The Tsunami: Measures of Contagion in the 2007-2008 Credit Crunch

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The credit crunch of 2007-2008 is the most substantial financial crisis since those that preceded the Great Depression in the US and the banking crises prior to the first World War. For the first year of its development the crisis seemed to remain relatively constrained to developed markets, but from the dramatic events of October 2008 has clearly become a truly global phenomenon, enveloping emerging and developed financial markets and likely to result in recession and substantial slowdowns in most regions. Comparisons with the Asian crisis of 1997-1998 have fallen by the wayside, and made a mockery of the economic policy advice given to developing markets in the throes of financial crises in the last 20 years: The Washington consensus advised widespread fiscal reform, the liberalization of financial services to external investors and the removal of leaders of failing financial institutions. Policy responses to the credit crunch to date have instead promoted looser credit conditions, fiscal stimulus, wide spread deposit guarantees, reregulation, mergers and nationalization of financial institutions. The spread of the credit crunch has not been caused by a lack of institutions or poor institutional design or macroeconomic policy, as per standard crisis theory, see for example the overview in Flood and Marion (1999), but rather seems to have originated in poor assessment of risks and less than transparent interlinkages between financial institutions as a result of financial innovation. The very products intended to diversify risk now appear to have simply transformed it to liquidity and counterparty risk. Network models of financial markets may provide greater insights to the current crises than traditional crisis models, see Allen and Babus (2008).

The credit crunch has been deepening for a remarkably long time. Arguably a good starting point for tracking the emergence of the current difficulties is the problems reported with Bear Stearns hedge funds in July 2007 (there were some earlier warnings of this in earnings downgrades for Bear Stearns the previous month). Liquidity at the short-end of the market began to evaporate, leading to serious funding difficulties for a number of financial firms. The most dramatic indication of the difficulties spreading beyond the US was the run on Northern Rock in September 2007, halted only by the guarantee placed by the UK Government on deposits in this institution. From here things proceeded to worsen, punctuated by revelations of increasing subprime mortgage associated portfolio losses and rating downgrades for financial institutions, the formal nationalization of Northern Rock in February 2008, the takeover of Bear Stearns by JP Morgan Chase in March 2008, repeated central bank interventions to increase liquidity in the market, the lowering of official interest rates, and rights issues to raise funds for beleaguered financial institutions - for example the Royal Bank of Scotland and UBS. In September and October 2008 the pace of events increased, encompassing the rescue of Fannie Mae and Freddie Mac in the US, the forced sale of Washington Mutual to JP Morgan, the bailout of Dexia in Europe, the non-rescue and subsequent bankruptcy of Lehman Brothers, the takeover of HBOS by Lloyds TSB in the UK, of Merrill Lynch by Bank of America and Wachovia by Citigroup, the rescue of AIG, the nationalization of Bradford and Bingley in the UK, and part-nationalization of Fortis in Europe. A further consequence of this turmoil was fear of loss of confidence in the banking system, prompting the Irish and Australian Governments to guarantee bank deposits, which in Australia led directly to instability in the non-depository financial sector with the suspension of investor access to a number of institutions. This period has also marked the realization of serious problems in emerging markets and the re-emergence of international lending packages including funding from the IMF, such as to Hungary in October 2008, and at the end of October the release of a formal IMF short-term liquidity facility to address the needs of economies with otherwise sound policies facing liquidity difficulties.

The spread of the credit crunch has been widespread and dramatic. When crises spread across different financial markets it may be for a number of identifiable reasons. Common factors may lead to simply increased volatility in multiple markets, see Pericoli and Sbracia (2003), Forbes and Rigobon (2001). Trade and direct economic or financial linkages such as common banking structures, lead to the existence of spillovers or fundamentals-based contagion (Dornbusch, Claessens and Park, 2000, Kaminsky and Reinhart, 2000). In addition, new linkages between markets may emerge, and it is this transmission of volatility in addition to the common factor and spillover channels which is labeled contagion.

Contagion effects have been documented in previous crises both between geographical markets, and across financial asset classes. While the majority of existing work documents contagion across borders for a single asset class or transmissions within a single country (for example Forbes and Rigobon, 2002, Granger and Huang, 2000), a growing body of work considers cross-asset class contagion effects, see Dungey and Martin (2007) and Hartmann and de Vries (2004).

The current paper adapts the method developed in Dungey and Martin (2007) to establish a measure of the extent of contagion which has been experienced thus far in the credit-crunch of 2007-2008.

Characterizing the Credit Crunch

To examine whether the credit crunch is associated with contagion effects, a reference period is chosen beginning July 1 2004. This captures the point in the business cycle when the Fed had returned to a tightening monetary policy stance (the Federal Funds rate was raised by 25 basis points to 1.25% on 30 June 2004, following 12 months at its low point of 1%). The period from that point until the beginning of the credit crunch was relatively benign and in historical terms was a relatively low volatility, low inflation, strong growth period. The credit crunch period is set to date from July 17, 2007, when Bear Stearns informed investors of its failing hedge funds (problems at Bear Stearns had been evident somewhat earlier as a result of downgraded expected earnings results in May, and their subsequent realization in mid-June). The demise of Bear Stearns in the US and nationalization of Northern Rock in the UK have become the defining features of the first 6 months of the credit crunch.

This paper considers the interactions between money markets and the major equity market indices during the credit crunch compared with the immediate prior reference period. The dataset consists of 3 month money market rates and major equity indices representing 5 countries. The selected economic regions are the US, UK, Europe, Japan and Australia. The choice of developed market reflects that the credit crunch was until recently relatively confined to these markets. The US and the UK were the first markets to be seriously affected. From June 30, 2007 to September 30, 2008, the FTSE100 declined by 26% and the S&P500 by 22%. The difficulties in obtaining interbank funding have been particularly apparent in these economies – leading to numerous takeovers of insolvent financial institutions by authorities (the nationalization of Northern Rock, organised takeovers of Bear Stearns and Countrywide and government takeover of Fannie Mae and Freddie Mac being prominent), the collapse of Lehman Brothers worldwide and the strategic move of Goldman Sachs and Morgan Stanley to regulated bank status. Figure 2 shows the yields on 3 month Libor and 3 month US Treasury bills over the period. Excess demand for US Treasuries has led to the lowest yields recorded since World War II being recorded during September 2008.

The situation in Europe from June 30, 2007 to end September 2008 had been less dire, although still difficult. Problems in the European banking sector seemed initially more localized, with the Societe Generale problems revealed in January 2008 mainly due to a single rogue trader. However, there have been ongoing smaller problems in particularly the German banking system, resulting in smaller scale bailouts than seen in the US, but nevertheless significant – in August 2007 Sachsen Landesbank was sold to Landesbank Baden-Wuerttemberg, and in August 2008 the European insurer Fortis was partially nationalized, Daxia was bailed out and Ireland acted to guarantee bank deposits, while just outside the sample period the ECB extended access to its cash auctions to more market participants. Developments in Europe since the end of the data sample have revealed substantial weakness in the European banking system, including the takeover of Landsbanki by the Icelandic Government, problems with the German giant Hypo Real Estate, and further guarantees on bank deposits by the Swedish and Danish governments. The 3 month Euroibor rate and German DAX index are used to represent European conditions, and these are shown in Figures 1 and 2. The DAX fell by 27% from June 30, 2007 to September 30, 2008.

Australia and Japanese market have both been affected by the global credit crunch, although with less dramatic failings of domestic financial institutions to date. Equity markets in both countries have also fallen dramatically; in the case of the Australian ASX200 the index reached its lowest level for 5 years in early October 2008, losing 26% between the end of June 2007 and end of September 2008. In Japan the Nikkei2000 has fallen 37% over the same period. The short term yields for both countries are shown in Figure 2.

All of the data cited in this paper are in domestic currencies. During the sample period the Australian dollar and Yen have been relatively volatile, greatly influencing the returns to an international investor – Table 1 shows the variance of the daily bilateral exchange rates for each of Australia, the UK, Japan and Europe against the US dollar in the reference and credit crunch periods. The computation of returns in US dollars is one means of addressing the problems for the international investor; however, in this case we are more concerned with the actual transmission of shocks between the various markets, so that incorporating the exchange rates using the domestic currency data is more appropriate. Previous studies have found that the use of domestic or USD based data makes little difference to the qualitative results produced in this type of exercise.

An Empirically Implementable Model for Contagion Effects

This paper builds on the long-standing latent factor modeling approach adopted for example by Solnik (1974). The framework adapts the contagion model of Dungey and Martin (2007) which captures the potential for linkages between different financial markets to alter during times of stress. This approach has been shown to nest many of the existing methods of modeling contagion, and be consistent with the definitions of contagion as the opening of new and unanticipated channels of transmission during periods of stress, see particularly the review of methodologies in Dungey, Fry, Gonzalez-Hermosillo and Martin (2005).

In a multi-asset multi-country environment the returns, $y_{i,k,t}$ for an asset in asset class *i*, and country *k*, at time *t* can be represented by a four factor model given by

$$y_{i,k,t} = \theta_{i,k} W_t + \alpha_{i,k} C_{k,t} + \beta_{i,k} M_{i,t} + \phi_{i,k} f_{i,k,t} , \qquad (1)$$

where W_t represents the common factor affecting all assets, $C_{k,t}$ is the factor representing effects common to country *k*, $M_{i,t}$ represents effects common to asset class *i*, and $f_{i,k,t}$ are idiosyncratic factors unique to each individual asset.

Each of these latent factors is time varying, thus allowing for the increased common influences that might be posited during the credit crunch period and overcoming the problems of correlation based testing as discussed in Forbes and Rigobon (2002). However, the parameter loadings are fixed over the sample period; for the common, country, market and idiosyncratic factors these are given by $\theta_{i,k}, \alpha_{i,k}, \beta_{i,k}, \phi_{i,k}$ respectively. To identify the parameters a standardizing assumption is commonly applied so that each of the unobserved factors is assumed to be drawn from a N(0,1) distribution. To capture the potential for fat-tailed, GARCH and autocorrelation effects in the returns data Dungey and Martin (2007) allow the common factor to evolve with a GARCH(1,1) structure. In the current work that refinement is ignored, as it has been shown to make little difference to the quantitative results.

In applying these latent factor model approaches to contagion, it has been usually possible to express returns on various assets as premiums over some risk free rate – the usual procedure being to utilize US money or Treasury bond markets for that purpose. In the current situation that would be inappropriate, as the source of the shocks to other markets in this case stem from the US money markets themselves. To that end we adapt a refinement of the latent factor model approach first posited by Mahieu and Schotman (1994) in dealing with bilateral exchange rates by modeling changes in each of the currencies involved using latent factors. This creates an extra common factor (called the 'numeraire' factor in exchange rate work) which will here relate to the influence of the US money market.

Consider the case of modeling the premium via an observed asset return for an asset in market *i* located in country *k*, $y_{i,k,t}$, less the US money market rate used as the risk free rate and denoted $y_{r,US,t}$ (where here there will be two markets, the money market, denoted by *r*, and the equity market, denoted by *q*). In a multi-asset multi-country environment the excess returns, $y_{i,k,t} - y_{r,US,t}$ for an asset in asset class *i*, and country *k* over the risk free rate, at time *t*, can be represented by using appropriate combinations of equation (1) for each return. Hence generally, where $i,k \neq r,US$

$$y_{i,k,t} - y_{r,US,t} = \tilde{\theta}_{i,k} W_t + \alpha_{i,k} C_{k,t} - \alpha_{r,US} C_{US,t} + \beta_{i,k} M_{i,t} - \beta_{r,US} M_{r,t} + \phi_{i,k} f_{i,k,t} - \phi_{r,US} f_{i,k,t}, \quad (2)$$

where $\tilde{\theta}_{i,k} = \theta_{i,k} - \theta_{r,US}$. In the special cases where $i = r, k \neq US$ (that is the assets are in the same asset class but different countries)

$$y_{i,k,t} - y_{r,US,t} = \tilde{\theta}_{i,k} W_t + \alpha_{i,k} C_{k,t} - \alpha_{r,US} C_{US,t} + (\beta_{i,k} - \beta_{r,US}) M_{r,t} + \phi_{i,k} f_{i,k,t} - \phi_{r,US} f_{i,k,t} \quad (3)$$

and when the assets are in the different asset classes but the same country, $i \neq r, k = US$

$$y_{i,k,t} - y_{r,US,t} = \tilde{\theta}_{i,k} W_t + (\alpha_{i,k} - \alpha_{r,US}) C_{US,t} + \beta_{i,k} M_{i,t} - \beta_{r,US} M_{r,t} + \phi_{i,k} f_{i,k,t} - \phi_{r,US} f_{i,k,t}. \quad (4)$$

The volatility of the asset returns represented by equation (2) can be used to give a variance decomposition which is invariant to the standardization assumption used in identification.

In the case where $i,k \neq r,US$ the variance can be decomposed into 7 separate components as follows:

Portion of volatility due to common effects $$= \frac{\tilde{\theta}_{i,k}^2}{\tilde{\theta}_{i,k}^2 + \alpha_{i,k}^2 + \alpha_{r,US}^2 + \beta_{i,k}^2 + \beta_{r,US}^2 + \phi_{i,k}^2 + \phi_{r,US}^2} \quad (5)$$

Portion of volatility due to country k effects $$= \frac{\alpha_{i,k}^2}{\tilde{\theta}_{i,k}^2 + \alpha_{i,k}^2 + \alpha_{r,US}^2 + \beta_{i,k}^2 + \beta_{r,US}^2 + \phi_{i,k}^2 + \phi_{r,US}^2} \quad (6)$$

Portion of volatility due to market i effects $$= \frac{\beta_{i,k}^2}{\tilde{\theta}_{i,k}^2 + \alpha_{i,k}^2 + \alpha_{r,US}^2 + \beta_{i,k}^2 + \beta_{r,US}^2 + \phi_{i,k}^2 + \phi_{r,US}^2} \quad (7)$$

Portion of volatility due to idiosyncratic effects $$= \frac{\phi_{i,k}^2}{\tilde{\theta}_{i,k}^2 + \alpha_{i,k}^2 + \alpha_{r,US}^2 + \beta_{i,k}^2 + \beta_{r,US}^2 + \phi_{i,k}^2 + \phi_{r,US}^2} \quad (8)$$

Proportion of volatility due to US country effects $$\frac{\alpha_{r,US}^2}{\tilde{\theta}_{i,k}^2 + \alpha_{i,k}^2 + \alpha_{r,US}^2 + \beta_{i,k}^2 + \beta_{r,US}^2 + \phi_{i,k}^2 + \phi_{r,US}^2} \quad (9)$$

Proportion of volatility due to bond market effects $$= \frac{\beta_{r,US}^2}{\tilde{\theta}_{i,k}^2 + \alpha_{i,k}^2 + \alpha_{r,US}^2 + \beta_{i,k}^2 + \beta_{r,US}^2 + \phi_{i,k}^2 + \phi_{r,US}^2} \quad (10)$$

Proportion of volatility due to US bond market idiosyncratic effects $$\frac{\phi_{r,US}^2}{\tilde{\theta}_{i,k}^2 + \alpha_{i,k}^2 + \alpha_{r,US}^2 + \beta_{i,k}^2 + \beta_{r,US}^2 + \phi_{i,k}^2 + \phi_{r,US}^2} \quad (11)$$

In the case where the assets are both from the US, that is $k=US$, the proportion of volatility (6) and (9) are replaced with an expression with a numerator of $(\alpha_{i,US} - \alpha_{r,US})^2$. In the case where the assets are both from the same money market, that is $i=r$, the proportion of volatility due to market effects replaces (7) and (10) with an expression with a numerator of $(\beta_{r,k} - \beta_{r,US})^2$.

The decompositions in equations (5) to (11) give the relative importance of the four sources of volatility during the reference period.

During an identified period of crisis there may be contagion effects, where these are modeled as extra (either positive or negative) channels which emerge only during the crisis period. Here we are primarily interested in the effects from the US money markets on other asset classes and in other geographical markets. To allow for this, an idiosyncratic source of contagion (as opposed to a market based or country based impact) the model in equation (2) can be augmented so that it allows for a structural break in the effect of the US money market. That is we allow the transmission of shocks from the US money market to each of the other assets to change during the credit crunch period. However, we posit that the transmissions for the remaining market, country and common channels retain the same coefficients. Note that this does not preclude increases (or decreases) in the shocks traveling through these channels – each of the latent variables W_t, $C_{i,t}$, $M_{k,t}$, $f_{i,kt}$, are time varying – thus allowing for larger turmoil through, for example, global effects. However, the impact coefficients on each market are deemed to remain the same across the reference and credit crunch period. Instead, there is potentially an extra impact of the US money markets directly on each of the excess returns. This can be represented as follows, and the formal equivalence to a Chow test is evident (see also Dungey, Fry, Gonzalez-Hermosillo and Martin 2005 for the equivalence of the Forbes and Rigobon 2002 test to a Chow test and its multivariate equivalent).

$$y_{i,k,t} - y_{r,US,t} = \tilde{\theta}_{i,k} W_t + \alpha_{i,k} C_{k,t} - \alpha_{r,US} C_{US,t} + \beta_{i,k} M_{i,t} - \beta_{r,US} M_{r,t} + \phi_{i,k} f_{i,k,t} - \phi_{r,US} f_{i,k,t} + \delta_{i,k} I_t f_{r,US,t} \tag{12}$$

where I_t is an indicator variable taking the value of zero in the reference period and 1 during the credit crunch period.

In the credit crunch period the variance decomposition given in equations (5) to (11) are consequently modified to have the denominator

$\tilde{\theta}_{i,k}^2 + \alpha_{i,k}^2 + \alpha_{r,US}^2 + \beta_{i,k}^2 + \beta_{r,US}^2 + \phi_{i,k}^2 + \phi_{r,US}^2 + \delta_{i,k}^2$, and the additional component of the decomposition will be the portion of volatility due to contagion effects given by

$$\text{Portion of volatility due to contagion} = \frac{\delta_{i,k}^2}{\tilde{\theta}_{i,k}^2 + \alpha_{i,k}^2 + \alpha_{r,US}^2 + \beta_{i,k}^2 + \beta_{r,US}^2 + \phi_{i,k}^2 + \phi_{r,US}^2 + \delta_{i,k}^2} \qquad (13)$$

Estimation Techniques

The model is estimated by indirect estimation, by simulating the system comprising of equations (2) and (12) for a reference and credit crunch period under the assumption that each of the independent latent factors evolves as an iid normal process. Indirect estimation minimizes the difference between the simulated and actual sample data using an auxiliary model, see Gourieroux and Monfort (1994). In this case the auxiliary model is given by the variance and covariance properties of the different assets in the reference and credit crunch periods, see for example Dungey and Martin (2006, 2007). The independence of the latent factors allows the expression of the variance and covariance conditions in analytic form. This is most easily seen by considering the different cases which may occur in this 2 market multi country model as shown in Appendix A.

The difference between the theoretical second moment conditions in the reference and credit crunch periods is captured by the additional contagion effects given by $\delta_{i,k}^2$. Hence an appropriate test for the presence of contagion from the US money market to any particular excess asset return, $y_{i,k,t} - y_{US,r,t}$, is that under the null hypothesis of no contagion $\delta_{i,k} = 0, \forall i,k$, and these can be applied using an LR test.

One further complication arises from the differing time zones of the data. There is no overlap in trading time between the Australian and Japanese market hours and those of the US. The UK and European markets overlap with the US market, particularly for the key 8:30am EST (1:30pmGMT) macroeconomic news releases. However, the data used in this study represent closing prices in each case. Consequently, the time zone problem is dealt with by lagging US returns by one day – Australian, Japanese, UK and European returns are modeled as contemporaneous.[1]

Estimation is carried out in Gauss6.0 and makes use of the optimization module OPTMUM, with 100 simulations (resulting in a total of 110900 observations). To aid in convergence in estimation, without affecting the variance decomposition results, it is convenient to use a 10 variate VAR(1) in the 10 financial returns to prefilter the data.

Empirical Results

The model given in equations (2) and (12) is applied to the excess returns data in equity market index returns and changes in money market rates across the 5 different countries during reference and credit crunch periods. The most interesting form in which to examine the results is via the variance decompositions, as represented in equations (5) to (11) and (13).

In reporting the results of the estimation Tables 3 and 4 focus on the proportions of volatility due to global common effects, the identified individual country and market effects, the US country effect and the common money market effect on each asset which originates with the US money market, the unique effects for each asset return and the effects of contagion in the case of the credit crunch period. The missing portion of the total volatility report in Tables 3 and 4 in each case is the remnant attributable to the idiosyncratic US money market effect. A simple addition of the columns of the Table shows this to be relatively small in all cases.

Table 3 shows the variance decompositions of the money and equity markets during the reference period. The global common factor contributes around 50 percent of volatility to the individual money markets. The majority of the remainder is distributed across the

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[1] One could argue that this is a misrepresentation of the impact of European and UK data on Australia and Japan, however, experiments with different lag structures did not make a qualitative difference to the outcomes. This is strong supporting evidence of the importance of the US market in driving the spread of the problems associated with the credit crunch.

money market factor (ranging from 16 percent in the UK to almost 22 percent in Japan) and the common US country effect which ranged from 12 to 15 percent across the countries. The unique factor contributions were under 10 percent in each individual money market. This tends to suggest that money markets were moving in a way which reflected global conditions and that the money market is indeed very international at the short end. There is, however, some evidence that the UK market was responding to factors pertinent only to the UK, with a contribution of the UK country factor of 14.5 percent.

In the equity markets the global common factor is an important component of almost all excess returns volatility, at around 60 percent of volatility for all markets except the US. In the US the two dominant forces shaping equity market volatility are the equity market effect at just under 20 percent of observed volatility and the unique US equity market factor at 70.5 percent of volatility. This points to the important role of the US as a market leader for the other economies. What is global for the other countries is not driving innovations in the US market, supporting other research pointing to the leading role of the US in absorbing and distributing news effects to other economies, see Ehrmann and Fratzscher (2005). In the other countries, the US country effects are important, as they were in the money market results - in the equity markets these effects account for around 13 percent of total volatility. More important in the equity markets are individual country effects, at around 18 percent of observed volatility in the equity markets, compared with their relatively low weight in the majority of the money markets.

The credit crunch period results are shown in Table 4. The contributions of both the global factors in both markets are somewhat reduced in all non-US markets compared with the reference period. The contribution to volatility of all other factors also declines slightly. The major change is in the US equity market effects, where the equity market effect and the idiosyncratic effects decline substantially to give way to a dominant effect from contagion at 78 percent of observed volatility. In all other markets the contagion effects lie between 4 and 10 percent, with the greatest contribution in the Australian money market and the smallest in the Japanese equity market. The contagion effect from the US money markets on US equity markets is pronounced. The interpretation of this result is that there has been a significant and substantial change in the transmission of US money market conditions to the US equity markets. The relative stability of the remaining volatility decompositions suggests that given that observed volatility has increased dramatically in each of the markets, the US equity market is largely acting as the conduit to transmitting the effects of the changes in the US money market to the remainder of the countries in the sample. Kaminsky and Reinhart (2007) argue that developed markets such as the US act to transmit crises to emerging markets. The evidence here supports an extension of this hypothesis to developed markets also. The turmoil in equity markets seems to be coming from increased general turmoil, where individual effects are being absorbed by the US equity market directly and subsequently transmitted via market and common effects to other markets.

Comparison with Previous Crises

The extent of contagion evident in the volatility decompositions may seem relatively small. It is worth considering this in the context of evidence on contagion effects in other major crises. In the Asian crisis of 1997-1998 contagion effects between the currency markets of Korea, Indonesia, Thailand and Malaysia ranged between 9 and 46 percent of observed volatility (Dungey and Martin 2004), and in examining cross market links contagion between equity and currency markets resulted in contributions of contagion to volatility of up to 11 percent in equity markets and 36 percent in currency markets. Interestingly the contagion effects to equity markets in that crisis were a greater proportion of observed volatility for developed equity markets than emerging markets (Dungey and Martin 2007). In the LTCM crisis in 1998 contagion effects from the US and Russia on 12 international sovereign bond markets ranged up to 18 percent. Five of the countries had contagion effects in the 3 to 5 percent range, consistent with the current results (the highest effects were felt by Brazil, see Baig and Goldfajn 2001 and Netherlands, see Dungey et al 2006). For the same crisis in the equity markets the contagion effects were a much larger proportion of volatility, with only 3 of 10 countries examined having less than 20 percent of observed volatility due to contagion effects, and impacts ranging as high as 82 percent. In each of the cases, regardless of the proportion of contagion evident in the results, the contagion effects are always statistically significant. Further detail on these results can be found in Dungey and Martin (2004, 2007) and Dungey et al (2006, 2007).

The conclusion from this comparison is that the extent of contagion in the current credit crunch is not out of line with previous substantial crises. Interestingly, the proportion of contagion experienced in both the money and equity markets (with the exception of the US equity market) is relatively similar at between 4 and 9 percent. In the other papers examining cross country and cross asset market linkages in a single model one market has seemed to receive more contagion effects than another. In the East Asian crisis this was the currency market (compared with equity markets) and in the LTCM crisis it was the equity market (compared with the bond markets), whereas in the credit crunch the contagion effects are relatively similar in the equity and money markets.

Conclusion

The credit crunch of 2007-2008 seems in many ways to be quite different from other financial crises of the past two decades. It initially involved the deepest and most developed financial markets in the world, those of the US and the UK, but has expanded to other developed markets and post-August 2008 has become a truly global phenomenon adversely affecting many emerging economy markets. The underlying difficulties associated with the spread of the credit crunch have been lack of liquidity due to uncertainty about the value of sophisticated products, which were initially designed to diversify risk.

This paper has adopted a latent factor model of financial market returns developed by Dungey and Martin (2007) to consider simultaneously the transmission of shocks across both geographical borders and asset classes. Usually this model requires a concept of returns in excess of a benchmark risk free asset. In the current environment the usual risk free asset, the US Government short term money market is a primary source of the liquidity problems and the modeling framework was adapted to account for this.

Empirical implementation of this model for short term (3 month) money markets and equity markets for the US, UK, Europe, Japan and Australia supports a number of conclusions. First, the relative contribution of global common influences on the excess returns over the US money market in these economies and asset markets has not changed markedly between the reference period (from July 1, 2004 to July 17, 2007) and the credit crunch period (from July 17, 2007 to September 30, 2008). This means that increases in volatility in global shocks are being transmitted to all markets in the same manner as during the non-crisis period. Second, the contribution of contagion to volatility in the non-US markets in each asset class lie in the range of 4 to 10 percent, which is in line with results found for the contribution of contagion in evidence gathered for previous crises. Third, the US equity market seems to have a role in absorbing shocks from the US money market, having experienced a far greater degree of contagion than other markets, and may be interpreted as having acted as the distributor of these shocks to other jurisdictions via common effects, extending the hypothesis of centre and periphery behaviour proposed by Kaminsky and Reinhart (2000) beyond that of a developed market distributing shocks to emerging markets. Finally, there is little evidence in general for country and market based idiosyncratic behaviour driving the volatility in individual markets, which strongly supports the global nature of this problem, and that is not in fact driven by (although it may be exacerbated by) inappropriate domestic policy response; see Karolyi (2003). Important advances in attempting to explain the transmission of crises such as these are being made through the use of networks, see Allen and Babus (2008), which provide a convincing underlying theory for why we may mistakenly understand interlinked markets and entities as suffering from contagion when in fact the linkages exist in an identifiable way prior to the crisis occurring but are obscured due to complexity, see Kiyotaki and Moore (2002). Contagion itself only exists when new channels arise in periods of stress.

Table 1: Volatility in bilateral exchange rates against the US dollar in the reference and credit crunch sample periods, measured as the variance of daily log returns (%).

Period	USD/AUD	USD/EURO	USD/JPY	USD/GBP
Reference period: July 1, 2004 to July 16, 2007	0.3503	0.3102	0.2713	0.2556
Credit crunch period: July 17, 2007 to Sept 30, 2008	0.6301	0.2853	0.4117	0.2849

Table 2: Selected Descriptive Statistics for the excess returns data during the reference period and credit crunch period.

	Money Market			Equity Market		
Country	St Dev	Skew	Kurtosis	St Dev	Skew	Kurtosis
Reference period: July 1, 2004 to July 16, 2007						
US	0.0309	0.0270	7.4147	0.006	-0.2955	4.5678
UK	0.0188	0.6399	10.1829	0.006	-0.6591	4.3738
EU*	0.007	1.096	47.6277	0.008	-02373	3.8420
Japan	0.006	1.005	64.7907	0.008	-0.1983	4.0287
Australia	0.018	-0.0389	15.6141	0.005	-0.2273	4.0354
Credit crunch period: July 17, 2004.56787 to September 30, 2008						
US	0.0784	-0.3288	28.7389	0.0096	-1.0798	12.5580
UK	0.0339	-0.7722	74.6968	0.0094	-0.5634	8.6215
EU*	0.0101	1.4634	29.5396	0.0098	-0.6201	6.1989
Japan	0.0068	0.8547	33.1201	0.0101	-0.2939	4.4433
Australia	0.0282	-0.2971	13..3085	0.0076	-0.7457	10.4052

*EU is represented by the DAX equity market index.

Table 3: Variance decomposition of excess returns in money and equity markets for the reference period from July 1, 2004 to July 16, 2007, following equations (5) to (11), from estimation of the model given in equations (2) and (12). Numbers are in (%).

		US	UK	Europe	Japan	Australia
			Money Market			
Global	W_t	-	51.77	57.35	55.98	49.23
Money Market	$M_{r,t}$	-	16.32	18.38	21.59	21.27
Country	$C_{i,t}$	-	14.51	2.30	1.93	5.60
US country	$C_{US,t}$		11.82	13.30	14.77	14.03
Unique	$f_{i,k,t}$	-	5.56	8.58	5.72	9.86
			Equity Market			
Global	W_t	1.46	59.04	60.14	62.63	59.59
Equity Market	$M_{q,t}$	19.86	18.99	18.88	19.01	18.54
Money Market	$M_{r,t}$	0.00	18.73	18.57	18.79	18.24
Country	$C_{i,t}$	8.15	2.78	4.92	2.48	1.09
US Country		*	13.63	13.51	13.68	13.27
Unique	$f_{i,k,t}$	70.53	5.55	2.53	2.20	7.51

* This is included in the Country effect for the US

Table 4: Variance decomposition of excess returns in money and equity markets for the credit crunch period from July 17, 2007 to September 30, 2008, following equations (5) to (11) and (13), from estimation of the model given in equations (2) and (12). Numbers are in (%).

		US	UK	Europe	Japan	Australia
			Money Market			
Global	W_t	-	49.27	53.58	51.51	44.65
Money Market	$M_{r,t}$	-	15.53	17.17	19.86	19.29
Country	$C_{i,t}$	-	13.81	2.23	1.78	5.08
US Country	$C_{US,t}$	-	11.25	12.42	13.59	12.72
Unique	$f_{i,k,t}$	-	5.29	8.02	5.26	8.94
Contagion		-	4.83	6.57	7.99	9.31
			Equity Market			
Global	W_t	0.31	56.05	56.62	59.72	56.78
Equity Market	$M_{q,t}$	4.27	18.02	17.78	18.12	17.66
Money Market	$M_{r,t}$	0.00	17.78	17.49	17.92	17.38
Country	$C_{i,t}$	1.75	2.64	4.64	2.37	1.04
US Country	$C_{US,t}$	*	12.94	12.72	13.04	12.64
Unique	$f_{i,k,t}$	15.18	5.27	2.38	2.10	7.15
Contagion		78.47	5.07	5.85	4.65	4.72

* This is included in the Country effect for the US

Figure 1: Equity Market Indices in local currencies July 1, 2004 to September 30, 2008, vertical line marks July 17, 2007.

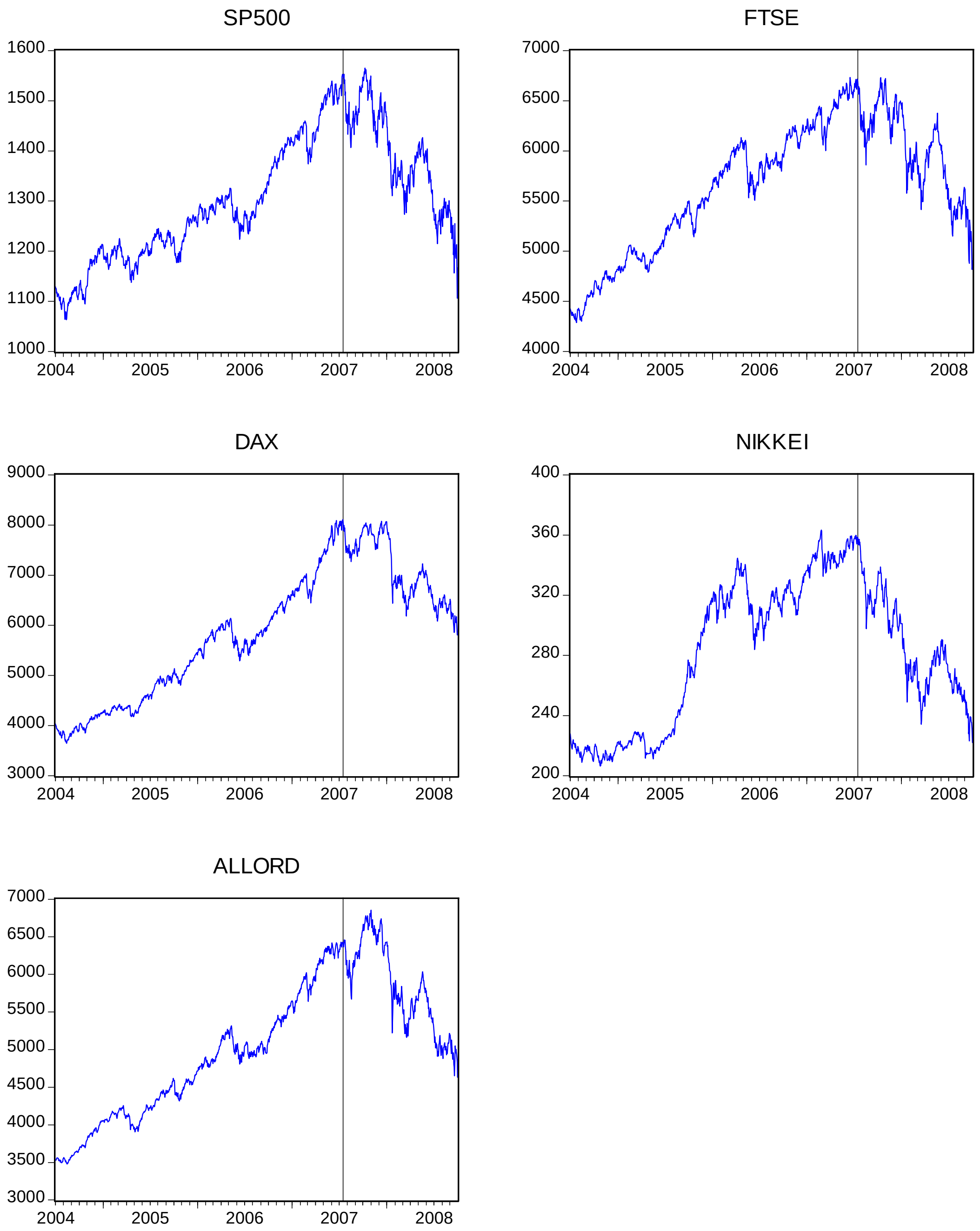
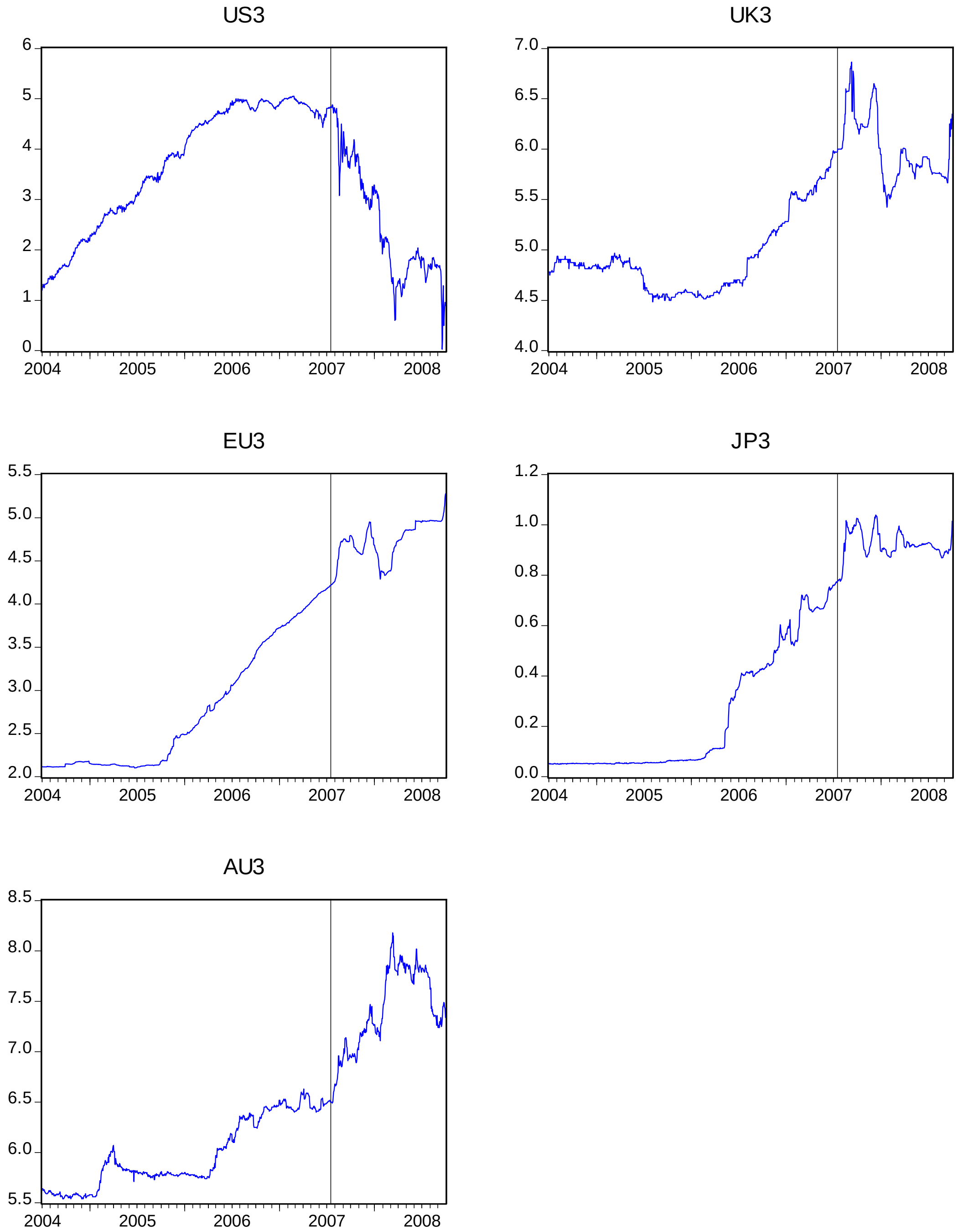


Figure 2: Yield on 3 month money market instruments in local currencies, July 1, 2002 to September 30, 2008, vertical line marks July 17, 2007.



Appendix A: Variance and Covariance Conditions:

These are most easily seen to identify the model when divided into a number of specific cases. Expressions A1 to A9 given below refer to covariance and variance expressions for the reference period. It is easily determined that the equivalent expressions in the credit crunch period are obtained by adding an extra term $\delta_{i,k}^2$ to each expression, where this represents the extra transmission channel emerging from US idiosyncratic shocks.

Variances for:

A1. Asset excess returns in the money market $y_{i,k,t} - y_{r,US,t}$ $y_{i,k,t} - y_{r,US,t}$ where $k \neq US$

$$\text{var}(y_{r,i} - y_{r,US}) = \theta_{r,i}^2 + \alpha_{r,i}^2 + \alpha_{r,US}^2 + (\beta_{r,i} - \beta_{r,US})^2 + \phi_{r,i}^2 + \phi_{r,US}^2$$

A2. Excess asset returns in the non-US equity markets

$$\text{var}(y_{q,i} - y_{r,US}) = \theta_{q,i}^2 + \alpha_{q,i}^2 + \alpha_{r,US}^2 + \beta_{q,i}^2 - \beta_{r,US}^2 + \phi_{q,i}^2 + \phi_{r,US}^2$$

A3. Excess asset returns in the US equity market

$$\text{var}(y_{q,US} - y_{r,US}) = \theta_{q,US}^2 + (\alpha_{q,US} + \alpha_{r,US})^2 + \beta_{q,US}^2 - \beta_{r,US}^2 + \phi_{q,US}^2 + \phi_{r,US}^2$$

Covariances between:

A4. Asset returns both in the money market for different countries (in which case neither can be the US)

$$\text{cov}(y_{r,i} - y_{r,US}, y_{r,j} - y_{r,US}) = \theta_{r,i}\theta_{r,j} + \alpha_{r,US}^2 + (\beta_{r,i} - \beta_{r,US})(\beta_{r,j} - \beta_{r,US}) + \phi_{r,US}^2$$

A5. Asset returns both in the same country, one in the money market and one in the equity market (in which case neither can be the US)

$$\text{cov}(y_{r,i} - y_{r,US}, y_{q,i} - y_{r,US}) = \theta_{r,i}\theta_{q,i} + \alpha_{r,US}^2 + \alpha_{r,i}\alpha_{q,i} + (\beta_{r,i} - \beta_{r,US})\beta_{r,US} + \phi_{r,US}^2$$

A6. Asset returns both in the equity market for different countries (where one of those countries is not the US)

$$\mathrm{cov}(y_{q,i} - y_{r,US}, y_{q,j} - y_{r,US}) = \theta_{q,i}\theta_{q,j} + \alpha_{r,US}^2 + \beta_{q,i}\beta_{q,j} + \beta_{r,US}^2 + \phi_{r,US}^2$$

A7. Asset returns both in the equity market for different countries where one of those is the US.

$$\mathrm{cov}(y_{q,i} - y_{r,US}, y_{q,US} - y_{r,US}) = \theta_{q,i}\theta_{q,US} + (\alpha_{q,i} - \alpha_{r,US})\alpha_{r,US} + \beta_{q,i}\beta_{q,US} + \beta_{r,US}^2 + \phi_{r,US}^2$$

A8. Asset returns with one in the US equity market and the other in non-US money market.

$$\mathrm{cov}(y_{r,i} - y_{r,US}, y_{q,US} - y_{r,US}) = \theta_{r,i}\theta_{q,US} + (\alpha_{q,US} - \alpha_{r,US})\alpha_{r,US} + (\beta_{r,i} - \beta_{r,US})\beta_{r,US} + \phi_{r,US}^2$$

A9. Asset returns with one in the money market, one in the equity market for different countries (neither is the US).

$$\mathrm{cov}(y_{r,i} - y_{r,US}, y_{q,j} - y_{r,US}) = \theta_{r,i}\theta_{q,j} + \alpha_{r,US}^2 + \beta_{r,US}^2 + \phi_{r,US}^2$$

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