GLOBAL FINANCIAL CONTAGION IDENTIFICATION: FROM RUSSIA TO BRAZIL

by

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PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF BUSINESS ADMINISTRATION

GLOBAL ASSET AND WEALTH MANAGEMENT

In the Faculty
of
Business Administration

SIMON FRASER UNIVERSITY

Spring 2006

Approval

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Degree: Master of Business Administration

Title of Project: Global Financial Contagion Identification: From Russia to Brazil

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Date Approved: April 10, 2006

Abstract

In the last several years, there has been a large amount of effort aimed at identifying the causes of contagion and how contagion can be measured. Recent studies have found that correlation coefficients overstate the existence of contagion due to the heteroscedasticity of market returns. Specifically, this paper applies an adjustment to the correlations between the Russian and Brazilian stock markets to determine whether or not the rise in variances during the Russian Cold crisis of 1998 was in fact an episode of contagion. A crisis period that causes an increase in the level of biasness leads to false conclusions of contagion – when in fact none exists. In light of these findings and given the immense fallout from the Russian Cold crisis of 1998, this paper will apply a methodology of adjusting for volatility to show that the Russian debt default did not lead to contagion in Brazil.

Dedication

To my parents, Baldev and Harbhajan Sull who have always encouraged me to pursue my education and have supported me throughout.

To my wife Kal, and daughters Rianna and Ralina, who put up with all of my long hours of studying.

Acknowledgements

I would like to take this opportunity to thank Prof. Peter Klein not only for his guidance in the preparation of this paper but also in helping to make the Global Asset and Wealth Management MBA a truly invaluable learning experience.

Thank you to my two closest friends – Aman Bhangu and Naveen Gopal. Without you, this program would not have been the same. The laughs we had made the commuting, the long hours and the stress all worthwhile. It is amazing that despite all the pressure of being students and working full time, we laughed as much as we did. Thanks guys.

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Section I: Introduction

In just over a decade, the world has experienced five international financial crises – the "Tequila Effect" of 1994 which centered on Mexico, the "Asian Flu" of 1997, the "Russian Cold" of 1998, the "Brazilian Sneeze" in January 1999, and the "Nasdaq Rash" of 2000. There have been many studies that examine the concept of contagion. The names given to the various crises that have taken place just over the last dozen years alone helps to provide an impression of just what contagion can do. However, most studies have not been able to agree on a common definition of contagion or even how to best measure it. Some studies, such as the work conducted by Rigobon (2001), have found that the use of correlation coefficients to measure co-movement between equity markets is misleading because of the heteroscedasticity of market returns.

The importance of Rigobon's finding is that if contagion is an occurrence that does not in fact occur as readily as some of the previous studies have found, then asset managers should still be able to find value in the diversification of assets across geographic markets.

Conversely, if asset managers believe that in times of crises, correlations will rise to offset the benefits of geographic diversification, they may decide to concentrate their assets in their home country – thereby exacerbating the home country bias exhibited by so many investors. The implication of an increase in the home country bias would indicate that capital is not being allocated efficiently.

One of the aspects of the study of contagion that has left many practitioners puzzled is that none of the contagion crisis exhibited much in the way of similarities. For

example, the Tequila Effect of 1994 that began with the devaluation of the Mexican Peso on December 19, 1994. This devaluation was brought about by a large and growing current account deficit. Most peculiar was that the government of Mexico was maintaining artificial strength in the Peso by selling US dollars and issuing short term debt that allowed for repayment in $US. As international investors began to take notice of the declining foreign currency reserves of Mexico, the financial markets began to assess their opinion of the Peso and concluded that it was significantly overvalued

However, it should be noted that this was not the first time that Mexico was forced to devalue its currency. In fact, this was the third devaluation in just over a decade.[1] But what is different is that the 1994 devaluation led to a severe impact on South America. Especially hard hit were Argentina and Brazil as their foreign exchange reserves and industrial output plummeted. Thus, the Mexican peso devaluation is deemed to have caused the "Tequila Effect". It should be noted that the "Tequila Effect" made its ways to the shores of Asia as the currencies of Thailand, Hong Kong and the Philippines came under the attack of international investors.

By 1997, the world faced another contagion crisis that came to be known as the Asian Flu crisis. Many of Asia's fastest growing economies were experiencing large current account deficits brought about by a rise of investment in future economic progress. This contrasts to the state of Mexico at the time of the Tequila Crisis. Mexico's current account deficit was largely induced by consumption – partly aided and

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[1] At the time of the1994 devaluation, Mexico had just had an election in which the Salinas administration widely seen to be corrupt was replaced. It is worthwhile to note that many investors were not surprised that Mexico had to devalue its currency because previous three devaluations had come right after an election.

abetted by poor monetary and fiscal policy that was largely influence by political considerations.

Economic theory would dictate that a current account deficit brought about by a rise in investment spending is more preferable than one that is induced by excessive consumption. While that may be true, the Asian nations were also beset by large amounts of government corruption that resulted in the inefficient allocation of capital and a declining marginal rate of productivity growth (Felipe 1997). That is, as more and more capital flowed into Asia chasing economic growth, the marginal returns on that capital were diminishing over time. Thus, there would appear to be a certain façade to the 1990s Asian miracle economies which made the region especially vulnerable to decreases in capital inflows.

The Asian Flu of 1997 began with the selling pressure put upon the Thai Baht in early 1997. By the middle of the year, this pressure resulted in the devaluation of the Baht. In turn, this lead to increased pressure being put upon other Asian currencies such as the Malaysian Ringgit. In turn, the Malaysian equity market, followed by that of South Korea, Indonesia and others began to fall. As was the case with the Tequila Effect, the Asian Flu also began to make an impact across continents. Specifically, this time Latin America became the recipient of the shock rather than the origin. It should be noted that most of Latin America did not have a meaningful trading relationship with South East Asia. This would serve to help counter the findings in the literature which state that trade links play a central role in the propagation of contagion,

In August 1998, the Russian Cold began when Russia defaulted on its debt obligations. At the time of the default, Russia was incurring large budget deficits that were being financed largely with short term debt. Investors had expected that given the small size of the Russian stock market, the aftershocks would most likely be contained to the emerging markets. However, this crisis distinguished itself further by the fact that unlike other crises, the Russian Cold strongly impacted the developed markets (Rigobon 2000). A key aspect as to why the global markets reacted so strongly to the debt default was because it may have been somewhat unexpected. The Russian government had just received a fresh round of financing from the IMF and official inflation projections for the second half of 1998 were about 8% - substantially lower than a year earlier.

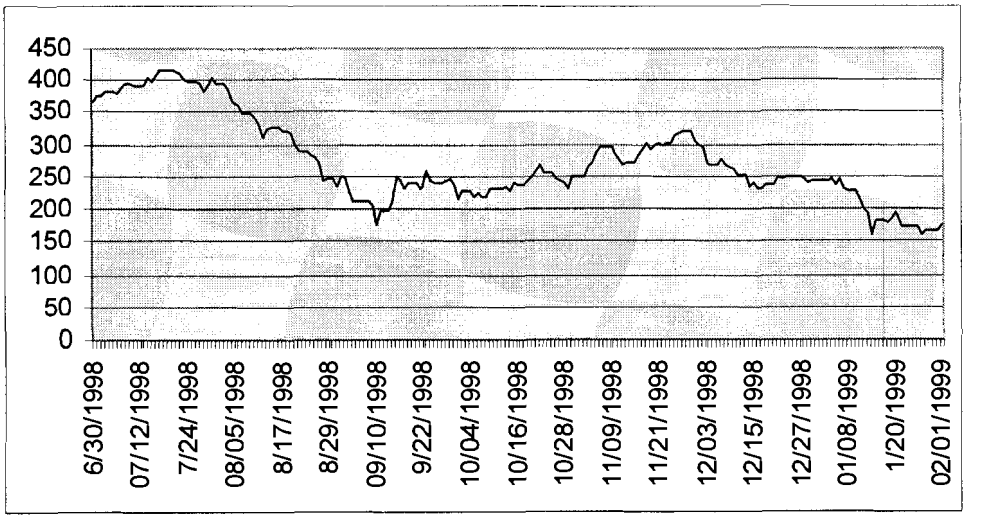
The last financial crisis of the 1990s was the Brazilian sneeze. The crisis began quickly after the Russian debt default as speculators circled the Brazilian Real for repeated attacks. The ultimate result was that Brazil had to devalue its currency and the Brazilian market had fallen in $US terms by about 48% as measured by the Dow Jones Brazil $US index. In local terms, the Brazilian market declined about 22%. Thus, this would help to demonstrate the impact of the Real's depreciation on the Brazilian stock market.

One interesting aspect – and one of the reasons that Brazil was chosen as one of the countries to be looked at for this paper - is that immediately after the Russian Cold crisis began to settle, Brazil and other markets around the world had begun to rise in line with the general trend in recovery of the global equity markets. However, by late

November 1998, as is shown in Figure 1 below, Brazil was isolated and came under attack again. Part of the reason that the magnitude of the decline shown in Figure 1 was so severe was because of the substantial depreciation of the Brazilian Real versus the $US.

Figure 1

Decline of the Dow Jones Brazil $US index (June 1998 to January 1999)



One unique aspect of the Brazilian Sneeze was that once Brazil came under pressure again by the end of November 1998, Mexico and Argentina – two of the more vulnerable countries in previous crises – were able to recover their stock market losses in a matter of a few short months with no meaningful lasting economic fallout. Also of note is that once Brazil devalued its currency in January 1999, this measure along with other policy initiatives allowed the Brazilian economy to regain a solid footing and begin expansion once again.

The fifth financial crisis that impacted the world's financial system was the Nasdaq Rash of 2000. Much like the 1998 Russian Cold, this crisis was also more global. This is not much of a surprise since it is thought to have originated from the US – a country that represented just over half of the world's stock market capitalization. The one difference about the Nasdaq Rash versus other episodes of contagion was that in this case, the currency of the shock origin country was not under attack. In the case of the Tequila crisis, the Asian Flu, the Russian Cold and the Brazilian Sneeze, the crisis was in part induced by the fact that these countries had unsustainable foreign exchange rates and also their sovereign bonds were facing immense selling pressures. Conversely, during the Nasdaq Rash, there was a bull market in the US bond market – in part due to both domestic and international investors seeking the safety of US treasuries. Also, the fear of deflation being exported from Asia was a concern of many investors which helped to contribute to the rise of the US bond market during this period. In this case, the sell off was initiated in large part due to the rather extreme valuations in the Nasdaq. But unlike other crisis originating countries, the currency and the bond market were not attacked.

It can be seen that no two crises described above exhibit similar causes or characteristics. For example, Mexico's crisis was resolved once it received an injection of capital from international monetary authorities but in the case of Russia, it was attacked even though it had just finished receiving an IMF loan package. An additional difference amongst these crises is that it would appear that a crises emanating from a developed country's market such as from the Nasdaq, exhibits a different set of characteristics in terms of its impact on the origin country's bonds and currency. For example, if we look at the US experience, when the Nasdaq Rash made its impact around

the world, there was no similar attack on US Treasuries or the $US. In fact, quite the opposite was true as the US bond market continued to thrive.

Another example of this dissimilarity is that when Mexico's 1994 Tequila Effect made its way around the world, many Latin American countries were impacted quite severely. But during the Brazilian Sneeze – some five years later – the event barely registered as the impacted Latin American countries recovered their stock market declines in a matter of several weeks.

Thus, these dissimilarities do not provide policy makers with ready made solutions with which they could try to prevent the spread of a crisis in one country into episodes of contagion. Furthermore, researchers have not come to a consensus to answer why a shock that originates in one country can make its way into countries that seemingly have little or no relation to the shock originating country.

This paper will use the framework of Rigobon (2001) to determine whether there was in fact no increase in correlation (and hence no occurrence of contagion) between Russia and Brazil during the 1998 Russian Cold crises. This pairing is being examined in this paper as other studies have found that the 1997 Asian Flu remained a regional crises but the Russian Cold had a global impact (Chan-Lau, Mathieson and Yao, 2004). Thus, this paper will try to see if the correlation adjustment of Rigobon (2001) will allow for a determination of whether or not contagion actually occurred as a result of the Russian Cold of 1998. Furthermore, it will allow for a useful comparison to the events of the Asian Flu of 1997 and the adjustments made to the data from that crisis. This is because it will allow for the comparison of the adjusted correlations for countries that are not in

the same neighbourhood.[2] This should help to lead support to answering the question as to whether or not the Forbes and Rigobon methodology is suspect to phenomena such as the neighbourhood effect in which investors begin to treat countries in close geographic proximity in an equally risk averse manner. It is also significant with respect to this pairing of countries in that Brazil seemed to be impacted much more than other countries by the Russian Cold.

Goldfajn and Baig (2002) examined the possibility that contagion was in fact transmitted from Russia to Brazil following Russia's debt default in August 1998. They also looked at whether the Long Term Capital Management (LTCM) crisis - which followed suit only one month later - helped to exacerbate the volatility in the financial markets. The issue of LTCM is important to address because it is an easy target to choose as being responsible for the fallout of the Russian Cold to Brazil. However, they determined that based on the fact that most of the widening of spreads in the Brazilian debt markets had almost completely taken place immediately after the Russian debt default in August 1998 – one month before the LTCM crisis.- that the LTCM collapse was not the source of the Brazilian crisis.[3]

They applied the methodology of Forbes and Rigoban (1999) to adjust for the increase in correlations during the crisis (contagion) period. When they applied the

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[2] Many studies have looked at the concept of a neighborhood effect in which it is theorized that a large contributor to contagion is geographic proximity to a source country of contagion and given that information can be asymmetric, this can lead to investors tarring the whole region with the same broad brush.

[3] Baig and Goldfajn, (2002)., pg 9. figure 2.

methodology of adjusting correlations to the sovereign debt spreads of Russia and Brazil, they found that "the correlations in the Brady markets are very high and increase significantly (even after adjusting for the bias) during the crisis. This gives support to the fact that if there was a contagion from Russia to Brazil, the most likely place of the transmission was the off-shore Brady markets"[4]

Significantly, Goldfajn and Baig noted that they were using the Forbes and Rigoban tests with a fair degree of apprehension. They felt that perhaps an examination of contagion should not control for the increased variances as volatility is a key component of any crisis that induces increased volatility in the financial markets. They go on to state that the very factors that contribute to the increased variances are what do in fact contribute to the existence of contagion. If these factors are then adjusted (controlled) for, then the test for contagion could lose power. Thus, this paper will look at both the adjusted and unadjusted correlations for the data series.

Given some of the issues raised by Baig and Goldfajn, a nonparametric test was also used in this paper based upon the methodology of Ng (2004). Ng studied the Asian Flu crisis in which Thailand was used as the shock origin country and Australia was a recipient country. This test provided mixed results about whether or not contagion occurred depending on whether common positive movements or common negative movements were measured.

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[4] Baig and Goldfajn (2002), pg. 38

Section II: Literature Review

Following the Asian Flu of 1997, the word contagion increased its circulation in the academic literature. There were in fact numerous studies prior to this crisis that looked at this topic but it gained momentum only after the Asian contagion. Furthermore, the fact that just over a year later, the Russian Cold hit the global financial system, only heightened contagion as an area of interest. It would be fair to say that the strength of the impact of the Russian Cold contagion episode surprised the markets with its devastation. It did not help matters when shortly after the Russian debt default that the Long Term Capital Management (LTCM) hedge fund collapsed.

One of the unique aspects of this topic is that there is no single universally accepted definition of contagion. For example, Fratzscher (2002) defines contagion as the transmission of a crisis that is not caused by the affected country's fundamentals. However, Calvo and Reinhart (1996) state that if the transmission mechanism of the "shock" is via the economic fundamentals such as trade relationships with other affected countries then that would be characterized as "fundamentals-based" or "spillovers" whereas non-fundamentals based contagion would be termed as "true contagion".

There is a fair weight of opinion expressed in other research papers that states that there is an element of weakness in the definition of contagion as stated by Calvo and Reinhart (1996) in that the markets' response to a change in fundamentals are simply responses to a new paradigm. Thus, contagion is only the source of creating some sort of

new equilibrium within the markets. Therefore, as Moser (2003) points out, true contagion is only a response to fundamentals-based contagion.

A significant argument of Moser (2003) is that true contagion is created and perpetuated by information and domino effects. His conclusion was that information effects are causes in which new information can trigger rational or irrational chain reactions with investors reallocating capital away from not only the original crisis country but also from countries perceived to be sharing similar characteristics such as common geographic region (e.g. being a Southeast Asian country following the Thai Baht devaluation) or common bilateral trade relationships with the country suffering from contagion.

Domino effects is a term that refers to a contagion propagation mechanism in which a financial institution – such as a bank, mutual fund, or a hedge fund – that is adversely impacted begins to withdraw its capital from the contagion impacted country. For example, if we take the example of a mutual fund mandated to invest across emerging markets, it may be forced to meet redemptions from worried unit holders. As a result, these mutual funds may be forced to begin to liquidate their holdings in other emerging markets – thereby spreading the contagion from one country to another. Alternatively, the mutual fund's portfolio manager may use the time of crisis to begin portfolio rebalancing by reducing the holdings in other emerging markets that were heretofore unaffected – thereby amplifying the effect of contagion. Thus, Moser's definition of true contagion is stating that "true contagion" can be brought about by an

iperfection in which information is either not rationally evaluated by an investor or not gathered at all and something as simple as "market gossip" can lead to market upheavals.

Karolyi (2003) seems to agree with the Calvo and Reinhart (1996) definition of contagion but if "true contagion" is to be investigated and understood, then that must begin with high-frequency data. This is defined as data such as stock market returns or bond yields that are sampled on a daily basis. He defines low-frequency data as data that is sampled at monthly, quarterly or yearly intervals. This would include such macroeconomic data as unemployment rate data or price levels measuring inflation trends. More significantly, Karolyi states that evidence of fundamental-based contagion would begin to show its presence in low-frequency data such as bi-lateral trade data within the original "contagion country" and its trading partners.

Furthermore, Karolyi reiterates that "true contagion" can be subdivided into "rational investor-based co-movements" and "irrational co-movements". It is these "irrational co-movements" that are exhibited in times of financial panic, irrational herd behaviour, loss of confidence and increases in risk-aversion that as possible causes of contagion.

Kaminsky, Reinhart and Vegh (2002) refine the basic definition along another line. They have stated that for contagion to exist there must be a "near simultaneity" of events as necessary conditions for contagion. Contagion occurs when a crisis in one country triggers an immediate adverse chain reaction across regions and where the reaction is what they call "fast and furious". That is, they effectively exclude lagged transmissions which they define as transmissions that do not happen within hours or days

of the "triggering event". They further assert that contagion is deemed to have occurred when it leads to large reductions in the value of assets, rises in the borrowing costs due to sharp increases in interest rates on international capital markets thereby inducing credit constraints and then economic recessions.

When we look at the Russian Cold of 1998, it can be seen that the default of the Russian government on its sovereign debt helped to trigger a more widespread contagion that had more geographically far-reaching consequences than the Asian Flu of 1997. In recognition of this difference, Kaminsky et al. (2002) state that the historical evidence would support this occurrence in that there have been ". . . far more crises without significant international consequences than crises that have given rise to fast and furious contagion".

Significantly, Kaminsky et al. (2002) state that financial collateral damage extends globally when the markets of the financial centres are impacted. If this does not occur, then the contagion will stay confined to the region where the crisis began. Thus, it would be no surprise to see the conclusion of Rigobon (2002) that there was no contagion from the Asian Flu. Rigobon (2002) found that within a month, the majority of the developed countries had recovered their losses from the Asian Flu. Thus, they were impacted but the markets were able to recover very quickly – unlike the emerging markets.

Kaminsky and Reinhart (2002) state that three transmission patterns can be identified. They have termed them as follows: periphery to periphery; periphery-center-periphery; and center to periphery. Under the periphery to periphery style of shock, a

shock to a particular country is transmitted from the host country to another country through bilateral trade relationships without impacting a major "financial center" country. Thus, the crisis remains a regional event. This is significant and could be part of the explanation for why the Asian Flu did not turn into a global crisis. In addition, this could help explain part of the Forbes and Rigoban findings.

Kaminsky et al. (2003) term periphery-center-periphery as a shock that originates in a country of the periphery that then transmits to another country through a world financial center. This happens when bilateral trade flows between two periphery countries are feeble. Transmission mechanisms include trade competition or portfolio rebalancing. This is what can be termed as a global contagion.

Their third transmission pattern could be termed as center-to-periphery. This is the no-contagion case since the source of the shock is a center country and can thus be treated as a common shock. By definition, common shocks are not contagion. An example of a common shock is a rise in US (world) interest rates, oil shocks or recessions in a large economy. Thus, these common shocks are shocks that do not originate in the crisis stricken country but are simply just exogenous to it. As Muller and Trumpler (2004) explain, "common shocks affect countries within a given region in essentially the same way, so that the eventual occurrence of crisis can be both simultaneous and similar in consequences." For this reason, they go on to state that researchers are unanimous in excluding crises due to common shocks from the definition of contagion.

Section III: Methodology

The central purpose of this paper is to determine whether or not contagion spread to Brazil as a result of the meltdown of the Russian stock market using the Rigobon (2002) methodology of adjusting the correlation coefficients between the rates of return of the two countries' stock markets. Specifically, the regressions that were run on the data of the Russian and Brazilian equity markets' returns were done with respect to the following regression :

$$\mathbf{Y_i = \alpha + \beta_x + \varepsilon_t} \qquad (1)$$

where the rates of return from the Moscow RTS Stock Exchange are the independent variable and the returns from the Dow Jones Brazil $USD index are the dependent variable.

The tests that are performed in this paper are to take into account the rise in the variances of equity markets during a time of crisis. In order to conduct this test, the following equation from Rigobon (2002) is used:

$$\boldsymbol{\rho^h} = \rho^l \sqrt{\frac{1+\delta}{1+\delta(\rho^l)^2}} \qquad (2)$$

where ρ^h is the adjusted correlation coefficient that takes into account increases in volatility amongst stock returns. The stock market returns data were obtained from the following sources:

Moscow RTS Exchange $US data was obtained from http://www.rts.ru/?tid=452. The data for the Brazilian equity markets was obtained by accessing http://www.djindexes.com/mdsidx/index.cfm?event=showTotalMarketIndexData.

Prior to calculating the adjusted correlations using the Rigobon framework from equation (2), unadjusted correlations were calculated on a monthly basis for the returns of the Russian and Brazilian markets. Plotting this correlation against the variance of the Russian market was done in order to determine how the two countries' equity markets move together in both times of crisis and during a tranquil or non-crisis period.

A nonparametric test was also performed on the data in order to gain some insight into the co-movements of the two markets. The proportional test was conducted by looking at the positive common movements and the negative common movements in each of the crisis and non-crisis periods.

In terms of the regression, a simple linear regression was performed in which the Brazilian market's returns are explained by the change in the Russian market's returns – all measured in $US. The information that the regressions generated was then used to calculate statistical tests such as the Breusch Pagan and the Chow test.

Section IV: Empirical Data

The returns of the Russian and Brazilian markets as measured in $US returns of the Moscow RTS and Dow Jones $US Brazil index were represented in a regression equation as follows:

i.) ***Russia: The Originator of the 1998 Contagion (To Determine X)***

The available literature makes it quite transparent that the 1998 global contagion began with the Russian debt default. This contrasts to the Asian contagion in which there is debate amongst researchers as to which country was the originator of the shock to the global financial system that set off contagion. This makes the Russian contagion similar to the 1994 Tequila Crisis in which the Mexican debt default set off a contagion crisis amongst the emerging markets. Since Russia was the source of the shock, the Russian market's returns data is the independent variable.

ii.) ***Brazil: The Recipient of the Shock (To Determine Y)***

In order to be able to adjust for heteroscedasticity, as was outlined in the introduction, the assumption that is made in this analysis is that there are no exogenous global shocks that impacted both Russia (x) and Brazil (y). As was outlined earlier in this paper, Miller and Trumpler reference the importance of this in their work. In addition, a second assumption is that there was no endogeneity. That is, there was no "feedback" from Brazil (the y country) to Russia (the x country). This is a valid assumption due to the fact that Russia and Brazil did not have a bilateral trade

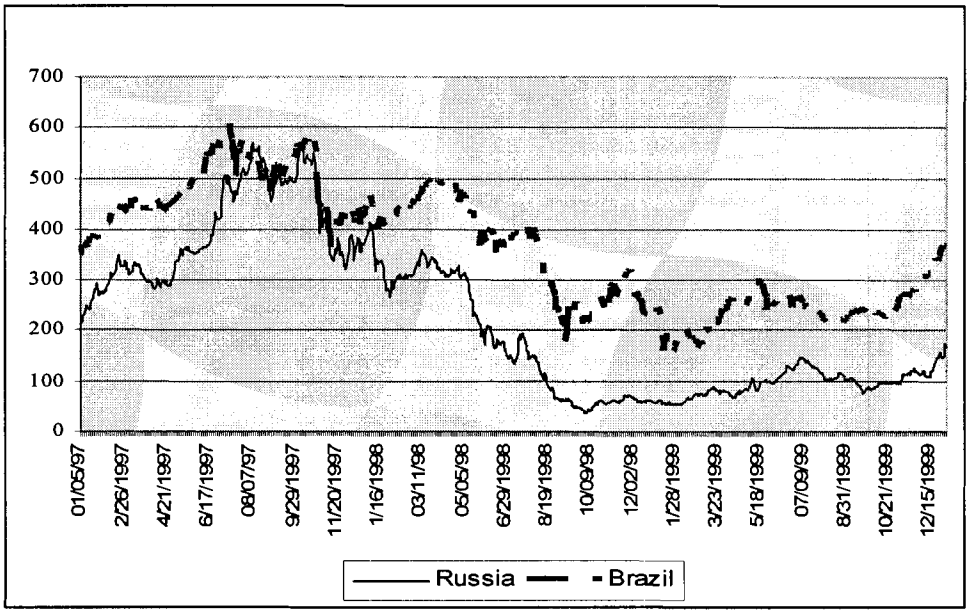
relationship to any great extent nor would be impacted through the so-called "neighbourhood effect". Given that Brazil was the recipient of the Russian Cold, then the returns data of the Brazilian index would serve as the dependent variable.

iii.) *Event Window*

The event window to which the correlation adjustment was applied began on August 17, 1998 which is the point in time in which the Russian government announced a moratorium on its debt obligations and a devaluation of the rouble was announced – setting off the 1998 Russian Cold contagion. The event window was extended to the end of January 1999 due to the fact that this was when the Brazilian government announced an "unpegging" of the Real to the $US. Shortly after, Brazil's episode of contagion came to a conclusion. Figure 2 shows how the Russian and Brazilian equity markets have performed before, during and after the crisis:

Figure 2

Performance of the Moscow RTS Exchange and Dow Jones Brazil Indices ($USD)



As can be seen, the Russian market began to put in a bottom much earlier than Brazil. Once the international investor community and Brazil's citizens began to sense that the Brazilian currency, the Real, was vulnerable, the downturn gathered strength and not until the Brazilian government devalued the currency in late January 1999 did the Brazilian stock market begin to gain its footing. This was despite the fact that the two markets had peaked together shortly before the Asian contagion of 1997.

iv.) *Data*

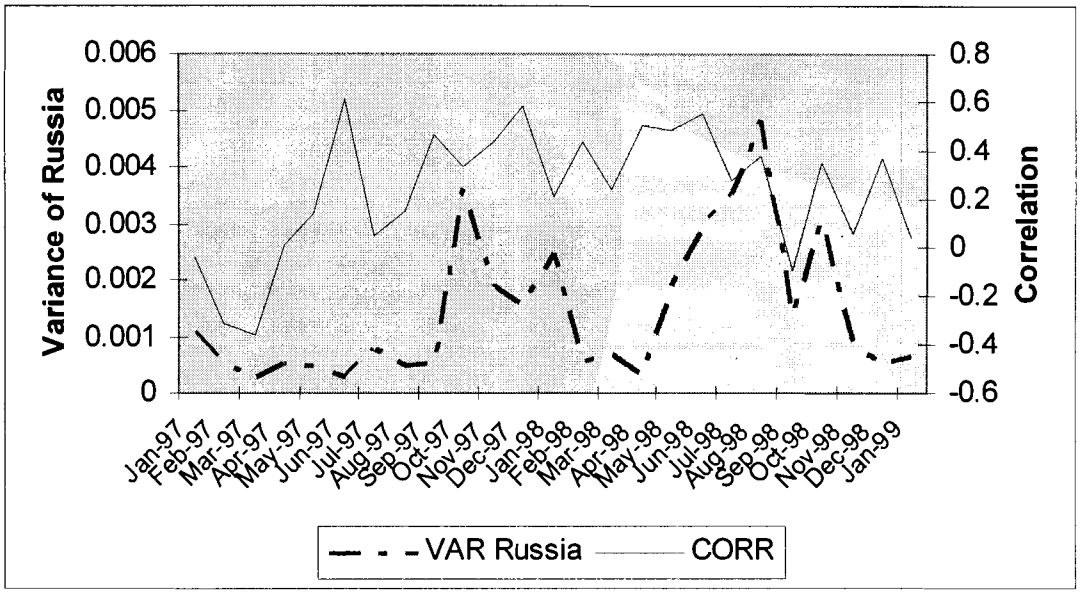
I collected daily index data for the Moscow and Brazilian markets for the period ranging from December 26, 1997 to February 5, 1999. I chose daily index data for the Moscow RTS Index in $USD and the Dow Jones Brazil $USD indices for this period in

order to capture the movements of these markets before the Russian Cold contagion crisis became apparent by August 17, 1998 and spilled into the global financial system.

Brazil was chosen as the recipient country (y). This is because following the expansion of the Russian Cold across the world, it was determined that Brazil was hit the hardest amongst the emerging markets. The impacted countries in Asia and Latin America recovered quite quickly. But in the case of Brazil, it was not until its devaluation of the Real did it even begin to stabilize. Given that there was no "neighbourhood" connection between Russia and a Latin American country such as Brazil, studying these two countries would be of interest to see if they exhibited any different characteristics during a contagion crisis than the Asian countries did in 1997 amongst the countries in the Asian and more so the South Asian neighbourhood. To this end, it was of interest to apply the correlation adjustment technique that adjusts for heteroscedasticity to the data from these two countries.

Figure 3

Unadjusted Correlation (Russian – Brazilian Markets) and the Variance of Russian Stock Market Monthly Returns (January 1997 to January 1999)



The results of the above chart show that the variance of Russian equity market returns expanded significantly in the period leading up to the Russian debt default which coincided with the advent of the Russian Cold. The spike in the variance of the Russian market marked the advent of the contagion crisis. On August 17, 1998, the Russian debt default impacted the markets severely.

With respect to the correlation between the Russian and Brazilian equity markets, it can be seen that the monthly correlations had stabilized and began to decrease as the facts related to Russia's problems were digested by the markets and the speculative attacks began to gather strength around Brazil.

As Figure 2 had showed, Russia's market had bottomed and began a gentle but sustained rise from its lows whereas Brazil bottomed at the same time as Russia in the

late summer of 1998 but did not have a sustained rise from its lows. That is, it tried to rally with the rest of the global markets – including the other emerging markets – but its rally attempt was feeble in its duration. This is due in part to the fact that its currency was beginning to face a sustained strength of attacks in the global currency markets

The results shown in Figure 3 stand in contrast to those found by Ng (2004) in which the markets of Thailand and Australia were looked at. It was observed that as the variance in the stock market of Thailand (the originator of the shock) rose, the correlation between its market and that of another (Australia) also rose. Similar results were also found when Hong Kong and Australian market returns were looked at. This further enhances my interest in trying to apply the Rigobon correlation adjustment.

v.) *Adjusted Correlation Coefficient for the Russian and Brazilian Equity Markets*

The methodology of Rigobon (2002) to adjust the correlation coefficients through the event window only was applied to an unadjusted correlation coefficient calculated by using the $US returns of the Moscow RTS index and the Dow Jones Brazil ($US) indices. The adjustment was made using equation (2) where ρ^h is the adjusted correlation coefficient adjusted for the increase in the level of volatility (δ). Specifically, it is computed as the variance of the crisis country (x) during the crisis window as a proportion of the variance of country x during the tranquil or non-crisis period minus 1. Furthermore, ρ^l is used to represent the correlation coefficient between the market returns of x (the originating country of the shock) and the market returns of y (the recipient

country) during the tranquil or non-crisis period and ρ^h represents the correlation coefficient adjusted for the increase in volatility δ during the crisis period. Recall, from equation (2) that the correlation adjustment was expressed as

$$\rho^h = \rho^l \sqrt{\frac{1+\delta}{1+\delta(\rho^l)^2}} \qquad (2)$$

$$1 + \delta \equiv \frac{(\sigma_x^h)^2}{(\sigma_x^l)^2} \qquad (3)$$

Intuitively, this equation demonstrates that for an increase in the variance of x_t of $1 + \delta$, the equation will allow for the stable period correlation coefficient to be adjusted, thereby yielding a new adjusted correlation coefficient of ρ^h. This adjusted correlation coefficient will be adjusted for any potential increase in the variance.

The procedure to adjust the correlation was conducted using weekly rates of return to arrive at correlations between the Russian and Brazilian indices for each week as follows: First the variance of the Russian equity market is calculated for the period encompassing both the tranquil and crisis periods for the time period specified (January 1998 to January 1999). Here, the δ represents the percentage change in the variance of Russia. The adjustment factor in (2) will adjust for increases and decreases in the variance. Thus, the rise in heteroscedasticity resulting from the rise in the variance will be corrected for.

Once the correlation coefficients originally obtained in Figure 2 were adjusted for the increase in volatility with equation (3), the results were plotted in the following figure:

FIGURE 4

Adjusted and Unadjusted Correlation Coefficients: Russia and Brazil

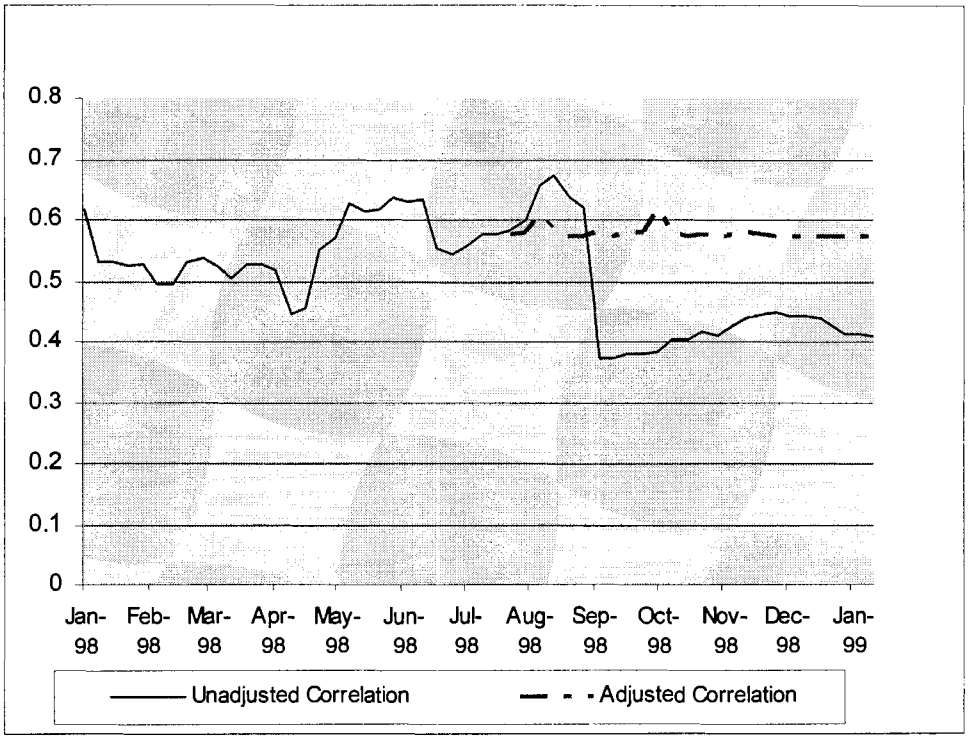


Figure 4 shows that while the unadjusted correlation coefficient began to decrease once the Russian crisis came to a flashpoint in August 1998 and international lenders renegotiated the terms of Russia's debt problem, the adjusted correlation was essentially stable throughout the crisis window. As was noted previously, the crisis window was defined as beginning in August 1998 until the end of January 1999 when Brazil agreed to unpeg its currency to the $US and the Brazilian equity markets began to stabilize. The

unadjusted correlation was decreasing due to the fact that the Brazilian markets took longer to regain their upward trends than the Russian markets. In fact, as was stated previously, the Brazilian market was virtually alone in sustaining its weakness following the Russian Cold.

vi.) Nonparametric Approach to Detect the Presence of Contagion

The co movements of the Russian and Brazilian markets were also looked at in a different manner using proportions. Following the methodology of Ng (2004), this nonparametric approach was used to provide a view of the movements of the Russian and Brazilian equity markets without making any assumptions about the distribution of the returns. It is designed to provide an intuitive look at the movements of these two countries' markets. Specifically, the time period that is being looked at was divided once again into a non-crisis (tranquil) period that was defined as January 1998 to the end of July 1998 and a crisis period that ranged from August 1998 to the end of January 1999 which represents a 55 week time period. Throughout this period, the weekly returns for each market were calculated and compared for common movements. That is, they were sorted to determine how many times in each of the non-crisis and crisis periods the markets moved in the same direction. The results are summarized in Table 3. Of this total, 30 weeks are observed for the tranquil or pre-crisis period ranging from January 9, 1998 to the week ending July 31, 1998. For the crisis period, there are 25 data observations ranging from the week ending August 7, 1998 to the week ending January

29, 1999. The results of this analysis can be seen in table 1 under the Stable and Crisis Period headings.

Table 1

Common Movements of the Russian and Brazilian Stock Markets

	Stable Period		Crisis Period		Results of Simulation
	Counts	%	Counts	%	
Both Recorded Positive Returns	7	23.3%	7	28.0%	30.8%
Both Recorded Negative Returns	12	40.0%	15	60.0%	23.3%
Total Common Movements	19	63.3%	22	88.0%	54.1%

Further to the calculations in the above table, the data was examined in order to gather information about whether or not the proportions of common movements during the stable period and the crisis period are statistically significant. This test was done with the following hypothesis test:

$$Ho: P_1 = P_2$$

$$H1: P_1 < P_2$$

In this hypothesis test, P_1 is the proportion or probability of common movements in the stable period whereas P_2 is the proportion or probability of common movement in the crisis period. The test statistic that was used for this particular hypothesis test was defined as the following:

$$Z = \frac{\hat{P}_1 - \hat{P}_2}{\sqrt{\hat{P}(1-\hat{P})(\frac{1}{n_1}+\frac{1}{n_2})}} \tag{4}$$

where

n1 = 30 or the number of observations in the stable period resulting in X1 co-movements

n2 = 26 or the number of observations in the crisis period resulting in X2 co-movements

$$\hat{P}_1 = \frac{x_1}{n_1} \tag{5}$$

$$\hat{P}_2 = \frac{x_2}{n_2} \tag{6}$$

$$\hat{P} = \frac{x_1 + x_2}{n_1 + n_2} \tag{7}$$

The results are shown in the following table:

Table 2

Proportional Test of the Russian and Brazilian Stock Markets

	Z-Statistic	Critical Value		Ho
		10%	5%	
Counting Both Negative and Positive Common Movements	-2.0916	-1.64	-1.96	Reject at both the 10% and 5% level
Counting Only Negative Common Movements	-1.4773	-1.64	-1.96	Fail to reject at both the 10% and 5% level
Counting Only Positive Common Movements	-0.3956	-1.64	-1.96	Fail to reject at both the 10% and 5% level

As per the above table, when we take into consideration both the negative and positive movements between the Russian and Brazilian markets' returns, we reject the hypothesis that there is no evidence of contagion. That is, when we consider both the negative and positive common movements, we find that under this test there is in fact evidence of contagion at both the 10% and 5% levels. Given the findings detailed in Table 1, there is a large increase in the negative proportions in the crisis period as opposed to the tranquil or non-crisis periods.

However, when we only look at negative common movements, it is apparent that the conclusion of the proportional test changes such that we fail to reject the hypothesis that there is no contagion. That is, we do not find evidence of contagion. In addition, when we look at the positive common movements, we also fail to reject the hypothesis and thus find that there is no contagion. Thus, the results of the proportion test shows

that when we take both positive and negative common co movements, there is evidence of contagion and when we isolate either the positive or negative common movements in the proportional test, the evidence of contagion weakens at both the 5% and the 10% levels.

A second nonparametric test was also applied in this paper. The methodology for this test consisted of generating 20000 random pairings of number such that each pair would consist of two values ranging between -1 and 1. The random numbers that were generated were used to simulate positive or negative common movements between the Moscow RTS Exchange and the Dow Jones Brazil ($USD) indices. The findings of this random number generation are as follows:

As can be seen from Table 1, when random numbers were generated, the number of negative common movements is quite less than the negative movements of the Russian and Brazilian stock markets. With respect to the positive common movements, they are also less than those recorded in table 1. Furthermore, if we look at the total common movements, it can be seen that 54.1% of the random simulations resulted in common movements. Had these common movements been higher or in line with those of Table 1, it would have cast a level of doubt on the degree of common movement as being significant. That is, those results could be considered to have occurred simply due to random movements. Thus, this was the purpose of generating the results in Table 3 – to show the difference between the randomly generated results and those in Table 1.

Section V: Specification Tests

This paper also performs specification tests. In order to validate the assumptions of the correlation adjustment factor as is outlined in equation (3), the Breusch-Pagan test is conducted in order to determine if heteroscedasticity is present. A second test is performed in order to test the stability of the regression parameters. This is tested for by using the Chow test.

i.) The Breusch – Pagan Test

Though the nonparametric test used in the previous section found evidence of some contagion, a second test using the Breusch–Pagan methodology was used to provide additional support to the initial conclusion in the previous section. The Breusch-Pagan test was conducted to test for the presence of heteroscedasticity in the linear regression that was outlined above. That is, I wanted to see whether or not the estimated variance of the residuals from the regression was dependent upon the values of the independent variable (the returns of the Moscow RTS exchange in $USD). Furthermore, we wanted to test for the occurrence of heteroscedasticity using data from more than one time period using both weekly and daily data. That is, the Breusch – Pagan test was performed to test whether the variance of the residuals remained constant during the tranquil period and the contagion episode. The principle that the variance of the residuals should be constant can be expressed as:

$$E(\varepsilon^2) = \sigma \qquad (8)$$

This test must be performed in order for the equation of the adjusted correlation (2) to be valid, since it is based in part on the assumption that the residuals maintain a constant variance (Rigobon, 2002). Thus, this test will help to validate or invalidate the use of the correlation adjustment. The null hypothesis under the Breusch – Pagan test is that there is no heteroscedasticity and that in fact homoscedasticity exists. This particular test for the presence of heteroscedasticity was conducted using three different time periods. The time periods were chosen so that the pre-crisis, post crisis and the crisis period itself could be looked at.

For the January 1998 to January 1999 time period in which weekly data was looked at, the null hypothesis of homoscedasticity was rejected and thus heteroscedasticity was found to be present in the data for the Russian and Brazilian markets. For the second time period which was looked at, in which daily data was used incorporating January 5, 1998 to February 5, 1999), the null hypothesis was also rejected and again this would indicate the presence of heteroscedasticity. For the third time period that was chosen – in which weekly data was chosen for the period from January 9, 1999 to December 31, 1999 – the null hypothesis was not rejected and heteroscedasticity was not found to be present. The results are summarized in the following table.

Table 3

The Breusch-Pagan Test Applied to the Russian and Brazilian Stock Markets

	Θ	Critical Values		H_0
		5%	1%	
Daily Data (January 5, 1996 – August 14, 1998)	**44.5377**	**3.8414**	**6.6349**	**Reject**
Weekly Data (January 5, 1996 – August 14, 1998)	**19.6495**	**3.8414**	**6.6349**	**Reject**
Daily Data (January 5, 1998 – February 5, 1999)	**5.0700**	**3.8414**	**6.6349**	**Reject at 5% but not at 1% level**
Weekly Data (January 9, 1998 – January 26, 1999)	**12.4061**	**3.8414**	**6.6349**	**Reject**
Daily Data (January 5, 1996 – February 5, 1999)	**2.6711**	**3.8414**	**6.6349**	**Do Not Reject**
Weekly Data (January 5, 1996 – December 31, 1999)	**20.2168**	**3.3814**	**6.6349**	**Reject**

To summarize, the Breutsch Pagan test was conducted to determine whether or not heteroscedasticity was present in the data that was looked at. The correlation coefficient adjustment in equation (2) has a diminished validity if heteroscedasticity is found to be present. Based on the results in table 3, it can be seen that the Breutsch Pagan test reveals that in fact heteroscedasticity does in fact exist for most time periods that were looked at. The first two rows of the table encompass data that is for the period prior to the crisis. The third and fourth rows capture data that begin at a point in time prior to

the crisis and end just after the point in time at which Brazil had begun to stabilize (the end of the crisis). Finally, the fifth and sixth rows of Table 3 capture the data for a longer pre-crisis period and end well-after the end of the crisis.

As can be seen from Table 3, the only time periods for which we cannot reject the null hypothesis that there is no heteroscedasticity is for row 5 (Daily Data for January 5, 1996 to February 5, 1999) and for row 3 at the 1% significance level.

In turn, this would indicate that heteroscedastticity does in fact exist for most of the time periods that were looked at for the data pertaining to the Russian and Brazilian data. Thus, this would tend to weaken the conclusion provided by the Rigobon correlation adjustment that there was no contagion between Russia and Brazil.

ii.) The Chow Test: Testing for Structural or Parameter Stability of the Regression

A Chow test was performed as a method to test for whether or not there was structural change or instability in the parameters of the regression over time. Given that this regression was looking at times series data as represented by the returns of the Brazilian and Russian equity markets, this test will help to determine if a structural break occurred in the data. Specifically, we wanted to test whether the β coefficients changed over time. That is, I wanted to see of they had changed from one sample of data to another. Thus, the Chow test was conducted to determine whether or not the relationship between the Russian and Brazilian markets holds over different time periods. The regressions that were run were as follows:

In order to generate the data in order to run the Chow Test, the following regressions were run:

i.) For the period of January 9,1997 to December 30, 1999, the following regression was obtained :

$$y = 0.00042752 + 0.189701x$$

where the Beta coefficient (β) represents the sensitivity of the change in the dependent variable (Brazilian market returns as measured by the Dow Jones $USD index) to a change in the returns of the Moscow RTS Index ($USD) returns.

The parameters that were obtained by running this **constrained or restricted model** were as follows:

Table 4

Regression and Residual Sum of Squares of the Constrained or Restricted Model (January 9, 1997 to December 30, 1999)

	Df	*SS*
Regression	1	0.039072
Residual	747	0.632034
Total	748	0.671106

ii.) For the period of January 9, 1997 to August 17, 1998, the following regression was obtained: $y = 0.000225 + 0.225655x$

The parameters that were obtained by running this unconstrained model in period 1 were as follows:

Table 5

Regression and Residual Sum of Squares: Unrestricted Model (Pre-Crisis)

	Df	*SS*
Regression	1	0.0287
Residual	401	0.21729
Total	402	0.24599

iii.) For the period of August 18, 1998 to December 30, 1999, the following regression was obtained:

$$y = 0.00077602 + 0.15025466x$$

The parameters that were obtained in this second unconstrained model were as follows:

Table 6

Regression and Residual Sum of Squares: Unrestricted Model (Post Crisis)

	Df	*SS*
Regression	1	0.011751
Residual	344	0.413154
Total	345	0.424906

The null hypothesis that was tested is:

$$H_0: \beta_1 = \beta_2$$

$$H_1: \beta_1 \neq \beta_2$$

The relevant test statistic is the F Statistic as follows:

$$\frac{\frac{(SSE_p - SSE_1 - SSE_2)}{k}}{\frac{(SSE_1 + SSE_2)}{(n-2k)}} \tag{9}$$

where

SSE_p is the sum of squared error for the regression run for the period from January 9, 1997 to December 30, 1999

SSE_1 is the sum of squared error term for the regression for the period from January 9, 1997 to August 17, 1998 which was stated earlier as the beginning of the crisis period or contagion

SSE_2 = is the sum of squared error for the regression for the period from August 18, 1998 to December 30, 1999

and **k** is the numerator degrees of freedom and **n**=the sum of the sample size regression 1 and regression 2 which are the sub period regressions as outlined under SSE_1 and SSE_2.

The F statistic was calculated to be 1.9369

Table 7

The Chow Test Applied to the Russian and Brazilian Stock Markets (Daily Data)

Regression	Time Period	Critical Value		H_0
		5%	1%	
SSE_p	January 9,1997 to December 30, 1999	3.00	4.61	Do Not Reject
SSE_1	January 9,1997 to August 17, 1998			
SSE_2	August 18,1998 to December 30, 1999			

Thus, since the test statistic of 1.9369 is less than the critical values at the 5% and 1% levels, we do not reject the null hypothesis.

Given that the null hypothesis was not rejected, it can be said that the parameters of the regression do not change over time for the variables that this regression was run upon. Alternatively, it can be said that there is no structural instability (i.e. the regressions in the periods looked at above do not differ during the time periods listed in Table 7).

Since the null hypothesis is true, the restrictions do not hurt the explanatory power of the model. This is also seen by the fact that the error sum of squares of the restricted model are only slightly greater than the error sum of squares of the unrestricted models. As the F test that was performed shows, in fact the difference between the restricted and unrestricted sum of squares is not significant. Thus, since we do not reject the null

hypothesis, we can state that the regression is valid for both the crisis and non-crisis period.

Section VI: Summary & Conclusions

This paper examined the issue of whether or not contagion can be said to have occurred as a result of the Russian Cold crisis of 1998 that impacted Brazil so severely. Other emerging market countries were also impacted but their quick recovery surprised many and the impact was limited. However, Brazil was impacted to a very large degree by the fallout from the Russian contagion. Given that the crisis seemed to appear at least on the surface to meet the criteria of an episode of contagion, the data for the Brazilian and Russian stock markets was examined. The data was examined with the intention of determining whether or not contagion did in fact occur after adjusting the correlation coefficients for the heteroscedasticity that can arise when looking at stock market returns data. This is especially so in times of volatile markets. Thus, it is clear that using correlation coefficients unadjusted for a rise in volatility can make it appear that contagion has occurred when in fact it may not have been present.

The correlation coefficients for the Russian and Brazilian stock markets were adjusted to account for the increase in volatility that resulted from the Russian Cold of 1998. It was determined that after adjusting for the rise in volatility, the correlation for Russia and Brazil was essentially at a steady level and did not increase once the contagion was deemed to have begun in August 1998.

The nonparametric approach that was used in this paper to detect common movements both before and after the crisis period began determined that there was an

increase in common movements between the Russian and Brazilian equity markets during the crisis period. It is important to note that this Proportional Test does not take make any adjustments such as that done by the Rigobon correlation adjustment so this result would tend to coincide with what one would have anticipated. The purpose was to simply provide a measure of common movements between the two markets.

Following upon this methodology, a simulation was performed in order to determine what the common returns data would like in the context of randomly generated numbers that simulated market returns. It was determined that the randomly generated returns did not in fact represent a significant level of common movements. This provides further validity to the resuls of the common movements that were found in Table 1.

In addition, this paper also tested for an increase in heteroscedasticity by looking at whether or not the variance of the residuals of the regression did in fact change during the Russian Cold crisis of 1998. The evidence would seem to indicate that the variance of the residuals did not remain constant throughout all of the time periods that were examined. This was done by performing the Breutsch Pagan test. Since the correlation adjustment factor requires that heteroscedasticity not be present, we had to test for this. The results of the Breutsch Pagan test concluded that heteroscedasticty was present in the majority of the time periods that were looked at – thus serving to weaken the results of applying the Rigobon correlation coefficient adjustment methodology in which no contagion was said to have existed.

The second issue that was looked at was whether or not the β coefficient remained constant or whether it changed as a result of the Russian stock market decline. The

evidence based on the Chow test would seem to indicate that the coefficients did not change through the time periods that were looked at in this paper. Thus, this provides some confidence as to the stability of the regression over the time periods both before and after the crisis period.

However, there are a number of other factors that additional research could consider. One such area would be for researchers to look at the role of information asymmetry. Specifically, it would be of interest to see what impact this would have on the herding behaviour of investors in which they perceive a problem in one emerging market as cause or justification for selling their holdings in another.

Another area that could be expanded on is to look at the impact that mutual fund redemptions play in times of financial crisis. Specifically, the role of the individual investor who might hold an emerging market bond or equity mutual fund in times of financial crisis could be reviewed. Research into whether their lack of information can perpetuate a crisis strictly out of rational or irrational fears.

Finally, an examination of the role that the emerging market bond markets play in the spread of contagion is another area that can be looked upon as possibly offering some strong possibilities for exploration and research. Specifically, an exploration of the path that the yields of sovereign bonds of emerging markets take in the months leading up to a crisis would be of interest to see if there is a common tendency. If this tendency is determined to in fact exist, then the bond markets of the emerging markets could provide the first warning of an impending financial crisis. This could be a relevant area in that researchers are trying to find an "early warning system" for contagion.

Yet another area would be to look at what role lenders – both amongst supranational organizations such as the International Monetary Fund (IMF) and commercial banks – play in international financial crises. Specifically, with respect to the IMF, it would be of interest to see if the issue of moral hazard is significant or not. That is, do international investors become less concerned with emerging market debt if they believe that the IMF will be there as a liquidity injector of last resort. Thus, when a crisis comes to pass in an emerging market country, do investors in non-crisis markets cause a contagion by selling their holdings in other emerging markets. This could be related to a liquidity induced sell off or simply due to imperfect information.

Similarly, another issue that could be looked at is the role that commercial banks play in the dissemination of contagion. For example, what is the impact of the risk control procedures of commercial banks that are caught in a situation where they have exposure to the sovereign debt of an emerging market country undergoing an economic downturn? If they are afraid of a devaluation of the borrower nation, they could decide to liquidate their holdings of that nation's debt or perhaps to begin a rebalancing of their overall holdings by selling other countries' debt.

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