0.6	-0.6	71.9
Russia	5516	5159	356	43.3	24.8	-8.7	54.2	-5.0	-5.8	-2.9
Venezuela	1504	1174	330	8.1	7.3	0.5	16.6	-1.8	0.4	68.8
USA	158	172	-14	-12.9	1.2	3.3	-4.3	-0.5	2.6	110.6
Canada	153	146	7	24.7	23.8	-6.2	15.1	-0.9	-6.5	50.0

Table 5: Mean Spread Decomposition (1998-2007) - NASDAQ Bubble Burst (2000)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	**Bench.**	**F. Err.**	**FF**	**Def**	**Liq**	**Vol**	**Int**	**EM**	**Idios**
Brazil	758	639	120	51.0	32.3	-2.0	4.0	-15.8	1.8	28.8
Bulgaria	767	568	199	25.7	24.0	-0.2	1.3	-5.3	1.3	53.2
Ecuador	3479	2778	701	37.8	30.2	-0.6	1.9	-12.1	0.4	42.5
Mexico	400	293	107	27.9	15.6	-1.4	2.3	-6.5	0.1	62.1
Panama	433	344	89	27.9	13.1	-1.8	1.4	-7.2	0.5	66.1
Peru	529	408	121	27.3	18.7	-1.7	2.2	-6.6	0.4	59.7
Russia	1323	1819	-496	-28.8	-18.7	1.6	-1.2	11.4	0.6	135.1
Venezuela	965	749	215	23.2	24.4	0.1	2.0	-1.6	-0.5	52.5
USA	188	158	30	19.0	-0.5	-1.9	0.4	0.7	0.4	82.0
Canada	187	174	13	42.7	50.5	-5.6	0.9	-11.1	1.9	20.7

Table 6: Mean Spread Decomposition (1998-2007) - Turkish Crisis (2001)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	**Bench.**	**F. Err.**	**FF**	**Def**	**Liq**	**Vol**	**Int**	**EM**	**Idios**
Brazil	734	680	54	46.3	39.3	25.1	30.7	10.8	-0.8	-51.3
Bulgaria	774	677	96	22.3	31.7	-8.0	12.3	4.7	1.1	35.9
Ecuador	1261	1219	41	96.8	119.0	-1.1	51.2	18.1	0.1	-184.1
Mexico	418	380	38	33.6	28.9	20.3	26.6	7.5	-0.4	-16.5
Panama	470	448	22	50.4	35.2	54.1	32.1	10.7	0.2	-82.7
Peru	639	676	-37	-50.1	-50.8	-26.9	-31.1	-6.1	1.7	263.3
Russia	1064	1007	57	63.5	64.5	51.6	35.0	12.8	-1.1	-126.3
Venezuela	850	842	8	228.3	365.0	-79.7	211.3	59.4	2.5	-686.8
USA	201	190	11	24.0	-1.2	28.7	1.6	-1.6	0.1	48.4
Canada	235	230	5	56.6	106.1	77.5	20.3	8.0	-1.2	-167.4

Table 7: Mean Spread Decomposition (1998-2007) - September 11th (2001)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	**Bench.**	**F. Err.**	**FF**	**Def**	**Liq**	**Vol**	**Int**	**EM**	**Idios**
Brazil	1155	974	181	-59.5	-11.4	17.6	73.8	25.7	-0.6	54.3
Bulgaria	666	595	71	-79.7	-21.7	-15.5	79.8	24.1	-2.4	115.4
Ecuador	1534	1427	107	-134.0	-31.8	-0.8	121.3	59.5	-1.2	87.1
Mexico	408	352	56	-67.9	-11.8	20.6	84.0	23.4	-0.2	51.9
Panama	479	400	80	-40.4	-5.9	23.2	44.5	14.9	-0.2	63.9
Peru	663	608	56	-94.6	-18.9	28.3	125.6	30.1	-1.7	31.2
Russia	923	832	91	-102.6	-19.5	44.4	103.2	54.3	-1.1	21.4
Venezuela	1017	924	94	-70.6	-22.4	-13.0	117.7	10.3	0.5	77.5
USA	208	188	20	-37.8	0.3	26.4	10.6	-2.0	-1.0	103.4
Canada	219	199	21	-35.8	-12.0	28.6	18.9	12.5	-1.6	89.4

Table 8: Mean Spread Decomposition (1998-2007) –
Brazilian Elections / WorldCom Accounting Scandal (2002)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	Bench.	F. Err.	FF	Def	Liq	Vol	Int	EM	Idios
Brazil	1904	709	1195	19.0	-6.5	2.9	7.0	0.0	0.0	77.6
Bulgaria	366	349	17	345.9	-175.2	-39.8	105.0	1.7	-3.6	-134.0
Ecuador	1703	953	750	30.8	-13.1	-0.3	8.0	0.1	0.0	74.4
Mexico	375	227	148	35.5	-11.1	5.7	13.3	0.1	0.0	56.5
Panama	513	346	167	34.6	-8.5	10.0	10.5	0.1	-0.1	53.5
Peru	780	424	356	24.8	-8.9	3.7	9.8	0.1	0.0	70.6
Russia	565	432	134	72.9	-24.8	16.4	21.0	0.0	-0.2	14.8
Venezuela	1109	904	205	57.9	-34.4	-6.0	28.7	0.5	0.2	53.1
USA	174	194	-20	-66.3	-1.0	-23.7	-6.1	0.1	0.4	196.6
Canada	193	191	2	590.5	-358.1	223.5	84.3	-0.5	-6.5	-433.2

Table 9: Mean Spread Decomposition (1998-2007) - Federal Funds Tightening (2003)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	Bench.	F. Err.	FF	Def	Liq	Vol	Int	EM	Idios
Brazil	697	531	166	22.5	9.9	-9.3	-18.1	0.6	-0.2	94.6
Bulgaria	179	156	23	39.9	24.9	11.6	-25.9	-0.2	-2.2	51.9
Ecuador	901	696	205	23.1	12.5	0.5	-13.3	1.2	-0.2	76.2
Mexico	215	176	39	30.3	11.9	-12.5	-24.3	0.2	0.0	94.5
Panama	367	332	34	45.3	14.9	-35.7	-31.9	1.4	-0.2	106.2
Peru	456	335	121	16.4	7.7	-6.5	-13.8	0.8	-0.1	95.6
Russia	302	243	60	29.7	13.1	-17.8	-19.2	2.5	-0.2	91.9
Venezuela	658	638	20	133.8	97.4	36.9	-147.6	-8.8	3.1	-14.7
USA	122	116	6	45.2	-1.0	-42.3	-7.7	0.3	-1.0	106.5
Canada	96	89	7	29.7	24.0	-28.8	-9.1	1.4	-0.9	83.8

Table 10: Mean Spread Decomposition (1998-2007) - Ford/GM Downgrades (2004)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	Bench.	F. Err.	FF	Def	Liq	Vol	Int	EM	Idios
Brazil	450	394	56	49.6	7.9	-9.4	-11.0	1.5	-0.5	61.9
Bulgaria	88	65	23	19.5	4.9	2.9	-3.4	0.4	0.2	75.4
Ecuador	736	634	103	41.9	8.7	0.6	-7.1	2.0	0.0	53.8
Mexico	184	153	31	34.4	5.1	-6.4	-8.1	0.7	0.0	74.2
Panama	299	289	10	138.0	17.8	-49.6	-29.3	4.7	-0.7	19.2
Peru	241	233	8	167.2	30.9	-29.8	-39.9	6.9	-2.2	-33.1
Russia	194	183	11	115.4	19.6	-32.2	-21.5	6.8	-1.4	13.3
Venezuela	476	464	12	175.3	50.0	23.5	-54.9	-3.1	1.3	-92.1
USA	104	102	2	151.3	-0.8	-65.1	-5.9	0.4	-3.0	23.2
Canada	117	115	2	110.5	34.9	-52.8	-10.5	3.6	-5.7	20.0

Table 11: Mean Spread Decomposition (1998-2007) - Turkish Crisis (2006)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	**Bench.**	**F. Err.**	**FF**	**Def**	**Liq**	**Vol**	**Int**	**EM**	**Idios**
Brazil	257	215	42	31.1	5.2	-4.0	8.2	-7.2	-0.5	67.3
Bulgaria	90	79	11	36.8	8.6	3.0	6.8	-5.9	-0.4	51.0
Ecuador	509	455	54	46.5	10.2	0.1	7.9	-10.4	-0.4	46.2
Mexico	138	117	21	31.8	5.1	-4.3	8.0	-5.8	-0.1	65.4
Panama	206	169	37	20.3	2.7	-4.9	4.2	-3.8	0.0	81.6
Peru	169	150	20	34.2	6.5	-4.7	10.2	-6.6	-0.7	61.1
Russia	121	99	22	29.0	4.8	-5.5	5.5	-8.1	-0.2	74.4
Venezuela	215	165	51	13.5	3.9	1.1	4.3	-0.8	0.1	78.0
USA	123	123	1	291.4	-2.2	-88.1	17.6	7.4	-7.8	-118.3
Canada	105	101	4	45.9	13.4	-15.3	4.5	-8.2	-2.2	62.0

Table 12: Mean Spread Decomposition (1998-2007) - Chinese Correction (2007)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	**Bench.**	**F. Err.**	**FF**	**Def**	**Liq**	**Vol**	**Int**	**EM**	**Idios**
Brazil	196	182	14	49.0	-3.7	-1.0	47.0	16.1	-0.4	-7.1
Bulgaria	68	64	4	61.7	-5.2	0.8	45.7	13.7	0.8	-17.5
Ecuador	715	692	24	108.1	-7.6	0.0	74.0	35.9	-0.5	-109.9
Mexico	114	107	7	56.7	-3.8	-0.8	52.6	14.0	-0.7	-18.1
Panama	167	156	11	40.3	-2.4	-2.1	33.7	11.3	0.2	18.9
Peru	138	125	14	29.3	-1.8	-0.6	29.8	7.0	0.2	36.0
Russia	112	103	10	44.3	-2.6	-1.4	33.0	17.3	0.0	9.5
Venezuela	225	209	15	36.1	-3.5	0.4	44.8	4.2	0.1	17.8
USA	112	109	3	53.0	-0.6	-3.1	11.4	-1.8	0.8	40.3
Canada	118	118	0	-578.0	63.9	47.4	-264.9	-170.1	0.9	1000.8

Table 13: Mean Spread Decomposition (1998-2007) - Subprime Mortgages Crisis (2007)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	**Bench.**	**F. Err.**	**FF**	**Def**	**Liq**	**Vol**	**Int**	**EM**	**Idios**
Brazil	167	136	31	15.8	11.5	-1.5	18.8	14.6	-0.5	41.3
Bulgaria	70	54	16	11.1	11.9	1.3	10.5	7.1	0.5	57.7
Ecuador	682	612	70	27.3	26.2	0.8	24.1	28.1	-0.7	-5.8
Mexico	99	70	29	9.2	6.2	-0.7	10.3	6.8	0.0	68.2
Panama	139	114	25	11.5	6.5	-2.1	12.0	9.6	0.0	62.6
Peru	126	95	31	8.8	7.4	-0.6	11.8	6.7	0.0	66.0
Russia	106	82	24	12.7	9.7	-1.9	12.3	15.5	-0.3	52.0
Venezuela	318	253	65	9.0	11.2	0.9	14.2	2.5	0.3	62.0
USA	135	126	8	18.6	-0.7	-4.2	4.8	-1.9	-1.1	84.6
Canada	124	125	-2	-76.9	-105.6	17.9	-38.8	-60.0	10.5	352.9

Table 14: Variance Decomposition, 2004-2007 (%)

	Federal Funds	Default Risk	Market Liquidity	Market Volatility	Int.-Rate Risk	Emerging Markets	Idiosyn.
Brazil	16.2	14.7	0.6	12.9	5.1	1.7	48.8
Bulgaria	0.7	3.6	1.9	6.8	2.3	2.4	82.3
Colombia	14.5	10.8	0.6	10.1	6.7	1.4	56.0
Ecuador	1.8	6.9	3.7	2.0	7.9	0.7	76.9
Egypt	0.5	2.7	1.2	6.2	1.5	0.9	87.0
Mexico	20.1	14.4	1.0	8.0	6.3	3.6	46.6
Panama	8.0	9.0	0.7	12.9	4.8	1.6	63.0
Peru	7.8	13.0	2.4	6.2	6.1	3.4	61.2
Philippines	15.1	12.2	1.6	8.2	4.0	1.7	57.0
Russia	7.1	10.1	1.6	8.2	3.4	1.3	68.3
South Africa	4.3	4.1	1.4	2.1	3.6	0.6	84.0
Turkey	9.7	12.2	1.6	6.8	1.8	2.3	65.5
Ukraine	7.7	5.8	3.7	6.2	4.0	0.5	72.0
Venezuela	3.8	9.8	1.5	10.9	6.4	1.3	66.3
USA	1.1	1.9	1.7	4.4	3.9	0.3	86.5
Canada	0.5	1.9	2.9	1.8	1.6	0.9	90.4
Japan	0.9	0.6	0.6	1.5	1.9	0.9	93.5
Eurozone	2.4	4.6	0.6	2.5	0.9	4.0	84.9

Table 15: Mean Spread Decomposition (2004-2007) - Ford/GM Downgrades (2005)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	Bench.	F. Err.	FF	Def	Liq	Vol	Int	EM	Idios
Brazil	450	380	70	48.3	64.9	6.6	-12.7	0.0	-0.1	-7.1
Bulgaria	88	67	21	19.3	40.1	2.1	-5.9	-0.2	0.8	43.8
Colombia	402	341	61	75.1	76.6	6.7	-17.9	0.5	-0.1	-40.8
Ecuador	736	630	106	18.9	54.6	3.7	-8.3	0.8	0.8	29.5
Mexico	184	152	32	61.6	65.8	7.3	-9.2	0.1	-0.2	-25.4
Panama	299	280	19	135.1	165.2	9.1	-32.3	2.8	0.6	-180.5
Peru	241	230	11	168.0	340.3	-39.3	-68.8	9.1	-1.9	-307.5
Philippines	431	388	43	89.1	93.9	8.7	-23.6	2.0	0.7	-70.9
Russia	194	180	14	104.8	136.1	12.0	-36.9	3.7	0.3	-119.9
South Africa	109	91	17	47.9	72.2	13.3	-3.2	2.7	0.2	-33.0
Turkey	315	257	58	37.0	59.3	2.3	-7.2	0.1	0.6	7.9
Ukraine	203	175	28	74.1	75.6	-3.2	-16.9	3.6	0.9	-34.0
Venezuela	476	460	16	131.6	322.0	23.6	-85.5	1.3	6.9	-299.9
USA	104	103	1	258.4	148.3	-202.1	15.4	19.6	-4.0	-135.5
Canada	117	115	2	18.6	160.9	-10.5	-18.7	1.2	2.8	-54.3
Japan	27	26	1	-75.8	-13.8	18.7	6.5	0.4	1.3	162.7
Eurozone	78	66	12	25.4	46.1	-3.7	-3.8	0.5	1.0	34.4

Table 16: Mean Spread Decomposition (2004-2007) - Turkish Crisis (2006)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	**Bench.**	**F. Err.**	**FF**	**Def**	**Liq**	**Vol**	**Int**	**EM**	**Idios**
Brazil	257	210	46	30.9	6.9	3.1	8.0	-6.0	0.6	56.6
Bulgaria	90	79	11	31.2	10.3	1.1	9.8	-7.0	-0.9	55.5
Colombia	223	161	62	29.4	4.3	1.9	7.3	-5.1	0.1	62.1
Ecuador	509	454	55	18.5	12.2	4.8	10.0	-20.1	-0.9	75.4
Mexico	138	117	21	53.7	8.6	3.7	8.4	-6.8	1.7	30.8
Panama	206	166	40	30.9	6.5	1.3	8.0	-8.5	-0.3	62.2
Peru	169	143	26	33.3	20.8	-4.7	20.0	-14.7	1.0	44.2
Philippines	250	193	57	29.6	5.2	1.6	7.6	-5.5	-0.1	61.7
Russia	121	98	23	29.3	6.2	2.2	10.9	-10.9	-0.1	62.4
South Africa	98	79	19	29.8	8.5	5.2	2.0	-16.4	-0.1	71.0
Turkey	255	171	84	14.6	4.8	0.4	3.1	-3.1	0.3	79.9
Ukraine	219	168	51	32.1	6.3	-1.6	8.1	-13.6	-0.3	69.1
Venezuela	215	163	52	11.8	5.3	1.7	8.9	-6.1	-0.2	78.7
USA	123	122	1	126.6	14.6	-74.9	-9.6	76.5	2.3	-35.6
Canada	105	101	4	7.7	11.8	-4.5	7.2	-13.0	-1.3	92.2
Japan	28	26	1	-23.9	-1.1	3.5	-3.5	-13.3	-0.2	138.5
Eurozone	106	99	7	47.2	15.9	-5.0	7.3	-10.7	-2.0	47.4

Table 17: Mean Spread Decomposition (2004-2007) - Chinese Correction (2007)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	**Bench.**	**F. Err.**	**FF**	**Def**	**Liq**	**Vol**	**Int**	**EM**	**Idios**
Brazil	196	180	17	80.3	9.6	-1.5	30.2	5.2	-1.0	-22.8
Bulgaria	68	64	4	77.4	14.9	1.2	36.6	6.9	4.5	-41.4
Colombia	180	166	14	132.7	9.2	-1.5	44.7	8.8	0.2	-94.2
Ecuador	715	687	29	60.7	18.2	-5.6	39.5	24.4	2.0	-39.3
Mexico	114	106	8	145.8	8.7	-1.2	30.5	7.7	1.1	-92.6
Panama	167	154	12	94.6	11.0	0.1	34.8	10.0	0.4	-51.0
Peru	138	122	16	54.1	11.8	3.3	33.4	7.0	-1.6	-8.0
Philippines	185	169	16	87.5	5.6	-0.1	29.8	6.5	0.5	-29.7
Russia	112	101	11	70.7	7.3	-0.4	33.7	8.7	0.5	-20.6
South Africa	76	75	1	463.9	61.3	-12.4	50.7	84.2	-1.0	-546.7
Turkey	238	218	20	77.1	10.5	0.6	21.6	5.5	1.4	-16.7
Ukraine	150	130	20	68.6	6.3	1.4	22.4	9.4	0.8	-9.0
Venezuela	225	210	15	52.3	11.3	-2.5	53.4	9.6	2.2	-26.4
USA	112	109	3	62.1	3.1	7.8	-5.4	-11.5	-1.7	45.7
Canada	118	118	0	196.5	155.2	74.9	397.2	215.2	50.4	-989.4
Japan	25	27	-2	23.6	0.3	-0.3	2.2	-4.4	-0.7	79.4
Eurozone	82	80	2	132.3	21.5	1.8	31.1	12.3	6.7	-105.6

Table 18: Mean Spread Decomposition (2004-2007) - Subprime Mortgages Crisis (2007)

	Spread Decomp. (bps)			Forecast Error Decomposition (%)						
	Actual	**Bench.**	**F. Err.**	**FF**	**Def**	**Liq**	**Vol**	**Int**	**EM**	**Idios**
Brazil	167	134	32	31.8	42.3	1.3	7.8	10.3	0.1	6.3
Bulgaria	70	55	15	18.2	37.5	1.5	6.1	6.9	0.3	29.4
Colombia	131	104	27	43.8	47.9	1.0	11.9	13.3	-0.1	-17.9
Ecuador	682	610	72	22.7	65.1	-1.2	9.8	38.2	-0.6	-34.1
Mexico	99	70	29	29.8	31.8	1.4	4.7	6.0	0.1	26.2
Panama	139	112	27	34.1	44.3	1.1	8.4	15.6	-0.1	-3.4
Peru	126	95	31	24.3	51.6	-1.1	9.9	15.3	0.1	-0.2
Philippines	165	129	36	32.2	34.3	1.3	8.0	10.6	0.0	13.5
Russia	106	81	25	25.5	33.5	1.3	9.2	15.3	-0.1	15.2
South Africa	96	66	30	17.0	27.7	1.6	1.5	16.0	0.0	36.2
Turkey	195	172	24	50.5	81.2	2.1	9.6	17.4	-1.4	-59.3
Ukraine	154	94	60	19.3	19.3	0.3	4.5	13.0	0.1	43.5
Venezuela	318	248	70	15.8	37.8	0.4	10.4	11.9	-0.4	23.9
USA	135	127	8	25.6	16.0	-4.1	-2.0	-25.9	0.1	90.4
Canada	124	126	-2	-16.7	-162.8	-3.8	-18.9	-54.6	0.8	356.0
Japan	29	30	-1	84.4	19.0	-11.4	6.2	-74.6	-0.2	76.6
Eurozone	90	77	13	22.4	43.7	-1.1	3.6	8.7	-0.1	22.8

Figure 5: Spread Decomposition (1998-2007) – Brazil

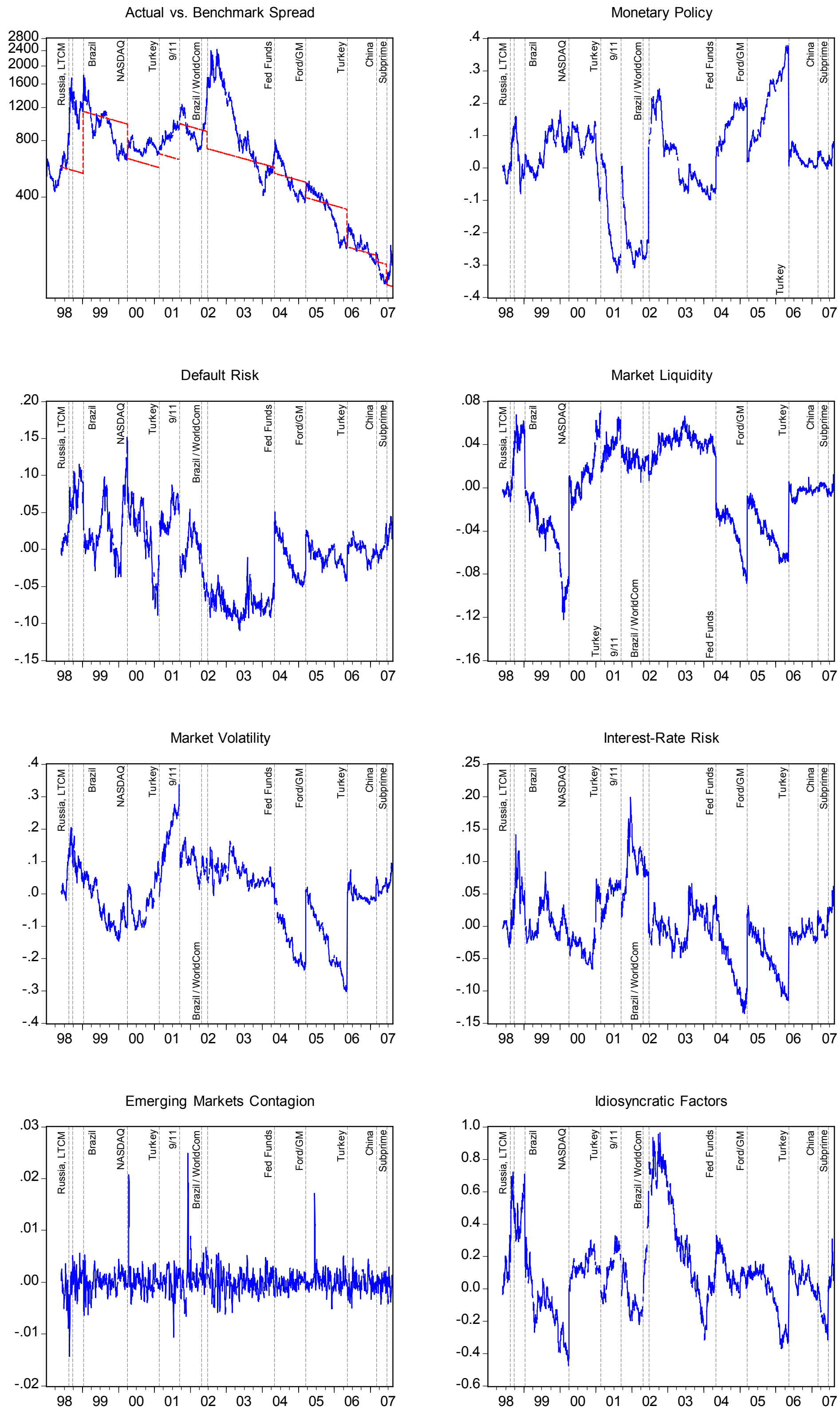


Figure 6: Spread Decomposition (1998-2007) - Bulgaria

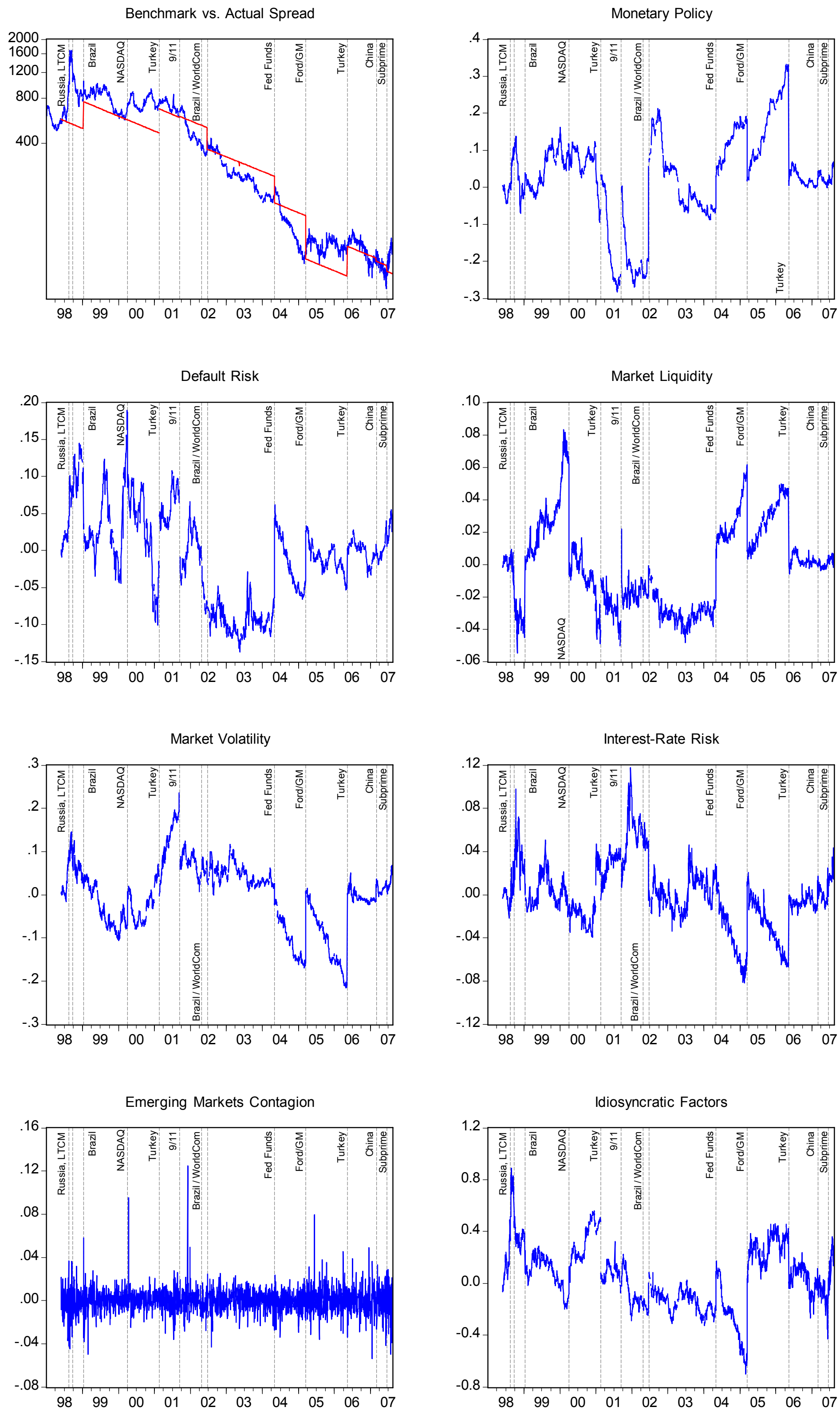


Figure 7: Spread Decomposition (1998-2007) – Ecuador

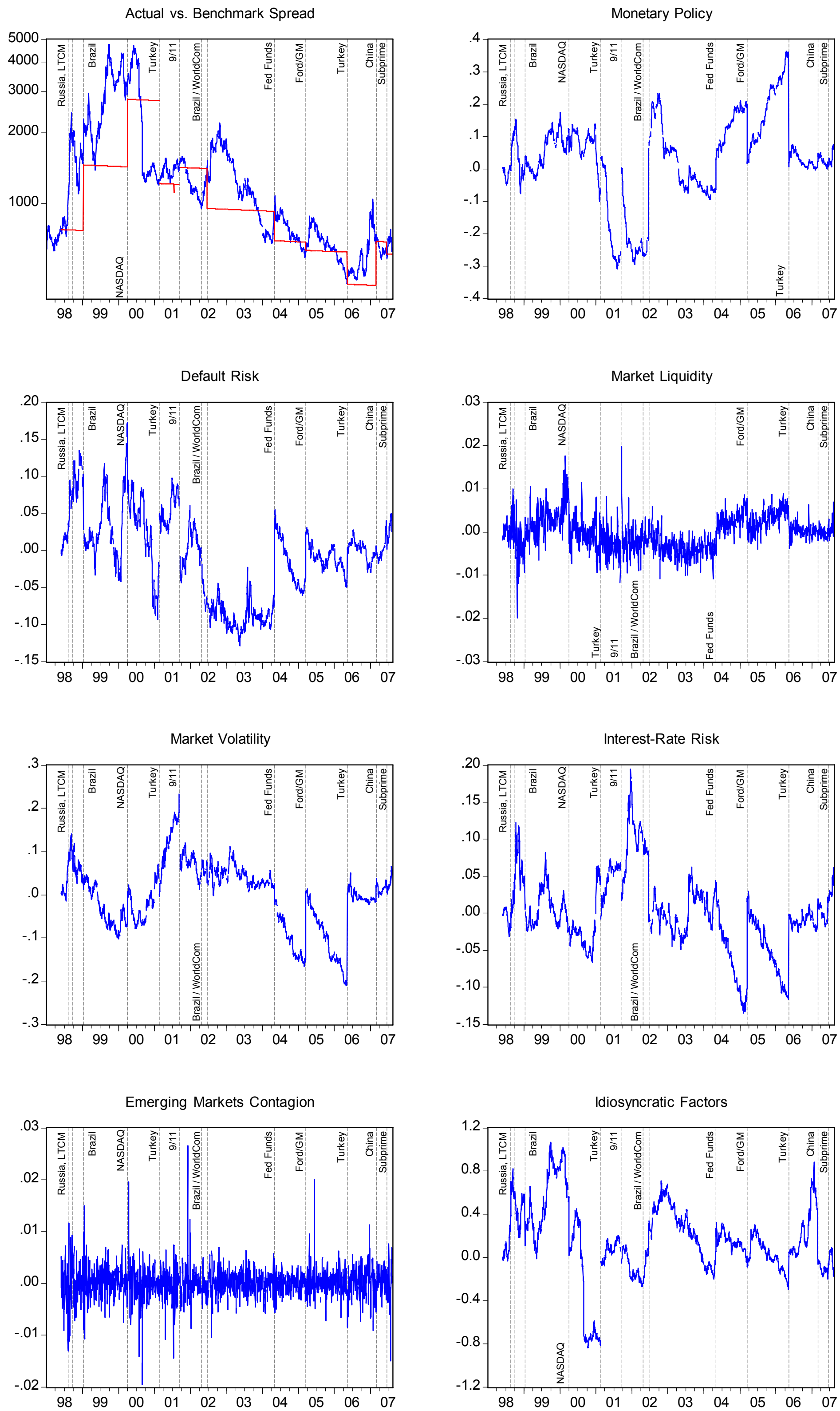


Figure 8: Spread Decomposition (1998-2007) - Mexico

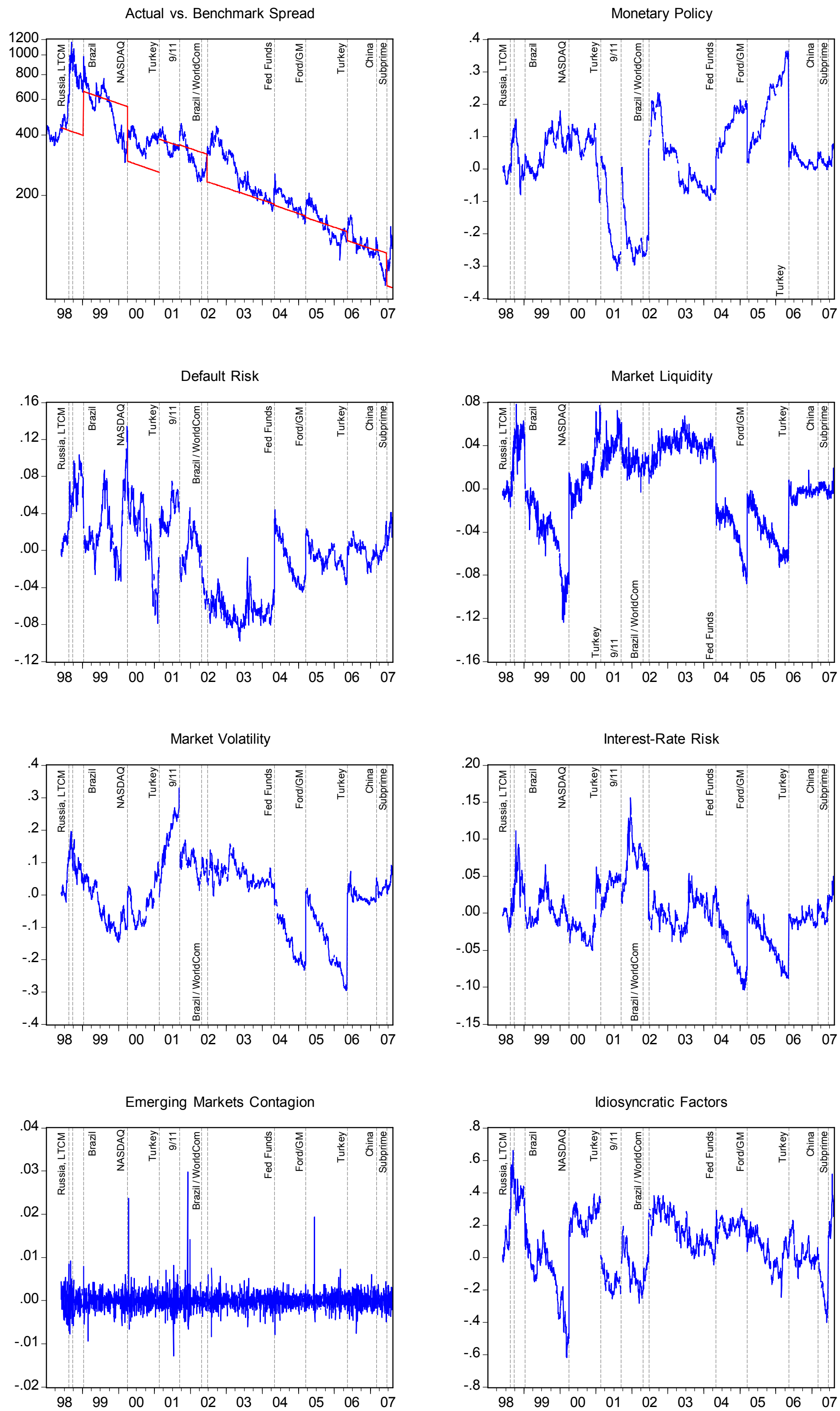


Figure 9: Spread Decomposition (1998-2007) - Panama

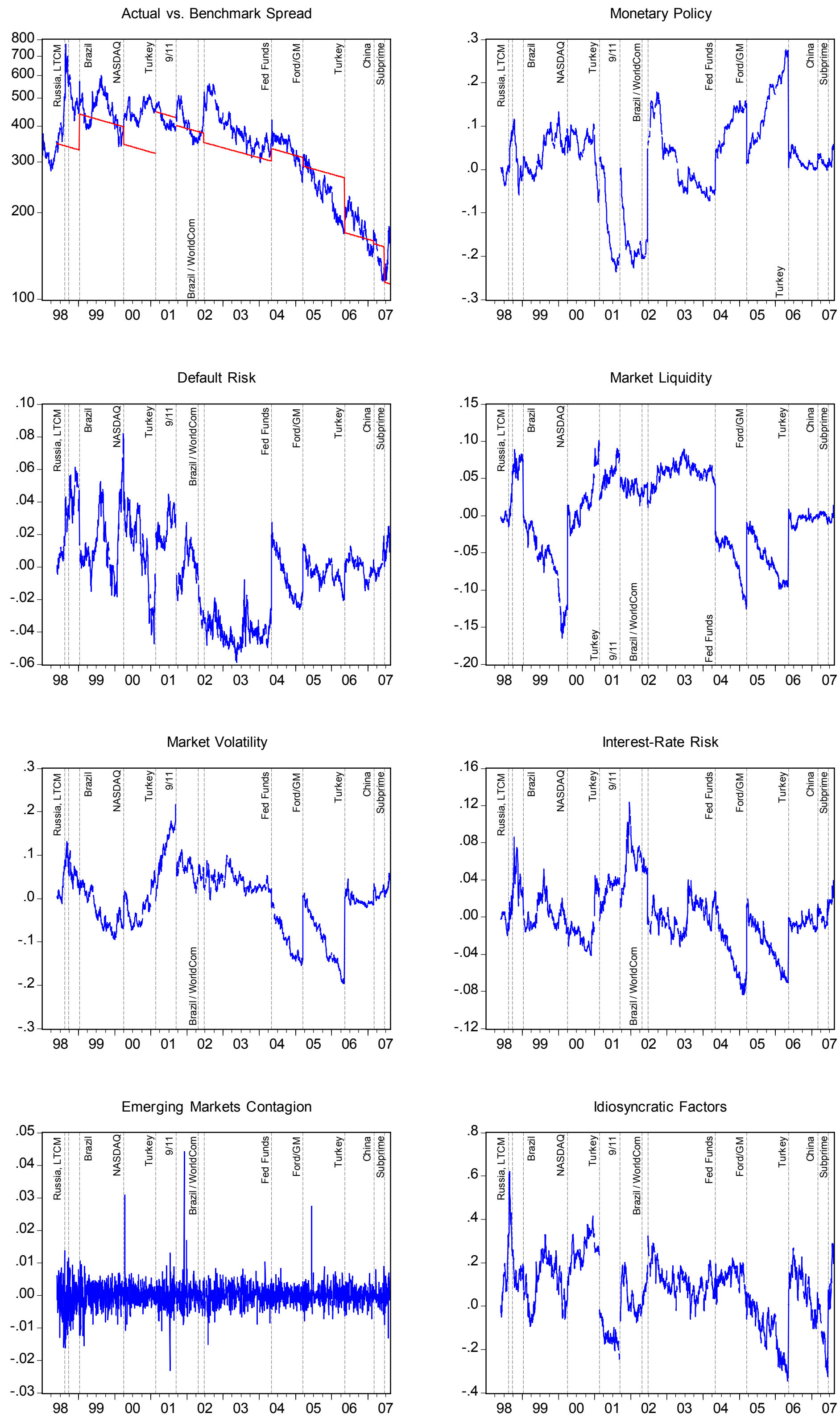


Figure 10: Spread Decomposition (1998-2007) – Peru

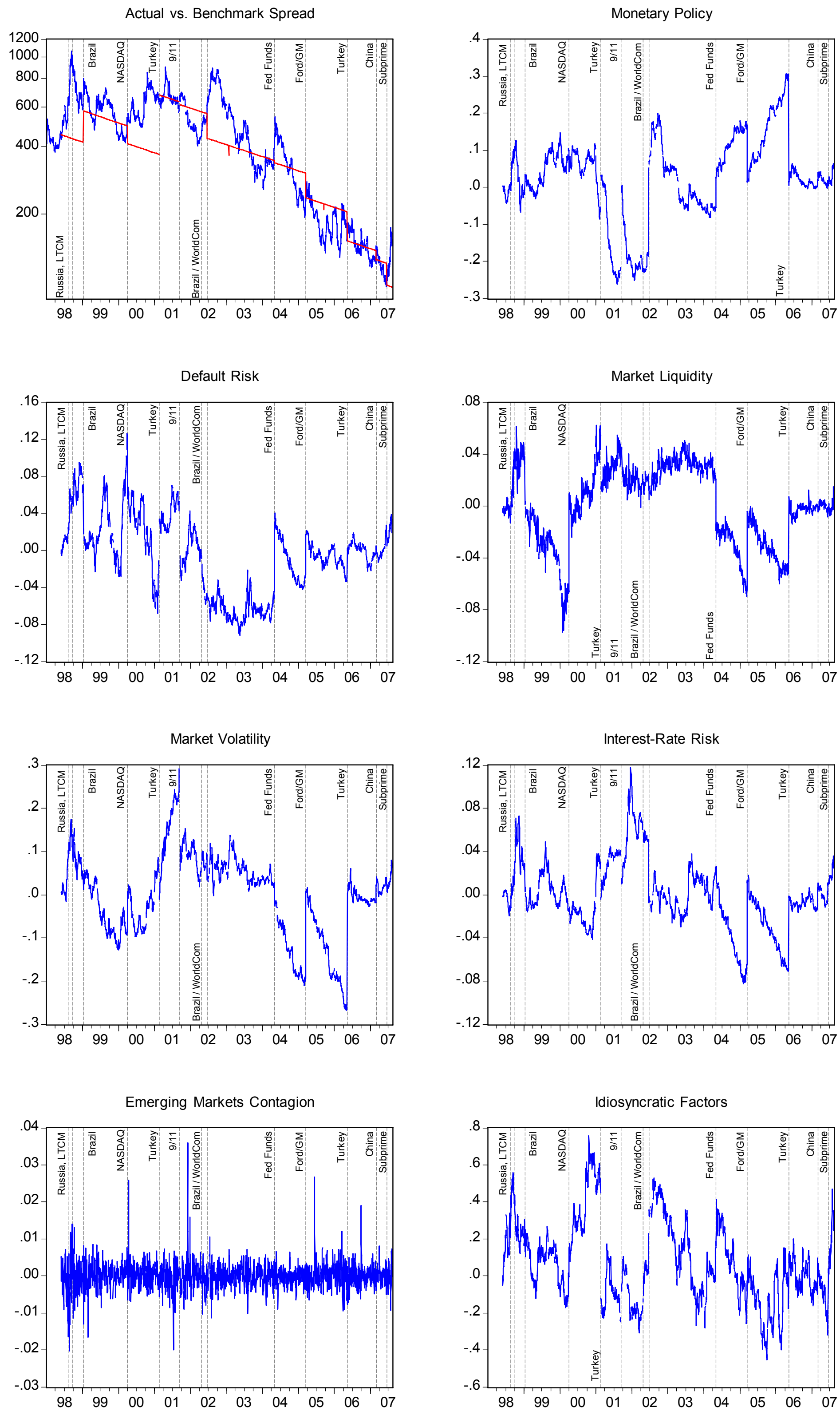


Figure 11: Spread Decomposition (1998-2007) - Russia

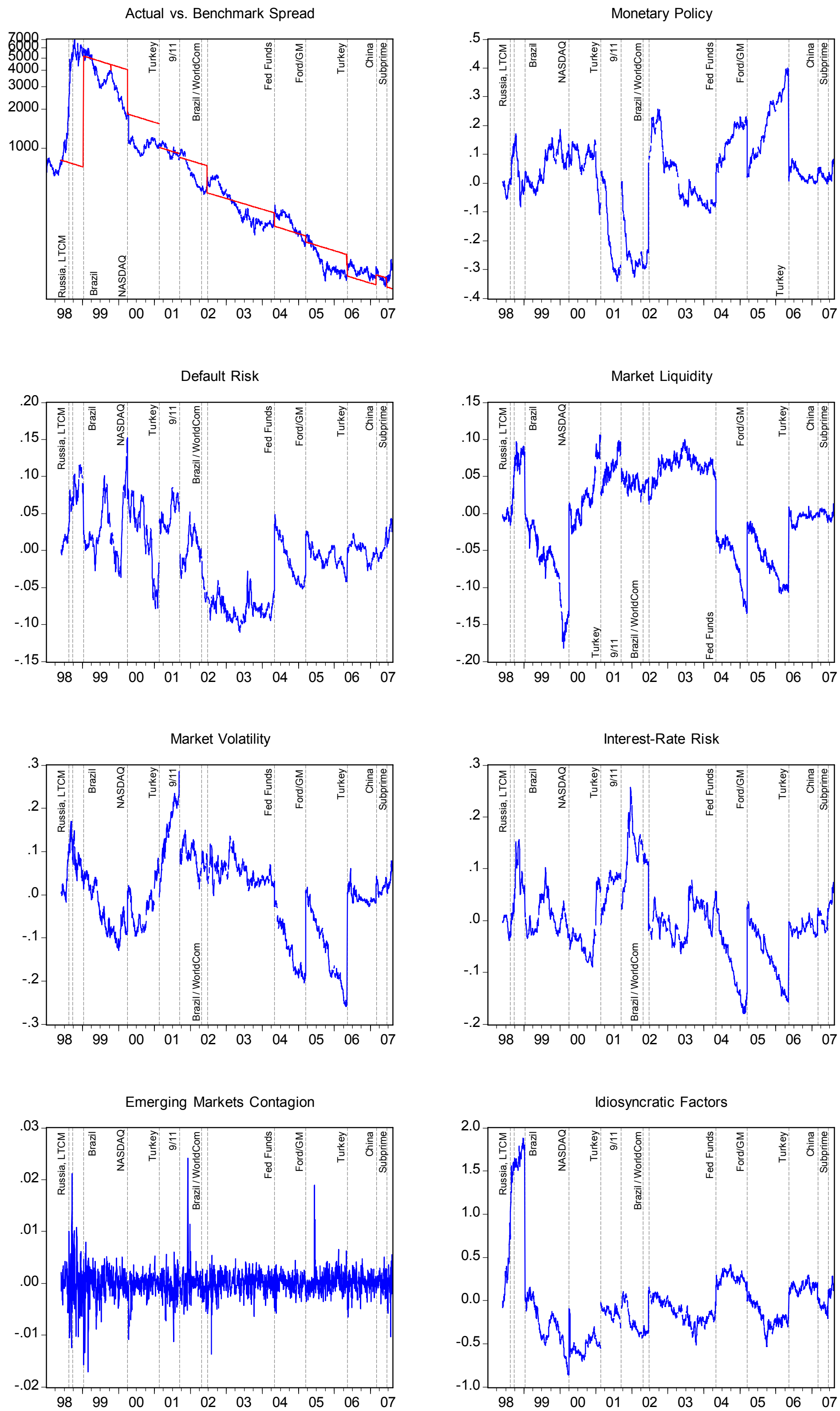


Figure 12: Spread Decomposition (1998-2007) – Venezuela

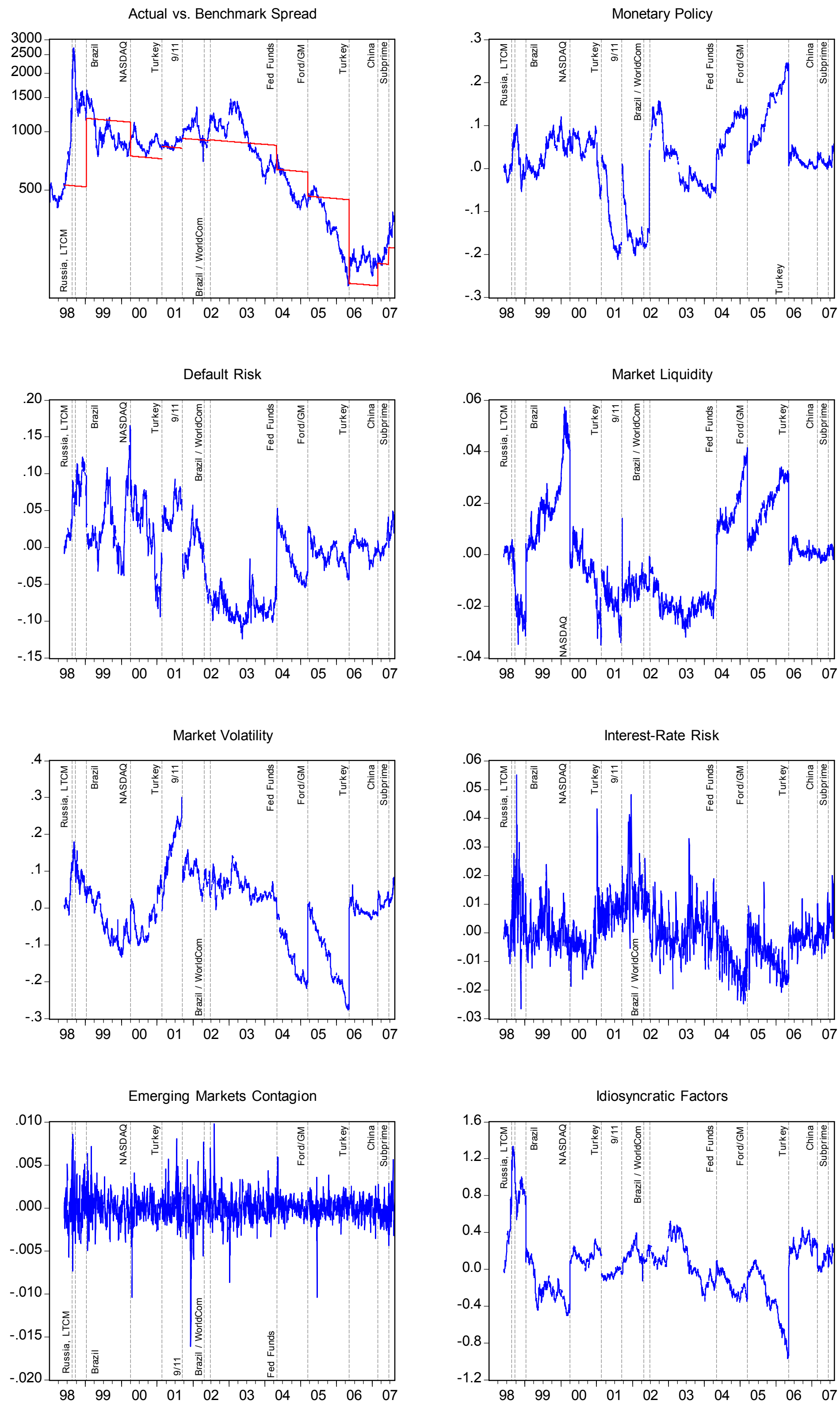


Figure 13: Spread Decomposition (1998-2007) - United States

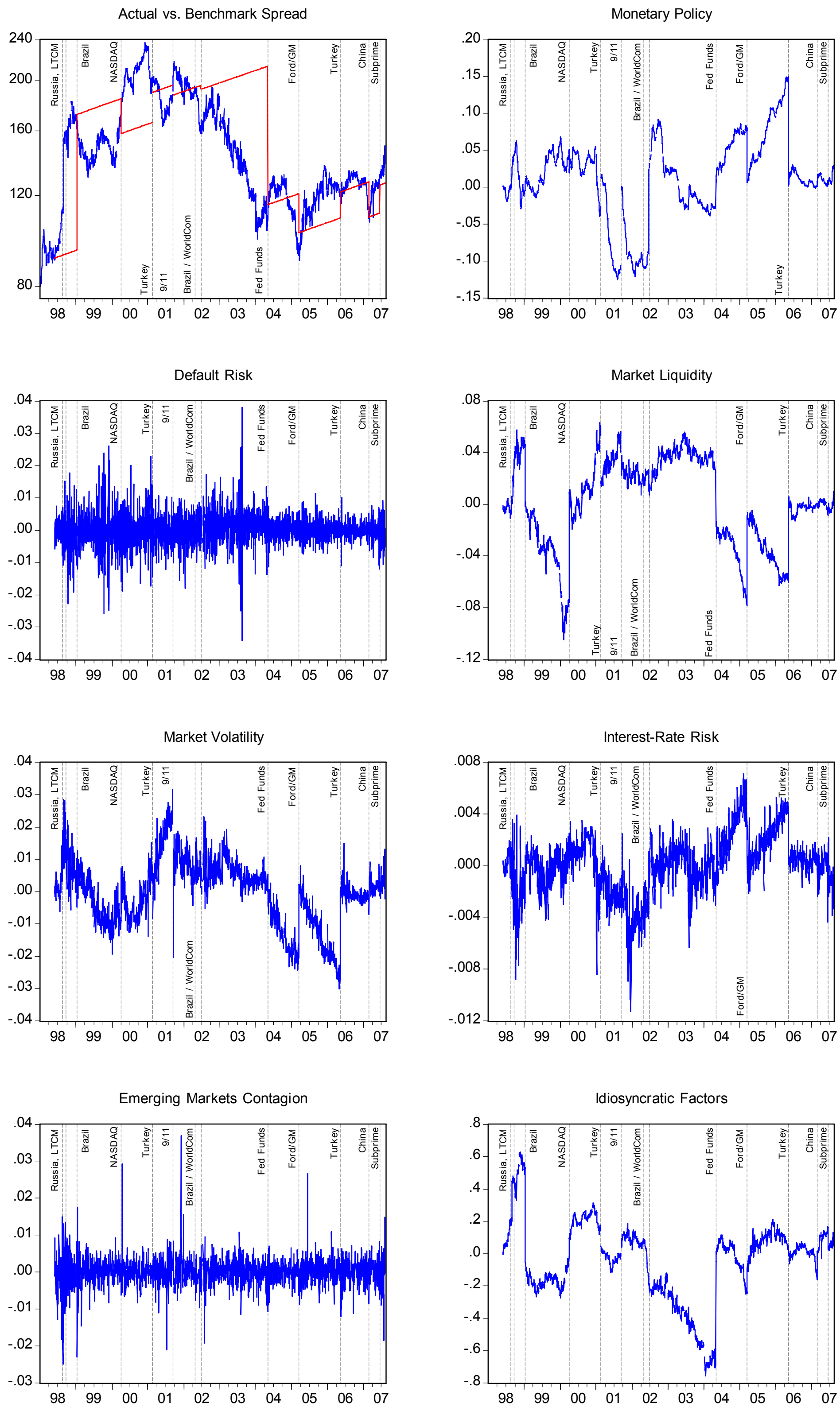


Figure 14: Spread Decomposition (1998-2007) - Canada

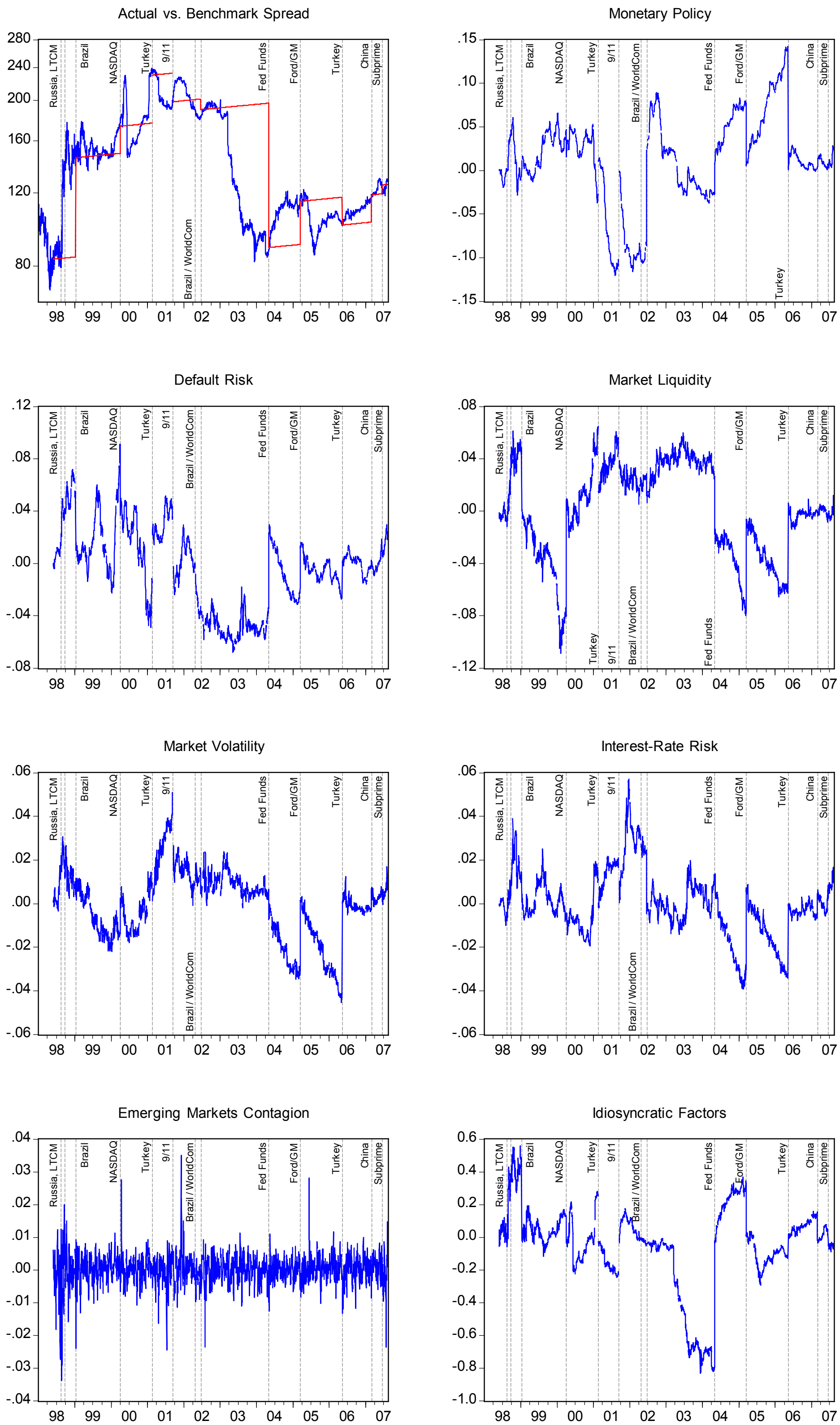


Figure 15: Spread Decomposition (2004-2007) - Brazil

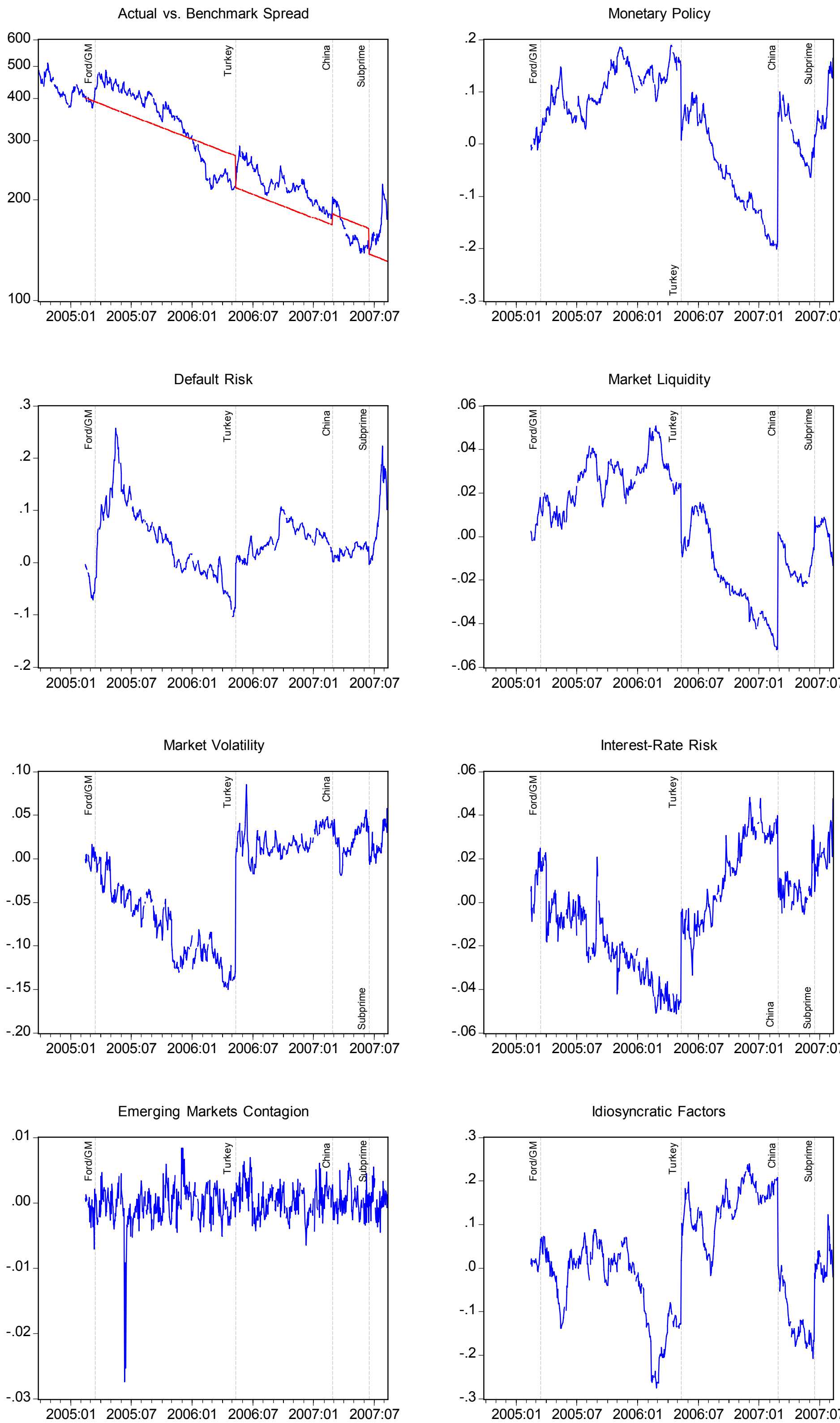


Figure 16: Spread Decomposition (2004-2007) - Bulgaria

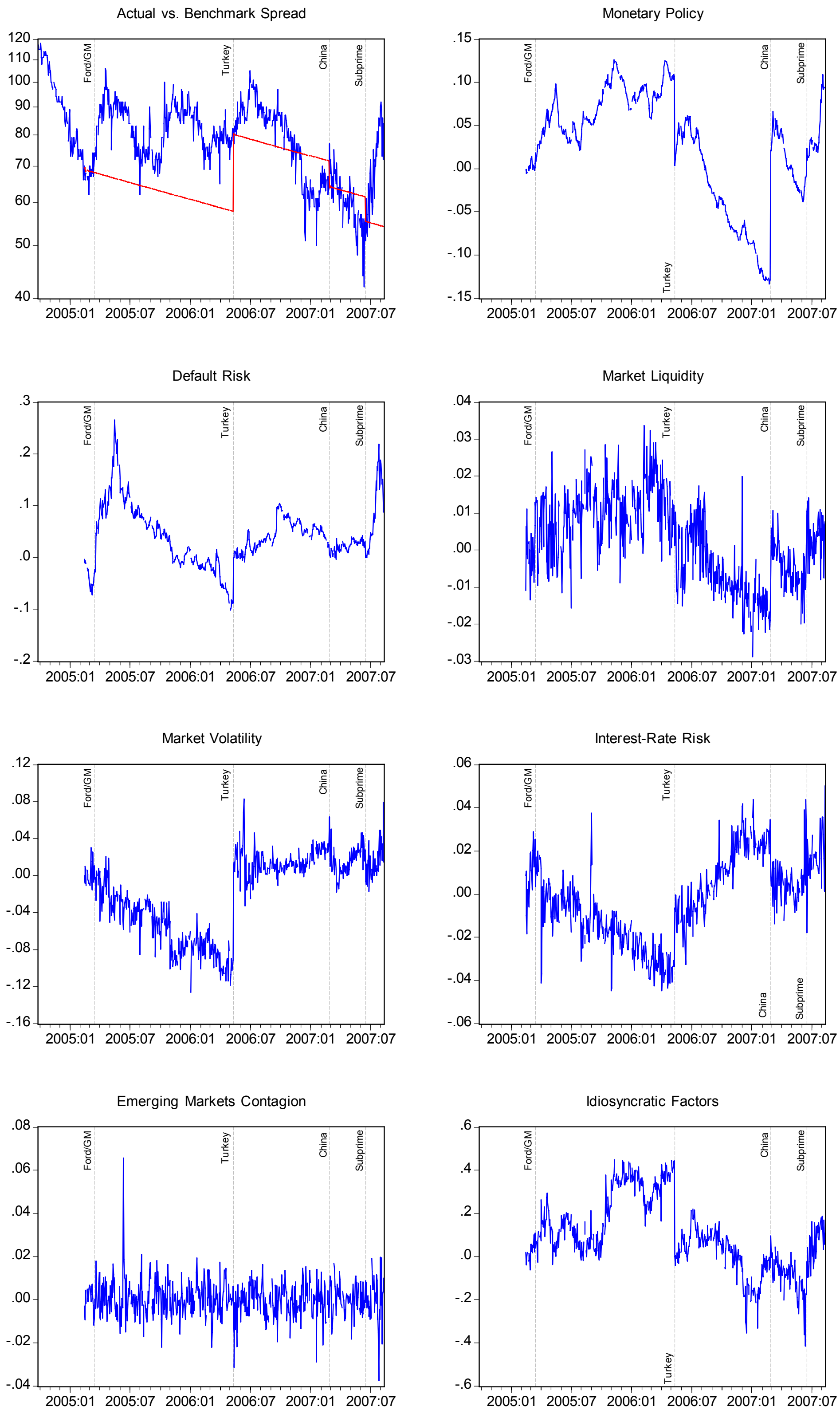


Figure 17: Spread Decomposition (2004-2007) - Colombia

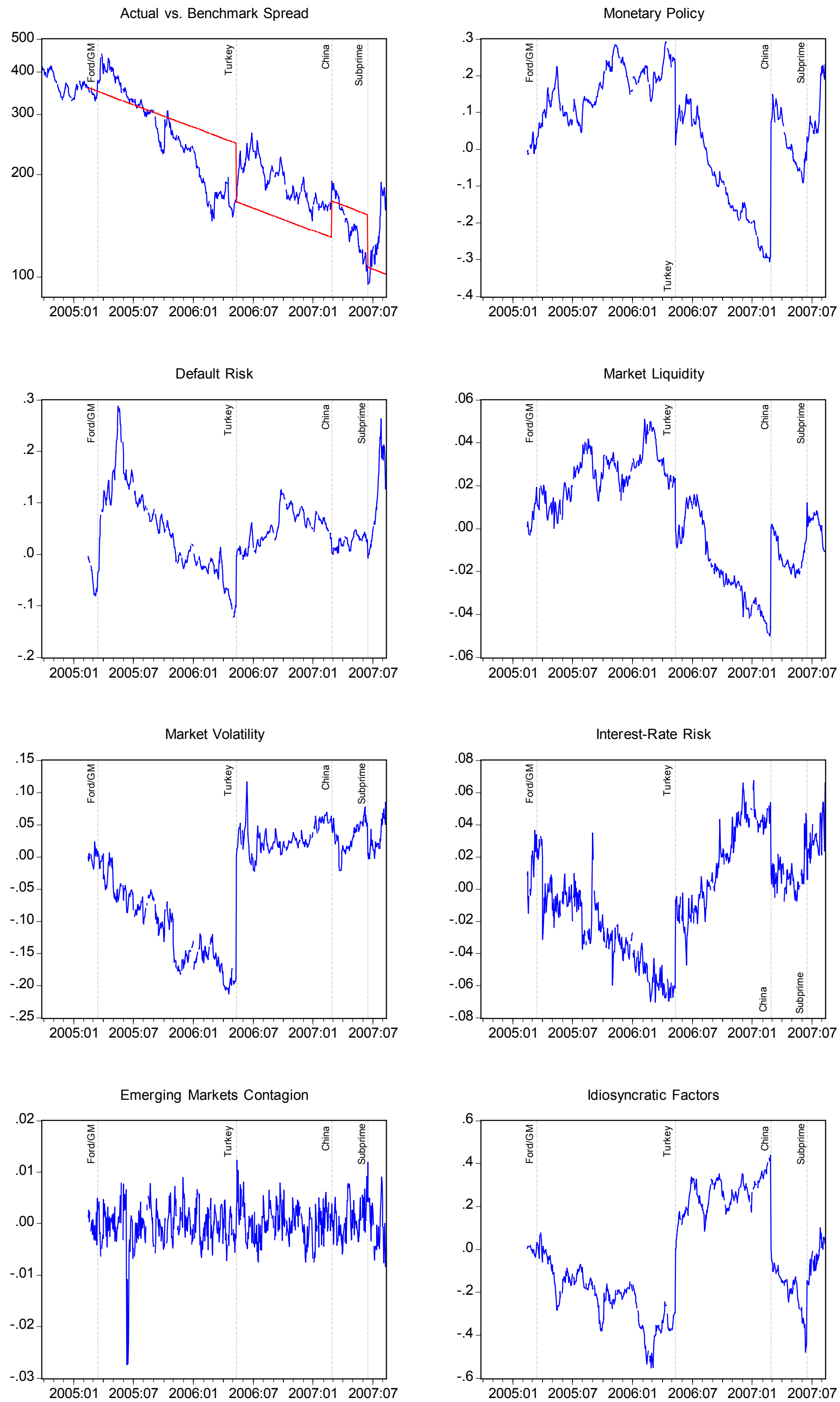


Figure 18: Spread Decomposition (2004-2007) - Ecuador

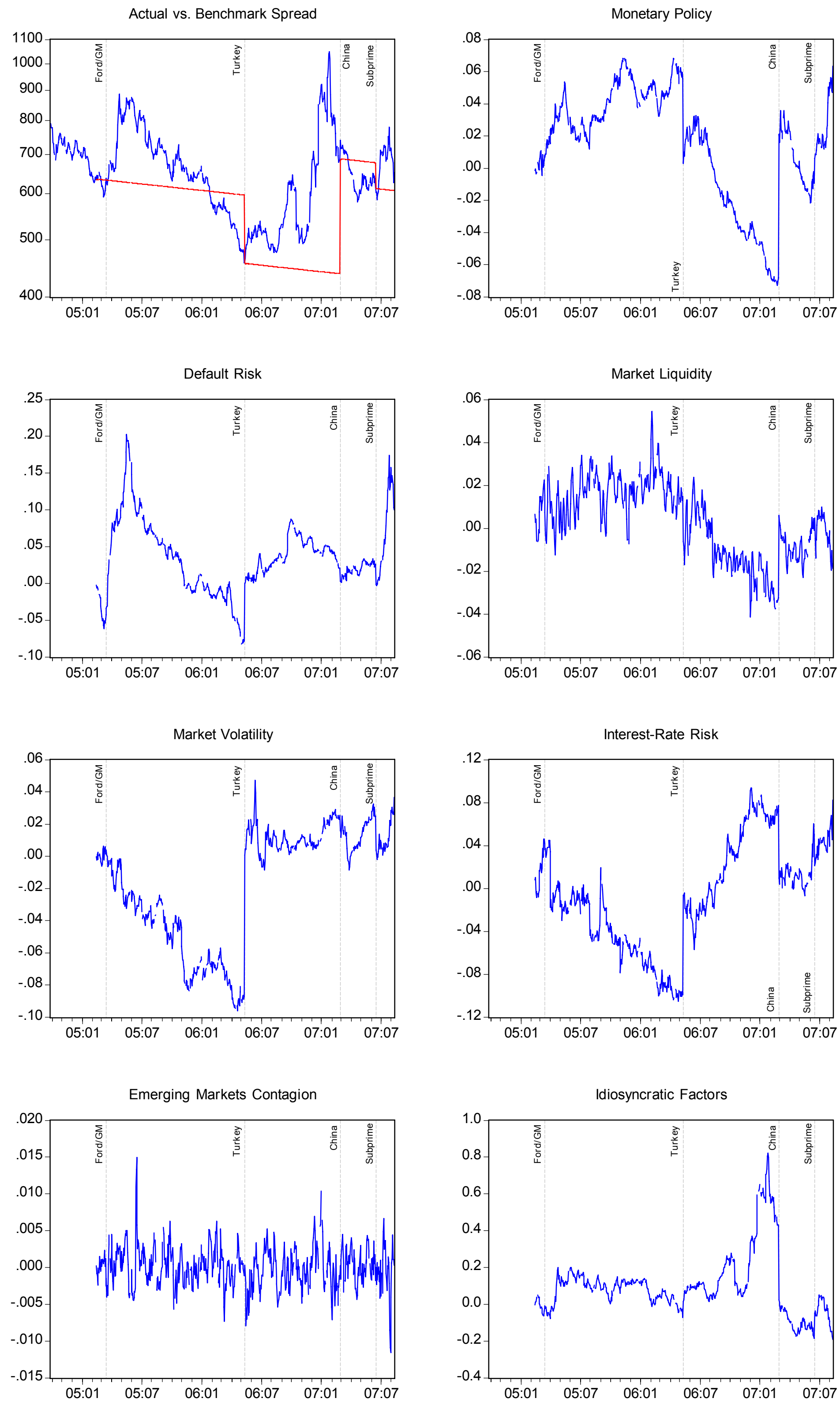


Figure 19: Spread Decomposition (2004-2007) - Mexico

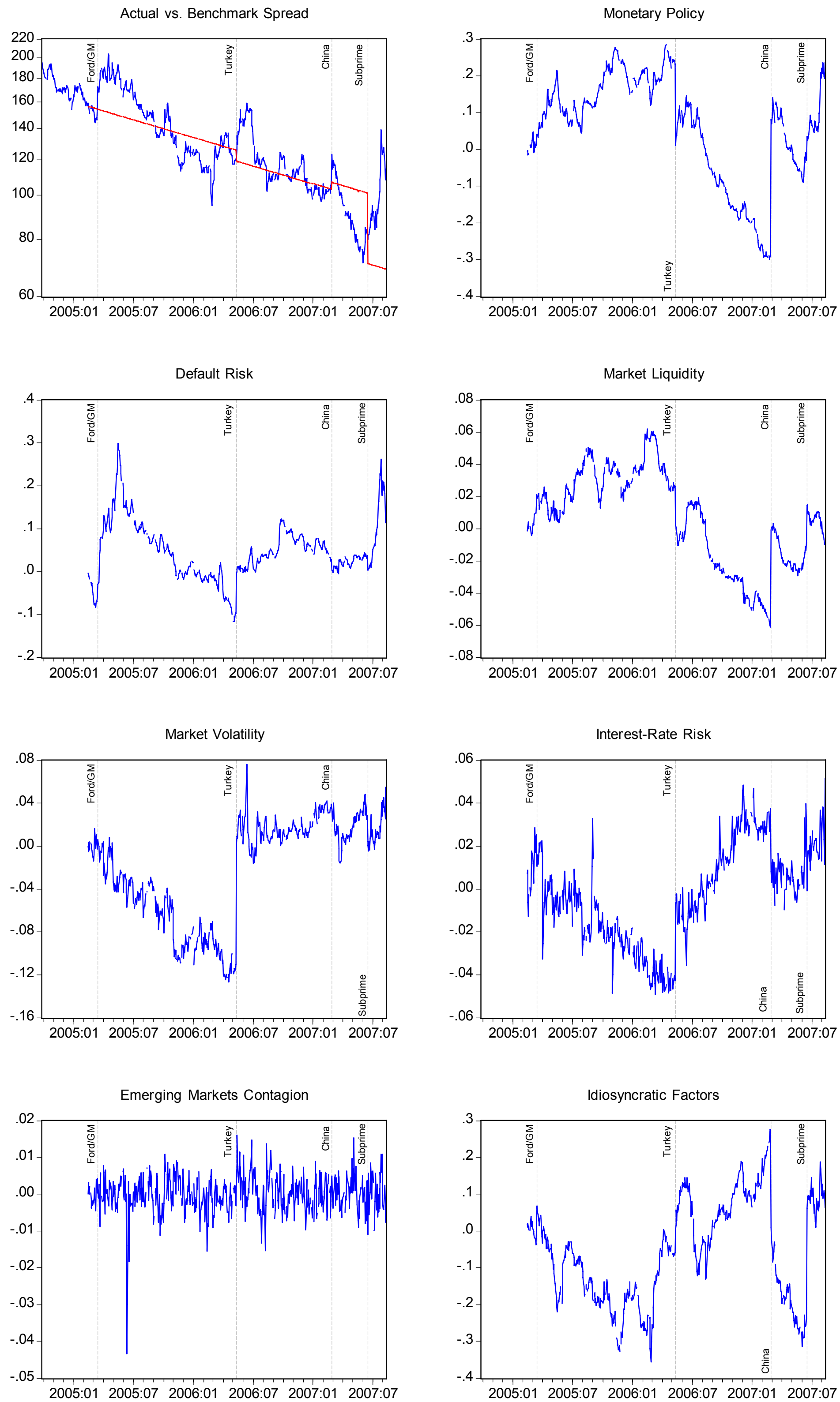


Figure 20: Spread Decomposition (2004-2007) - Panama

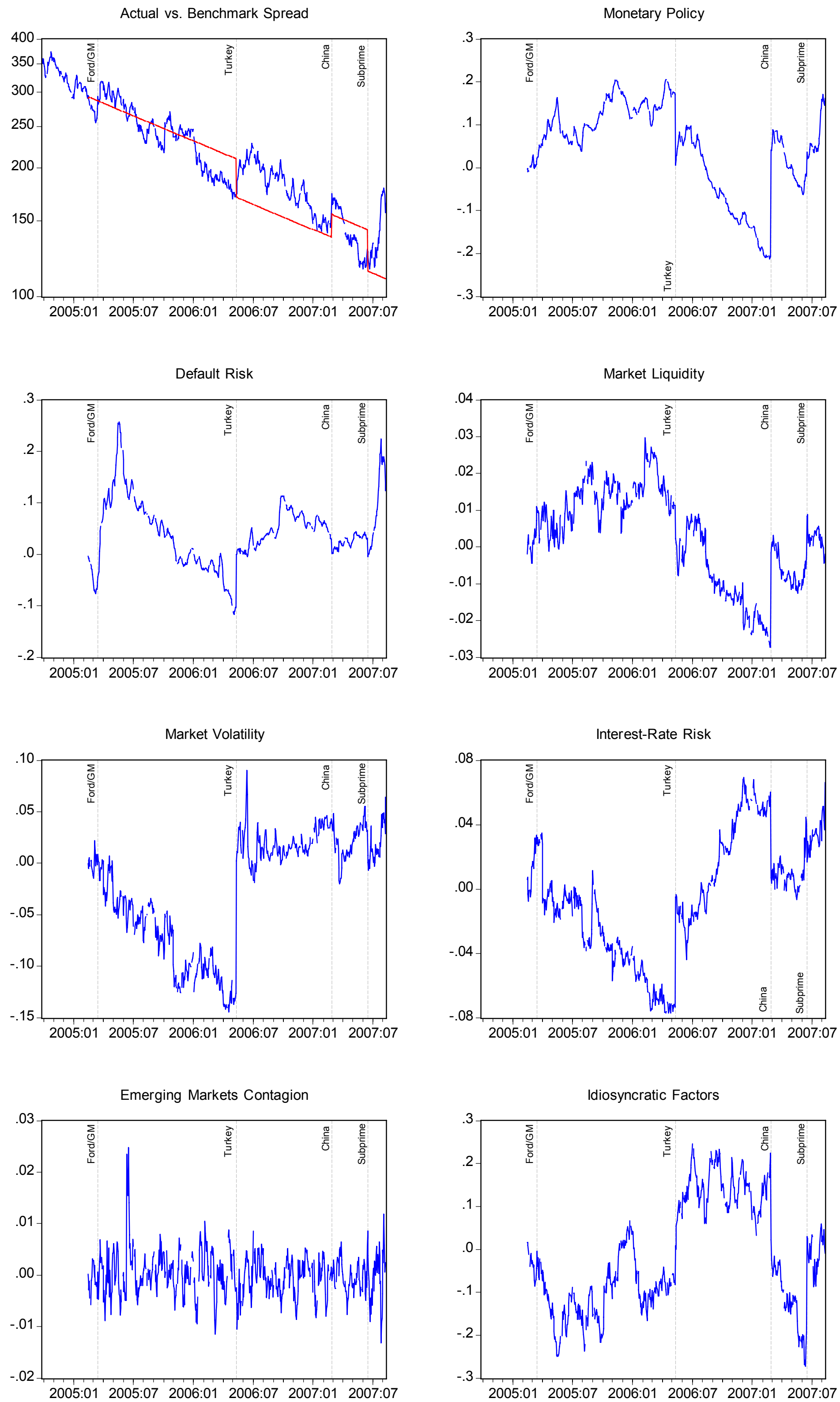


Figure 21: Spread Decomposition (2004-2007) - Peru

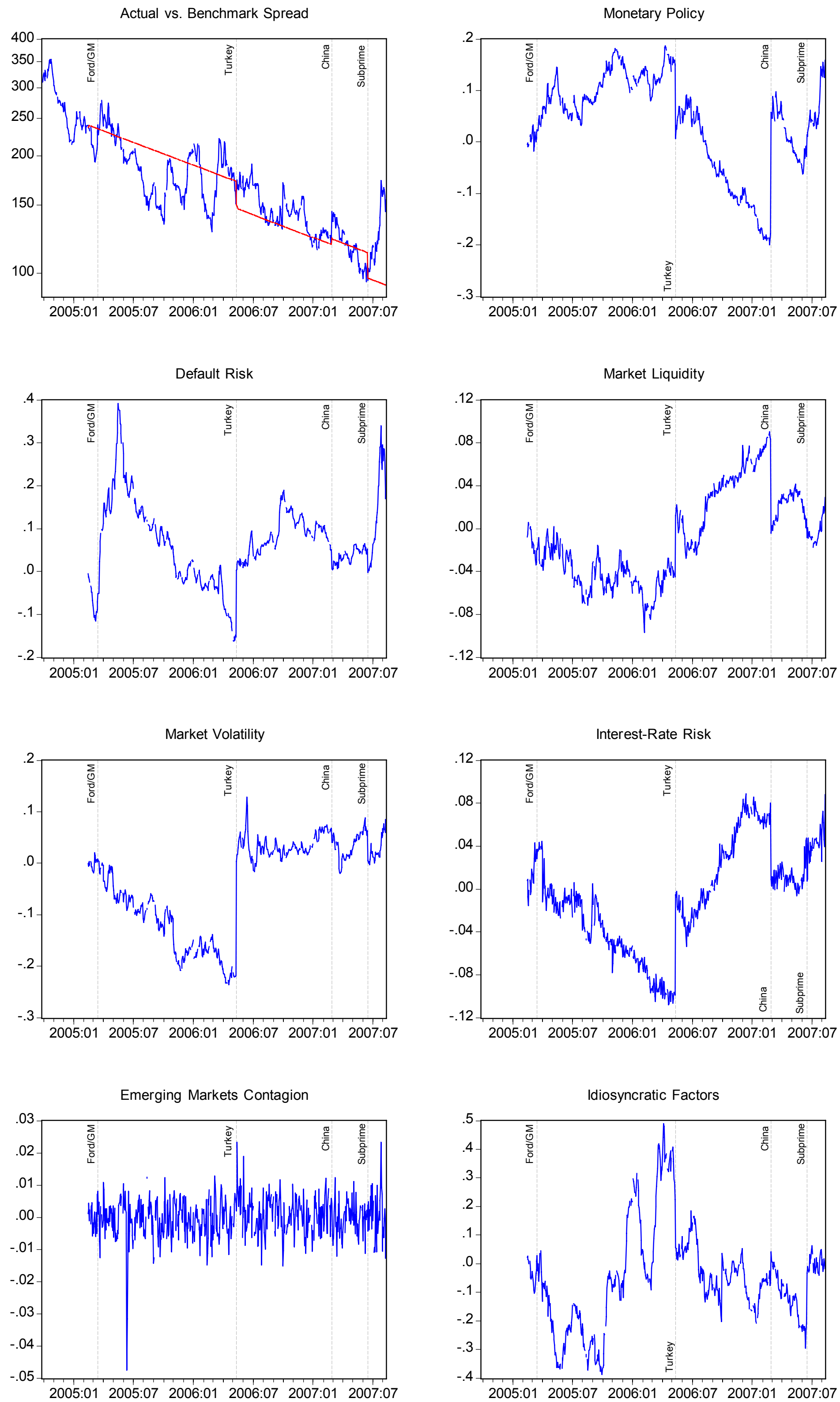


Figure 22: Spread Decomposition (2004-2007) - Philippines

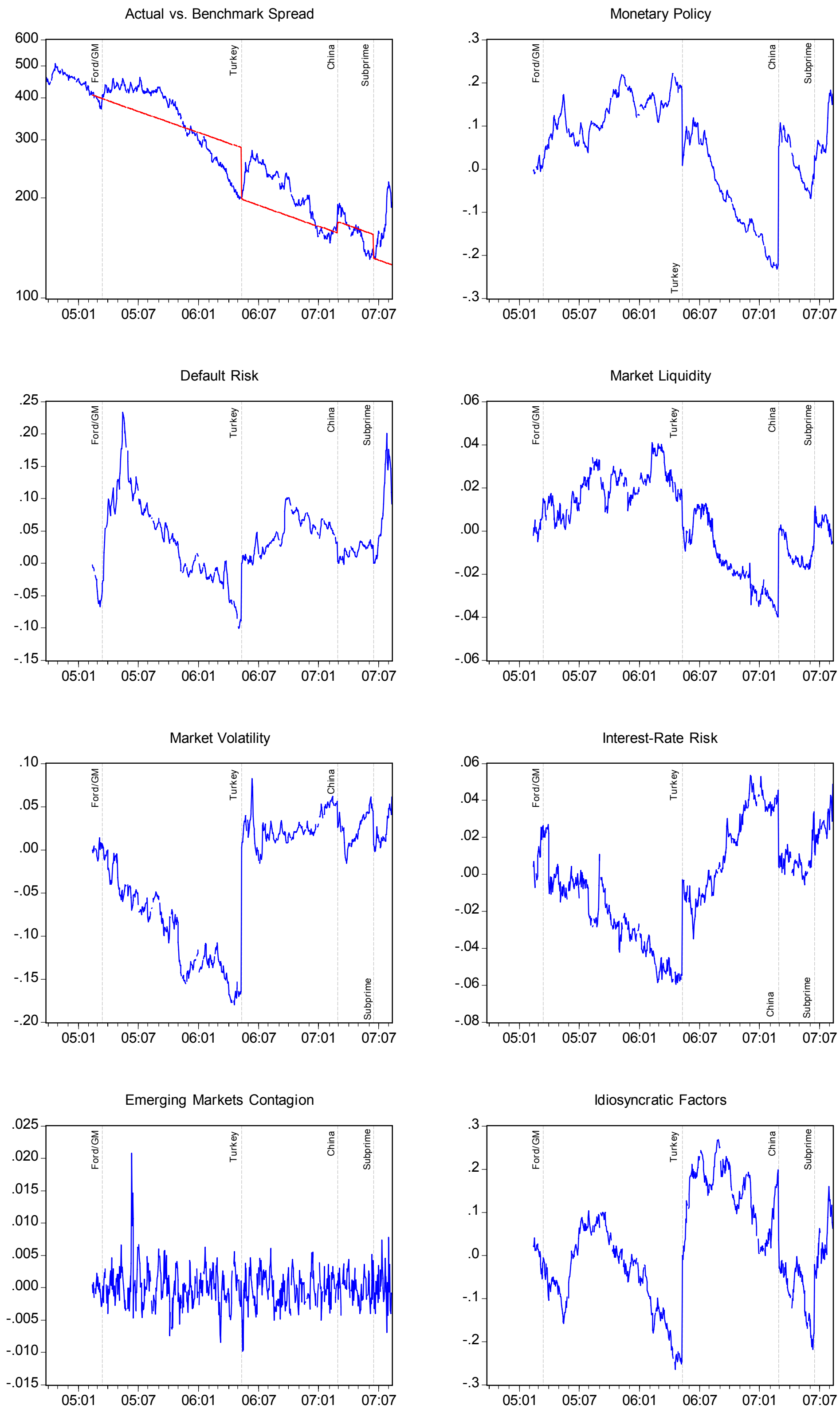


Figure 23: Spread Decomposition (2004-2007) - Russia

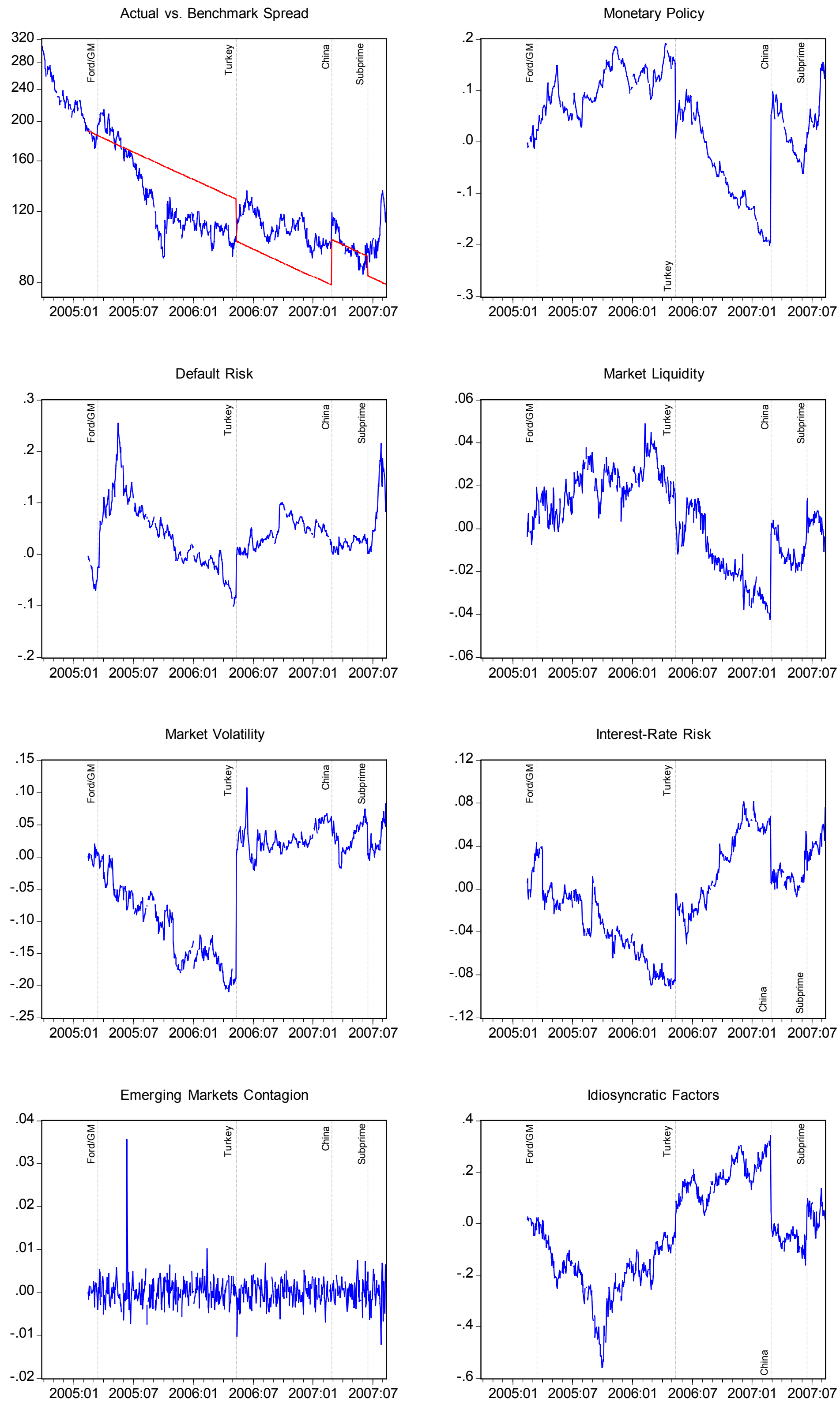


Figure 24: Spread Decomposition (2004-2007) - South Africa

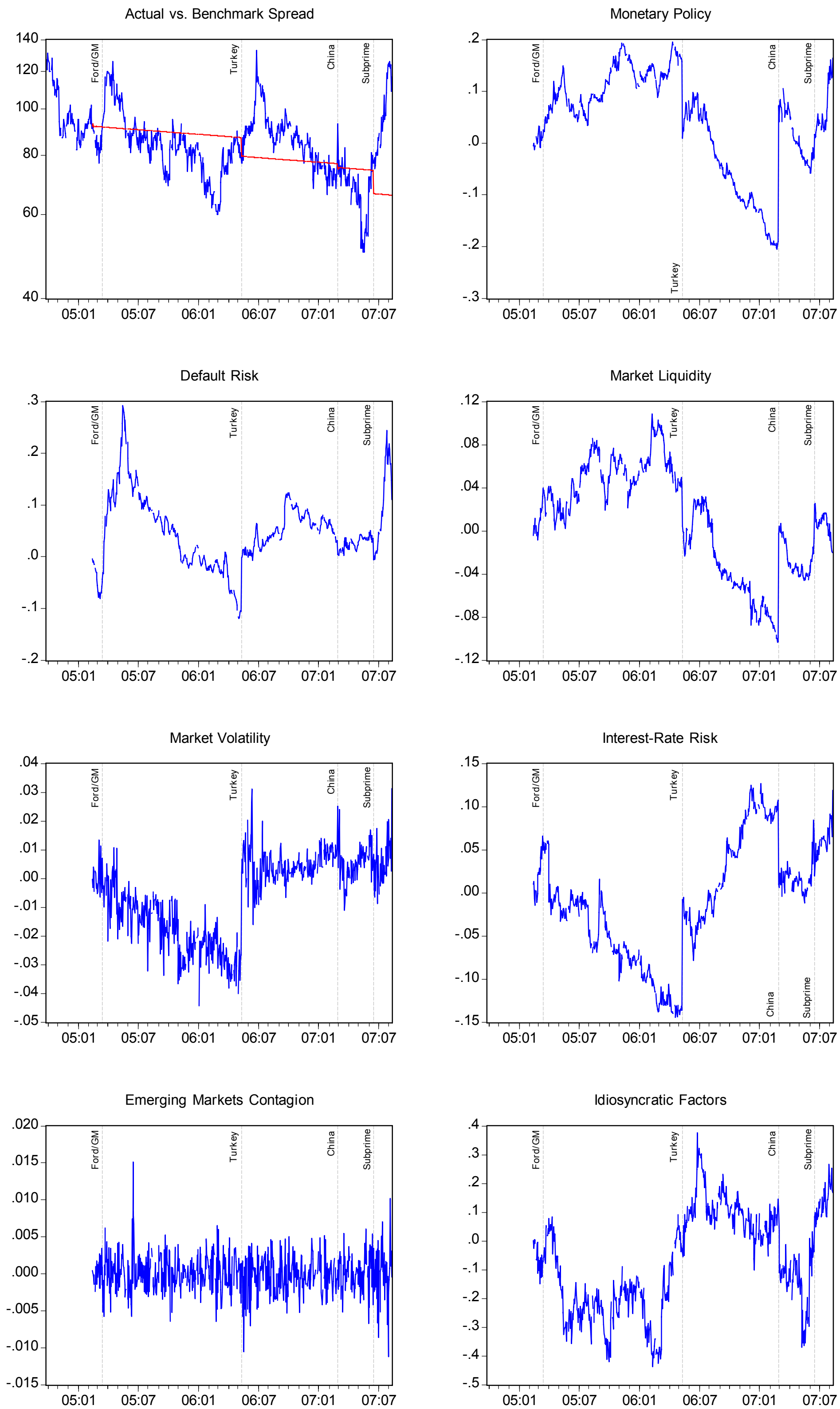


Figure 25: Spread Decomposition (2004-2007) - Turkey

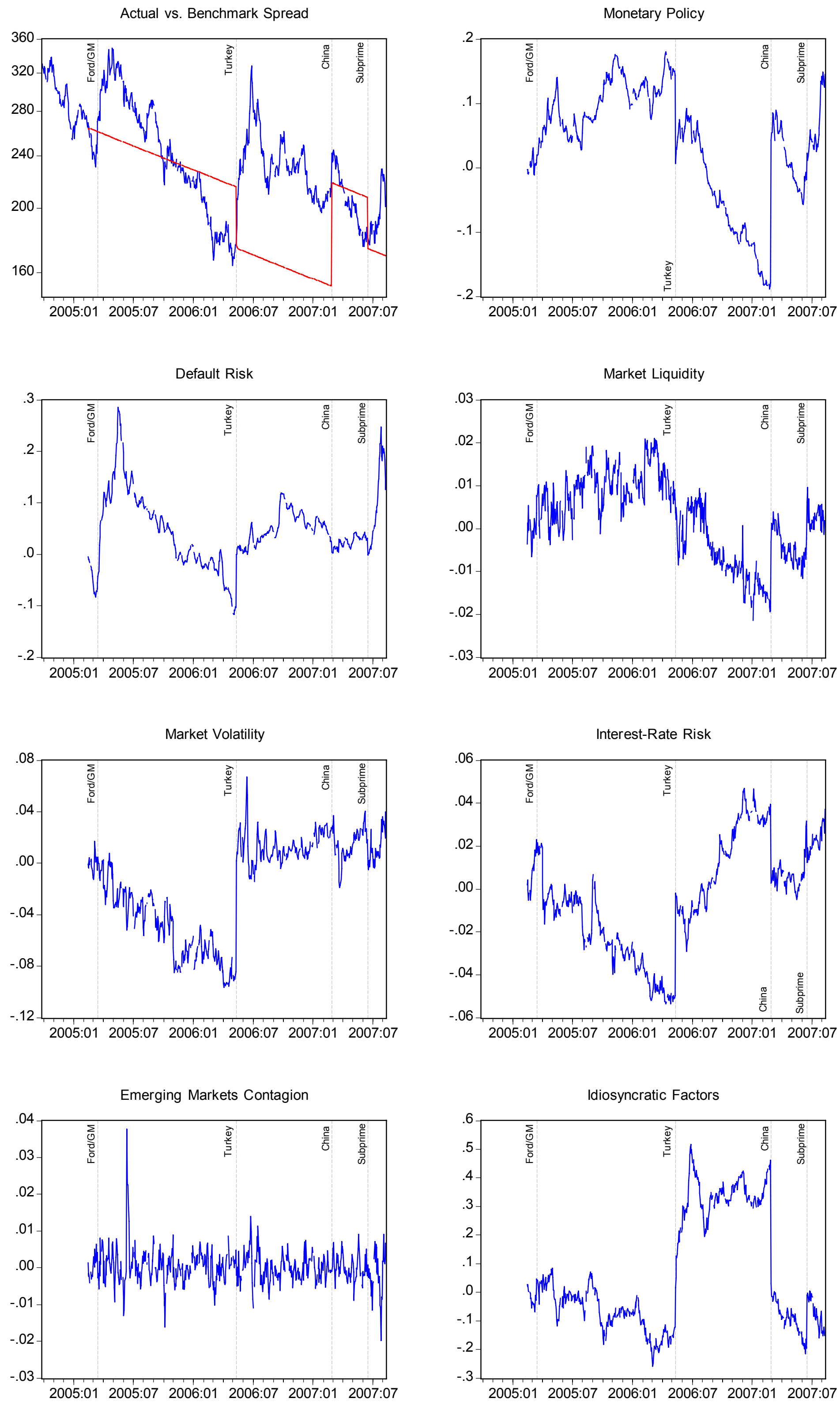


Figure 26: Spread Decomposition (2004-2007) - Ukraine

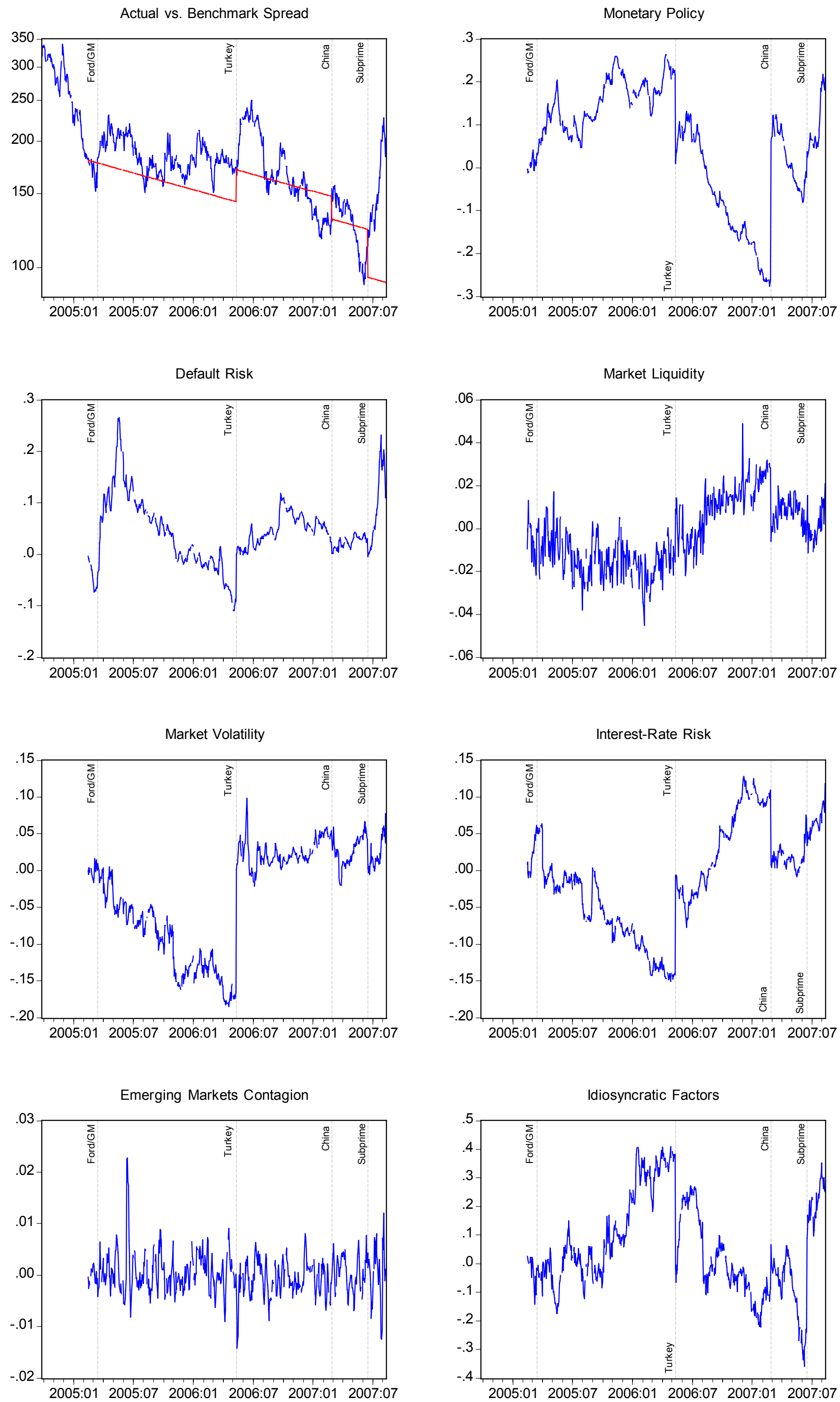


Figure 27: Spread Decomposition (2004-2007) - Venezuela

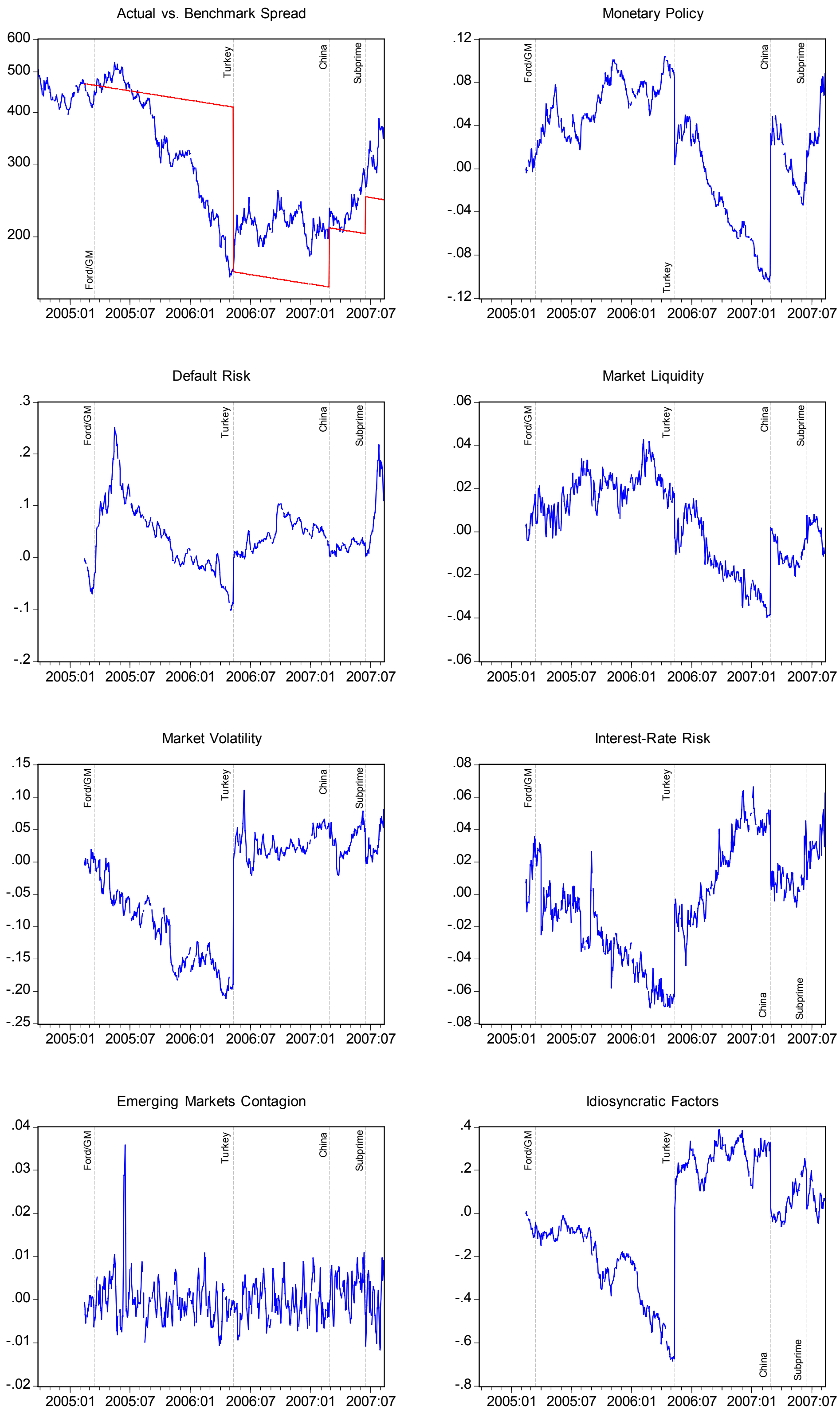


Figure 28: Spread Decomposition (2004-2007) - United States

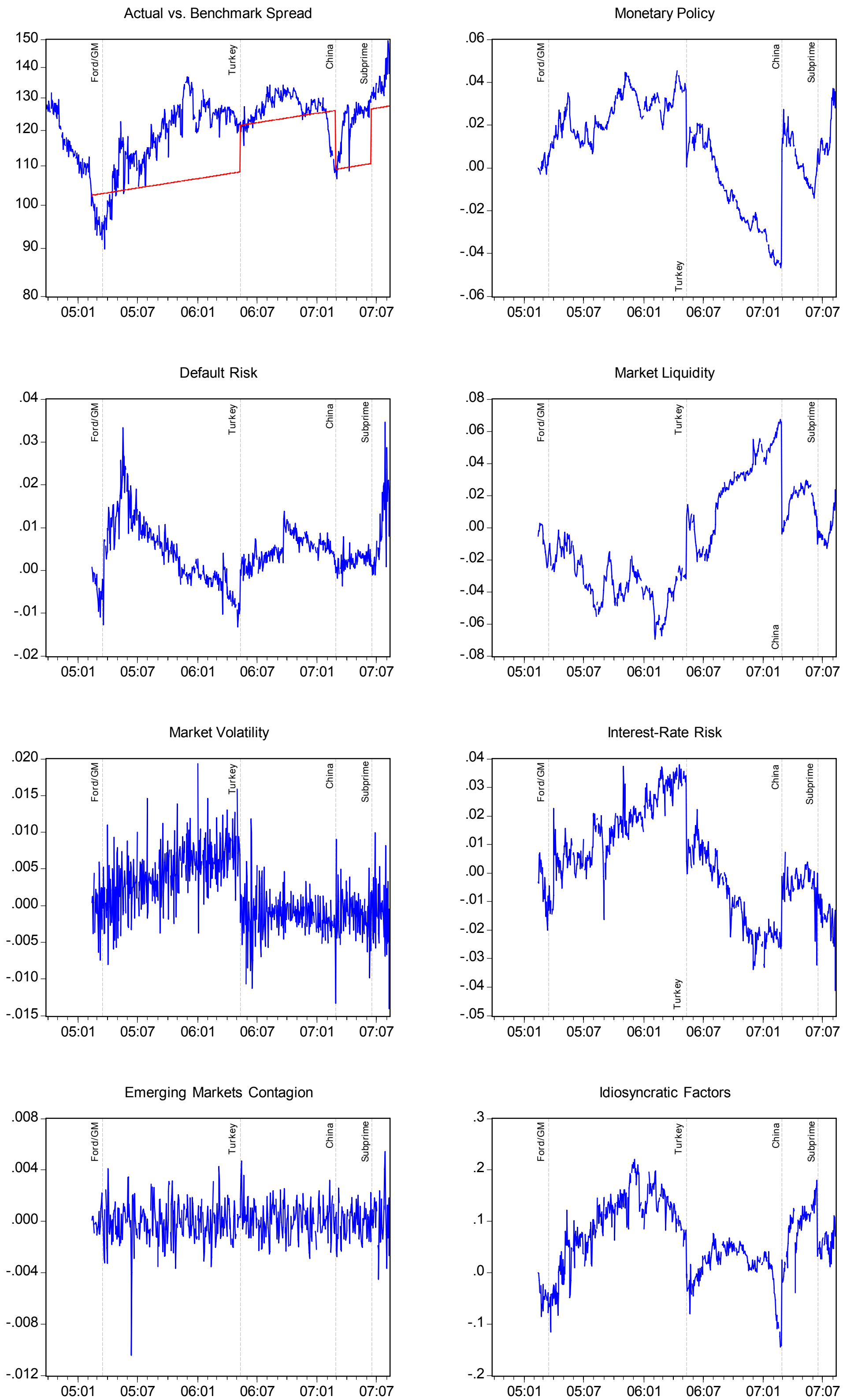


Figure 29: Spread Decomposition (2004-2007) - Canada

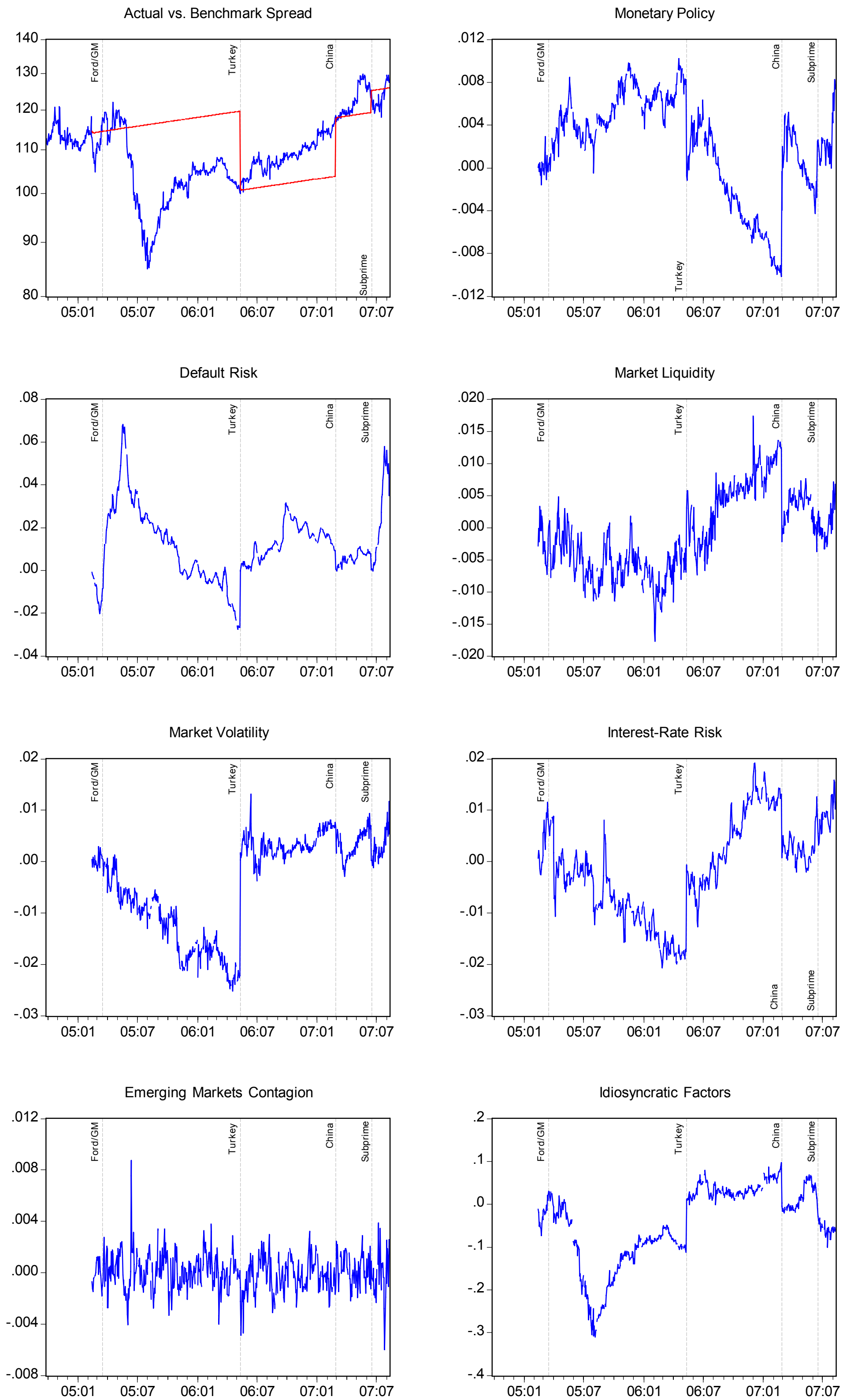


Figure 30: Spread Decomposition (2004-2007) - Japan

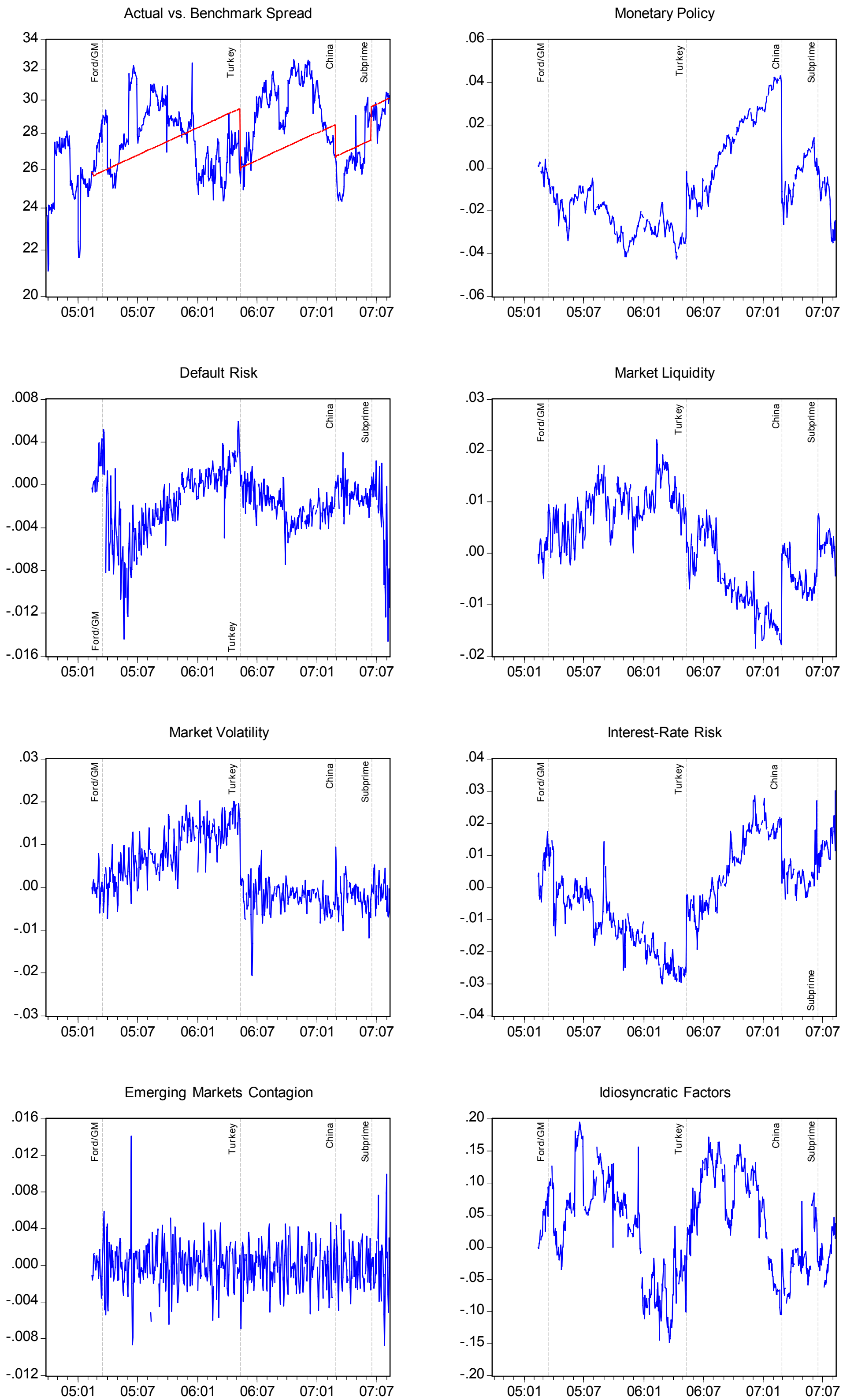
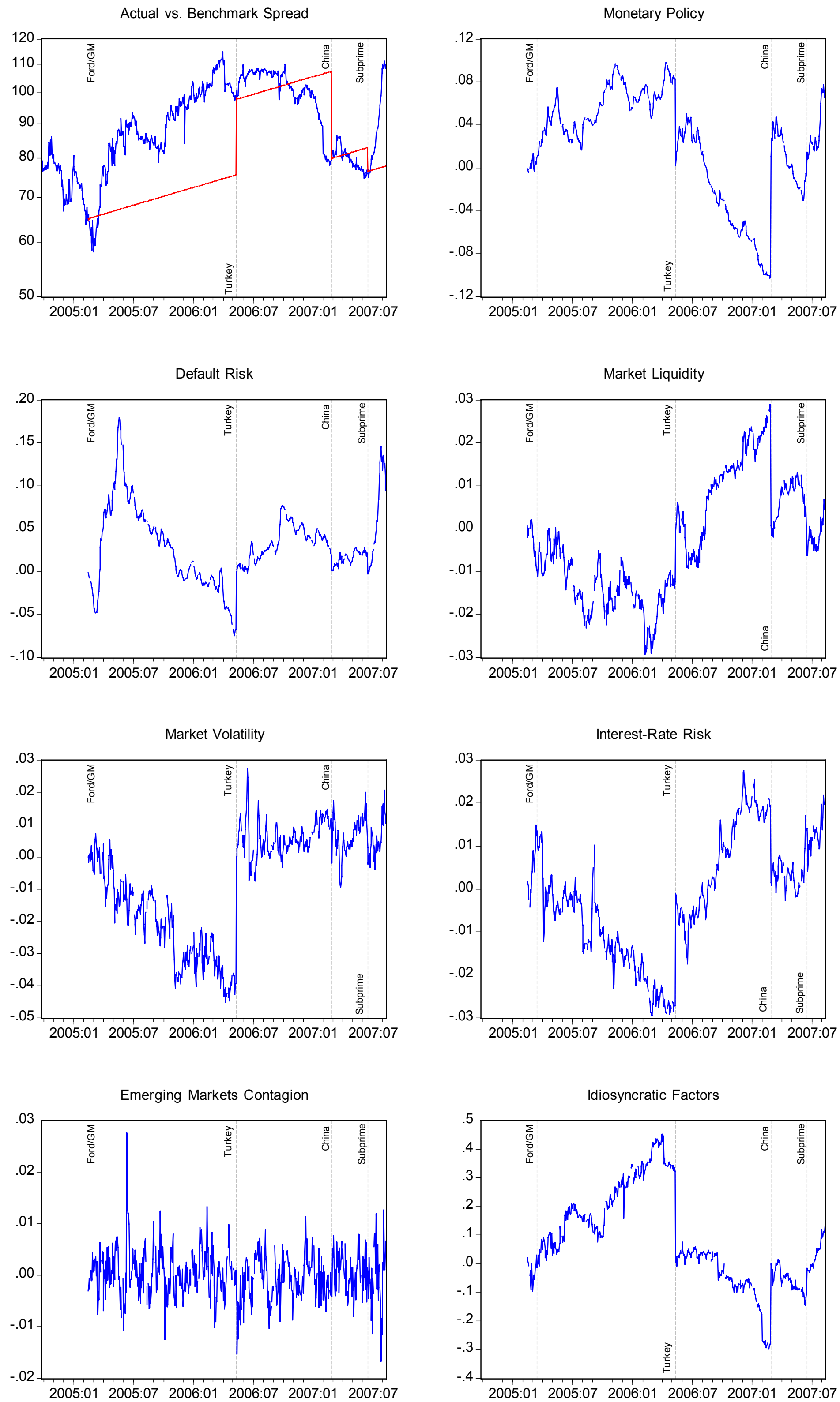


Figure 31: Spread Decomposition (2004-2007) – Eurozone



Chapter 7: Summary and Conclusions

1 Concluding Remarks and Future Research

This research examined the transmission of shocks across financial markets resulting from contagion and changes in investors risk appetite. As financial markets across the globe are increasingly becoming more integrated and intermingled in complex ways, contagion and global financial conditions more generally play a crucial role in the transmissions of shocks originated in a given market or country. Indeed, potentially systemic financial crises can be so costly that policy makers often intervene by bailing-out key financial institutions or relaxing monetary policy when there is a fear that contagion may spread financial crises.

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). These examples include countries with highly developed financial markets as well as a number of emerging markets.

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. These links are emphasized in third generation crisis models, where channels over and above the market fundamental mechanisms that link countries and asset markets during noncrisis periods appear during a crisis. These additional linkages are broadly known as contagion.

During much of the 1990s, several famous crises episodes shaped the policy in a number of emerging markets: from Latin America to Asia to Eastern Europe. The crises during 1998 were particularly important as Russia defaulted on its foreign debt obligations, while the shock was felt and propagated in mature economies. The near-collapse and bail-out of a highly leveraged hedged fund, Long-Term Capital Management (LTCM), was a key factor in spreading shocks globally during the fall of 1998. Although other episodes of financial distress occurred in subsequent years (notably the financial problems in Brazil during the first part of 1999 which appears to have been largely a result of contagion from the Russian and LTCM crises), financial crises have been fairly infrequent and largely contained within national borders since the Argentinean crisis in 2001. Some bouts of instability were evident during the spring and summer of 2006, when Iceland and Turkey faced a financial stress, and in late-February 2007 when China's Shanghai stock exchange experienced a significant correction. However, these recent episodes are generally viewed as seemingly idiosyncratic and relatively innocuous from the perspective of contagion in global financial markets. The vast academic literature that was sparked by the key episodes of financial crises in Latin America in 1994-1995, the Asian crisis in 1996, and the Russian crisis in 1998, has been fairly subdued in recent years as no major regional or global crisis has been evident in recent years. That is, until mid-2007 when a financial crises of apparent global proportions re-appeared, for the first time since late-1998.

The current setting following the U.S. subprime mortgage and liquidity crisis that began in mid-2007 has brought a renewed interest in financial crises. In the past, financial crises used to be thought as a characterization reserved for developing countries. Recent developments show that mature economies are not exempt. Furthermore, there is a new urgency in understanding the financial crises of the past so that the financial crises of the future can be anticipated and, hopefully, mitigated pre-emptively. Events during the second half of 2007 serve as a useful reminder that global financial crises are far from having become events from the past. Indeed, financial crises are far from being fully understood as crises often have different triggers and propagation mechanisms. Against this background, the research in this thesis attempts to address some of the key issues emerging from the key episodes of financial crises in the past decade.

This latest financial crisis was sparked by the softening in the U.S. housing market in recent years, and which led to a certain segment of the U.S. mortgage market deemed to be particularly risky because of the characteristics of the borrowers (e.g., self-employed, with limited income verification, etcetera), the "subprime" mortgages, defaulting in large numbers. What started as a seemingly idiosyncratic and market-specific crisis driven by problems in the subprime mortgage market in the United States during the spring and early summer of 2007, quickly led to defaults of financial institutions in other countries such as Germany, Canada, and the United Kingdom. The stress in financial markets was also felt in various measures of volatility and illiquidity in a number of global financial markets.

The policy interest in understanding financial crises is clear as contagion can play a key role in spreading globally what would have been otherwise, in the absence of contagion, contained idiosyncratic episodes of financial stress. Thus, contagion effects can lead to systemic financial crises. Indeed, the results in this thesis suggest that in the past decade there have been two episodes of significant contagion across markets and national boundaries: the Russian/Long-Term Capital Management (LTCM) crisis in 1998 and the 2007 U.S. subprime mortgage and liquidity crisis.

These two episodes during 1998 and 2007 were, in many respects, different. But in some respects they also shared some similarities. Thus, in 1998, the trigger was a default event as the Russian government became unable to service its sovereign bonds. The Russian economy had been affected by growing economic imbalances in the aftermath of the end of the communist rule in the early 1990s. Investors who had positioned themselves heavily in the Russian market by earning high returns, such as the hedge fund LTCM, faced resulting losses. This episode may not have been that different from previous periods of financial crises, such as Mexico in 1994 or Thailand in 1996, except for the fact that financial innovation had brought into the scene highly leveraged hedge funds with positions in different markets across the globe. Indeed, LTCM was one of the largest highly leveraged hedge funds that existed in 1998. The Russian shock led LTCM to rebalance its global portfolio in the aftermath of the initial default shock and, in a rush to rebuild capital-asset ratios, to deleverage its position elsewhere. The threat coming from the LTCM for the U.S. economy and the fear of "fire" asset sales were perceived to be so large that the U.S. New York Federal Reserve orchestrated the bail out of LTCM among a number of creditor banks. Furthermore, the U.S. Federal Reserve lowered interest rates quite aggressively in three steps during a period of a few weeks in an effort to stem what was perceived as the risk of a liquidity crunch in the aftermath of the unwinding of the leveraged financial positions by LTCM and possibly other financial institutions with similar exposures. There was intense contagion across global markets during those few weeks, but the policy reaction to inject liquidity made the episode be rapidly contained.

The U.S. subprime mortgage crisis during the first part of 2007 also began by a shock, this time by the realization that the housing market in the United States had become overvalued and a correction was impending. At first, during the spring of 2007, this shock was largely contained and largely reflected only financial instruments that had benefited from the hereto increase in property prices. But by mid-July 2007, there was a rush by credit rating agencies to re-evaluate the credit risk of various institutions and financial instruments, even those that up until then were assumed to be rated investment grade. As a result, it became clear that the shock was no longer contained within the riskiest sector of the mortgage market dubbed to be “subprime”. Indeed, at that point various financial institutions and banks began to reveal their losses resulting from bets on property values. Conduits established by banks as off-balance entities began to face funding liquidity pressures as their asset-backed-commercial paper (ABCP) programs began not to be rolled over by investors. This led to uncertainty about the risks in the overall financial system, leading to hoarding of liquid in the financial system. The monetary authorities in Europe, the United States and the United Kingdom intervened aggressively by providing liquidity to the financial markets beginning in August 9th 2007. The policy actions seemed to have modest success in reducing liquidity strains in the interbank market until a program of coordinated action among the three central banks was launched in mid-December 2007. Even so, global liquidity strains led to concerns about the solvency of many of the globally systematically important large complex financial institutions. These events were still unfolding at the time of the writing of this thesis. Many lessons are still to be gathered, but some can be already deduced after examining the various episodes of financial stress in modern times. This thesis is one attempt to do so.

The thesis begins by unifying the commonalities among what up until now seem to be “different” approaches in the empirical literature of contagion. This analysis and empirical survey is presented in Chapter 2. Typically, most references to contagion are made rather loosely, often failing to distinguish between normal asset-market linkages and the extreme co-movements that may exist only during periods of stress. In the empirical literature, existing research focuses primarily on the presence of contagion, while measuring the extent of contagion has received little attention. Furthermore, most studies focus on a single asset class across countries—often via some form of correlation analysis—despite our expectation that different asset markets, domestic or otherwise, are linked by a pool of global investors. This chapter clarifies the concepts and shows that some of the main strains in the literature are actually special cases of a more generally unifying framework.

The thesis then proceeds in Chapter 3 to examine contagion effects during the past decade in a number of episodes of financial stress first for the case of global bond markets. Novel in this approach is that emerging markets and mature economies are considered to be part of the global financial setting from which international investors transfer their assets. Most of the literature on contagion, and indeed on financial crises, has been devoted exclusively to emerging economies. In contrast, the approach in this thesis is to model global financial flows which have in common the fact that international investors are increasingly able to shift positions across the globe. In this chapter, it was found that contagion did exist during 1998 and that Brazil's financial crisis in early 1999 was likely the fallout of that contagion.

Chapter 4 then extends the analysis to global equity markets across a number of key emerging markets and mature economies. Again, the results seem to confirm similar findings.[1]

The subsequent chapters expand the data set to encompass the most recent episodes of financial stress, some of which were still ongoing at the time of writing. Thus, the Turkish crisis in the spring of 2006, the Chinese stock market meltdown in February 2007 and the U.S. supbrime mortgage and liquidity squeeze crisis that began in the summer of 2007 are also examined. In addition, Chapter 5 expands the analysis and it analyzes jointly bond *and* equity markets for a number of emerging markets *and* mature economies. The

[1] Versions of Chapters 2, 3 and 4 have been recently published in refereed economics journals. See Dungey, M., R. Renée Fry, B.González-Hermosillo, and V. Martin, (2005a, 2005b, 2006, 2007a).

analysis is based on daily data, comprising nearly a decade of observations (1998-2007) during which a number of modern financial crises occurred. The results confirm that the Russian/LTCM episode of financial stress in 1998 was associated with important contagious channels to other markets in the rest of the world. Moreover, it is found that the crises episodes after 1998 largely lacked this characteristic of spreading contagion across the world. However, contagious effects returned with vehemence during mid-2007 during the U.S. subprime mortgage and liquidity crisis. Both episodes of contagious effects (the fall of 1998 and mid-2007) occurred largely through bond markets and both of them involved stress in the financial markets of mature economies. This latter observation raises the possibility that the risk appetite of international investors, who are key players in major global financial centers, may play a role in the transmission of shocks across markets and countries.

In order to investigate this possibility formally, Chapter 6 empirically examines the role that international investors' risk appetite, through changes in global financial market conditions, may have played in transmitting shocks across markets during the various crises periods of the past decade. The data examined is daily, based on the bond spreads of sovereign bonds in developing countries and investment-grade bonds issued by BBB corporations in mature economies. Indeed, the results suggest that contagious effects are essentially no longer existent after controlling for the role of shifts in investors' risk appetite in response to changes in global financial market conditions. The results in Chapter 6 suggest that contagion essentially dissappears when identifying the actual channels of spillovers.

Some of the key conclusions that emerge from this research are the following: First, after examining the various episodes of financial stress across the past decade, it is found that the crises which generated the most contagion are the 1998 Russian/LTCM and the 2007 U.S. subprime crises, both of which began in credit markets and spread to stock markets. Second, once global financial market factors are explicitly considered as factors influencing investors' risk appetite, contagion from emerging markets is very small or essentially not existent. This finding appears to be at odds with some of the results in the empirical literature of contagion. The literature on contagion examines the links that exist over and above the market fundamental mechanisms that link countries and asset markets during noncrisis periods, which only appear during a crisis. However, the empirical literature on contagion does not in fact identify exactly how these additional channels are formed during periods of stress. One potential channel of contagion is that shocks in any given market may impact international investors' risk appetite through their rebalancing of portfolios or simply by a revised set of expectations. In effect, international investors' risk appetite appears to be a key channel producing contagion across global financial markets. Finally, this research shows that contagion can be important in transmitting shocks across markets and countries. In an increasingly integrated global financial market, contagion can affect both developing countries and mature economies. International investors' risk appetite can be an important conduit of that contagion.

In sum, this thesis develops an empirical methodology to examine financial market spillovers and quantifying the contribution of contagion during various critical episodes. As well, the role of international investors' risk appetite as a propagating mechanism for contagion is examined explicitly.

Recent events bring a renewed urgency for the need to understand the financial crises of the past, so that we can anticipate the crises of the future and perhaps be able to act pre-emptively to avoid the recurrence of systemic shocks sparked by contagion. Future research needs to examine further how liquidity shocks may transmit across markets and countries, particularly in the current context of complex financial instruments. Finally, the analysis in this thesis should be also helpful in elaborating a framework to assess global financial stability, another area for future research, as investors' risk appetite may play an important role in increasingly integrated global financial markets.

References

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

Bae, K.H, Karolyi, G.A. and Stulz, R.M. (2003), "A New Approach to Measuring Financial Contagion", *Review of Financial Studies*, 16(3), 717-763.

Baig, T. & Goldfajn, I. (2001). The Russian default and the contagion to Brazil. In S. Claessens & K. Forbes (Eds.), *International financial contagion* (pp. 267-300). Boston: Kluwer Academic Press.

Baig, T. and Goldfajn, I. (2000), "The Russian Default and the Contagion to Brazil", IMF Working Paper WP/00/160.

Baig, T. and Goldfajn, I. (1999), "Financial Market Contagion in the Asian Crisis." International Monetary Fund Staff Papers, June, *46*(2),167-195.

Barberis, N., Huang, M. and Santos, T. (2001), "Prospect Theory and Asset Prices", *Quarterly Journal of Economics*, Vol. 116, 1-53.

Bayoumi, T., Fazio, G. , Kumar, M. and MacDonald, R. (2003), "Fatal Attraction: A New Measure of Contagion", IMF Working Paper WP/03/80.

Bekaert, G. and Hodrick, R. (1992), "Characterizing Predictable Components in Excess Returns on Equity and Foreign Exchange Markets", *Journal of Finance*, 47, 467-510.

Bekaert, G., Harvey, C.R. and Ng, A. (2005), "Market Integration and Contagion", *Journal of Business*, 78, 39-69.

Blanchard, O., and Quah D. (1989), "The Dynamic Effects of Aggregate Demand and Supply Disturbances", *American Economic Review*, 79.

Bliss, R. and Panigirtzoglou, N. (2004), "Option-implied Risk Aversion Estimates", *Journal of Finance*, Vol. 59, 407-446.

Boyer, B.H., Gibson, M.S. and Loretan, M. (1999), "Pitfalls in Tests for Changes in Correlations", Federal Reserve Board, International Finance Division, Working Paper 597R.

Boyer, B.H., Kumagai, T. and Yuan, K. (2006)"How Do Crises Spread? Evidence from Accessible and Inaccessible Stock Indices", *Journal of Finance*, 61(2), 957-1004.

Butler, K.C. and Joaquin, D.C. (2002), "Are the Gains from International Portfolio Diversification Exaggerated? The Influence of Downside Risk in Bear Markets?", *Journal of International Money and Finance*, 21, 981-1011.

Calvo, G.A. and Mendoza, E.G. (2000). "Rational Contagion and the Globalization of Securities Markets." *Journal of International Economics*, *51*(1), 79-113.

Caporale, G.M., Cipollini A. and Spagnolo, N. (2002), "Testing for Contagion: A Conditional Correlation Analysis", Discussion Paper No. 01-2002 Centre for Monetary and Financial Economics, South Bank University.

Chernov, M.E., Gallant, R.A., Ghysels, E. and Tauchen, G. (2003), "Alternative Models for Stock Price Dynamics", *Journal of Econometrics*, 116, 225-257.

Chue, T.K. (2002), "Time Varying Risk Preferences and Emerging Market Covariances", *Journal of International Money and Finance*, 21, 1053-1072.

Cifarelli, G. and Paladino, G. (2004), "The Impact of the Argentine Default on Volatility Co-Movements in Emerging Bond Markets", *Emerging Markets Review*, 5, 427-446.

Cizeau, P., Potters, M. and Bouchard, J. (2001), "Correlation Structure of Extreme Stock Returns", *Quantitative Finance*, 1(2), 217-222.

Cochrane, J. (2001), *Asset Pricing*, Princeton University Press, Princeton NJ.

Committee on the Global Financial System (1999), Bank for International Settlements. *A Review of Financial Market Events in Autumn 1998.* Basel, Switzerland, October.

Corsetti, G., Pericoli, M. and Sbracia, M. (2003), "Some Contagion, Some Interdependence": More Pitfalls in Testing for Contagion", mimeo University of Rome III.

Corsetti, G., Pericoli, M. and Sbracia, M. (2001), "Correlation Analysis of Financial Contagion: What One Should Know Before Running A Test", mimeo University of Rome III.

Coudert, V., and M. Gex (2007), "Does Risk Aversion Drive Financial Crises? Testing the Predictive Power of Empirical Indicators", Centre d'Etudes Prospectives et d'Informations Internationales, Working Paper No. 2007 – 02.

Craine, R. and Martin, V.L. (2007), "International Monetary Policy Surprise Spillovers", *Journal of International Economics*.

Del Torre, A., Levy Yeyati, E. and Schmulker, S. (2003), "Living and Dying with Hard Pegs: The Rise and Fall of Argentina's Currency Board", *Economia*, Spring 2003, 43-107.

Diebold, F.X. and Nerlove, M. (1989), "The Dynamics of Exchange Rate Volatility: A Multivariate Latent-Factor ARCH Model", *Journal of Applied Econometrics*, 4, 1-22.

Dooley, M.P. (2000), “A Model of Crises in Emerging Markets.” *Economic Journal*, 256-272.

Dornbusch, R., Park, Y.C. and Claessens, S. (2000), "Contagion: Understanding How It Spreads", *The World Bank Research Observer*, 15(2), 177-97.

Duffie, D. and Singleton, K. (1993), “Simulated Moments Estimator of Markov Models of Asset Prices.” *Econometrica*, July, *61*(4), 929-962.

Dumas, B. and Solnik, B. (1995), "The World Price of Foreign Exchange Risk", *Journal of Finance*, 50, 445-479.

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

Dungey, M., R. Fry, González-Hermosillo, B. and V.L. Martin (2007a), "Contagion in Global Equity Markets in 1998: The Effects of the Russian and LTCM Crises", *North American Journal of Economics and Finance*, 18, 155-174.

Dungey, M., Fry, R., González-Hermosillo, B., V.L. Martin, and C. Tang (2007b), "Are Financial Crises Alike?–From the 1998 Russian/LTCM Crisis to the 2007 Subprime Debacle and Liquidity Crisis”, manuscript, International Monetary Fund, October.

Dungey, M., Fry, R., González-Hermosillo, B. and Martin, V.L. (2006), "Contagion in International Bond Markets During the Russian and LTCM Crises", *Journal of Financial Stability*, 2, 1-27.

Dungey, M., Fry, R., González-Hermosillo, B. and Martin, V.L. (2005a),"A Comparison of Alternative Tests of Contagion with Applications", in Dungey, M. and Tambakis, D. (eds), *Identifying International Financial Contagion: Progress and Challenges*, Oxford University Press.

Dungey, M., Fry, R., González-Hermosillo, B. and Martin, V.L. (2005b), "Empirical Modelling of Contagion: A Review of Methodologies", *Quantitative Finance*, 5, 9-24.

Dungey, M., Fry, R., González-Hermosillo, B. and Martin, V.L. (2004), "A Monte Carlo Analysis of Alternative Tests of Contagion", mimeo, Australian National University.

Dungey, M., Fry, R., González-Hermosillo, B. and V. Martin (2003a), "Characterizing Global Investors' Risk Appetite for Emerging Market Debt during Financial Crises", IMF Working Paper 03/251.

Dungey, M., Fry, R., González-Hermosillo, B. and Martin, V.L. (2003b), "Unanticipated Shocks and Systemic Influences: The Impact of Contagion in Global Equity Markets in 1998", IMF Working Paper WP/03/84.

Dungey, M., Fry, R., González-Hermosillo, B. and Martin, V.L. (2002a), "The Transmission of Contagion in Developed and Developing International Bond Markets", in Committee on the Global Financial System (ed), *Risk Measurement and Systemic Risk*, Proceedings of the Third Joint Central Bank Research Conference, 61-74.

Dungey, M., Fry, R., González-Hermosillo, B. and Martin, V.L. (2002b) "International Contagion Effects from the Russian Crisis and the LTCM Near Collapse." International Monetary Fund Working Paper WP/02/74, April 2002.

Dungey, M. and Martin, V.L. (2007), "Unravelling Financial Market Linkages During Crises", *Journal of Applied Econometrics*, 22 (1), 89-119.

Dungey, M. and Martin, V.L. (2004), "A Multifactor Model of Exchange Rates with Unanticipated Shocks: Measuring Contagion in the East Asian Currency Crisis", *Journal of Emerging Markets Finance*, 3, 305-330.

Dungey, M., Fry, R., and Martin, V.L. (2003), "Equity Transmission Mechanisms from Asia to Australia: Interdependence or Contagion?", *Australian Journal of Management*, 28(2), 157-182.

Dungey, M. and Martin, V.L. (2001), "Contagion Across Financial Markets: An Empirical Assessment", New York Stock Exchange Conference Paper, February 16-17, 2001, Hawaii.

Dungey, M., Martin V.L., and Pagan A.R. (2000), "A Multivariate Latent Factor Decomposition of International Bond Yield Spreads", *Journal of Applied Econometrics*, 15(6), 697-715.

Durbin, J.M. (1954), "Errors in Variables", *Review of the International Statistical Institute*, 22, 23-32.

Edwards, S. (2000), "Interest Rates, Contagion and Capital Controls." National Bureau of Economic Research (Cambridge, MA) Working Paper No. 7801, July.

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

Eichengreen, B., A.K. Rose and C. Wyplosz (1996), "Contagious Currency Crises", NBER Working Paper 5681.

Eichengreen, B., A.K. Rose and C. Wyplosz (1995), "Exchange Market Mayhem: The Antecedents and Aftermath of Speculative Attacks", *Economic Policy*, 21, 249-312.

Ellis, L. and Lewis, E. (2000), "The Response of Financial Markets in Australia and New Zealand to News about the Asian Crisis", BIS Conference on International Financial Markets and the Implications for Monetary and Financial Stability, Basle, 25-26 October, 1999, Vol. 8.

EMTA Survey (2007), "Emerging Markets Debt Trading", August.

Engle R.F., T. Ito and W. Lin (1990), "Meteor Showers or Heat Waves? Heteroskedastic Intra-Daily Volatility in the Foreign Exchange Market", *Econometrica*, 58, 525-42.

Engle, R.F. and Kroner, K.F. (1995),"Multivariate Simultaneous Generalized ARCH", *Econometric Theory*, 11(1), 122-50.

European Central Bank (2007), *Financial Stability Review*, Section D: Measuring Investors' Risk Appetite, June.

Favero, C.A. and Giavazzi, F. (2002), "Is the International Propagation of Financial Shocks Non-linear? Evidence from the ERM", *Journal of International Economics*, 57(1), 231-46.

Financial Times (2007), various issues (9/26/07 and 10/26/07).

Fiorentini, G., Sentana, E. and Shephard, N. (2004), "Likelihood-Based Estimation of Latent Generalized Arch Structures", *Econometrica*, September, *72*(5), 1481-1517.

Fitch Ratings (2007), *Russian Federation Special Report- Premium*, October.

Fitch Ratings (2007),"Russian Bank Liquidity: CBR Support is Positive, but More May be Needed", October.

Flood, R. and Marion, N. (1998), "Perspectives on the Recent Currency Crisis Literature", NBER Working Paper #6380.

Flood, R. and Marion, N. (1999), "Perspectives on the Recent Currency Crisis Literature", *International Journal of Finance and Economics*, 4, 1-26.

Flood, R. and Rose, A.K. (2005), "Equity Integration in Times of Crisis", *Market Discipline*.

Forbes, K. and Rigobon, R. (2001), "Measuring Contagion, Conceptual and Empirical Issues." In Claessens, S. and Forbes, K. (eds.), *International Financial Contagion*, Kluwer Academic Publishers.

Forbes, K. and Rigobon, R. (2002), "No Contagion, Only Interdependence: Measuring Stock Market Co-movements", *Journal of Finance*, 57(5), 2223-61.

Frank, N., B. González-Hermosillo, and Hesse H. (2008), "Global Transmission of Liquidity Shocks: Evidence from the 2007 Subprime Crisis," manuscript, International Monetary Fund.

Gai, P. and N. Vause (2005), "Measuring Investors' Risk Appetite", Bank of England Working Paper 283.

Gallant, A.R. and Tauchen, G. (1996), "Which Moments to Match?" *Econometric Theory*, October, *12* (4), 657-681.

Glick, R. and Rose, A.K. (1999), "Contagion and Trade: Why are Currency Crises Regional?", *Journal of International Money and Finance*, 18(4), 603-17.

Goldstein, M. (1998), "The Asian Financial Crisis: Causes, Cures and Systemic Implications." *Policy Analysis in International Economics*, 55, Institute for International Economics, Washington D.C., June.

Goldstein, M., Kaminsky, G.L. and Reinhart, C.M. (2000), "Assessing Financial Vulnerability: An Early Warning System for Emerging Markets." Institute for International Economics, Washington D.C., 2000.

González-Hermosillo, B. (2007a), "Spillovers and Contagion in International Capital Markets", *The IMF Institute Courier*, Washington D.C., Vol. 13.

González-Hermosillo, B. (2007b), "Investors' Risk Appetite and Global Financial Market Conditions," International Monetary Fund Working Paper, WP/08/85.

González-Hermosillo, B. and J. Li (2008), "A Banking Firm Model: The Role of Market, Liquidity and Credit Risks", in *Computational Methods in Financial Engineering,* E.J. Konotghiorghes, B. Rustem and P. Winker (eds.), (Springer, Heidelberg).

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

Gourieroux, C. and Monfort, A. (1994), "Simulation Based Econometric Methods" CORE Discussion Paper.

Gourieroux, C., Monfort, A., and Renault, E. (1993), “Indirect Inference.” *Journal of Applied Econometrics*, December, *8*, S85-S118.

Granger, C., B. Huang and C. Yang (2000) "A Bivariate Causality Between Stock Prices and Exchange Rates: Evidence from Recent Asian Flu", *The Quarterly Review of Economics and Finance*, 40, 337-354.

Greenspan, A. (1999). Risk, Liquidity and the Economic Outlook. *Business Economics*, January, 20–24.

Gregory, A.W. and Watts, D.G. (1995), “Sources of Variation in International Real Interest Rates.” *Canadian Journal of Economics*, November, *28*, S120-S140.

Grubel, H.G. and Fadner R. (1971), "The Interdependence of International Equity Markets", *Journal of Finance*, 26, 89-94.

Hamilton, J (1994). *Time series analysis.* Princeton, New Jersey: Princeton University Press.

Hartmann, P., Straetmans, S. & de Vries, C.G. (2004). Asset market linkages in crisis periods. *Review of Economics and Statistics*, 86 (1), 313-326.

Hernandéz, L. & Valdés, R. (2001). What drives contagion: trade, neighborhood, or financial links? *International Review of Financial Analysis*, 10 (3), 203-218.

International Monetary Fund (2007), *Global Financial Stability Report*, October.

International Monetary Fund (2005), *Global Markets Monitor*, Global Markets Analysis Division, Monetary and Capital Markets Department, Friday May 27 2005.

International Monetary Fund (2001), “Assessing the Determinants and Prospects for the Pace of Market Access by Countries Emerging from Crises - Country Cases.” International Monetary Fund, September 13, 2001.

J.P. Morgan (2004), “Emerging Markets Bond Index Plus (EMBI+) Rules and Methodology”, December.

Jeanne, O. and Masson, P. (2000), "Currency Crises, Sunspots and Markov-Switching Regimes", *Journal of International Economics*, 50(2), 327-50.

Jorion, P. (2000). Risk management lessons from long-term capital management. *European Financial Management*, 6 (3), 277-300.

Kaminsky, G.L. (2006), "Currency Crises: Are They All the Same?", *Journal of International Money and Finance*, 25, 503-527.

Kaminsky, G.L., and Reinhart, C.M. (2003), "The Center and the Periphery: The Globalization of Financial Turmoil", NBER Working Paper 9479.

Kaminsky, G.L. and Reinhart, C.M. (2001), "Financial Markets in Times of Stress", NBER Working Paper 8569.

Kaminsky, G.L. and Reinhart, C.M. (2000), "On Crises, Contagion and Confusion", *Journal of International Economics*, 51(1), 145-168.

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

Karolyi, A. and Stulz, R. (1996), "Why Do Markets Move Together? An Investigation of U.S.-Japan Stock Return Comovements", *Journal of Finance*, 51(3), 951-986.

Kashiwase, K., and L. Kodres (2005), “Emerging Market Spread Compression: Is it Real or is it Liquidity?”, manuscript, International Monetary Fund.

Kendall, M. and Stuart, A. (1969), The Advanced Theory of Statistics, Vol.1, Charles Griffin and Co., London.

Kendall, M. and Stuart, A. (1973), The Advanced Theory of Statistics, Vol.2, Charles Griffin and Co., London.

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

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

King, M., Sentana, E. & Wadhwani, S. (1994). Volatility and links between national stock markets. *Econometrica*, 62 (4), 901-933.

Kiyotaki, N. and Moore, J. (2002), "Balance-Sheet Contagion", *American Economic Review Papers and Proceedings*, 92(2), 46-50.

Kodres, L.E. and Pritsker, M. (2002), "A Rational Expectations Model of Financial Contagion", *Journal of Finance*, 57(2), 768-99.

Kose, Ayhan M., Otrok C., and Whiteman C. H. (2003), “International Business Cycles: World, Region and Country-Specific Factors.” *American Economic Review,* September, 93 (4), 1216-39.

Krueger, A. (2002), “Crisis Prevention and Resolution: Lessons from Argentina”, Conference on “The Argentina Crisis”, Cambridge, July. Accessed at http://www.imf.org/external/np/speeches/2002/071702.htm.

Kruger, M., Osakwe, P.N. and Page, J. (1998), “Fundamentals, Contagion and Currency Crises: An Empirical Analysis.” Bank of Canada (Ottawa, Ontario) Working Paper No. 98-10, July.

Krugman, P. (1998), “What Happened to Asia?” Mimeo, Massachusetts Institute of Technology.

Kumar, M. & Persaud, A. (2002). Pure Contagion and Investors' Shifting Risk Appetite: Analytical Issues and Empirical Eevidence. *International Finance*, 5 (3), 401-436.

Kyle, A. and Xiong W. (2001), "Contagion As a Wealth Effect", *Journal of Finance*, 56(4), 1401-40.

Liu, J., F. Longstaff, and R. Mandell (2006), “The Market Price of Risk in Interest Rate Swaps: The Roles of Default and Liquidity Risks”, *Journal of Business*, Vol. 79, No. 5.

Loisel, O. and Martin, P. (2001), “Coordination, Cooperation, Contagion and Currency Crises.” *Journal of International Economics*, April, *53*(2), 399-419.

Longin, F. and Solnik, B. (1995), "Is the Correlation in International Equity Returns Constant: 1960-1990?, *Journal of International Money and Finance*, 14(1), 3-26.

Loretan, M. and English, W. (2000), "Evaluating "Correlation Breakdowns" During Periods of Market Volatility", Board of Governors of the Federal Reserve System, International Finance Discussion Paper No. 658.

Lowell, J., Neu, C.R. and Tong, D. (1998), “Financial Crises and Contagion in Emerging Market Countries.” RAND, MR-962.

Lowenstein, R. (2001). *When genius failed: the rise and fall of long-term capital management*. London: Fourth Estate.

Mahieu, R. and Schotman, P. (1994), "Neglected Common Factors in Exchange Rate Volatility", *Journal of Empirical Finance*, 1, 279-311.

Malliaroupulos, D. (1997), "A Multivariate GARCH Model of Risk Premia in Foreign Exchange Markets", *Economic Modelling*, 14, 61-79.

Masson, P. (1999a). Contagion: macroeconomic models with multiple equilibria. *Journal of International Money and Finance*, 18 (4), 587-602.

Masson, P. (1999b), "Contagion: Monsoonal Effects, Spillovers, and Jumps Between Multiple Equilibria" in Agenor, P.R., Miller, M., Vines, D. and Weber, A. (eds), *The Asian Financial Crisis: Causes, Contagion and Consequences*. Cambridge University Press, Cambridge, Thailand.

Masson, P. (1999c), "Multiple Equilibria, Contagion and the Emerging Market Crises", IMF Working Paper 99/164.

Mody, A. and Taylor, M.P. (2003), "Common Vulnerabilities", University of Warwick, mimeo.

Mody, A. and Taylor, M.P. (2003), “Common Vulnerabilities”, CEPR Discussion Papers: 3759.

Nelson, C.R. and Startz, R. (1990), "The Distribution of the Instrumental Variables Estimator and Its t-Ratio When the Instrument is a Poor One, *Journal of Business*, 63, S125-S140.

Ng, V.K., Engle, R.F. and Rothschild, M. (1992), “A Multi-Dynamic Factor Model for Stock Returns.” *Journal of Econometrics*, April – May, *52*(1-2), 245-66.

Pavlova, A. and Rigobon, R. (2007), "Asset Prices and Exchange Rates", *Review of Financial Studies*, forthcoming.

Pericoli, M. and Sbracia, M. (2003), "A Primer on Financial Contagion", *Journal of Economic Surveys*, 17(4), 571-608.

Pesaran, H. and Pick, A. (2003), "Econometric Issues in the Analysis of Contagion", CESifo Working Paper 1176.

Pritsker, M. (2001), “The Channels for Financial Contagion”, in Claessens, S. and Forbes, K. (eds) *International Financial Contagion*, Kluwer Academic Publishers.

Radelet, S. and Sachs, J. (1998), “The Onset of the East Asian Financial Crisis.” Mimeo, Harvard Institute for International Development.

Rasmus, Ruffer and Livio Stracca (2006), “What is Global Excess Liquidity, and Does it Matter?”, European Central Bank Working Paper Series, No. 696, November.

Reside Jr, R.E. and Gochoco-Bautista, M.S. (1999), “Contagion and the Asian Currency Crisis.” *The Manchester School, 67*(5), 460-474.

Rigobon, R. (2003). On the measurement of the international propagation of shocks: is the transmission stable? *Journal of International Economics,* 61 (2), 261-283.

Rigobon, R. (2003a), "Identification Through Heteroskedasticity", *Review of Economics and Statistics*, 85(4), 777-792.

Rigobon, R. (2002), "The Curse of Non-Investment Grade Countries", *Journal of Development Economics*, 69, 423-449.

Rigobon, R. & Sack, B. (2004). Measuring the reaction of monetary policy to the stock market. *Quarterly Journal of Economics*, 118 (2), 639-669.

Sachs, J., Tornell, A. and Velasco, A. (1996), "Financial Crises in Emerging Markets: The Lessons from 1995." *Brookings Papers on Economic Activity*, (1), 146-215.

Sentana, E. & Fiorentini, G. (2001). Identification, estimation and testing of conditionally heteroskedastic factor models. *Journal of Econometrics*, 102 (2), 143-164.

Sharpe, W. (1964), "Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk", *Journal of Finance*, 19, 425-442.

Shirreff, D. (1998), "The Eve of Destruction." *Euromoney,* November, 355, p.34.

Solnik, B.H. (1974), "The International Pricing of Risk: An Empirical Investigation of the World Capital Market Structure", *Journal of Finance*, 29(2), 365-378.

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

Stock, J.H., Wright, J.H. and Yogo, M. (2002), "A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments", *Journal of Business and Economic Statistics*, 20(4), 518-529.

Toyoda, T. and Ohtani, K. (1986), "Testing Equality Between Sets of Coefficients After a Preliminary Test for Equality of Disturbance Variances in Two Linear Regressions", *Journal of Econometrics*, 31, 67-80.

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

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

Van Rijikeghem, C. and Weder, B. (2003), “Spillovers Through Banking Centers: A Panel Data Analysis of Bank Flows.” *Journal of International Money and Finance*, August, *22*(4), 483-509.

Van Rijikeghem, C. and Weder, B. (2001), "Sources of Contagion: Is it Finance or Trade?", *Journal of International Economics*, 54(2), 293-300.

Wald, A. (1940), "The Fitting of Straight Lines if Both Variables are Subject to Error", *Annals of Mathematical Statistics*, 11, 284-300.

Warsh, Kevin (2007), “Market Liquidity: Definitions and Implications,” Speech delivered at the Institute of International Bankers Annual Conference, Washington D.C., March.

Wirjanto, T.S. (1999), “Empirical Indicators of Currency Crises in East Asia.” *Pacific Economic Review*, June, *4*(2), 165-183.

Yuan, K. (2005), "Asymmetric Price Movements and Borrowing Constraints: A Rational Expectations Equilibrium Model of Crises, Contagion, and Confusion", *Journal of Finance*, 60, 379-411.

Nederlandse Samenvatting (Summary in Dutch)

Dit onderzoek analyseert de rol van besmetting in het zenden van schokken doorheen markten. Een van de mogelijke geleidingsbanen voor besmetting is een zich wijzigende zin voor risico van internationale investeerders. Het doel van dit onderzoek is de empirische literatuur over besmetting onder de loep te nemen en een methodologie voor benadering van de huidige hiaten in de literatuur voor te stellen. Het onderzoeksprogramma bestudeert een aantal financiële crisissen over de voorbije tien jaar op basis van dagelijkse financiële gegevens voor een representatieve groep van ontwikkelingslanden en rijpe economieën[1].

Het belang van een beleid op dit gebied is duidelijk, gezien besmetting een belangrijke rol kan spelen in een wereldwijd spreiden van wat anders, bij afwezigheid van besmetting, beheerste idiosyncratische episodes van financiële spanning zouden geweest zijn. Besmetting kan dus systematische financiële crisissen veroorzaken. Inderdaad, beleidsmakers hebben bijna steeds op typische wijze tussengekomen, door financiële instellingen uit de nood te helpen of het monetaire beleid te versoepelen wanneer episodes van financiële spanning tengevolge van besmetting dreigden systematisch te worden. Het onderzoek werd georganiseerd rond vijf afzonderlijke hoofdstukken die de verschillende aspecten van dit probleem analyseren[2].

Hoofdstuk 1 leidt het onderwerp in met een overzicht van de daaropvolgende hoofdstukken. Hoofdstuk 2 bekijkt kritisch de hoofdthema's in de actuele empirische literatuur over besmetting, met het doel blijkbaar ongerelateerde benaderingen die tot nu toe als een wijze tot onderzoek van financiële besmetting werden voorgesteld met elkaar te verzoenen. In hoofdstuk 3 wordt de rol van besmetting in de obligatiemarkten in een aantal ontwikkelingslanden en rijpe economieën gedurende diverse periodes van financiële crisis onderzocht. Men heeft vastgesteld dat besmetting duidelijk merkbaar was gedurende het najaar van 1998 in de Russische crisis wanneer het Long-Term Capital Management (LTCM) hedge fund bijna ineenstortte. Hoofdstuk 4 onderzoekt de rol van besmetting in een aantal opkomende markten en rijpe economieën, doch gesteund op hun aandelenmarkten. Gelijkaardige uitwerkingen als deze die de Russische/LTCM crisis op andere economieën

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[1] Onderzocht in González-Hermosillo, Brenda, (2007a), "Spillovers and Contagion in International Capital Markets", *IMF Institute Courier*, Washington D.C., Vol. 13.

[2] Hoofstukken 2, 3, 4 en 5 zijn deels een gezamenlijk werk met Mardi Dungey (Cambridge University), Renee Fry (Australian National University), Vance Martin en C. Tang (Melbourne University).

veroorzaakte worden vastgesteld. Versies van hoofdstukken 2, 3 en 4 werden onlangs in de aangehaalde economische tijdschriften of boeken[3] gepubliceerd.

De daaropvolgende hoofdstukken breiden de gegevensset uit om de recentste periodes van financiële spanning behandelen, waarvan sommige op het ogenblik van opstellen van deze publicatie nog aan de gang waren. Aldus worden eveneens de Turkse crisis in het voorjaar van 2006, de instorting van de Chinese beurs in februari 2007 en de crisis van de subprime-hypotheken en contantenschaarste van de Verenigde Staten die in de zomer van 2007 begon onderzocht.

Bovendien wordt in hoofdstuk 5 de analyse uitgebreid en worden in de literatuur voor de eerste maal de obligatiemarkten èn aandelenmarkten voor een aantal opkomende markten en rijpe economieën gezamenlijk onderzocht. Het opzet is dagelijkse gegevens uit observaties over een periode van bijna tien jaar (1998-2007) gedurende dewelke een aantal moderne financiële crisissen zich voordeden te behandelen. De resultaten bevestigen dat de Russische/LTCM episode van financiële spanning in 1998 samenhing met belangrijke besmettingskanalen voor andere markten in de rest van de wereld. Men stelde eveneens vast dat de crisisperiodes na 1998 dit kenmerk van spreiden van besmetting doorheen de wereld praktisch niet vertoonden. Nochtans kwam besmetting midden 2007 gedurende de crisis van de subprime-hypotheken en contantenschaarste in de Verenigde staten met alle heftigheid terug opduiken. Beide besmettingsepisodes (najaar 1998 en midden 2007) deden zich voornamelijk voor via obligatiemarkten en beiden hadden betrekking op spanning in de financiële markten van rijpe economieën. Deze laatste observatie schijnt erop te wijzen dat zin voor risico van internationale investeerders die tevens hoofdfiguren in de voornaamste wereldwijde financiële zijn misschien een rol in het zenden van schokken doorheen markten en landen kan spelen.

Om deze mogelijkheid formeel te onderzoeken bestudeert hoofdstuk 6 empirisch de rol die zin voor risico van internationale investeerders, wegens toestandswijzigingen in de wereldwijde financiële markten, over de laatste tien jaren in het zenden van schokken doorheen de markten gedurende de diverse crisisperiodes zou kunnen hebben gespeeld. De onderzochte gegevens zijn

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[3] Dungey, Mardi, Renée Fry, Brenda González-Hermosillo, en Vance Martin, (2005a), "A Comparison of Alternative Tests of Contagion with Applications," hoofdstuk 3 in Identifying *International Financial Contagion: Progress and Challenges*, uitgegeven door M. Dungey and D. Tambakis, Oxford University Press, New York;

Dungey, M., Fry, R., González-Hermosillo, B. en Martin, V.L. (2005b), "Empirical Modelling of Contagion: A Review of Methodologies", *Quantitative Finance*, 5, pp. 9-24;

Dungey, M., R. Fry, B. González-Hermosillo en V.L. Martin (2006), "Contagion in International Bond Markets During the Russian and LTCM Crises", *Journal of Financial Stability*, 2, pp. 1-27;

Dungey, M., R. Fry, B. González-Hermosillo en V.L. Martin (2007b), "Contagion in Global Equity Markets in 1998: The Effects of the Russian and LTCM Crises", *North American Journal of Economics and Finance*, 18, pp. 155-174.

dagelijkse gegevens, gesteund op de spreiding van staatsobligaties in ontwikkelingslanden en obligaties van investeerkwaliteit uitgegeven door gerenommeerde vennootschappen in rijpe economieën. Inderdaad, de resultaten schijnen aan te duiden dat er praktisch geen besmetting meer bestaat nadat de rol van wijzigingen in de lust voor risico van investeerders als reactie op de wijzigende toestanden in de wereldwijde financiële markten werd beheerst.

Hoofdstuk 7 besluit met een aantal gevolgtrekkingen uit dit onderzoek en stelt een aantal domeinen voor toekomstige studie voor. Hierna volgen enkele van de hoofdbesluiten uit dit onderzoek:

- Vooreerst werd na onderzoek van de diverse episodes van financiële spanning over de voorbije tien jaar vastgesteld dat de Russische/LTCM-crisis van 1998 en de subprimecrisis van de Verenigde Staten in 2007 de meeste besmetting veroorzaakten. Beide crisissen begonnen in de kredietmarkten en spreidden zich uit naar de beurzen.
- Ten tweede, eens dat de factoren van de wereldwijde financiële markten uitdrukkelijk beschouwd worden als factoren die de zin voor risico van de investeerders beïnvloeden, is besmetting van opkomende markten zeer gering of nagenoeg onbestaand. Deze bevinding lijkt tegenstrijdig te zijn met sommige resultaten in de empirische literatuur over besmetting. De literatuur over besmetting onderzoekt de buiten de fundamentele marktmechanismen bestaande verbanden die landen en vermogensmarkten gedurende de periodes zonder crisis verbinden en die zich enkel gedurende een crisis manifesteren. Maar in feite bepaalt de empirische literatuur over besmetting niet precies hoe deze bijkomende kanalen gedurende periodes van spanning worden gevormd. Een mogelijk kanaal van besmetting is dat schokken in een bepaalde markt eventueel een invloed kunnen hebben op de zin voor risico van internationale investeerders, die zich uit via herschikking van hun portefeuilles of eenvoudigweg herziening van hun verwachtingen. Inderdaad, zin voor risico van internationale investeerders blijkt een belangrijk kanaal in het veroorzaken van besmetting doorheen de wereldwijde financiële markten te zijn.
- Tenslotte toont dit onderzoek aan dat besmetting belangrijk kan zijn in het zenden van schokken doorheen markten en landen. In een steeds meer geïntegreerde wereldwijde financiële markt kan besmetting zowel ontwikkelingslanden als rijpe economieën treffen. Zin voor risico van internationale investeerders kan een belangrijke geleidingsbaan van deze besmetting zijn.