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Dynamic Linkages among the Stock Exchanges of the Emerging Tigers of the Twenty First Century

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ABSTRACT

This paper analyzes the dynamic interrelationships among the stock exchanges of the United States and of the four Emerging Tigers of the Twenty First Century, namely Brazil, China, India, and Russia. Using Vector Auto-Regression Models and daily data that span from May 1995 until October 2005, the dynamic linkages among these markets are studied.

JEL Classification: *F0, F3, G0, C3, C5, E4, P0*

Keywords: *Stock Market Linkages; S&P 500; Brazil, China, India, Russia; North-South and East-West relationships; Vector Auto-Regression Models; Correlograms; Impulse Responses, Variance Decompositions.*

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I. INTRODUCTION

This paper investigates the dynamic linkages among the stock exchange rates of return for the following countries: Brazil, China, India and Russia (BRICs). The daily data spans from May 1995 until the end of 2004 with 2,641 observations for each stock market. Vector Auto Regression (VAR) models are used to study the dynamic interrelations among these rates of return in stock exchanges. These markets are becoming increasingly more important as the progression of globalization accelerates. These economies are rapidly growing relative to one another. Therefore, it is essential to study their economies to gain a better understanding of the world economy. The countries studied are reshaping world trade, world finances, global manufacturing, as well as North-South and East-West relationships. As these countries open themselves to the world, they are merging their relatively low costs and manpower reserves with the financial and technological strengths of the wealthier countries of the United States, Western Europe, and Japan. Unlike other nations, the BRICs have the scale and trajectory to challenge today's major developed economies in terms of their impact on the world economy and the evolution of globalization.[1]

Table 1 presents some economic data, population figures, and government structures for the countries in this study. Specifically, the table reports the Gross Domestic Product (GDP) in purchasing power parity dollars for the year 2004 in trillions, the GDP per capita, the estimated population in 2005, the government type, the gross fixed investment as percentage of GDP, the inflation rates, the unemployment rate in 2004, the public debt as a percentage of GDP, the amount of exports and imports in 2004, the amount of foreign reserves of foreign exchanges and gold in billion dollars, the amount of external debt and the currency used in each country in the study. Note that the unemployment rate in China and Russia are conservative estimates since both have substantial unemployment and underemployment in rural areas.

Klein (2004) terms the economies of China, India and Russia as *The New Growth Centers*. However, he recognizes that Brazil certainly could qualify for that distinction in the near future. According to Goldman Sachs's projections (O'Neill, 2005), if things go right, in less than 40 years from today, the BRICs economies together could be larger than those of the U.S., Japan, and the four largest European economies of Germany, France, Italy and the United kingdom (G6) in US dollar terms. By 2025, the BRICs could account for over half the size of the G6. Of the current G6, only the US and Japan may be among the six largest economies in US dollar terms in 2050. Consequently, the list of the world's ten largest economies may look quite different in 2050. The largest economies in the world (by GDP) may no longer be the richest (by income per capita), thus making strategic choices for firms more complex.[2]

While the BRICs economies are generally progressing, considerable policy improvement is needed in each country. The capacity of the BRICs to influence global dynamics relies on their ability to establish and sustain a growth-supportive policy environment. A number of BRICs investment funds have been established since 2003 and others are in the process of being launched. The interplay between the BRICs economies and those of the G6 and Canada (what is known as the G7) is viewed by the investment community as the critical aspect of globalization and interdependence.

Table 1

	GDP (Purchasing Power Parity) (2004) (trillion)	GDP/Capita (Purchasing Power Parity) (2004)	Population (July 2005 est.)	Govern. Type	Investment (gross fixed) (% of GDP)	Inflation Rate (cons. prices)	Unemployed Rate (2004)	Public Debt (% of GDP) (2004)	Exports (2004)	Imports (2004)	Reserves of Foreign Exchange and Gold (Billion) (2003)	Debt-External	Currency
USA	$11.75	$40,100	295,734,134	Constitution-based federal republic; strong democratic tradition	15.70%	2.50%	5.50%	65%	$795 billion	$1.476 trillion	$85.94 (2003)	$1.4 trillion (2001)	US dollar (USD)
Brazil	$1.49	$8,100	186,112,794	federative republic	19.80%	7.60%	11.50%	52%	$95 billion	$61 billion	$52.94 (2004)	$219.8 billion (2004)	Real (BRL)
China	$7.26	$5,600	1,306,313,812	Communist state	46%	4.10%	9.8% (1)	31.40%	$583.1 billion	$552.4 billion	$609.9 (2004)	$233.3 billion (2003)	Yuan (CNY)
India	$3.32	$3,100	1,080,264,388	federal republic	23.80%	4.20%	9.20%	59.70%	$69.18 billion	$89.33 billion	$126 (2004)	$117.2 billion (2004)	Indian rupee (INR)
Russia	$1.41	$9,800	143,420,309	federation	19.10%	11.50%	8.3% (2)	28.20%	$162.5 billion	$92.91 billion	$124.5 (2004)	$169.6 billion (2004)	Russian ruble (RUR)

(1) in urban areas; substantial unemployment and underemployment in rural areas; an official Chinese journal estimated overall unemployment (including rural areas) for 2003 at 20%

(2) plus considerable underemployment

Source: CIA's The World Fact Book, http://www.cia.gov/cia/publications/factbook/docs/profileguide.html

Improving long-term conditions to promote growth including macroeconomic stability, political institutional development, trade and investment openness, and education is crucial to further progress.

Between the years 2000 and 2005, the BRICs contributed about 28 percent of global growth expressed in U.S. dollar terms, and 55 percent in Purchasing Power Parity (PPP) terms. The BRICs' share of global trade is currently 15 percent annually since 2001. Furthermore, trade among the BRICs has also accelerated, with intra-BRICs trade now nearly 8 percent of their total trade compared with 5 percent in 2000. There has been a sharp increase in Brazilian trade with China and Chinese investment commitments in Brazil. India has exported intellectual property to Brazil and Brazil has greatly increased exportation of its agricultural products to India.

As of the year 2005, the BRICs have 30 percent of world reserves. China is the dominant contributor, but Russia, India and Brazil have all accumulated substantial reserves as well. The share of the BRICs as a destination for global Foreign Direct Investment (FDI) continues to rise; in 2005, the BRICs' FDI was 15 percent of net global FDI, nearly three times higher than in the year 2000. More striking is that the BRICs' FDI *outflows* have picked up to more than 3 percent of the global total in 2005, a six-fold increase since 2000.

Yet these economies are evolving on different time paths and instituting different policies. One can hardly compare the shock therapy treatment of the former Soviet Economy to the gradual path China has undertaken. The question of which policies are best suited to these and other economies are left to future historians. However, at this point one can only note that for example in 1978, the year the U.S. established formal diplomatic relations with China, Chinese per capita income was 15 percent of that of the former Soviet Union. By 2004 it was 57 percent of its level (see Table 1).

The synergies between economic well-being, sustainability, macroeconomic fundamentals on the one hand and the well-functioning of a country's financial markets in general and the stock markets in particular are still an open question. Further research is needed to disentangle the effects of specific institutional channels on growth and to understand the impact of institutional change on growth.[3] Glaeser, La Porta, Lopez-de-Silanes, and Shleifer (2004) revisit the debate over whether political institutions cause economic growth, or whether, alternatively, growth and human capital accumulation lead to institutional improvement (See Chow, 2006, Perkins, 2006 in this issue and Levine, 2001). They find that most indicators of institutional quality used to establish the proposition that institutions cause growth are constructed to be conceptually unsuitable for that purpose. Furthermore, some of the instrumental variable techniques used in the literature are found to be flawed. Basic OLS results, as well as a variety of additional evidence, suggest that (a) human capital is a more basic source of growth than are the institutions, (b) poor countries rise out of poverty through good policies, often pursued by dictators, and (c) these countries can only improve their political institutions once political and economic stability has been achieved.

Several studies are devoted to the issue of whether financial development affects growth.[4] For example, Greenwood and Jovanovic (1990), and Atje and Jovanovic (1993) find it surprising that more countries are not developing their stock markets as quickly as they can as a means of speeding up their economic development. Beck and

Levine (2004) investigate the impact of stock markets and banks on economic growth using a panel data set for the period 1976-1998 and applying recent generalized-method-of-moments techniques developed for dynamic panels. On balance, they find that stock markets and banks positively influence economic growth and these findings are not due to potential biases induced by simultaneity, omitted variables or unobserved country-specific effects.[5]

La Porta, Lopez-de-Silanes, Shleifer, and Vishny (1997) show that countries with poorer investor protections, measured by both the character of legal rules and the quality of law enforcement have smaller and narrower capital markets. These findings apply to both equity and debt markets. The same authors find evidence supporting the claim that diversified shareholders are unlikely to be important in countries that fail to protect their rights (La Porta, Lopez-de-Silanes, Shleifer, and Vishny, 1998). The book edited by Demirguc-Kunt and Levine (2001) presents essays which dissect the relationship between financial structure—the degree to which a country has a bank-based or market-based financial system—and long-run economic growth using a broad cross-section of countries. Papers address the cross-country comparisons of bank-based and market-based financial systems; a corporate finance perspective on whether financial structure matters for economic growth.

The remainder of the paper is organized as follows: Section II gives a brief review of the literature; Section III presents the Vector Auto-Regression Model; Section IV describes the data; and Sections V through VII present the empirical results. Section V presents some diagnostic statistics for the lag structure and residuals tests. Section VI reports the result of the impulse response functions, and Section VII discusses the variance decomposition analysis. Section VIII provides a brief conclusion.

II. A BRIEF LITERATURE REVIEW

There has been much research relating to the dynamic linkages among stock markets especially in the Asian, Asian-Pacific, European, and North American regions of the world. Koch and Koch (1991) explore how these linkages between the daily rates of return of eight national stock indexes have developed over a 30 year period. These eight indices include those of Japan, Australia, Hong Kong, Singapore, Switzerland, West Germany, the United Kingdom, and the United States. The authors look at lead and lag correlations for the years 1972, 1980, and 1987 and find that due to very little indication of lagged responses across these markets beyond a twenty-four hour period, the international markets display a high level of efficiency. While Koch and Koch's study focuses on regions all over the world, Masih and Masih (2004) investigate the dynamic linkages of five European stock market indices including Italy, France, Germany, the Netherlands, and the United Kingdom. They pay attention specifically to the lead-lag correlations around the period of the 1987's stock market crash and conclude that lead-lag relationships changed considerably over the post-crash sample.

Fernandez-Izquierdo and Lafuente (2004) investigate the relationships between international stock market volatility during the Asian crisis within 12 stock exchanges including Argentina, Chile, Germany, Hong Kong, Italy, Japan, Mexico, Singapore, South Korea, Spain, United Kingdom, and the United States. They find that substantial leverage effects are due to foreign negative shocks in addition to negative shocks in the market area itself. Hassan and Naka (1996) investigate the dynamic linkages between Japanese, United States, United Kingdom and German stock market indices using daily data for the period April 1, 1984 to May 31, 1991. Both short-run and long-run inter-market relationships among these four stock markets are studied. Significant evidence shows that both short-run and long-run relationships exist among these four stock market indices. The U.S. stock market leads all other markets in the long-run in all periods and leads other stock markets in short-run in the pre and post October 1987 crash. Hassan and Naka (1996) determine that the presence of a long-run co-integrating equilibrium relationship among the four stock market indices signifies that there could be only a minimal role of international diversification for investors with long holding periods. However, because the other indices are not cointegrated with each other, international portfolio diversification may be the result in the long-run. Hassan and Naka (1996) conclude that these conflicting results can not be utilized to provide conclusive evidence on the efficiency of the international stock market.

There has similarly been an increased focus on the dynamic linkages among Asian emerging stock markets especially those of Malaysia and Thailand. In an earlier study, Masih and Masih (1999) support the common view of the leadership of the U.S. stock market over both the short-term and long-term and the existence of an important short and long-term relationship between the emerging Asian markets and the established OECD markets. They find that the stock market fluctuations within these Asian markets are determined mainly by their regional markets, as compared with more advanced markets. Baharumshah, Sarmidi, and Tan (2003) also explore the short-term and long-term dynamic linkages within Asian Markets by focusing on Malaysia, Thailand, Taiwan, and South Korea and exploring the influence of financial reforms and the Asian financial crisis on these four markets. They used three time periods to divide their sample: pre-liberalization (1988-91), post-liberalization (1992-96) and post-crisis (1997-99). Like Masih and Masih (1999), Baharumshah, Sarmidi, and Tan (2003) find significant relationships between Asian markets and world capital markets which especially held true in the post-liberalization era. These increased inter-correlations have been further intensified since the beginning of the Asian crisis. Also, due to the Asian crisis, Malaysia and Thailand are evermore interconnected with South Korea and Taiwan in the post-crash period.

Many financial economists have also studied trends within specific emerging market Asian countries. Elyasiani, Perera, and Puri (1998) study the dynamic linkages between the Sri Lankan market and the markets of its major trading partners: Taiwan, Singapore, Japan, South Korea, Hong Kong, India, and the United States. Using the vector auto-regression (VAR) technique, they discover a lack of interdependence between the Sri Lankan markets and those of its major trade partners. Elyasiani, Perera, and Puri (2004) attribute this lack of correlation to small capitalization, lack of liquidity, high concentration in blue chips, and unilateral investment barriers that burden the Sri Lankan investors. Chong, Tan, and Baharumshah, (2001) study the relationships between the Kuala Lumpur Stock Exchange stock prices, macroeconomic fundamentals, and economic growth in Malaysia before the Asian crisis in 1997. As expected, they conclude that macroeconomic fundamentals are vital in determining movements in both short-run and long-run stock prices. Thus, a strong, well-functioning stock market is important in promoting a country's economic growth. Ibrahim and Aziz (2003) also analyze the dynamic linkages within Malaysian markets and specifically map out the relationship between stock prices and macroeconomic variables such as the exchange rate and the money supply using VAR and co-integration techniques.

Other studies of dynamic linkages have involved direct comparisons between two or more specific indices. Lai, Lai and Fang (1993) explore the correlation between the New York and Tokyo stock markets using daily index data and state that the two stock markets display both short and long-term feedback relationships. Their analysis suggests that the New York and Tokyo stock markets have become increasingly interdependent over time, especially after the stock market crash of 1987. Shamsuddin and Kim (2003) examined the Australian stock market and analyzed the incorporation of Australian market with the United States and Japan, its two primary trading partners. The results show that prior to the Asian crisis, there was a stable long-run relationship between the Australian, U.S., and Japanese equity markets. However, this relationship vanished in the post-Asian crisis period. While the U.S. influence on the Australian market diminished, Japan's impact remained at a moderate level.

Shachmurove (2005) examines the relationship among the stock markets of the United States and Middle Eastern countries of Egypt, Israel, Jordan, Lebanon, Morocco, Oman, and Turkey. His analysis demonstrates how a shock in one of these markets can be diffused to the others. The results show that the dynamic linkages among these stock markets are fairly insignificant. Cheng and Glascock (2005) investigate the dynamic linkages among the three stock markets of the Greater China Economic Area (GCEA), namely Mainland China, Hong Kong, and Taiwan and the developed stock markets of Japan and the United States. They find small nonlinear relationships between the GCEA markets, but there exists no co-integration with either the U.S. or Japan. However, the U.S. market has greater impact on the GCEA markets than the Japanese market.

The dynamic linkages between oil prices and stock market returns have also been investigated. A recent example, Ciner (2001), examines the dynamic linkages between oil prices and the stock market. Previous studies conclude that daily future-oil price changes and the S&P 500 stock index movements are not linked. Ciner (2001) notes that this result is probably due to the fact that only linear linkages have been studied and that using nonlinear causality tests provide evidence that oil shocks affect stock index returns. In a later study, Maghyereh (2004) investigates the dynamic linkages among crude oil price shocks and stock market returns in 22 emerging market economies and utilizes daily data spanning over six years from January 1998 to the end of April 2004. Using vector auto-regression (VAR) analysis, Maghyeraeh (2004) finds that oil shocks have no substantial influence on stock index returns in emerging economies. The findings also indicate that stock market returns in these economies do not necessarily imply shocks in the crude oil market.

The current paper is the first to study the simultaneous dynamic interrelations among the stock markets of the United States and of the four Emerging Tigers of the twenty-first century, namely Brazil, China, India, and Russia.

III. THE VECTOR-AUTO-REGRESSION MODEL

As is currently well-known, economic theory by itself is not often able to provide a dynamic specification that identifies all the dynamic interrelationships between stock market indices. This issue is further complicated due to the fact that endogenous variables appear on both sides of the estimated equation, hindering appropriate statistical inferences. These problems lead to inferences based on the non-structural approach to modeling the co-movements among several time series. See, for example, Pindyck and Rubinfeld (1998) and Sims (1972, 1980, and 1986). Sims (1980) argues that the structural models are based on unrealistic constraints being used for identification and, thus, are unreliable (see, Granger and Jeon, 2003).

The Vector Auto-regression (VAR) is used for analyzing the dynamic impact of random disturbances on the system of variables. The VAR model treats every endogenous variable in the system as a function of the lagged value of all the endogenous variables in the system of equations.

The mathematical representation of a VAR is:

$$y_t = A_1 y_{t-1} + \ldots + A_p y_{t-p} + B\, x_t + \varepsilon_t, \tag{1}$$

where y_t is a *k* vector of endogenous variables, x_t is a *d* vector of exogenous variables, $A_1, \ldots, A_p$ and B are matrices of coefficients to be estimated, and ε_t is a vector of innovations that may be contemporaneously correlated, but is uncorrelated with both its own lagged values along with all of the right-hand side variables.

Since only lagged values of the endogenous variables appear on the right-hand side of the equations, problems of simultaneity are avoided. In this case, Ordinary Least-Squares (OLS) yields consistent estimates. Moreover, even though the innovations may be contemporaneously correlated, OLS is efficient and equivalent to Generalized Least Squares (GLS) because all of the estimated equations in the system have the same right-hand side variables.

The determinant of the residual covariance (degree of freedom adjusted) is computed as:

$$|\Omega\hat{}| = \det \{[1/(T - p)]\, \Sigma\, \varepsilon\hat{}_t\, \varepsilon\hat{}'_t\} \tag{2}$$

where *p* is the number of parameters per equation in the VAR. The unadjusted calculation ignores *p*. The log likelihood value is computed assuming a multivariate normal (Gaussian) distribution as:

$$£ = -(T/2)\{k(1 + \log 2\pi) + \log|\Omega\hat{}|\} \tag{3}$$

The two information criteria are computed as:

$$AIC = -2\, £/\, T + 2n/T \tag{4}$$

and

$$SC = -2\, £/\, T + n \log T/T, \tag{5}$$

where $n = k(d + pk)$ is the total number of estimated parameters in the VAR. These information criteria are used for model selection such as determining the lag length of the VAR, with smaller values of the information criterion being preferred (see Akaike, 1973 and Schwarz, 1968). It is worth noting that some reference sources may define the AIC/SC differently, either omitting the "inessential" constant terms from the likelihood, or not dividing by T (see Grasa, 1989 and Lütkepohl, 1991).

IV. DESCRIPTION OF THE DATA

The database includes daily stock market indexes of the four major emerging tigers of Brazil, China, India and Russia at closing time. In addition, in order to investigate external shocks to these stock markets, the United States' S&P 500 index is included in the analysis. The data is compiled from DataStream. The data spans from September 1, 1995 until October 14, 2005, for a total of 2,641 observations for each stock market. For each exchange, daily returns, r_t, are computed as the first differences of the natural logarithms of P_t, the daily closing values of the stock indices, $r_t = (\ln P_t - \ln P_{t-1})*100$.

If one calculates the annual rates of return in the five stock markets studies in this paper for the entire period, i.e., 1995-2005, then the rate of return for the U.S. market is 7.72 percent, almost similar to the stock market return of India at 7.9 percent. The Brazilian stock market return during this period is 10.91 percent. The fast growing economy of China has annual stock return of only 4.8 percent. Only the Russian annual stock return is high at 24.73 percent. If however one looks at the returns say from January 1, 2003 until the end of the sample, where the U.S. market has 16.13 percent, the Russian annual stock market return is 59.3 percent and the Indian, 73.3 percent. Brazilian returns more than doubled at an annual return of 103.7 percent. China again provides a warning that stock market returns do not necessarily dove tail the economic growth values, where in the last two years the annual return is negative 7.33 percent. Considering the substantial risk of participating in these emerging stock markets, these volatile returns as shown in the above two examples of ten and two-year samples are not surprising. Recalling the discussion on the relationship between economic growth potential and the stock market, the above limited examples of only four emerging markets place some doubt on the synergy between economic growth and financial market development in these four markets. It does not follow from this argument that improved transparencies, rule of law, respecting human right etc. are not a necessary step towards sustainability of economic growth, especially as these economies' per capita income will increase towards western level.

V. EMPIRICAL RESULTS

A. Diagnostic Statistics

To check the suitability of the estimated VAR, various tests are performed. The constants are assumed to be the only exogenous variables in the system of equations. The results on the lag structure of the estimated VAR are reported in Section V.I. Subsection V.2 reports the test statistics of the Residual Test.

A.1 Lag structure

Some of the lag structures were conducted.

a. Lag exclusion tests

For each lag in the VAR, the χ^2 Wald – statistics (Wald, 1940, 1943) for the joint significance of all exogenous variables at that lag are calculated for each equation, both separately and jointly.

b. Autoregression (AR) roots

The inverse roots of the characteristic AR polynomial are calculated. The estimated VAR is stable, or stationary, if all roots have modulus less than one and lie inside the unit circle. If the VAR is not stable, certain results, including the impulse response standard errors, are not valid. The examination of all roots reveals that no root lies outside the unit circle. Thus, the VAR satisfies the stability condition. These results are available upon request from the author.

c. Lag length criteria

Various tests for selecting the lag order of the unrestricted VAR are performed. All of these criteria are discussed in Lütkepohl, 1991, Section 4.3. The sequential modified likelihood ratio test (LR) is carried out by starting from the maximum lag and testing the hypothesis that the coefficients on lag ζ are jointly zero using the χ^2 statistics:

$$LR = (T - m)\{\log|\Omega_{\zeta-1}| - \log|\Omega_{\zeta}|\} \sim \chi^2(k^2), \quad (6)$$

where m is the number of parameters per equation under the alternative. Sims' (1980) small sample modification uses (T – m) rather than T. Based on the different tests, the lag length chosen for this study is 92 lags. Each equation consists of 92 lagged values of all five stock market returns plus a constant, i.e., 92*5 + 1 = 461 parameters to be estimated for each equation. Experiments with lower lag numbers show that some results are sensitive to the number of lags chosen. It appears that when studying dynamic relations among stock market returns for daily data, the number of lags required to capture the dynamic of the interrelationships is high. For example, studying different stock markets, Friedman and Shachmurove (1996, 1997) and Shachmurove (1996, 2005) found that only 25 lags are adequate to represent the dynamic character of the data. Some Portmanteau Autocorrelation tests performed based on the computation of multivariate Box-Pierce (1970) / Ljung-Box (1978) Q-Statistics for residual serial correlation show that lags of up to 203 may be necessary.[6] This issue is left for further research.

d. Pair-wise granger causality tests

This section reports the test statistics for pair-wise causality tests and tests whether an endogenous variable can be treated as exogenous. For each equation of the 92-lag VAR, the output displays χ^2 Wald–statistics for the joint significance of each of the other lagged endogenous variables in that equation. The number of observation is thus 2,548. The statistics in the last row (ALL) is the χ^2 Wald statistic for joint significance of all other lagged endogenous variables in the equation. The tests indicate whether a variable, the return in the Brazilian stock market expressed in U.S. dollars for example, can help forecast the stock market return of the Chinese stock market one step ahead. It is worth noting that the Brazilian return can still affect, for example the Chinese stock return, through other equations in the system. An important advantage of this test is that it is insensitive to the order of the equations in the VAR system. It is presented alphabetically by country name, except for the U.S. which is placed first in the table.

Table 2 presents the results for the VAR Granger Causality/Block Exogeneity Wald Tests. The statistics in the last row (ALL) present the χ^2 Wald statistic that tests for joint significance of all other lagged endogenous variables in the equation. In this VAR model, the United States stock market seems to be not affected by the other four stock exchanges. This phenomenon is also true for the Chinese stock exchange, which shows no *joint* significance of all other lagged variables in the Chinese equation. All other countries' stock market returns show that jointly, the effects of other exchange rates are significant. It is clear from the table that China has pursued a different dynamic path as compared to the other potential tigers.

Table 2 also shows that the Brazilian stock returns are affected significantly by the U.S market and by both the Russian and the Indian stock exchanges, but not by the Chinese stock returns. Although it was found that jointly the Chinese stock exchange is not being affected by all other markets combined, one can still find influences by the Russian and the Brazilian stock market returns. The Indian stock exchange is affected by all markets combined as well as the Brazilian stock market. The Russian stock market returns are affected by both the U.S. and the Brazilian stock returns.

A.2 Residual Tests - Correlograms

Table 3 presents the Residual Correlation Matrix and the Residual Covariance Matrix for the five stock exchanges for the VAR system with 92 lags. Of interest is the relatively high residual correlation between the rates of return of the U.S. and Brazil (0.45), and the modest correlation between the U.S. and Russia of 0.15. Concentrating on the four future potential tigers, the highest residual correlation is between the Brazilian and the Russian markets. The residual correlations between China and those of all other markets in this study are very low. As for the residual covariance matrix, note that the variances for Brazil and Russia are high relative to the other variances. A similar pattern to the residual correlation matrix is also observed.

Table 2
VAR Granger Causality/ Block Exogeneity Wald Tests, 92 Lags
Sample: 9/1/199510/14/2005

Dependent Variable	Excluded Variables	Probability
RRUS500		
	RRBRAZIL	0.8768
	RRCHINA	0.8341
	RRINDIA	0.6375
	RRRUSSIA	0.5794
	All	0.8667
RRBRAZIL		
	RRUS500	0.0206
	RRCHINA	0.4573
	RRINDIA	0.0757
	RRRUSSIA	0.0615
	All	0.0007
RRCHINA		
	RRUS500	0.3951
	RRBRAZIL	0.0786
	RRINDIA	0.6760
	RRRUSSIA	0.0386
	All	0.2240
RRINDIA		
	RRUS500	0.2717
	RRBRAZIL	0.0456
	RRCHINA	0.4330
	RRRUSSIA	0.3402
	All	0.0020
RRRUSSIA		
	RRUS500	0.0139
	RRBRAZIL	0.0177
	RRCHINA	0.1003
	RRINDIA	0.2040
	All	0.0000

Table 3

Residual Correlation Matrix					
	RRUS500	**RRBRAZIL**	**RRCHINA**	**RRINDIA**	**RRRUSSIA**
RRUS500	1.00	0.45	-0.02	0.04	0.15
RRBRAZIL	0.45	1.00	0.00	0.04	0.19
RRCHINA	-0.02	0.00	1.00	0.03	-0.01
RRINDIA	0.04	0.04	0.03	1.00	0.09
RRRUSSIA	0.15	0.19	-0.01	0.09	1.00

Table 3 (continued)

Residual Covariance Matrix

	RRUS500	RRBRAZIL	RRCHINA	RRINDIA	RRRUSSIA
RRUS500	1.29	1.27	-0.04	0.07	0.47
RRBRAZIL	1.27	6.19	-0.02	0.16	1.30
RRCHINA	-0.04	-0.02	2.52	0.08	-0.03
RRINDIA	0.07	0.16	0.08	2.51	0.39
RRRUSSIA	0.47	1.30	-0.03	0.39	7.65

VI. IMPULSE RESPONSES

In general, a shock to the Chinese stock exchange returns not only directly affects its own Chinese returns, but is also transmitted to all of the other endogenous stock returns of the different countries through the dynamic lagged structure of the VAR. The impulse response function traces the effect of a one-time shock to one of the innovations on current and future values of the endogenous exchange rates, assuming the estimated VAR model is correct. For this section, the order of the VAR is USA, Russia, Brazil, China, and India.

If the innovations ε_t are contemporaneously uncorrelated, interpretation of the impulse response is as follows: The i-th innovation $\varepsilon_{i,t}$ is simply a shock to the i-th endogenous variable $y_{i,t}$. However, innovations are generally correlated, and may be viewed as having a common component which cannot be associated with a specific variable. In order to interpret the impulses, it is common to apply a transformation P to the innovations so that they become uncorrelated, i.e.,

$$v_t = P\ \varepsilon_t \sim (o, D), \tag{7}$$

where D is a *diagonal* covariance matrix.

The results are presented in Figures 1–4. Figure 1 and Figure 2 show the impulse responses, 100 periods ahead. Figure 1 presents the multiple graphs. The figure plots the response to Cholesky (with degree of freedom adjusted) with one standard deviation innovations and a band of plus/minus two standard deviations for 100 periods ahead. The response standard errors are calculated (asymptotically) analytically. Figure 2 presents the combined figure, for 100 periods ahead. For stationary VARs, the impulse responses should die out to zero. Figures 1 and Figure 2 confirm that this is indeed the case for the VAR studied in this paper.

Figures 3 and 4 present the *accumulated* impulse responses for 100 periods where the response standard errors are computed using 100 Monte Carlo simulations. Figure 3 displays multiple figures of the accumulated response to Cholesky One Standard Deviation (S.D.) Innovations, together with plus/minus two standard deviation bands around the S.D. Figure 4 plots the combined figures of accumulated response. For stationary VARs, the accumulated impulse responses should asymptote to some non-zero constant. These are the cases in all the displays of Figures 3 and 4.

Figure 1

Response to Cholesky (degree of freedom adjusted) one standard deviation innovations with ± 2 standard deviations. The order of the VAR is USA, Russia, Brazil, China and India, 100-period ahead. The response standard errors are calculated asymptotically analytically.

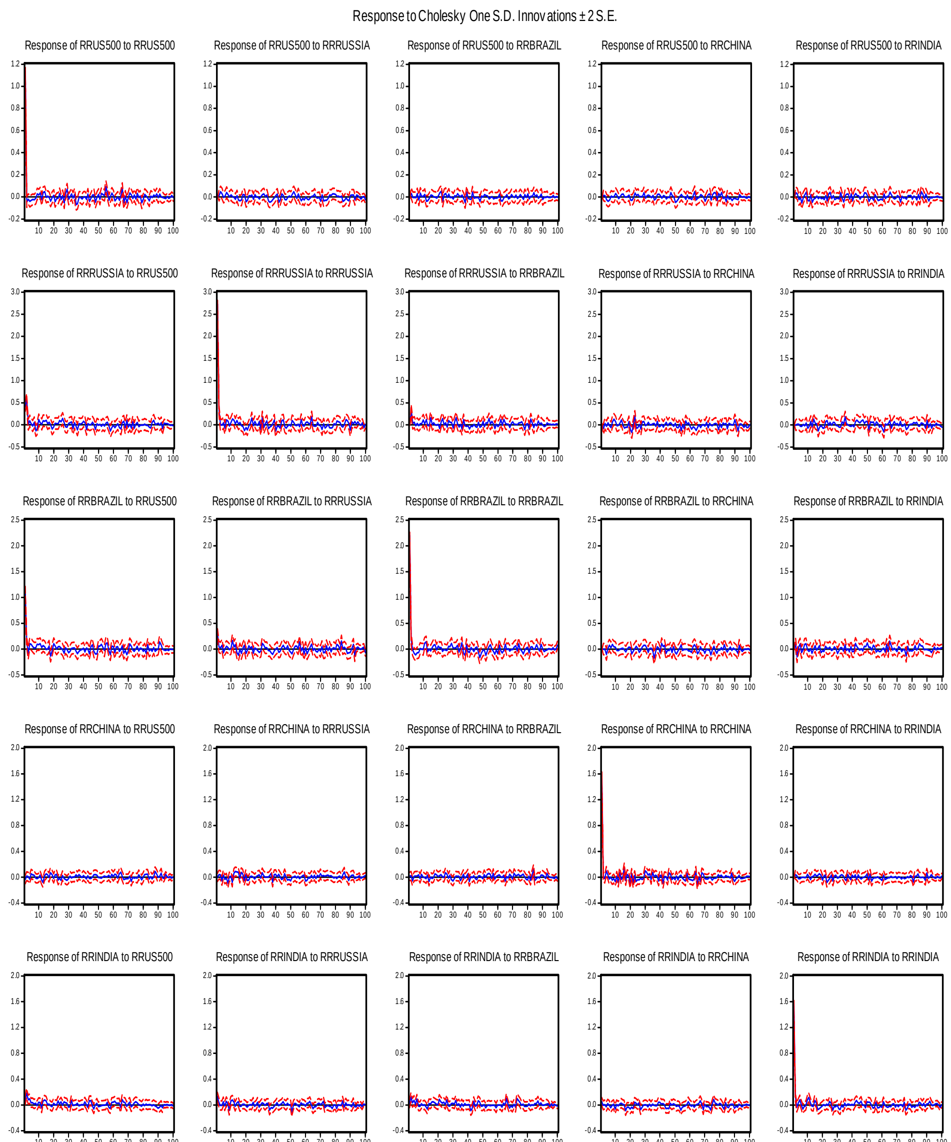


Figure 2
Combined figure, the order of the VAR is USA, Russia, Brazil, China and India, 100-period ahead

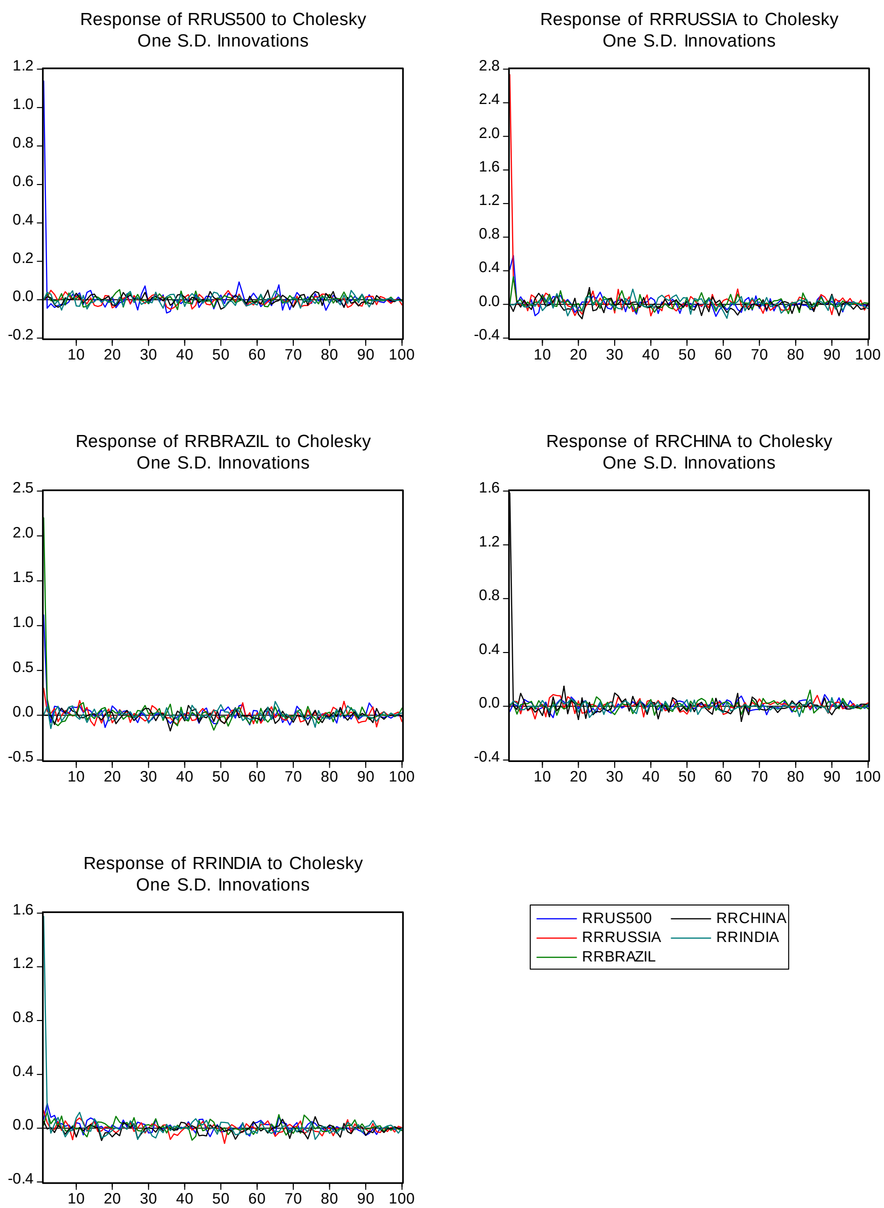


Figure 3

Multiple figures of accumulated response to Cholesky one standard deviation innovations ± 2 s.d. The response standard errors are computed using 100 Monte Carlo simulations, for 100 periods.

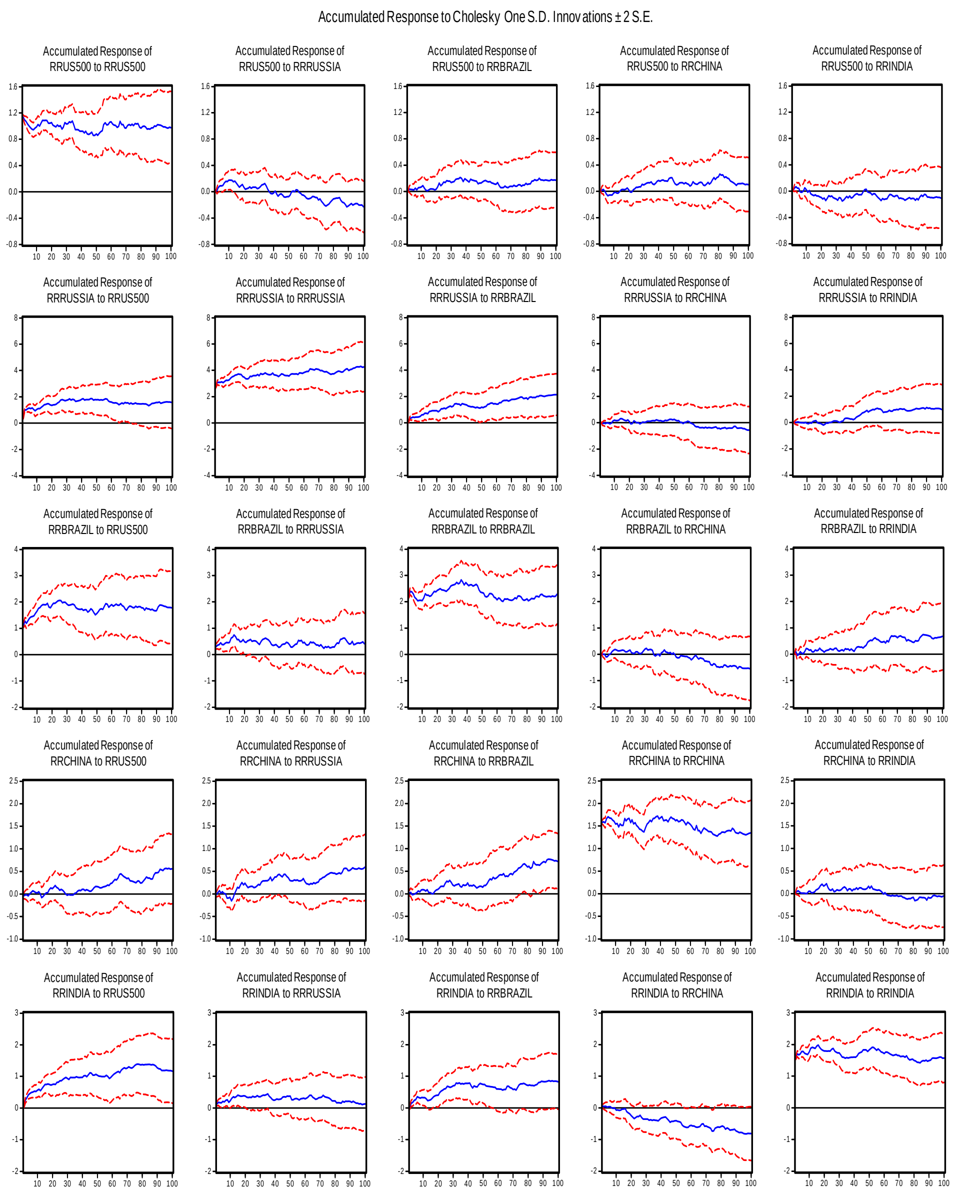
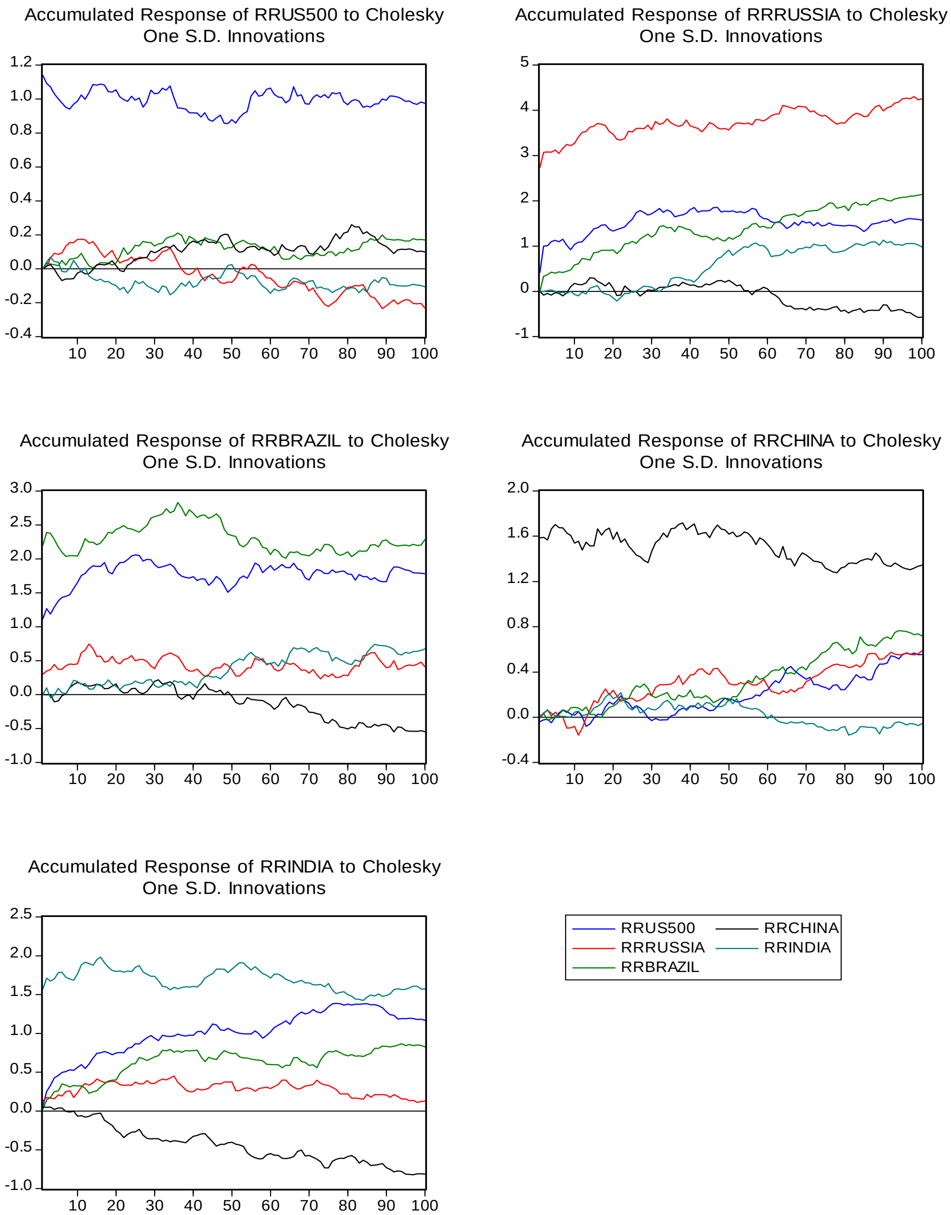


Figure 4

Combined figures of accumulated response to Cholesky one standard deviation innovations ± 2 s.d. The response standard errors are computed using Monte Carlo 100 simulation.



VII. VARIANCE DECOMPOSITION

Whereas the impulse response functions trace the effect of a shock on the returns of one stock market to the returns of other stock markets in the VAR model, the variance decomposition separates the variation in the returns of one stock market into the component shocks to the VAR. In this way, the variance decomposition provides information about the relative importance of each random innovation in affecting the stock market returns present in the VAR.

Table 4 displays a separate variance-decomposition for each stock market. The second column, labeled "S.E.", contains the forecast error of the variable at the given forecast horizon. The source of this forecast error is the variation in the current and future values of the innovations to each stock market returns in the VAR. The remaining columns give the percentage of the forecast variance due to each innovation, with each row adding up to 100 percent. The last column, labeled "AOM" displays the percentage of All Other Markets combined. Note that the impulse responses and the variance decomposition based on the Cholesky factor can change dramatically if the ordering of the variables in the VAR is altered.

Table 4 presents the results. To save space, the results in the table are given only for 5, 10, 20, 30 step-ahead forecasts up to 100 periods ahead. The discussion below is limited to the 100 period forecast ahead. The VAR model is ordered after taking into account the different time zones which these markets operate in and by the GDP per capita. This criterion leads to the following ordering: the U.S., Russia, Brazil, China, and India. Table 4 shows that although the United States stock market is ordered first in the Cholesky decomposition, after 100 periods, about 12 percent in the innovations originated in the United States are affected by markets outside of the United States itself. The Russian stock market explains about 80 percent of its own innovation. It is being affected by the U.S. market by about 8.5 percent. The effects of the other emerging stock markets are small, about 4 percent each. In contrast, the Brazilian stock market returns show that this market is greatly affected by the other markets; it explains only about 67 percent of its own innovation. This market is the most open to foreign effects compared to all other markets in the study. However, most of the weight is due to the U.S market (about 21 percent) and, to a lesser extent, the Russian market (5.7 percent). The Chinese stock market explains about 86 percent of its own innovation. However, none of the other markets in this study affect more that 3 to 4 percent of the innovations. The Indian market is affected by about five percent from each of the U.S. and the Brazilian Stock exchanges. The main conclusion drawn from Table 4 is that all markets are affected by outside markets. Furthermore, only the Brazilian market is affected to a large extent by the other markets; in particular, by those of the United States and Russia. One may note that the Chinese and Indian stock markets are less affected relative to those of Russia and Brazil.

Table 4
Cholesky ordering: RRUS500 RRRUSSIA RRBRAZIL RRCHINA RRINDIA
Standard errors: Monte Carlo (100 repetitions)

	Period	S.E.	RRUS500	RRRUSSIA	RRBRAZIL	RRCHINA	RRINDIA	AOM
RRUS50	5	1.14	99.23	0.26	0.09	0.20	0.23	0.77
	10	1.15	98.18	0.44	0.31	0.35	0.72	1.82
	20	1.16	96.87	0.89	0.61	0.56	1.07	3.13
	30	1.18	95.39	1.06	1.20	0.88	1.47	4.61
	40	1.19	93.70	1.59	1.62	1.09	2.00	6.30
	50	1.20	92.43	1.97	1.92	1.40	2.28	7.57
	60	1.22	91.43	2.36	1.98	1.61	2.62	8.57
	70	1.23	90.40	2.54	2.24	1.99	2.83	9.60
	80	1.24	89.27	2.92	2.38	2.44	3.00	10.73
	90	1.25	88.15	3.19	2.58	2.76	3.32	11.85
	100	1.25	87.82	3.35	2.59	2.85	3.40	12.18
RRRUSSIA	5	2.87	6.32	92.13	1.39	0.14	0.02	7.87
	10	2.89	6.76	91.05	1.55	0.51	0.12	8.95
	20	2.94	7.08	89.14	2.03	1.02	0.74	10.86
	30	2.99	7.37	86.89	2.60	2.09	1.05	13.11
	40	3.03	7.61	85.49	3.17	2.20	1.53	14.51
	50	3.06	7.79	84.33	3.41	2.30	2.17	15.67
	60	3.09	7.97	82.97	3.78	2.72	2.56	17.03
	70	3.12	8.23	81.58	4.12	3.05	3.02	18.42
	80	3.14	8.36	80.89	4.29	3.24	3.22	19.11
	90	3.17	8.44	79.97	4.66	3.49	3.44	20.03
	100	3.18	8.51	79.55	4.67	3.72	3.55	20.45
RRBRAZIL	5	2.52	20.42	1.65	77.07	0.17	0.69	22.93
	10	2.54	20.49	1.68	76.33	0.45	1.05	23.67
	20	2.58	20.63	2.74	74.72	0.55	1.37	25.28
	30	2.60	20.60	2.99	73.82	0.97	1.61	26.18
	40	2.63	20.32	3.46	72.79	1.59	1.85	27.21
	50	2.67	20.39	3.68	71.50	2.09	2.34	28.50
	60	2.70	20.64	4.23	70.30	2.30	2.53	29.70
	70	2.73	20.64	4.49	69.04	2.72	3.11	30.96
	80	2.76	20.59	4.71	68.28	2.99	3.43	31.72
	90	2.78	20.48	5.32	67.39	3.12	3.69	32.61
	100	2.80	20.57	5.68	66.70	3.28	3.76	33.30
RRCHINA	5	1.60	0.21	0.27	0.18	99.22	0.13	0.78
	10	1.60	0.32	0.67	0.33	98.48	0.20	1.52
	20	1.65	1.08	2.20	0.70	95.43	0.59	4.57
	30	1.67	1.51	2.41	1.24	93.64	1.20	6.36
	40	1.69	1.63	3.03	1.53	92.26	1.55	7.74
	50	1.71	1.79	3.42	1.79	91.23	1.78	8.78
	60	1.72	1.88	3.58	2.24	90.18	2.12	9.82
	70	1.74	2.35	3.78	2.49	89.19	2.19	10.81
	80	1.75	2.59	3.86	2.86	88.45	2.24	11.55
	90	1.77	3.07	4.12	3.54	86.61	2.66	13.39
	100	1.78	3.26	4.20	3.67	86.12	2.74	13.88
RRINDIA	5	1.62	2.10	0.83	0.82	0.16	96.09	3.91
	10	1.63	2.20	1.34	1.16	0.40	94.89	5.11
	20	1.66	2.80	1.78	1.53	0.97	92.92	7.08
	30	1.68	3.14	1.97	2.24	1.50	91.15	8.85
	40	1.69	3.32	2.45	2.48	1.67	90.08	9.92
	50	1.71	3.84	2.57	3.18	1.99	88.42	11.58

60	1.73	4.12	3.06	3.28	2.38	87.17	12.83
70	1.75	4.63	3.35	3.75	2.73	85.54	14.46
80	1.77	4.78	3.59	4.29	3.23	84.12	15.88
90	1.78	4.86	3.85	4.44	3.58	83.28	16.72
100	1.78	4.95	3.99	4.48	3.65	82.93	17.07

In order to further investigate whether the variance decomposition results hold with a different ordering, the order of the stock markets (after taking into account the different time zones these markets operate in) is changed to an ordering based on Total Gross Domestic Product rather than GDP per capita. This ranking is similar to a ranking based on gross fixed investment as a percentage of GDP. This results in the following ranking: the U.S., China, India, Brazil, and Russia. This ordering does not change the results for the United States, which is placed first in the two VARs. However, in principal, the ordering will affect the results for the other markets in the study, making the countries which are higher in the ranking less affected by the other markets. Table 5 displays the results. Interestingly enough, although the order is changed for all the emerging markets, the VAR variance decompositions are strikingly similar. For example, Russia, which has been moved from the second place in the ordering to the last place, is now being affected by 22.8 rather than 20.5 before. Brazil with 33.30 (when it is ranked third in Table 4) is now ranked fourth and is being affected by 32.2 percent. Although it is shifted to second in the ordering, China keeps its results. These outcomes indicate that the statistics reported in Table 4 are robust to the ordering of the variables.

Table 5

Variance Decomposition, US, China, India, Brazil, and Russia

	Period	S.E.	RRUS500	RRCHINA	RRINDIA	RRBRAZIL	RRRUSSIA	AOM
RRUS500	5	1.14	99.23	0.20	0.24	0.09	0.24	0.77
	10	1.15	98.18	0.35	0.72	0.31	0.43	1.82
	20	1.16	96.87	0.56	1.09	0.59	0.88	3.13
	30	1.18	95.39	0.88	1.50	1.14	1.09	4.61
	40	1.19	93.70	1.09	1.99	1.58	1.64	6.30
	50	1.20	92.43	1.40	2.25	1.87	2.05	7.57
	60	1.22	91.43	1.61	2.61	1.98	2.36	8.57
	70	1.23	90.40	1.98	2.83	2.26	2.53	9.60
	80	1.24	89.27	2.44	3.02	2.41	2.87	10.73
	90	1.25	88.15	2.75	3.33	2.59	3.19	11.85
	100	1.25	87.82	2.83	3.41	2.59	3.35	12.18
RRCHINA	5	1.60	0.21	99.23	0.15	0.16	0.26	0.77
	10	1.60	0.32	98.49	0.23	0.32	0.64	1.51
	20	1.65	1.08	95.44	0.65	0.68	2.14	4.56
	30	1.67	1.51	93.65	1.23	1.19	2.43	6.35
	40	1.69	1.63	92.26	1.60	1.52	2.98	7.74
	50	1.71	1.79	91.23	1.80	1.76	3.41	8.77
	60	1.72	1.88	90.18	2.15	2.21	3.58	9.82
	70	1.74	2.35	89.19	2.21	2.46	3.79	10.81
	80	1.75	2.59	88.45	2.25	2.88	3.83	11.55
	90	1.77	3.07	86.61	2.70	3.48	4.15	13.39
	100	1.78	3.26	86.12	2.77	3.59	4.25	13.88

Table 5 (continued)

	Period	S.E.	RRUS500	RRCHINA	RRINDIA	RRBRAZIL	RRRUSSIA	AOM
RRINDIA	5	1.62	2.10	0.16	96.85	0.80	0.09	3.15
	10	1.63	2.20	0.40	95.65	1.10	0.65	4.35
	20	1.66	2.80	0.97	93.72	1.48	1.03	6.28
	30	1.68	3.14	1.50	91.95	2.10	1.31	8.05
	40	1.69	3.32	1.67	90.84	2.36	1.81	9.16
	50	1.71	3.84	1.98	89.16	3.09	1.92	10.84
	60	1.73	4.12	2.37	87.85	3.19	2.47	12.15
	70	1.75	4.63	2.73	86.21	3.61	2.83	13.79
	80	1.77	4.78	3.22	84.79	4.09	3.13	15.21
	90	1.78	4.86	3.57	83.95	4.26	3.36	16.05
	100	1.78	4.95	3.64	83.60	4.29	3.52	16.40
RRBRAZIL	5	2.52	20.42	0.18	0.73	78.48	0.19	21.52
	10	2.54	20.49	0.46	1.09	77.71	0.26	22.29
	20	2.58	20.63	0.55	1.36	76.11	1.36	23.89
	30	2.60	20.60	0.98	1.61	75.16	1.66	24.84
	40	2.63	20.32	1.59	1.85	74.13	2.11	25.87
	50	2.67	20.39	2.09	2.30	72.78	2.45	27.22
	60	2.70	20.64	2.30	2.49	71.54	3.03	28.46
	70	2.73	20.64	2.71	3.06	70.21	3.37	29.79
	80	2.76	20.59	2.99	3.38	69.46	3.59	30.54
	90	2.78	20.48	3.12	3.66	68.52	4.22	31.48
	100	2.80	20.57	3.28	3.75	67.80	4.60	32.20
RRRUSSIA	5	2.87	6.32	0.14	0.65	3.39	89.50	10.50
	10	2.89	6.76	0.51	0.74	3.54	88.44	11.56
	20	2.94	7.08	1.01	1.39	4.01	86.51	13.49
	30	2.99	7.37	2.09	1.72	4.55	84.27	15.73
	40	3.03	7.61	2.21	2.14	5.07	82.98	17.02
	50	3.06	7.79	2.30	2.74	5.27	81.89	18.11
	60	3.09	7.97	2.72	3.11	5.57	80.63	19.37
	70	3.12	8.23	3.05	3.56	5.93	79.22	20.78
	80	3.14	8.36	3.24	3.78	6.09	78.53	21.47
	90	3.17	8.44	3.49	4.00	6.46	77.60	22.40
	100	3.18	8.51	3.73	4.09	6.47	77.21	22.79

VIII. CONCLUSION

This paper uses VAR modeling to study the dynamic interrelationships among stock market returns for the United States' S&P500, and the stock exchanges of the emerging tigers of the twenty-first century (BRICs): Brazil, China, India and Russia. The model uses daily observations spanning from September 1, 1995 until October 14, 2005, for a total of 2,641 observations for each stock market.

One interesting and surprising result is the number of lags required in order to capture the dynamics of the data. There are 92 business-day lags in this study. In addition, it is found that the Brazilian stock market returns are affected to a large extent by other stock markets. This finding is true also for the Russian stock market returns, although to a lesser extent. The Chinese and Indian markets are much less affected by dynamic linkages originating from other markets. Currently, the Chinese stock exchange seems the most isolated from exogenous disturbances. Moreover, this market is the least influenced by the American stock market. This result seems to encourage a larger extent of American purchases and activities in the Chinese stock markets in order to improve diversification.

Since international financial integration throughout the world may further promote economic development by encouraging improvements in the domestic financial system, as long as these countries fail to improve both transparencies and respect for the law, including preservation of human rights, their financial institutions including their stock market performances will not be closely associated with their economic per-capita GDP growth. Although investment in the BRICs countries may improve diversification, failure to enact financial-reform policies may hinder their future increase in per capita income as their levels of per-capita income approach the Western per capita GDP.

ENDNOTES

1. According to Goldman Sachs's projections, by 2050, the largest economies in U.S. dollar terms will be China, U.S., India, Japan, Brazil, Mexico, and Russia.
2. Given the dismal performance of the Japanese economy in the last decade, a note of caution is in place. One may recall Adam Smith's (1876) observation with regard to China: "China has been long one of the richest, that is, one of the most fertile, best cultivated, most industrious, and most populous countries in the world. *It seems, however, to have been long stationary*." (p. 71), italic added.
3. North (1981) defines an economic institution as "a set of rules, compliance procedures and moral and ethical behavioral norms designed to constrain the behavior of individuals in the interests of maximizing the wealth or utility of principals." (pp. 201-202).
4. See Shleifer and Vishny (1993), Murphy, Shleifer, and Vishny, (1993), Lee and Barro (2001), Barro (2003), Hanushek (2003), Barro and Sala-i-Martin (2004), and recently Kaufmann (2005), and Mastruzzi, Kraay, and Kaufmann, (2005).
5. See also Beck, Levine, and Loayza (2000), Beck, Demirguc-Kunt, and Levine (2000), and Levin, Loayza, and Beck (2000).
6. The Ljung-Box Q-statistics and their p-values are given in the Table. The Q-statistic at lag k is a test statistic for the null hypothesis that there is no autocorrelation up to order k and is computed as:

$$Q_{LB} = T(T + 2) \sum_{j=1}^{k} [\tau_j^2/(T- J)],$$

where τ_j is the j-th autocorrelation and T is the number of observations. Under the null hypothesis, Q_{LB} is asymptotically distributed as a χ^2 with degrees of freedom equal to the number of autocorrelations. The Q-statistic is often used as a test of whether the series is white noise. There remains the practical problem of choosing the order of lag to use for the test. If one chooses too small a lag, the test may not detect serial correlation at high-order lags. However, if one chooses too large a lag, the test may have low power since the significant correlation at one lag may be diluted by insignificant correlations at other lags. For further discussion, see Ljung and Box (1979) or Harvey (1990, 1993).

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