More confusion in contagion tests: the effects of a crisis sourced in US credit markets*

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Abstract

The involvement of the world’s primary developed credit markets in the US at the heart of the global financial crisis poses some particularly difficult challenges to the contagion modelling literature. US credit markets have often been used as a benchmark market for global economic conditions, but their intrinsic involvement further complicates our understanding of the transmission of financial market shocks. This paper demonstrates how the involvement of benchmark assets may result in falls in the correlation between asset markets, even in the presence of increased volatility in common or benchmark assets and the presence of contagion.

Keywords: contagion, correlation, factor models, global financial crisis.

JEL Classification:

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1 Introduction

The financial crises of the 1990s and early 2000s stimulated the development of a number of new methodologies for understanding and measuring the transmissions of crises between markets. One of these developments has been in the measurement, detection and analysis of contagion effects. Contagion is generally taken to refer to the extra transmissions of shocks between financial markets that occur through additional linkages which appear only during the crisis period. These additional linkages or channels may arise through transmissions between particular asset markets (for example credit market conditions) or from a particular country (such as the US) or from a particular asset (such as subprime mortgages). Theoretical support for such changes occurs via informational asymmetries (Yuan, 2005 and Calvo and Mendoza, 2000), wealth effects (Kyle and Xiong, 2001) and portfolio rebalancing (Flemming, Kirby and Ostdiek, 1998 and Kodres and Pritsker, 2002) for examples. More recently, the effects of crises in breaking down linkages between financial institutions under stress has been explored using network theory (Allen and Babus, 2008).

The involvement of the world’s primary developed credit markets in the US at the heart of the current crisis poses some particularly difficult challenges to the contagion modelling literature. Contagion has previously been regarded as a mainly developing markets problem, with developed markets acting as mere conduits of volatility from a source problem market to another developing market; see Kaminsky and Reinhart (2003). This assumption results in some convenient modelling properties, as the developed market, particularly the US, then provide a benchmark for global economic conditions, see for example Forbes and Rigobon (2002) and Dungey et al (2006). An implication of this is that a number of the contagion modelling techniques are seriously challenged by the current crisis. This paper examines these problems, and demonstrates, using a simulation experiment, that the involvement of a benchmark asset such as the US credit market, results in a further complication in untangling the linkages between financial markets during crises.

The analysis highlights the effects of volatility in a benchmark asset on the correlation structure of asset returns during financial crises. It is well known that in many crises the correlation between assets increases, partly as a result of generally increased volatility. Change in correlations evident after controlling for increased volatility in
common conditions is usually interpreted as evidence of contagion. While Forbes and Rigobon (2002) consider contagion as increased correlation only, most authors allow for effects in either direction - network theory provides a theoretical interpretation of declines in correlation as contagion via broken linkages during crises.

The simulation experiments conducted here show that observed changes in correlation coefficients may result from any of a number of changes in shock propagation. Additional volatility in common global conditions undoubtedly increases correlations. But increased volatility in a benchmark asset, without the addition of contagion channels, is consistent with both increased and decreased correlation effects. Contagion effects in a system with a benchmark asset may be associated with either increases or decreases in correlation between asset returns compared with a non-crisis period. This leads us to suggest a need for caution in interpreting evidence - the role of the benchmark asset needs to be clearly separated from other effects, and indeed from the increasingly popular view of the current crisis as a failure of financial networks.

The paper proceeds as follows. In Section 2 we outline three simple tests for the existence of contagion effects drawn from the existing literature and present some evidence on contagion in international equity markets during the current crisis. This forms the background for our discussion of evidence for contagion. Section 3 then lays out the challenges posed to contagion testing by the existence of common global influences and benchmark assets. This section develops a formal model for incorporating these aspects into financial returns. In section 4 we conduct a number of experiments using a calibrated version of the theoretical model. The simulated returns are subject to the three tests conducted in the earlier section, and we examine the behaviour of returns in response to increases in volatility in common factors, in the benchmark asset and in response to contagion effects in turn. The results form the basis of our conclusions in Section 5.

2 Collecting Empirical Evidence

As an example of the difficulties in interpreting the empirical evidence for contagion three relatively straight forward tests for the existence of contagion are applied to equity market data for the crisis of 2007-2009. The three tests are the heteroskedasticity adjusted correlation test of Forbes and Rigobon (2002), denoted FR, a multivariate
Chow test version of the Forbes and Rigobon test developed in Dungey et al (2005a) denoted here as the contagion Chow test or CCT, and the non-linear contagion test of Bae, Karolyi and Stulz (2005), denoted BKS. The basics of these tests are outlined below with more details provided in Dungey et al (2005a,b), including a discussion of their interrelationships.

### 2.1 Test specifications

Consider the case of a matrix of return series for $n$ markets and $T$ observations, where a return for a particular market at a particular time is denoted $y_{i,t}, i = 1 \ldots n, t = 1 \ldots T$. The FR test is conducted on correlation coefficients of returns, where the correlation coefficient of a non-crisis period is compared with the correlation coefficient of the crisis period to gauge whether there has been a statistically significant increase in correlation between the two periods. The innovation of the FR test is that it takes into account that correlation coefficients generally (although not necessarily - see Dungey et al, 2005a) rise during a crisis, and controls for this heteroskedasticity. Denoting the correlation coefficient between two asset returns during the non-crisis period as $\rho_{x,il}$ where following Forbes and Rigobon, $x$ the non-crisis period is defined as the total sample period, and $i, l$ the two assets involved in the correlation, and correspondingly $\rho_{z,il}$ as the correlation coefficient between the corresponding asset returns in the crisis period the FR test can be represented as

$$ FR = \frac{\frac{1}{2} \ln \left( \frac{1 + \nu_{z,il}}{1 - \nu_{z,il}} \right) - \frac{1}{2} \ln \left( \frac{1 + \rho_{z,il}}{1 - \rho_{z,il}} \right)}{\sqrt{\frac{1}{T_x - 3} + \frac{1}{T_z - 3}}} $$

(1)

where $T_x$ is the number of observations in the total sample period, $T_z$ the number of observations in the crisis period, and $\nu_z$ is the correlation coefficient in the crisis period adjusted for the higher volatility

$$ \nu_z = \frac{\rho_{z,il}}{\sqrt{1 + \left( \frac{\sigma^2_{z,il} - \sigma^2_{x,il}}{\sigma^2_{z,il}} \right) (1 - \rho^2_{z,il})}}. $$

(2)

The denominator of $\nu_z$ contains the volatility of the asset return in the country which is deemed to be transmitting the contagious shocks. For this reason the FR test has a strong exogeneity assumption and the crisis country should be identified exogenously.
Extending the FR test to a multivariate version (the CCT test) involves recognising that the test is essentially a Chow test. By scaling the returns appropriately, the FR test can be recast as a single test on a parameter. The test can be written as

\[
\frac{y_{l,t}}{\sigma_{x,l}} = \alpha_0 + \alpha_1 d_t + \theta_1 \left( \frac{y_{l,t}}{\sigma_{x,i}} \right) + \gamma_1 \left( \frac{y_{l,t}}{\sigma_{x,i}} \right) d_t + \eta_t \tag{3}
\]

where \(y_{l,t}\) are the returns for the market receiving contagion from the designated crisis market whose returns are denoted \(y_{i,t}\), and \(\sigma_{x,l} (\sigma_{x,i})\) represents volatility in returns in market \(l (i)\) during the non-crisis period. The dummy variable \(d_t\) takes the value 1 during periods of crisis and 0 otherwise. A test of whether \(\gamma_1 = 0\) in equation (3) is equivalent to the FR test in equation (1). The Chow test form can clearly be extended to a multivariate case where testing for contagion to the market represented by \(y_{l}\) from multiple other potential sources is

\[
\frac{y_{l,t}}{\sigma_{x,l}} = \alpha_0 + \alpha_1 d_t + \sum_{m=1, m\neq l}^{n} \vartheta_m \left( \frac{y_{m,t}}{\sigma_{x,m}} \right) + \sum_{m=1, m\neq l}^{n} \gamma_m \left( \frac{y_{m,t}}{\sigma_{x,m}} \right) d_t + \eta_t. \tag{4}
\]

Tests of no contagion may then be constructed as tests of the significance of parameters \(\gamma_m\).

The BKS test takes the view that the relationship between returns is non linear across the distribution of returns, so that the interrelationship between tail returns in different assets should be modelled separately from the remainder of the distribution. To this end a threshold (\(THRESH\)) defining the tails of the returns distribution needs to be predetermined, usually this is chosen to be the 5% tail. The BKS methodology then constructs a dummy variable \(d_{i,t}\) which takes the value 1 when the return \(y_{i,t}\) is in the tail of the distribution, and 0 otherwise. More formally

\[
d_{i,t} = \begin{cases} 
1 : |y_{i,t}| > THRESH \\
0 : \text{otherwise}
\end{cases} \tag{5}
\]

Once this variable has been constructed a count of coexceedances is undertaken, where a coexceedance between \(y_{i,t}\) and \(y_{l,t}\) occurs when \(d_{i,t} d_{l,t} = 1\). To obtain the coexceedance index for crises originating with asset return \(y_{i,t}\) any point in time we calculate

\[
\Psi_{i,t} = \sum_{m=1, m\neq i}^{n} d_{i,t} d_{m,t}. \tag{6}
\]

The BKS test for the presence of contagion effects in return \(i\) is then constructed by running a multinomial logit regression with dependent variable \(d_{i,t}\) and explanatory
variables which include coexceedances between other assets returns, $\Psi_{t,t}$, as well as a set of variables expected to explain asset returns in each market involved (for example Bae, Karolyi and Stulz (2005) consider interest rates and exchange rates in modelling contagion in stock returns).

While the FR test is clearly bivariate, both the CCT and BKS test provide results for bivariate pairs and overall tests of contagion between multiple asset returns. Each test requires some exogenous choices to the model. Prior to implementation, both the FR and CCT test require choices of the (exogenous) source market of the contagion effects as well as the definition of the crisis and non-crisis sample periods. Neither of these choices is innocuous. The BKS test requires an a priori choice of the source country for contagion, but does not require a crisis subsample definition. The crisis observations are determined endogeneously given an exogeneously chosen threshold for the tail events in equation (5).

2.2 Test implementation

To illustrate the difficulties in interpreting contagion test results the FR, CCT and BKS tests are applied to equity market returns for the Euro Area, the UK and the US using the EuroSTOXX50 index, the FTSE100 index and the S&P500 index, respectively. All series are collected in US dollar terms to control for potential exchange rate effects, and are recorded at 4pm GMT to control for potential time zone effects; see Martens and Poon (2001) and Kleimeier, Lehnert and Verschoor (2008). The tests are applied to examine contagion effects emerging from the US as the source country with data collected from August 2, 2004 until March 23, 2009, a total of 1212 observations. In the FR and CCT tests the non-crisis period is designated as prior to August 9, 2007. On this date, the European Central Bank initiated a series of actions to distribute funds to the market which was suffering a liquidity squeeze in the wake of reassessment of the creditworthiness of the asset backed security market, an action which accompanied the announcement of the cessation of redemptions on a number of BNP Paribas investment funds. The US Federal Reserve and several other central banks acted to extend liquidity to the market very shortly thereafter. The non-crisis period in the sample covers 788 observations, and the crisis period 424 observations.

Descriptive statistics and correlation coefficients for the asset returns are shown in
Table 1:

Descriptive Statistics for returns on the EuroSTOXX50, FTSE100 and the S&P500 indices for August 2, 2004 to March 23, 2009. All data are recorded at 4pm GMT.

<table>
<thead>
<tr>
<th></th>
<th>Euro Area</th>
<th>UK</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>mean</strong></td>
<td>0.055</td>
<td>0.043</td>
<td>0.033</td>
</tr>
<tr>
<td><strong>max</strong></td>
<td>2.362</td>
<td>2.604</td>
<td>2.005</td>
</tr>
<tr>
<td><strong>min</strong></td>
<td>-2.793</td>
<td>-3.197</td>
<td>-2.245</td>
</tr>
<tr>
<td><strong>variance</strong></td>
<td>0.596</td>
<td>0.476</td>
<td>0.374</td>
</tr>
</tbody>
</table>

| **mean**         | -0.175    | -0.117| -0.149|
| **max**          | 8.895     | 9.384 | 10.945|
| **min**          | -8.042    | -9.266| -10.136|
| **variance**     | 4.343     | 4.332 | 4.524 |

| **mean**         | -0.024    | -0.012| -0.028|
| **max**          | 8.895     | 9.384 | 10.945|
| **min**          | -8.042    | -9.266| -10.136|
| **variance**     | 1.916     | 1.829 | 1.833 |


Tables 1 and 2. The tables are broken into the sub-period of the non-crisis period, the crisis period and the total sample period. It is clear that the general expectation of higher unconditional correlation coefficients during periods of crisis, often taken as evidence of reduced diversification opportunities, is evident in the data considered here.

In applying the tests of contagion, the returns are assumed to have been stripped of common factors, and thus represent excess returns. Here we follow Forbes and Rigobon (2002) for the FR test and create excess returns by gathering the residuals from a single VAR(1) in the daily equity returns over the entire period with an exogeneous control variable of the US federal funds rate to represent the common global conditions.

Table 3 shows the results of the three contagion tests. Each test has the null hypothesis of no contagion, so that a statistically significant result is consistent with a rejection of the null hypothesis, and is evidence for contagion. In the illustrative
Table 2:
Correlation coefficients between returns in on the EuroSTOXX50, FTSE100 and the S&P500 indices for August 2, 2004 to March 23, 2009. All data are recorded at 4pm GMT.

<table>
<thead>
<tr>
<th></th>
<th>Euro Area</th>
<th>UK</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro Area</td>
<td>1.000</td>
<td>0.818</td>
<td>0.797</td>
</tr>
<tr>
<td>UK</td>
<td>1.000</td>
<td>0.689</td>
<td></td>
</tr>
<tr>
<td>US</td>
<td></td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Euro Area</td>
<td>1.000</td>
<td>0.888</td>
<td>0.881</td>
</tr>
<tr>
<td>UK</td>
<td>1.000</td>
<td>0.827</td>
<td></td>
</tr>
<tr>
<td>US</td>
<td></td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Euro Area</td>
<td>1.000</td>
<td>0.875</td>
<td>0.864</td>
</tr>
<tr>
<td>UK</td>
<td>1.000</td>
<td>0.806</td>
<td></td>
</tr>
<tr>
<td>US</td>
<td></td>
<td>1.000</td>
<td></td>
</tr>
</tbody>
</table>
equity data used here, the bivariate FR tests find no evidence of contagion, while the BKS test finds evidence of contagion from the US equity market to all other markets. The CCT tests are somewhere in between with mixed results. Although the joint test reveals contagion from the US to the Euro Area and the UK, contagion just to the Euro Area is not significant.

Table 3:
Test statistics for null of no contagion from the US equity market to the equity markets of the UK and Euro Area using the bivariate FR test, the CCT test and the BKS test.

<table>
<thead>
<tr>
<th>Test</th>
<th>Recipient country</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Euro Area</td>
</tr>
<tr>
<td>FR</td>
<td>-5.187</td>
</tr>
<tr>
<td></td>
<td>(1.000)</td>
</tr>
<tr>
<td>CCT</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>(0.968)</td>
</tr>
<tr>
<td>BKS</td>
<td>56.688*</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

note: the CCT bivariate and joint tests have 1 and 2 degrees of freedom respectively.
* denotes significance at the 0.05 level of significance.

3 The global economic conditions problem

The examples given in Section 2.2 illustrate the performance of three common contagion tests on equity markets in the global financial crisis. However, many would argue that this is simply the sideshow to the real problems which have emerged. The pivot of this crisis has been in credit markets, and particularly with the behaviour of short term credit markets such as interbank markets which has, at times, frozen. Hence, we may wish to measure contagion in credit and bond markets. Ideally, we wish to examine cross market, cross country contagion effects within a single model. There is a small, but
growing literature attempting to implement such models, see for example Dungey and Martin (2007) who consider foreign exchange and equity markets jointly, Dungey, Fry, González-Hermosillo, Martin and Tang (2009) who consider sovereign bond markets and equity markets jointly, as well as Hartmann, Straetmans and de Vries (2004) who examine pairs of equity and bond markets across geographical borders. This would be one way to approach the problem.

Two particular problems arise in the current crisis. The first is that short term US interest rates are commonly used in the literature as the control for the global factor as in the example in Section 2 and Forbes and Rigobon (2002). The second is that in modelling crises in credit markets the interest rate data display high persistence. This is usually overcome by examining instead the spread between the credit market of interest and some benchmark rate - where the benchmark is often the US short term money market rate.

These two problems present us with essential challenges. We need to know how contagion tests are affected by problems arising from volatility in benchmark assets, such as US interest rates, as well as in global control variables. To examine this we return to a workhorse model previously used to simulate the behaviour of markets in crisis, and amend it to accommodate these most recent crisis period characteristics. The model is drawn from the work in Dungey and Martin (2004, 2007) and used in simulation experiments in Dungey, Fry and Martin (2006). In the latter case the role of a common benchmark is not accounted for. Here, a model is simulated based on that recently estimated for equity and bond markets in the current crisis in Dungey (2008). Dungey (2008) augments a factor model of contagion to account for a common benchmark asset, namely a US Treasury rate.

3.1 Global market linkages in non-crisis times

To motivate the model design, consider that many financial market asset prices or returns may be represented by a latent factor model, as suggested in Longin and Solnik (1995) and Mahieu and Schotman (1994). In this case the return for an asset type $i$ in country $k$ at time $t$, $y_{i,k,t}$, may be modelled as a linear combination of two latent factors, representing systematic and diversifiable risk

$$y_{i,k,t} = \theta_{i,k} W_t + \phi_{i,k} f_{i,k,t}$$  \hspace{1cm} (7)
where \( W_t \) represents the time-varying systematic risk affecting all assets, \( i \), although with potentially different impact coefficients, \( \theta_{i,k} \), and \( f_{i,k,t} \) is the time-varying idiosyncratic risk associated with that asset, which has a constant impact coefficient \( \phi_{i,k} \). In the case of a multimarket, multicountry model, this can be augmented for any given asset by a factor representing the country of origin, and a factor representing the asset market concerned. Thus we capture common country risk and common market risk by modifying equation (7) as follows

\[
y_{i,k,t} = \theta_{i,k} W_t + \alpha_{i,k} C_{k,t} + \beta_{i,k} M_{i,t} + \phi_{i,k} f_{i,k,t}
\]  

where \( C_{k,t} \) represents the time varying country specific factor, and \( M_{i,t} \) the time varying market specific factor. To illustrate, if we desire to model the bond market and the equity market simultaneously for 3 countries, then \( k = 3 \) and \( i = 2 \), making a total of 6 assets in the model under consideration.

However, to examine bond markets appropriately in this model, it needs to be augmented to control for the behaviour of a benchmark interest rate. This allows interest rates in each country to be assessed relative to that benchmark. In the past this has been easily achieved by using the US interest rate as the benchmark and not considering the US specifically as a source country for contagion. Clearly, modification is needed to account for this in the current environment.

Consider then, the case of modelling the interest rate in country \( k \) as a premium over the US interest rate. Denoting the credit market as \( i = r \), the US interest rate itself can be expressed as

\[
y_{r,US,t} = \theta_{r,US} W_t + \alpha_{r,US} C_{US,t} + \beta_{r,US} M_{r,t} + \phi_{r,US} f_{r,US,t}
\]  

and the premium for an interest rate in country \( k \neq US \), over the US interest rate can be expressed as

\[
y_{r,k,t} - y_{r,US,t} = (\theta_{r,k} - \theta_{r,US}) W_t + \alpha_{r,k} C_{k,t} + (\beta_{r,k} - \beta_{r,US}) M_{r,t} + \phi_{r,k} f_{r,k,t}
\]  

while equity market returns, \( i = q \), continue to be expressed as

\[
y_{q,k,t} = \theta_{q,k} W_t + \alpha_{q,k} C_{k,t} + \beta_{q,k} M_{q,t} + \phi_{q,k} f_{q,k,t}.
\]
The system represented by equations (10) and (11) then contains a number of common elements. The first is that due to the global common factor, or systematic risk factor, given by \( W_t \) which affects all markets regardless of geographical location or asset type. The second is a market factor, \( M_{q,t} \) for the equity market and \( M_{r,t} \) for the bond markets. Then there are common country factors which link across the different asset markets in a particular country denoted by \( C_{i,t} \). The country factor of \( C_{US,t} \) plays a special role. It appears in every interest rate spread as well as the US equity market return. This links US equity market developments firmly to international bond markets, and represents the commonly observed importance of the US market in transmitting shocks across asset markets. Finally there are undiversifiable shocks to each of the asset markets in each country \( (f_{i,k,t}) \).

### 3.2 Global market linkages in crisis times

Equations (10) and (11) represent the linkages between a system in normal times. During times of crisis, contagion refers to the emergence of additional linkages (either positive or negative) which may occur during these periods. This enables the capture of many different forms of contagion as explained in the survey article of Dungey et al. (2005a). These extra linkages do not result from the existing links: a transmission of additional common shocks during crisis would be captured by the same parameters as the model already given, but be represented by increased volatility in the time varying factors themselves. Rather, the contagion effects come about through newly emerging links between the \( y_{i,k,t} \) and the idiosyncratic factors.

The global financial crisis has created a particular interest in the effects of contagion from US markets to others - and most importantly the effects of contagion from the US credit and equity markets. Consider first a model which allows for contagion effects from the US credit market by augmenting equations (10) and (11) with an additional effect from the idiosyncratic factor \( \phi_{r,US} f_{r,US,t} \). This results in an expression for the premium of an interest rate in country \( k \neq US \), over the US interest rate

\[
y_{r,k,t} - y_{r,US,t} = (\theta_{r,k} - \theta_{r,US}) W_t + \alpha_{r,k} C_{k,t} + (\beta_{r,k} - \beta_{r,US}) M_{r,t} + \phi_{r,k} f_{r,k,t} - \alpha_{r,US} C_{US,t} + (\delta_{r,k} - 1) \phi_{r,US} f_{r,US,t} \tag{12}
\]
while equity market returns \((i = q)\) are

\[
y_{q,k,t} = \theta_{q,k}W_t + \alpha_{q,k}C_{k,t} + \beta_{q,k}M_{q,t} + \phi_{q,k}f_{q,k,t} + \delta^{q,US}_{q,k} \phi_{r,US}f_{r,US,t}. \tag{13}
\]

The parameter \(\delta^{j,m}_{i,k}\) represents the contagion effect on asset type \(i\) in country \(k\), originating from asset type \(j\) in country \(m\).

In the case where the contagious shock originates in the US equity market then equations (10) and (11) take the form

\[
y_{r,k,t} - y_{r,US,t} = (\theta_{r,k} - \theta_{r,US})W_t + \alpha_{r,k}C_{k,t} + (\beta_{r,k} - \beta_{r,US})M_{r,t} + \phi_{r,k}f_{r,k,t} - \alpha_{r,US}C_{US,t} - \phi_{r,US}f_{r,US,t} + \delta^{q,US}_{r,k} \phi_{q,US}f_{r,US,t} \tag{14}
\]

while equity market returns, \(i = q\), are expressed as

\[
y_{q,k,t} = \theta_{q,k}W_t + \alpha_{q,k}C_{k,t} + \beta_{q,k}M_{q,t} + \phi_{q,k}f_{q,k,t} + \delta^{q,US}_{q,k} \phi_{r,US}f_{r,US,t}. \tag{15}
\]

To combine effects from both markets, that is potential contagion from the US credit market and the US equity market the final form of the equations representing bond premia and equity market returns are respectively

\[
y_{r,k,t} - y_{r,US,t} = (\theta_{r,k} - \theta_{r,US})W_t + \alpha_{r,k}C_{k,t} + \beta_{r,k}M_{r,t} + (\beta_{r,k} - \beta_{r,US})M_{r,t} + \phi_{r,k}f_{r,k,t} - \alpha_{r,US}C_{US,t} + (\delta^{q,US}_{r,k} - 1)\phi_{r,US}f_{r,US,t} + \delta^{q,US}_{q,k} \phi_{q,US}f_{r,US,t} \tag{16}
\]

and

\[
y_{q,k,t} = \theta_{q,k}W_t + \alpha_{q,k}C_{k,t} + \beta_{q,k}M_{q,t} + \phi_{q,k}f_{q,k,t} + \delta^{q,US}_{q,k} \phi_{r,US}f_{r,US,t} + \delta^{q,US}_{q,k} \phi_{r,US}f_{r,US,t}. \tag{17}
\]

Individual tests of the hypothesis of no contagion from the benchmark US credit market are represented by whether \(\delta^{q,US}_{i,k} = 0\) for a chosen \(i, k\), and tests for contagion from US equity markets are represented by whether \(\delta^{q,US}_{i,k} = 0\) for a chosen \(i, k\). Thus a test of no contagion from US equity markets to any other markets would be represented as \(\delta^{q,US}_{i,k} = 0\) for all \(i, k\) and for no contagion from US credit markets to any other markets as \(\delta^{q,US}_{i,k} = 0\) for all \(i, k\), and an overall joint test of no contagion in the system by \(\delta_{i,k}^{US} = 0\), for all \(i, j, k\).

## 4 Simulation experiments

The aim of this paper is to examine the properties of correlations between asset classes when subject to an increase in volatility of a common benchmark asset which may in
fact be the source asset for the crisis. A series of simulation experiments based on
the model above provides the framework for the analysis. The impacts of changing
different elements of the linkages existing in a crisis period are analyzed in terms
of their impacts on contagion tests. In doing this we also examine the impact of
increases in the volatility of common factors. Increased volatility in common factors
has previously been shown to reveal itself as changes in correlation structures, and the
additional benchmark factor here may exacerbate or moderate their effects in terms of
the analysis of contagion evidence.

The results are also analyzed in the presence of pure contagion in a way that con-
tagion as outlined in the previous section. Consistent with common tests of contagion,
the simulation results are all presented in terms of the changes in the correlation be-
tween the asset returns attributable to alternative sources of change in the structure.
These are the result of the introduction of structural breaks to accommodate greater
volatility in factors, or the introduction of contagion effects from either the US credit
market or the US equity market. The correlations for the simulated data reported
without structural breaks of contagious linkages (the baseline case) provide the point
of comparison. This is akin to the non-crisis case in the real data.

4.1 The baseline

The design of the baseline simulation is as follows. First we consider a parameterisation
of the model for 3 countries, consistent with the number of countries in the empirical
example in Section 2. We denote the third country, $k = 3$, as the US or benchmark asset
and the two assets represent credit and equity markets, $i = r, q$. This parameterization
corresponds with the model in equations (10) and (11) of the baseline representing the
non-crisis period and are summarized in Table 4. Each of the factors, $W_t, C_{k,t}, M_{i,t}$ and
$f_{i,k,t}$ are initially randomly drawn from a $N(0, 1)$ distribution. The sample size of the
simulated dataset is 700 observations, which is roughly the size of the non-crisis sample
period considered in Section 2.2 This parameterisation gives a set of asset returns which
look as given in Figure 1 representing asset returns.1

1 The Figures show that the simulated data are not dissimilar to observed data, although the
presence of volatility clustering and fat tails is not incorporated into the simulation model.
Figure 1:
Simulated data for the non-crisis period based on parameter estimates contained in Table 4.

(a) credit market 1 \([y_{r,1,t}]\)

(b) equity market 1 \([y_{q,1,t}]\)

(c) credit market 2 \([y_{r,2,t}]\)

(d) equity market 2 \([y_{q,2,t}]\)

(e) credit market US \([y_{r,US,t}]\)

(f) equity market US \([y_{q,US,t}]\)
markets, and that credit markets reflect the underlying fundamentals (or country risk) of a country much more closely than do equity markets. Given these premises, the common factor parameters, $\theta_{i,k}$, are chosen so that the credit markets are less affected by the common factors than the equity markets, with a range between 0.2 and 0.4 for the credit markets ($\theta_{r,k}$), and between 0.4 and 0.7 for the equity markets. Of the credit markets, the parameter for the US ($\theta_{r,US}$) is 0.2 which is the smallest for the credit markets reflecting that it is likely that the US actually provides much of the common factor in its observed behaviour given that it represents the benchmark already. The parameters on the country factor ($\alpha_{i,k}$) are higher in each country for the bond market than the equity market. The bond markets respond little to the bond market factor ($\beta_{r,k}$) which captures movements common to the bond market internationally in comparison to the response of the equity market to its own market factor shocks ($\beta_{q,k}$). Finally, the idiosyncratic parameters ($\phi_{i,k}$) are substantially higher for the bond market than the equity market. Within each asset return, examination of the relative parameter magnitudes also reflects that the country and idiosyncratic parameters are most important for the bond market and that the global and market factors are most important for the equity market.

To illustrate the properties of the simulation under the parameterization of the benchmark scenario, Table 5 presents the correlation matrix for the data as in Figure 1. Comparison of the non-crisis correlations of the simulated returns with those of the actual equity returns data in Table 2 shows that the values are reasonably close in range. This provides the baseline scenario to which the crisis period scenarios explored in the simulation experiments are compared in Section 4.2.
Table 5:
Correlation coefficients of simulated model in non-crisis period.

<table>
<thead>
<tr>
<th></th>
<th>$k = 1$</th>
<th></th>
<th>$k = 2$</th>
<th></th>
<th>$k = US$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r$</td>
<td>$q$</td>
<td>$r$</td>
<td>$q$</td>
<td>$r$</td>
</tr>
<tr>
<td>$k = 1$</td>
<td>1.000</td>
<td>0.156</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$k = 2$</td>
<td>0.379</td>
<td>0.129</td>
<td>1.000</td>
<td>0.057</td>
<td>0.707</td>
</tr>
<tr>
<td>$k = US$</td>
<td>-0.603</td>
<td>0.212</td>
<td>-0.497</td>
<td>0.104</td>
<td>0.782</td>
</tr>
<tr>
<td></td>
<td>0.039</td>
<td>0.874</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.2 The experiments.

The fundamental problem facing analysts and policymakers when examining crisis data is that it is unclear whether an observed change in the correlation structure is due to a change in the underlying volatility of the common global factor ($W_t$), a change in the volatility of the benchmark factor being propagated throughout markets ($f_{r,US,t}$), or contagion from either of two markets involved in the system, propagated as shown in equations (16) and (17). By simulating the system we can cleanly differentiate these effects. Thus 4 experiments are undertaken as follows.

1. Experiment I: Increased volatility in the common world factor $W_t$. In the benchmark non-crisis case $W_t \sim N(0, 1)$, in experiment I, $W_t \sim N(0, \omega_1)$ where $\omega_1 > 1$.

2. Experiment II: Increased volatility in the benchmark credit market factor $f_{r,US,t}$. In the benchmark non-crisis case $f_{r,US,t} \sim N(0, 1)$, in experiment II, $f_{r,US,t} \sim N(0, \omega_2)$ where $\omega_2 > 1$.

3. Experiment III: Contagion from US credit markets to other markets. This is achieved by setting $\delta^{r,US}_{t,k} > 0$ in equation (16).

4. Experiment IV: Contagion from US equity markets to other markets. This is achieved by setting $\delta^{e,US}_{t,k} > 0$ in equation (17).

Table 6 gives the values of the contagion parameters used in the simulations which range across the values 0.5 to 0.9. Figure 2 presents the simulated data generated.
under each experiment. There are 500 observations simulated for each experiment, again consistent with the sample size of the crisis period data considered in Section 2.2. The results of each experiment with more specific details on the crisis period parameterisations are discussed in the following subsections.

Table 6:
Parameterization of the contagion effects in the simulation experiments III and IV.

<table>
<thead>
<tr>
<th></th>
<th>Experiment III</th>
<th>Experiment IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta_{i,k}^{r,US}$</td>
<td>$\delta_{i,k}^{q,US}$</td>
<td>$\delta_{i,k}^{r,US}$</td>
</tr>
<tr>
<td>$i = r, i = q$</td>
<td>$i = r, i = q$</td>
<td></td>
</tr>
<tr>
<td>$k = 1$</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>$k = 2$</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>$k = US$</td>
<td>-</td>
<td>0.6</td>
</tr>
</tbody>
</table>

4.2.1 Experiment I: increased volatility in the common global factor

Experiment I represents the case most commonly cited as causing problems in detecting contagion vis-à-vis simply increased interdependence; most notably Forbes and Rigobon (2002). In conducting these experiments, the simulations are run with increasing levels of volatility in the common world factor, such that $\omega_1 = 1, 2...10$. An example of the simulated data in this experiment is given for the case of $\omega_1 = 5$ in the first column of Figure 1. Compared with Figure 2 (or the first 700 observations in Figure 1) there is an increase in volatility in each asset shown. This is most evident in the equity market plots (panels m, q and u) which have the larger corresponding parameters $\theta_{i,k}$.

The changes in the correlation coefficients between each of the different assets from the benchmark during Experiment I are noted for each asset at each value of $\omega_1$, and the corresponding plots are given in the first column of Figure 3. Positive values on these figures mean that the correlation coefficient between those assets has increased over the benchmark correlation given in Table 5. As the volatility of the common factor rises (as $\omega_1$ increases), the correlation coefficient for each asset pair also increases, as shown in the left hand column of Figure 3. It is worth noting that the correlation increases the most for the pairs $y_{r,1}y_{r,US}$ and $y_{r,2}y_{US}$ (panel I(a) of Figure 3). Both
Examples of the simulated data for each experiment. The first 700 observations correspond to the benchmark data in each case. The final 500 observations correspond to the data generated in the experiments. Experiment I (column 1) with \( \omega_1 = 5 \), Experiment II (column 2) \( \omega_2 = 5 \), Experiment III (column 3) \( \delta_{i,k} = \sigma_{rUS} \times 5 \), Experiment IV (column 4) \( \delta_{qUS} = \sigma_{qUS} \times 5 \).
y_{r,1} and y_{r,2} have the highest degree of response to the common factor (see Table 4 on parameter set up), but they display the greatest increase in correlation when paired with the lower reacting credit market, the US. When paired together, their increase in correlation is not as evident. This is particularly interesting, as the pair $y_{r,1}y_{r,2}$ are the least correlated of the credit markets in the benchmark case given in Table 7 but the only slightly more correlated case of $y_{r,1}y_{r,US}$ experiences the greatest increase in correlation during the crisis.

4.2.2 Experiment II: increased volatility in the benchmark asset factor

In experiment II the volatility of the benchmark asset factor, $f_{r,US,t}$, given by $\omega_2$ is increased such that $\omega_2 = 1, 2...10$. The right hand column of Figure 3 shows the impact on correlation coefficients of each asset pair of an increase in the volatility of the benchmark US credit factor, with the horizontal axis in each figure showing the case for increasing levels of volatility, $\omega_2$.

Unlike the case of the increase in the volatility of the common factor from experiment I, the increases in volatility in the benchmark US credit factor present varying results. In the case of the correlation between $y_{r,1}$ and $y_{r,2}$ the asset $y_{r,US}$ acts as a common factor as it enters both equations with coefficients $-\phi_{r,US}$, and the correlation rises (see panel II(a) of the right hand column of Figure 3) This is consistent with the common factor results in I(a) of the same figure. However, in that same panel it is apparent that the increase in the volatility in the benchmark factor has reduced the correlation between each of $y_{r,1}$ and $y_{r,2}$ with the benchmark asset $y_{r,US}$. This is clearly a result of the different signs on coefficients entering any expression explaining the evolution of $y_{r,US}$ where $f_{r,US,t}$ enters with the opposite sign to that apparent in the construction of the premia $y_{r,k,t} - y_{r,US,t}$ as shown in equation (10).

Panel II(b) of the right hand column of Figure 3 shows no change in the correlation structure of the equity market returns, reflecting the lack of impact that the benchmark US credit factor has in the equity market equations - see equation (11). Panels II(c) to II(e) of the right hand side of Figure 3 show that correlations decrease in the cross market correlations. The correlations are affected by the benchmark factor but in the opposite direction to the effects of a volatility increase in the common global factor.

The results make for an interesting tie with the existing literature where the majority of the literature on contagion reports rising correlation in response to conta-
gion effects, although not always ruling out decreases as evidence, while the relatively newer network literature on contagion, particularly related to banking networks, views contagion as breaks in linkages in the network which are consistent with decreasing correlation. In the simulations of experiments I and II we have shown that it is possible to produce both of these outcomes. Simply changing the extent of volatility in the common factor causes an increase in correlation, while increasing volatility in the benchmark factor can be causal to a decrease in correlation. It appears that the involvement of a benchmark market can lead to observed outcomes consistent with what network contagion predicts without any actual changes in the network.

4.2.3 Experiments III and IV: Contagion effects

Contagion effects from the US credit market are simulated in Experiment III by introducing positive values of the parameter $\delta^{r,US}_{j,k}$. In each simulation the relative size of the contagion parameters reported in Table 6 are multiplied by an integer, ranging from 0 to 10. The corresponding change in correlation coefficient over the baseline is given for each pair of assets in the left hand column of Figure 4. It is apparent in panel III(a) of the figure that the correlation coefficient between all combinations of credit markets increase. Contagion effects from US credit markets also have a positive effect on correlations between equity markets, panel III(b) and on correlations between the non-US credit markets and each of the equity markets, panels III(c) and III(d). However, the correlation pairs involving the US benchmark interest rate and all equity markets, panel III(e) decline as a result of the contagion effects.

The simulation of contagion effects from US equity markets on the asset pairs produce some similarities, shown in the right hand side column of Figure 4. At stronger levels of contagion, $\delta^{q,US}_{r,k} > 1$, the correlation coefficient between all credit markets and the US credit market unambiguously rise in each instance, panel IV(a). Correlations between all equity pairs rise, although contagion effects do dampen this slightly registering a fall in correlations for the pairing with the US equity market $(y_{r,1}y_{r,US}$ and $y_{r,2}y_{r,US})$ where contagion is relatively weaker. In cross market pairings not involving the US credit market, correlations rise, panels IV(c) and IV(d). However, for cases where the US credit market is involved as one part of the correlation pair, panel IV(e), the correlation coefficients fall, unambiguously for the case of $y_{r,US}, y_{q,US}$.

In the case of the cross correlations involving the US credit market and the equity
Figure 3:
Change in correlation over baseline case associated with Experiment I: increase in common factor volatility (left hand side column) and Experiment II: increase in benchmark US credit factor volatility (right hand side column).
markets $y_{q,1}$ and $y_{q,2}$ at low levels of contagion $\delta_{r,k}^{q,US} = 1$ the contagion effect results in a slightly positive increase in correlation compared with the benchmark case for these pairs.

The results of the simulation experiments show how difficult it may be in observed data to sort out the relative effects of changes in volatility in common factors, benchmark markets and contagion from alternative markets. From a casual examination of the correlation coefficient between asset $y_{r,1}$ and $y_{r,2}$ it is very difficult to determine whether an observed increase in that coefficient during a period of crisis is due to an increase in volatility in the common factor, an increase in volatility in the benchmark market factor or indeed due to contagion from any of a number of markets. In each of the simulations for different experiments the correlation between these two assets was increased. On the other hand, where the benchmark market is clearly separated from the other market under consideration (equity markets here), an increase in contagion between assets in the other asset class seems to be attributable to either an increase in volatility in the common factor or contagion from the non-benchmark market at low levels. This is consistent with other literature pointing to the misleading effects of common factors on correlation coefficients, see for example Pericoli and Sbracia (2003).

However, there is a caveat to even this result - in the presence of low levels of contagion from the market in question, here the US equity markets, correlation coefficients may in fact rise. But in this case it is important to know that one of the assets involved is the source of the contagion effects.

Increased correlation between equity markets, here the non-benchmark market, is attributable in our simulations to any of an increase in the volatility of the common world factor or contagion from either market. Only in the case of correlations between equity markets themselves is this distinguished as there is no change in the correlation structure. Cross market effects are even more complex. Increases in correlations not involving $y_{r,US}$ are potentially due to increases in common factor volatility or contagion from either market. Only increases in volatility of the benchmark assets result in a decline in correlation between these assets. However, in the case of correlations involving the benchmark asset, the only evidence for increases in these correlations is sourced with an increase in common factor volatility, or from relatively low levels of contagion effects in the non benchmark market. Increases in benchmark asset volatility
Figure 4:
Change in correlation over baseline case associated with Experiment III: contagion from the US credit market (left hand side column) and Experiment IV: contagion from the US equity market (right hand side column).

III (a) credit market

III (b) equity market

III (c) credit mkt 1 with equity

III (d) credit mkt 2 with equity

III (e) US credit mkt with equity

IV (a) credit market

IV (b) equity market

IV (c) credit mkt 1 with equity

IV (d) credit mkt 2 with equity

IV (e) US credit mkt with equity
and contagion effects otherwise all result in lower correlation coefficients. This result may well account for why the evidence in the most recent crisis is more supportive of the network theory of failing linkages evidenced by reductions in correlation coefficients - structurally the result is the effect of the source of the contagion being the benchmark asset, a phenomenon not experienced in crises in recent history.

This section has used a relatively simple factor model to explore why the change in the correlation structure observed with a financial crisis is quite difficult to interpret. While previous literature had uncovered the important role of the common factor effects in understanding this process, until the most recent crisis it had not been strictly necessary to consider the impact of the involvement of benchmark markets in the role of crisis market. The results show the important impact this has on the results. The involvement of the benchmark asset can account for observed falls in correlation coefficients between asset returns, which are nevertheless consistent with the presence of contagion effects. As well as the overall common factor effects on increasing volatility, we also demonstrate that increased volatility in the benchmark factor can additionally result in reduced volatility. Hence a number of the features of the current crisis - where the originating market is the benchmark US credit market - are revealed as being logical outcomes of the interactions of the data when both common shocks and benchmark assets are involved.

Rather than being simply the developed market centre through which crises are delivered to the periphery without being particularly involved in the volatility, as proposed for earlier crises by Kaminsky and Reinhart (2002), where the benchmark asset is involved it distributes the effects in a way that may at first seem counterintuitive. Correlations increase between other markets, but correlations between the benchmark asset and other markets may decrease. This may serve to confuse as previous evidence has characterized crises as involving increased correlation effects. The simulation demonstrates that, as in the recent crisis, this does not always have to be the case. More particularly, decreases in correlation may in fact be consistent with relatively large contagion effects.
4.3 Application of contagion tests to the simulated data

Finally, we return to the application of the three simple contagion tests in Section 2, and consider how those tests perform on the simulated data. Table 7 reports the effects of testing for contagion using the FR, CCT and BKS tests for the simulated credit market data (where benchmark effects are most evident) during each experiment. In the first and second experiments the simulations do not involve contagion, but rather an increase in global volatility conditions and benchmark asset volatility. In the third and fourth experiments contagion effects are present from the US credit markets to all other markets and from the US equity market to all other markets. Thus if the tests are performing well they should distinguish the cases of increased volatility (by accepting the null of no contagion) from the cases of contagion (experiments III and IV).

In fact the tests are unsuccessful in distinguishing between the cases. In the case of no contagion (experiments I and II), the FR test accepts the null of no contagion, and the CCT test accepts the null of no contagion from the US credit market to $y_{r,2}$ but rejects it in the case of $y_{r,1}$. The BKS tests both indicate the presence of contagion pairs of assets (originating with asset 3, the US). The CCT test for joint contagion, shown in the final column of the Table, accepts the null of no contagion, but rejects it using the BKS test. The results for experiment II are no more encouraging, with rejection of the null of no contagion for all but the FR tests and the CCT test for contagion from US credit markets to $y_{r,2}$.

In experiments III and IV where contagion effects exist, the FR test continues to accept the null of no contagion. The evidence on rejection of the null of no contagion is more mixed for the other tests. Most of the CCT and BKS tests reject the null of no contagion for most cases. However, the CCT test finds no contagion from US credit markets to $y_{r,1}$ in experiment III and the BKS finds no contagion to $y_{r,2}$. In summary, the FR test always finds no contagion, regardless of whether it exists, consistent with the known poor size of this test, while the BKS test is likely to find contagion in most situations. The CCT test is more mixed, but here finds more evidence of contagion than it should. These results compound the difficulties in interpretation reported in Section 2.
5 Conclusion

Disentangling the effects of contagion from increased volatility has important policy implications. Prescribing the correct medicine will be more difficult without an accurate diagnosis of the source of infection. If contagion is the culprit there may be a cause for reform of financial market infrastructure or regulatory policy. If increased volatility is the cause then there may be macroeconomic reform required. The first requirement is to understand the source of the difficulties.

Prior to the global financial crisis of 2007-2009 the main focus of contagion testing and financial reform had been on distinguishing increased common conditions volatility from contagion effects. Emerging markets seemed to evidence the largest contagion effects and developed markets acted merely as a transit for shocks between emerging markets. However, the current crisis is intrinsically concerned with financial market products from developed markets, and particularly from the US credit markets. This has added a new layer to the complexity of understanding the crisis. Previously, US credit markets were used as a benchmark asset in contagion studies, to either control for common global conditions, or in calculating emerging market spreads.

This paper demonstrates that when contagion effects are emanating from the benchmark asset it is even more difficult to apply and interpret traditional contagion testing. Using simulations of a latent factor model which has previously been shown to nest most existing tests for contagion, the paper demonstrated that increased correlations between asset markets may be due to any of increased volatility in common conditions, contagion effects or increased volatility in a benchmark asset. But, equally, decreased correlations between asset markets may be evidenced by increased volatility in benchmark assets or contagion effects. The role of the benchmark asset can reinforce or offset the impact of other channels of transmission. The challenge arising is to develop theoretical models which reflect these known data characteristics and accommodate each of these scenarios, in order to be able to provide appropriate policy reform advice.

References


Contagion tests on the simulated data from experiments I to IV. The tests are performed on data with the parameters set as in Table 4 for the non-crisis parameters with the additions of \( \omega_1 = 5 \) in experiment I, \( \omega_2 = 5 \) in experiment II, \( \delta_{i,k}^{\mu,US} = \delta_{i,k}^{\mu,US} \times 5 \) in experiment III, and \( \delta_{i,k}^{\rho,US} = \delta_{i,k}^{\rho,US} \times 5 \) in experiment IV.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Test</th>
<th>( y_{r1,t} )</th>
<th>( y_{r2,t} )</th>
<th>( y_{r1,t} \text{ and } y_{r2,t} )</th>
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<tbody>
<tr>
<td>Experiment I</td>
<td>FR</td>
<td>-0.102</td>
<td>-0.380</td>
<td>n.a.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.541)</td>
<td>(0.648)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CCT</td>
<td>56.528*</td>
<td>0.538</td>
<td>2.707</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.000)</td>
<td>(0.463)</td>
<td>(0.258)</td>
</tr>
<tr>
<td></td>
<td>BKS</td>
<td>40.295*</td>
<td>33.651*</td>
<td>91.879*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Experiment II</td>
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<td>-1.000</td>
<td>n.a.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.293)</td>
<td>(0.841)</td>
<td></td>
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<tr>
<td></td>
<td>CCT</td>
<td>4.478*</td>
<td>0.646</td>
<td>5.191*</td>
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<td>(0.422)</td>
<td>(0.075)</td>
</tr>
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<td>BKS</td>
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<td>46.954*</td>
<td>92.565*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
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<tr>
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<td></td>
<td>(0.532)</td>
<td>(0.612)</td>
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<tr>
<td></td>
<td>CCT</td>
<td>0.564</td>
<td>47.222*</td>
<td>119.935*</td>
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<td></td>
<td></td>
<td>(0.453)</td>
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<td>BKS</td>
<td>31.256*</td>
<td>42.073*</td>
<td>59.171*</td>
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<td></td>
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<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
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<tr>
<td>Experiment IV</td>
<td>FR</td>
<td>-1.324</td>
<td>-0.448</td>
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<td></td>
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<td>(0.907)</td>
<td>(0.673)</td>
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<tr>
<td></td>
<td>CCT</td>
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<td>234.06*</td>
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<td>(0.000)</td>
<td>(0.739)</td>
<td>(0.041)</td>
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