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Cointegration of International Stock Markets: An Investigation of Diversification Opportunities

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Cointegration of International Stock Markets: An Investigation of Diversification Opportunities

Abstract

Abstract: This paper examines the long-run convergence of the United States and 22 other developed and developing countries. I use daily data and run the Johansen (1988) and the Gregory and Hansen (1996) test to show that stock markets of most countries have become cointegrated by 2010. I also look at short-run diversification opportunities across the countries by comparing their daily returns to the daily returns of the global index (S&P 1200). China, Malaysia and Austria stand out as countries with highly favorable diversification opportunities as they are not cointegrated about with the US and are insensitive to the global index. Finally, I use the relative risk of each country (obtained from the CAPM model) to measure performance of each country over the great recession of the 2000s. I find that the relative risk of a country is a good predictor of country performance in a recession.

Keywords

Stock market integration, Long-run convergence, Cointegration, Portfolio diversification, Capital Asset Pricing Model

Cover Page Footnote

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1. Introduction

One of the fundamental tenants of investing is holding a diversified portfolio of securities and reducing one's exposure to risk. Consequently, fund managers are always on the look-out for securities that do not correlate together and hence provide for better opportunities to hedge risk. In recent years that has meant moving beyond the confines of one's borders and investing in other countries as well. Geographic diversification generates superior risk-adjusted returns for institutional investors while capturing the higher rates of returns offered by the emerging markets. There are two main reasons for why investing across countries has been increasing. The first has to do with the global trend of liberalization of capital flows. Most developed countries eased capital controls around 1980s and 1990s (Yang, Khan and Pointer, 2003) with the developing countries following suit. While the Asian Financial Crisis of 1997 certainly challenged the notion of the supremacy of free capital flows, liberalization still very much remained the global trend until 2009[1]. Secondly, globalization has resulted in a better network of communication through which it has become very easy for institutional as well as individual investors to invest in international stock markets. Indeed, this desire to invest abroad and to diversify one's portfolio has resulted in a flow of capital across borders, especially from the developed to developing economies.

The increasing mobility of capital implies that we are moving towards a more financially and economically integrated world. While this results in a more efficient global financial sphere, it also means stock markets will stop exhibiting independent price behavior and so it will not be possible to reap the benefits of diversification across borders. Consequently, we need to examine the cointegration of stock markets using the latest data to investigate which countries are the least integrated and hence provide with the most diversification opportunity. In this paper, I examine the co-integration of international stock markets of various countries over the past 11 years.

The study of cointegration of stock markets is essential because it is a direct consequence of globalization and it has important implications for investors. One other motivation I have for using the latest data is that I want to examine country and stock performance over the global financial crisis that spanned from 2007 to 2010. An examination of the crisis reveals that economies are already fairly integrated which has resulted in the crisis spreading from the United States to the rest of the world. I want to see if countries that were more closely integrated were hit more adversely by the recession than countries that were segmented.

[1] (post the great recession, there has been a resurgence of Keynesian thought and implementing stricter restrictions of capital flows)

I use the Johansen and Gregory and Hansen tests to investigate cointegration in the stock markets of the US, Australia, Austria, Brazil, Canada, China, France, Germany, Hong Kong, India, Japan, Korea, Malaysia, Mexico, Netherlands, New Zealand, Norway, Singapore, Spain, Sweden, Switzerland, Taiwan and United Kingdom. These countries are all important players in the global economy and they form a geographically diverse mix of developing and developed countries. Moreover, they have large capitalization, huge volume of shares traded, and most of them are affiliated with one of the three major economic blocks namely the Association of Southeast Asian Nations (ASEAN block), the European Union (EU) or the North Atlantic Free Trade Agreement (NAFTA). Together, these three primary blocks account for 80 percent of the world trade and so I am confident that the inclusion of these countries paints a complete picture of the global economic climate.

While previous studies have focused on only developed or developing countries or have focused on regional analyses, my study is unique because it takes into account some of the leading developed countries and developing countries. Furthermore, I use daily stock market indices values for each of these countries whereas most studies use monthly values. I use daily data because I believe that information flows instantly and markets react to the information revealed in prices on other markets very quickly. Cerny and Koblas (2008) find that information flows (from Europe) and is reflected in the stock markets of other countries (including the United States) within an hour. Consequently, using monthly values is rather arbitrary and one should use daily values to see if stock markets move together in the long-run. Finally, I believe that using a data set that includes the 2007 global recession will provide interesting results.

While studying stock market indices, I look to answer three questions. Firstly, does a stable, long-run bivariate relationship between the US and each of the other country's stock markets exist? This tests the efficient market hypothesis. If I find that the chosen markets cointegrate, then there will be no arbitrage opportunity and hence it will not be possible to make abnormal profits in the long-run. The efficient market hypothesis will be proven. On the other hand, while it might not be possible to make abnormal profits through international portfolio diversification in the long-run, it is still possible to make abnormal profits in the short-run. Part two of my study looks to answer the question: What are the sensitivities of stock markets to global events and where exactly do we expect to find the greatest opportunities for diversification? I answer this question by using the Capital Asset Pricing Model (CAPM) and comparing individual stock market returns to a global index (obtained from Standard and Poor's Global 1200 Index). Finally, I compare the sensitivities (or relative risk) of individual countries to the country's performance over the current financial crisis.

Essentially, the question I am looking to answer in the third part of my study is: Did the markets with a low sensitivity (β) fare well in the global recession?

My results indicate that the stock markets of almost all countries (16 out of the sample of 22) are cointegrated with the United States. That would mean that there is no diversification opportunity for investors looking to invest pair-wise into the stock market indices of these countries. However, the CAPM analysis shows that countries do have diversification opportunities in the short-run. Finally, an analysis of country performance from the 1st quarter of 2007 to the 3rd quarter of 2010 produces intuitive results. My results indicate that the countries that were more closely integrated with the world economy fared worse over the recession in terms of maximum percentage fall in real gross domestic product as compared to countries that were less sensitive to the world economy.

The rest of the paper is organized as follows. Section 2 provides an overview of existing literature on the topic. Section 3 discusses the data and the specific methodology I used to conduct my tests. Section 4 reports and provides an interpretation of the results. Section 5 suggests other avenues for future research on the topic and concludes.

2. Review of Existing Literature

The existing literature can be broken down along the lines of cointegration of stock markets, which is provided in Section 2.1, and correlation of stock markets, which is discussed in Section 2.2.

2.1: Cointegration Analysis:

The topic of cointegration amongst stock markets has been thoroughly explored in existing literature. The first body of research focused on using the Johansen (1988) test towards finding cointegration across the various international stock markets. In this basic model, one regresses the stock market index price of one country against that of the other. If the residuals obtained from the regression are stationary, then a long-run relationship exists between the two countries, or in other words, the stock markets of the countries are cointegrated. The results from such analyses were generally mixed. Jochum (1999) examined the price patterns of the Eastern European stock markets from 1995 to 1998 and found that long-run linkages existed in the stock markets leading into the 1997/98 market crisis. However, he found that during and post-crisis the common stochastic trend seemed to vanish. Herein lies the limitation of such an approach. As Gregory, Nason and Watt (1994) showed, the power of the Johansen test falls sharply in the presence of a structural break. The Johansen test does not account for structural breaks in the stock market data, which can be caused by major political or economic events or policy changes. Hence, they might falsely signal the absence of cointegration in a system while actually it might be present. However, advances in the field of econometrics have refined the techniques to also account for structural breaks in the data. The Gregory and Hansen (1996) residual-based cointegration analysis tests for cointegration in the presence of structural shifts.

Consequently, the focus of the literature shifted to studying cointegration using the Gregory and Hansen test. Cointegration in the presence of structural breaks can be thought of as holding over some long period of time and then shifting to a new 'long-run' relationship (Gregory and Hansen, 1996). According to Gregory and Hansen, we postulate that a single break of unknown timing occurs in the time series data. The break can be a level shift, which is a change in the intercept, a level shift with trend, which introduces a time trend into the level shift model or it can be a regime shift which changes the y-intercept and the slope of the model with a time trend. The standard testing procedure is to evaluate modified ADF, Za and Zt statistics in the presence of a one-time regime shift of unknown timing to see if one can reject the null of no cointegration.

Most papers used identical models to evaluate cointegration of stock markets; however, they differed from each other because they used different countries and different time periods in their analyses. The authors usually selected countries and dates based on the premise of investigating the effects of various financial events and trends. For example, Narayan and Smyth (2005) used both the Johansen and the Gregory and Hansen test to examine the cointegration between the New Zealand and the G-7 economies. They chose to focus on New Zealand because it witnessed a period of major financial deregulation in the mid-1980s. Theory tells us that financial deregulation would be accompanied by investment flows and an increase of trade. This would result in closer integration with other countries. They did not find any evidence of cointegration using the Johansen methodology, however, when they accounted for structural breaks using the Gregory and Hansen methodology, they found that the stock markets of New Zealand and the United states were cointegrated.

Similarly, Fernandez-Serrano and Sosvilla-Rivero (2001) used both methods to investigate linkages between the Far East Asian economies. According to the Johansen test, there was no cointegration between the stock markets of Asia from 1977 to 1999. However, when they ran the Gregory and Hansen test, they found that there was a major break around October 1987, which was the stock market crash on Black Monday. When structural breaks are taken into account, they find that there is strong cointegration between Taiwan and Japan post-1987 and marginal cointegration (cointegration in event windows) between Japan and Singapore and Japan and Korea. Chiang and Wang (2008) further examined the relationship between the stock markets of Taiwan, Japan, Hong Kong and Singapore. Specifically, they used daily spot and nearby futures prices for MSCI Taiwan, the Nikkei 225, the Hong Kong Hang-Seng and the Singapore Straits Times index from 1995 to 2003. They employed the Gregory and Hansen test and found that they could reject the null of no cointegration at a 95% level of confidence. Their significant results are one of the reasons I want to run my model using current data. Even though some studies haven't found cointegration in the international stock markets, I believe that we are going towards a more globalized world with free flow of capital across borders. If this is the case, then I need to look at the latest data from various developed and developing countries for my cointegration analysis.

Yang, Khan and Pointer (2003) also investigate the 1987 stock market crash and its impact on the long-run integration between the United States and 14 developed countries. As expected, the Johansen test does not find any cointegration between the countries from 1970 to 2001. However, the authors also employ a recursive cointegration analysis to examine the time-varying nature of long-run relationships. Specifically, they test to see if the number of cointegration vectors between each county remains constant after the abolition of capital control and the 1987 crash. They find no marked change in constancy of the number of cointegration vectors after the stock market crash and the abolition of capital control. While they do not find any proof of long-run cointegration between the US and the larger markets (Japan, United Kingdom and Germany), they do find increasing integration between the US and many smaller markets such as Belgium, Norway, Denmark and Sweden in the late 1990s.

Fraser and Oyefeso (2005) examine a similar time frame (monthly data from January 1974 to January 2001) but get slightly different results. They run a Johansen multivariate cointegration test between the US, the UK, Germany, France, Italy, Germany, Belgium, Spain, Denmark and Sweden and find that there is a single common stochastic trend to which all markets have a long- run relationship. Although the aforementioned studies use different models to test for cointegration, one other reason for the discrepancy might be that Fraser and Oyefeso (2005) use real stock prices in their model. These are calculated by using Consumer Price Index (CPI) as a deflator for stock price indices. The premise is that using real prices abstracts from inflationary and exchange rate dynamics. Their approach is a significant departure from the other literature. It seems sensible to control for inflationary and exchange rate movements across countries when looking to identify common trends. However, I do not use such an approach in my study because I am using daily data whereas data on CPI is available on a monthly basis. So, it is not possible to calculate real prices on a daily basis. Additionally, there is less theoretical justification for using real prices in my study because the time frame is much smaller (11 years versus 27 years) and this time period did not experience as much exchange rate and inflationary movement.

As the overview of current literature shows, there is a lack of consensus about the presence of cointegration in international stock markets. However, the literature does seem to support the view that cointegration may exist for certain regions or certain time periods and that generally, there is a trend of moving towards increasing integration. As I use the latest data, my study builds on the existing literature by investigating whether the observed trend of increasing integration actually transforms to cointegration amongst the countries by 2010. As mentioned earlier, the other way in which my study builds on the current literature is that I use daily data, which not only provides a better means to investigate cointegration, but which also controls for inflation and exchange rate swings.

2.2: Analysis of Diversification Opportunities:

Cointegration of stock markets has a direct impact on diversification opportunities. If cointegration is present, then that means that there is a long-run relationship between the two series. In other words, it indicates the presence of common factors which limit the amount of independent variation among the series. But what does one mean by common factors? What is the mechanism through which it is ensured that stock markets are forced to move together? Lack of barriers and free capital flows ensure that investors can exploit arbitrage opportunities in different countries. Consequently, we would expect similar yields for financial assets of similar risk and liquidity irrespective of nationality or location (von Furstenberg and Jeon, 1989) and thus a high degree of shared price movement. So, while cointegration implies the absence of long-run diversification opportunities, it is still possible to derive gains from portfolio diversification in the short run. The second part of my study looks to investigate which countries provide the most opportunities for diversification in the short-run.

Lagoarde-Segot and Lucey (2007) consider the same question but they focus their study on the Middle Eastern and North African (MENA) countries. Using daily data, they use various cointegration analyses to find that the markets of MENA are not cointegrated with the European Union, a regional index or the United States. On the other hand, they use a recursive cointegration analysis to prove that the MENA markets have started to move toward more international financial integration. Next they investigate the diversification opportunities across the different markets. They decompose each country's stock market variance into regional variance and global variance. When these scores are normalized for market capitalization, they provide measures of integration with the European Union, the Middle Eastern and North African countries and the world. The countries which are the least integrated, Tunisia and Lebanon, provide the most diversification opportunity.

The international risk decomposition model, as used by Lagoarde et. al. was a modified version of the original model used by Akdogan (1996). Akdogan measured the time-varying integration of 26 national equity markets against a global benchmark. He used a version of the Capital Asset Pricing Model where the returns of each country were regressed against the global benchmark from 1972 to 1980 and from 1980 to 1990. The resulting coefficient, β, represented the sensitivity of the country's stock market to the global benchmark. This coefficient, when normalized for market capitalization, represented the fraction of systematic risk in total country risk relative to the global benchmark. A growing systematic risk fraction suggested that the market had become more integrated with the world. There are many other studies (For example Errunza and Losq, 1985; Solnik, 1974) that used variations of the CAPM to measure degree of integration with the world. However, Barari (2004) modified the model used by Akdogan (1996) to also incorporate regional integration by regressing a country's returns against global returns and regional returns. She examined countries in Latin America and found that post mid-1990 global integration was taking place at a faster rate than regional integration.

This result is significant for my study as it provides a motive to examine the latest data to see how far the countries are in the integration process. My process of obtaining global integration scores (βs) is similar to that of Lagoarde et. al. I run the CAPM model to examine how the daily returns of the stock market in a country correlate with the daily returns of the 'global market.' However, in a departure from Lagoarde et. al, I do not normalize the global integration score by the market capitalization because that would assign weights to countries in a global portfolio, which is irrelevant to the scope of my study. Finally, my study goes a step further to see if integrated stock markets are a good explanation for country performance in the great recession of the 2000s.

3. Data and Methodology

Section 3.1 gives an overview of the data sources and the data transformations used for my study. In Section 3.2, I explain in detail the empirical models used to conduct this study.

3.1: Data:

The data for the cointegration analysis comprised of daily opening price for the major stock market index for each country. I chose stock market indices based on what had been used in existing literature and what was considered as the most comprehensive index for the country. The time frame for my analysis was from 1st January 1999 to 1st November 2010. I chose the start year to be 1999 because 11 years is a sufficient period to be considered long-run and because I wanted to avoid the influence of the Asian Financial Crisis of 1997/98 and I wanted to include data after the formation of the European Union. I was able to obtain data from 1999 for each country with the exception of Sweden, Norway and New Zealand for which I had data from January 2001, February 2001 and May 2004 respectively. Table 1 gives an overview of the data used for the study.

Table 1: Summary of stock market data

Country	**Index**	**Source**	**Beginning date**
Australia	Australian Stock Exchange All Ordinaries	Yahoo Finance	1-Jan-1999
Austria	Austrian Traded Index	Yahoo Finance	1-Jan-1999
Brazil	Bovespa	Yahoo Finance	1-Jan-1999
Canada	S & P TSX Composite	Yahoo Finance	1-Jan-1999
China	SSE Composite Index	Lexis Nexis Statistical Database	1-Jan-1999
France	CAC 40	Yahoo Finance	1-Jan-1999
Germany	DAX	Lexis Nexis Statistical Database	1-Jan-1999
Hong Kong	Hang Seng Index	Lexis Nexis Statistical Database	1-Jan-1999
India	BSE Sensex	Lexis Nexis Statistical Database	1-Jan-1999
Japan	Nikkei 225	Lexis Nexis Statistical Database	1-Jan-1999
Korea	Kospi	Yahoo Finance	1-Jan-1999
Malaysia	FTSE Bursa Malaysia Index	Yahoo Finance	1-Jan-1999
Mexico	IPC	Yahoo Finance	1-Jan-1999
Netherland	AEX index	Yahoo Finance	1-Jan-1999
New Zealand	NZX 50	Yahoo Finance	1-May-2004
Norway	OSE All Share	Yahoo Finance	1-Feb-2001
Singapore	Straits Times Index	Yahoo Finance	1-Jan-1999
Spain	IBEX 35	Yahoo Finance	1-Jan-1999
Sweden	OMX Stockholm All Share	Yahoo Finance	1-Jan-2001
Switzerland	SMI (Swiss Market Index)	Yahoo Finance	1-Jan-1999
Taiwan	TSEC Weighted Index	Yahoo Finance	1-Jan-1999
UK	FTSE 100	Lexis Nexis Statistical Database	1-Jan-1999
US	S&P 500	Lexis Nexis Statistical Database	1-Jan-1999

Data on stock market indices prices was obtained from Lexis Nexis Statistical Datasets and Yahoo Finance. One complication I ran into was that Lexis Nexis Statistical Datasets gave prices in United States Dollars (USD) whereas Yahoo Finance gave prices in units of local currency. Therefore, I used daily spot exchange rates from the Federal Reserve of Saint Louis to convert all prices into USD. Since I was comparing each country's index to the US index, I also had to make sure that all the dates lined up for comparison. There were some dates where I had the price for the index of one country but not the other. This was due to the fact that each country had different holidays on which the stock markets are closed. Rather than taking a weekly or 3 day average, I chose to ignore such data points. Since the stock prices evolved in a clearly monotonous nonlinear fashion, I took the natural logarithm of all the series.

For the CAPM analysis, I use Standard and Poor's Global 1200 Index as the global index. The S&P Global 1200 Index, which is available for free at the Standard and Poor' website, is a free-float weighted stock market index of global equities that covers 31 countries and approximately 70 percent of global stock market capitalization. The index is a good proxy for the global stock market. Barari (2004) used the Morgan Stanley Capital International All Country World Free Index (ACWFI) which is another good proxy for the world stock market; however, I decided not to use it because it has daily data for only a few years.

I used daily values of the S&P 1200 and the country's index to get daily returns (again making sure that all the dates lined up). Since the scope of this part of my study is the short-run, I used data from 2005 to 2007 to estimate the βs and then compared each β to real GDP performance of the country from 2007 to 2010.

I obtained quarterly nominal GDP and the GDP deflator (with 2005 as the base year) from International Financial Statistics. I found the real GDP for each country (from Q1 2007 to Q3 2010) by dividing the nominal GDP by the GDP deflator. However, this figure was in units of local currency so I used quarterly exchange rates to convert it to United States Dollars.

3.2: Methodology:

The methodology section is divided into three sections, the Johansen test, the Gregory and Hansen test and the Capital asset pricing model.

3.2(a) Johansen Test (1988):

I started by plotting the logarithmic values of each country's time series with that of the United States. As the graphs in the appendix show, most of the country indices follow a trend of decline from 2000 to 2002, followed by about 5 years of steady growth and then a sharp plunge in 2007. Since these graphs are normalized by the value of the index at the starting date, it is easy to make comparisons across the two countries. The time series do seem to vary together which does imply the existence of a long-run relationship, however, I needed a more thorough analysis before I could conclude that cointegration exists in the stock markets.

Cointegration is defined as a situation where linear combinations of non-stationary time series are stationary. This implies the existence of a long-run equilibrium between the variables. Therefore, before I could proceed with the tests of cointegration, I had to make sure that the series were non-stationary and hence integrated of order 1. I ran the Augmented Dickey Fuller tests on the series and the differenced series to confirm that the series were indeed I (1). I used the

Schwartz Information Criterion (*SIC*) for lag selection as it seems to be the criterion of choice in most studies. The ADF test is as follows:

$$\Delta y_t = \alpha + \phi y_{t-1} + \mu t + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \epsilon_t \qquad (1)$$

where α is a constant, μ the coefficient on a time trend and k the lag order of the autoregressive process. The unit root test is then carried out under the null hypothesis $\phi = 0$ against the alternative hypothesis of $\phi < 0$. If we can reject the null, we know the series is stationary and if the null cannot be rejected, we proceed with the assumption that the time series is non-stationary. The table I in the appendix shows the results for the ADF test for each country. The ADF test on the stock market time series tells us that we cannot reject the null. On the other hand, I can reject the null for the differenced series. This means that all the time series are integrated to the order of 1.

Having established that the series are I (1), I ran the Johansen test of co integration. The lags were selected based on the Schwartz Information Criteria. The long-run bivariate relationship between the stock prices of US and other countries is:

$$y_{i,t} = \alpha_{1,i} + \beta x_t + \varepsilon_{i,t} \qquad (2)$$

where x is the natural log of stock price of the United States (S&P 500), y is the natural log of stock price of the i^{th} country, where i = {Australia, Austria, Brazil, Canada, China, France, Germany, Hong Kong, India, Japan, Korea, Malaysia, Mexico, Netherlands, New Zealand, Norway, Singapore, Spain, Sweden, Switzerland, Taiwan or United Kingdom} and $\varepsilon_{i,t}$ is the white noise process (and it is I (0)). Intuitively, the Johansen procedure regresses one series against the other then runs an augmented Dickey-Fuller test on the residuals to check if they are stationary. If the residuals are stationary, then one can assume that the variables are cointegrated. For each time series, the null hypothesis is that there is no cointegration and the alternate hypothesis is that there is one or greater than one cointegrating relationship. If we reject the null, then the next null hypothesis will be that there is one cointegrating relationship and the alternative will be that there are 2 cointegrating relationships.

3.2 (b) Gregory and Hansen (1996):

After the Johansen test, I moved on to the Gregory-Hansen test which incorporates structural breaks into the relationship. The discussion of this model follows Gregory and Hansen (1996). Gregory and Hansen explain that it is possible that cointegration might hold over some (fairly long) period of time, and then shift to a new 'long-run' relationship. In other words, the series are cointegrated, in the sense that a linear combination of the non stationary variables is stationary, but that this linear combination (the cointegrating vector) has shifted at one unknown point in the sample. In such a scenario, the standard test for cointegration (Johansen test) is not appropriate since it presumes that the cointegrating vector is time-invariant under the alternative hypothesis. Gregory, Nason, and Watt (1994) proved that the power of the conventional ADF test falls sharply in the presence of a structural break. Consequently, Gregory and Hansen (1996) propose models where the cointegrating vector is allowed to change at a single unknown time during the sample period. They use dummy variables to model the structural change through a change in slope and/or y-intercept.

The dummy variable is defined as:

$$D_t^\tau = \begin{cases} 0 \text{ if } t \leq [n\tau] \\ 1 \text{ if } t > [n\tau] \end{cases}$$

where the unknown parameter $\tau \in (0,1)$ denotes relative timing of the change point and [ ] denotes integral part (Gregory and Hansen, 1996). The break point is searched over the range of the sample (0.15T, 0.85T). It is selected by choosing a value of τ for which the test statistics take the smallest (the largest negative) value and hence provide with most favorable evidence to reject the null hypothesis of no cointegration.

Their first model tests for cointegration in the presence of a level shift. This is modeled by a change in the intercept α after the break of unknown timing τ, while the slope coefficient β is held constant. It is denoted by:

$$y_t = \alpha_1 + \alpha_2 D_t^\tau + \beta x_t + \varepsilon_{i,t} \quad t = 1, \ldots, n. \tag{3}$$

The dummy variable takes a value of 1 after the break and so we get a change in the intercept. The second model contains a level shift with trend and it is denoted by:

$$y_t = \alpha_1 + \alpha_2 D_t^\tau + \beta_0 t + \beta_1^\tau x_t + \varepsilon_{i,t} \quad t = 1, \ldots, n. \tag{4}$$

The addition of $\beta_0 t$ adds a time trend in the level shift model. The third model builds on this by allowing the slope vector to change as well. Thus, we allow the equilibrium relation to rotate as well as shift parallel. This model is called the regime shift model and it takes form:

$$y_t = \alpha_1 + \alpha_2 D_t^\tau + \beta_0 t + \beta_1^\tau x_t + \beta_2^\tau x_t D_t^\tau + \varepsilon_{i,t} \quad t = 1, \ldots, n. \tag{5}$$

In this model, α_2 gets added to the y-intercept after the break and β_2^τ gets added to the slope coefficient after the break. For each of these tests, the null hypothesis is still that there is no cointegration in the system. The alternate hypothesis is that there is cointegration with the presence of a structural shift.

Now, the standard statistics calculated in the cointegration tests are the ADF statistic, the Phillips Z_α statistic and the Phillips Z_t statistic. However, in these models, they posit that a break of unknown timing occurs. Consequently, they run the models recursively over the break points. The three test statistics to test the null are:

$$ADF^* = inf_{\tau\varepsilon T} ADF(\tau) \quad (6)$$

$$Z_\alpha^* = inf_{\tau\varepsilon T} Z_\alpha(\tau) \quad (7)$$

$$Z_t^* = inf_{\tau\varepsilon T} Z_t(\tau) \quad (8)$$

They take the smallest values (largest negative) ADF(τ), Z_α (τ), Z_t (τ) across all the break points and to check if they can reject the null hypothesis.

3.2 (c) Capital asset pricing model:

After I ran all the models for cointegration, I proceeded analyze the short term diversification opportunities across the countries. I used a modified version of the risk decomposition model that Akdogan (1996) employed. First of all, I used the stock prices data to calculate the rate of return for each country. The equation for calculating daily return is:

$$R_i = (lny_{i,t} - lny_{i,t-1}) * 100 \quad (9)$$

where *y* is the stock price for the global index or the stock price for the index of country *i* (*i* being all the countries in the sample). After calculating the daily returns for each country, I compared them to the daily global rate of return (obtained from the S&P Global 1200 index). The model for obtaining each country's β is:

$$R_i = \alpha + \beta R_g + \varepsilon_i \quad (10)$$

Where R_i is the rate of return on the i^{th} country, R_g is the global rate of return and β is the sensitivity of the i^{th} country to the global index. β is essentially the country's exposure to worldwide systematic risk and hence it can be used to measure market integration.

After ranking all countries based on diversification opportunities, I moved on to the final part of my study, where I compared each country's sensitivity to the global index to how its economy fared from Q1 2007 to Q3 2010. For each country, I picked a value where the real GDP peaked (before the recession) and then I picked a value where real GDP was the smallest. Using these two values, I calculated the negative growth rate or fall in real GDP. The formula I used is:

$$\Delta GDP_i = (\ln(minGDP_{i,t}) - ln(maxGDP_{i,t-1})) * 100 \quad (11)$$

After calculating the βs and the maximum fall in real GDP for each country, I plotted a scatter plot to see whether there was a significant relationship between the two. Theory tells us that the greater the β or sensitivity or relative risk of a country, the bigger should be the fall in real GDP in a recession. Consequently, I also ran a regression with β as the explanatory variable to the fall in real GDP. This regression took the form:

$$\Delta GDP_i = \alpha + \mu\beta + \varepsilon_i \quad (12)$$

where α is the y-intercept and μ is the slope of the relationship. μ tells us how a unit increase in relative risk of a country corresponds to a percentage fall in real GDP.

4. Discussion of Results

4.1: Cointegration Analysis:

This paper has used daily opening prices of stock market indices from the USA and 22 developing and developed countries. The ADF test characterized all series as I (1) allowing me to proceed with the cointegration analysis. As mentioned earlier, the Johansen procedure tests for cointegration in the absence of any structural break in the data. Therefore, it is used as a benchmark test for cointegration before the more appropriate tests for cointegration in the presence of structural breaks are run. I did not find any evidence of cointegration between the United States and the 21 other countries in the sample; however, I found strong evidence of cointegration between the United States and the Netherlands. The trace test rejects the null hypothesis of no cointegration with a low p-value of 0.0007 and the maximum eigenvalue test rejects the null of no cointegration with a p-value of 0.0016. Since the null of at least one cointegrating relationship cannot be rejected, I have shown that the stock markets of the United States and the Netherlands do have a long-run relationship.

My results for the Johansen test are in line with most of the existing studies which do not find cointegration amongst stock markets when using this rather rudimentary test. On the other hand, I found cointegration between US-Netherlands whereas Yang, Khan and Pointer (2003) failed to do so even though they used the more sophisticated recursive cointegration analysis. This could be due to the fact that they used the time frame 1970-2001 whereas I look at 1999-2010. My data is more recent, and if the hypothesis that we are moving towards a more financially integrated world is correct, then, we would expect to see cointegration in the more recent data. One other reason could be the fact that I use daily data in my model whereas Yang et. al. (2003) used monthly data. I believe that using monthly data unnecessarily reduces one's data points and makes it harder to get a read on a long term relationship between two series as it tosses out 29 of the 30 readings.

As the plots of the time series in the Appendix C show, there does seem to be a common trend which binds the series together in the long-run. While the Johansen test did not find such a relationship, the Gregory and Hansen test did a much better job at finding the long-run relationship between the series. I found even more proof that either countries are becoming more integrated or that using daily data is a better measure of finding cointegration. As the results in Table III show, I was able to reject the null hypothesis of no cointegration for 16 of the 22 countries. These results build on the results of Yang et. al. (2003) for they found evidence of cointegration between the US and Australia, Hong Kong, Norway, Sweden and Canada in event windows that started in the late 1990s. They interpreted this as evidence that stock market cointegration was increasing. My study proves that from 1999 onwards, these markets are cointegrated. I also found the US to be cointegrated with New-Zealand (in line with the findings of Narayan and Smyth, 2005), the UK and Japan (corresponding with the findings of Awokuse, Chopra and Bessler, 2009).

I found cointegration between the S&P 500 and the Mexican IPC and the Brazilian Bovespa, which is consistent with the findings of Fernandez-Serrano and Sosvilla-Rivero (2003). Yang et. al. (2003) did not found any evidence of cointegration with Netherlands, Switzerland, UK and Germany using the recursive cointegration analysis, however, Fernandez-Serrano and Sosvilla-Rivero (2001) used the Stochastic Permanent Breaks (STOPBREAK) model to find that Germany, Netherlands and Switzerland are temporally cointegrated with the US stock market. When compared with the existing literature, my results for the afore mentioned countries show that the countries evolved from being temporarily cointegrated (in event windows) to being strongly cointegrated. Studies conducted in the early 2000s that had employed the recursive cointegration analysis had found a trend of increasing integration. My results show that the countries did follow that trend and they were cointegrated by 2010.

There can be two reasons for this. The first could be due to the fact that I am using the latest data and so my results reflect the global trend towards more financial integration. Secondly, it could be due to the fact that I am using daily data which could be a better instrument for finding cointegration.

The case of India also proves to be very interesting. The government of India took significant measures in 1990s to open up its capital markets. Furthermore, since 1999, there have been structural reforms in the Indian financial markets which have enhanced the investibility of Indian securities globally (Mukherjee and Bose, 2008). In fact, by 2003 India ranked third in Asia in terms of citizen's access to foreign capital markets, foreign access to domestic capital markets, and foreign ownership restrictions[2]. Theory implies that free capital flows should result in cointegration between the financial markets. My results prove this as the S&P 500 and the Sensex are found to be significantly cointegrated.

My results for the countries that are cointegrated are interesting because they use the Gregory and Hansen methodology to prove cointegration whereas the older studies which used this methodology were not as successful at finding cointegration. However, they are consistent with other studies which use the more advanced methods (such as recursive cointegration or rolling cointegration) to

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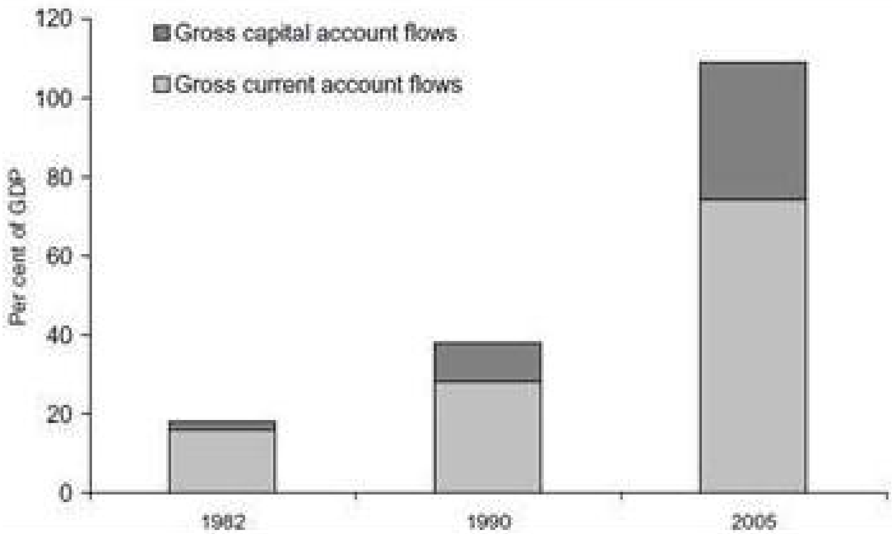
[2] As measured by the Economic Freedom index of the World sub index

find cointegration. The implications for institutional investors are that the potential long-term gains from international portfolio diversification into these countries may not be substantial. On the other hand, there seem to be significant gains from diversification in Austria, China, France, Korea, Malaysia and Spain as I found no evidence of cointegration between the United States and these countries. These findings merit a closer look as some of them, for example the lack of cointegration between the US and France, are surprising.

China and Malaysia are not found to cointegrate with the US and this is very intuitive because of the strict capital controls in these countries. China has always had many restrictions on the movement of money in and out of the mainland for anything except payments associated with exports and imports (NYT)[3]. However, there were some reforms in the 1990s to embrace market forces. While the Asian financial crisis disrupted this process, there have been new measures directed at loosening up controls over capital account transactions to achieve so-called "fundamental convertibility" with full convertibility on the current account but conditional convertibility on the capital account that allows free long-term capital flows but restricts short-term capital flows (Garnaut and Song, 2007). The recent reforms feature a strategy of selective liberalization and China is making progress in reducing the intensity of controls, particularly controls on capital outflow (Garnaut and Song, 2007). As the graph shows, capital is flowing across borders:

[3] http://www.nytimes.com/2007/08/20/business/worldbusiness/20iht-yuan.4.7186691.html

Figure 1: China's gross cross-border flows*, 1982, 1990 and 2005
(percentage of GDP)



* Defined as the sum of debit and credit flows on China's balance of payments, excluding net errors and omissions. **Source:** CEIC Data Company

So, according to the theory, we would expect to find increasing integration between the US and China. I failed to find cointegration between the S&P 500 and the SSE. This could be due to two reasons. First, that some capital controls are still in place, so there is not enough capital flow between the two countries. Second, it could be because it takes some time after (relatively) free capital flow results in the markets entering a long run relationship. Whatever the reason might be, my results identify China as a country where there are significant diversification opportunities for US investors

I also did not find any cointegration between the stock markets of the US and Malaysia. This is to be expected because the Malaysian government imposed restrictions on the international purchases and sales of financial assets on September 1, 1998 (post the Asian Financial Crisis of 1997/98). These measures restricted the amount of currency and investments that Malaysians could take abroad and foreign investors were required to have a one-year "stay period" before they could withdraw capital. This policy was aimed at reducing exposure to financial speculators and the global financial turmoil[4] by restricting free flow of capital. Consequently, there should be no cointegration between the stock markets of Malaysia and the United States.

While the results for China and Malaysia are very intuitive, the results for France, Spain and Austria are not. My results contradict the findings of Ruxanda

[4] http://www.henciclopedia.org.uy/autores/Khor/Malaysia.htm

and Stoenescu (2009) who use daily data in the Engle Granger procedure to show that France and Romania are cointegrated and use the Johansen procedure to show that the US, France and Romania form a cointegrated system. The time frame they looked at was January 2006 to December 2007. Yang, Khan and Pointer (2006) also found cointegration between US-France in the window of late 1998 to early 2000. On the other hand, Fadhlaouia, Bellalahb, Dherryc and Zouaouiid (2009) did not find cointegration between the United States and France from 2000 to 2006. However, they used the Johansen test for finding cointegration, which we have established is a poor method for finding cointegration. It is interesting to note that Spain, Austria and France are all members of the Euro zone. Perhaps the fact that they use a common currency means that they are closely integrated to each other but not to the United States. On the other hand, the Netherlands and Germany are also members of the Euro zone and are found to be cointegrated with the US. Consequently, the lack of cointegration between the US, France Spain and Austria remains a puzzle.

Korea is another puzzling case. After the currency crisis of 1997, Korea liberalized the capital account and introduced a free floating exchange rate system. Consequently, capital inflows and outflows increased drastically. In the equity market, the proportion of shareholdings of foreigners and institutional investors increased from 18% and 13.7% to 37.2% and 18.6%, respectively from 1998 and 2005.[5] The bond market received an influx of capital and the foreign-held share in total Korean Treasury Bonds and Monetary Stabilization Bonds increased from 1% at the end of 2005 to 9.5% at the end of 2007[5]. Therefore we would expect to find increasing integration between the United States and Korea. As Table 2 shows, this relationship is seen in the short run as the correlation between the Korean stock exchange and the US stock exchange increases.

Table 2: Correlation between the KOSPI and US stock indices

	1995–97	**1999**	**2001**	**2003**	**2005**	**2006**	**1999–2006**
Nasdaq	–0.17	0.71	0.46	0.95	0.79	0.79	0.72
Dow Jones	–0.27	0.88	0.48	0.95	0.38	0.58	0.61

Source: Bank of Korea, *Monthly Bulletin*, September 2007.

However, as the data shows, there is significant variability in the correlation of the stock markets. The time series graph for KOSPI (Korea Composite Stock Price Index) and the S&P 500 (provided in Appendix C) also shows this trend as the graph fluctuates wildly over the 11 year period. One possible reason for this is that the South Korean Won fluctuated tremendously in the 2000s. It depreciated suddenly in 2000, followed by a slow appreciation till

[5] http://www.bis.org/publ/bppdf/bispap44p.pdf

2008 followed by another significant and sudden depreciation. Since I use stock index price in dollars, the exchange rate movements translate to movements of the index which could be the reason that I could not find cointegration with the United States.

To reiterate, my results show that the stock markets of the United States, China, Malaysia, France, Spain, Austria and Korea are not cointegrated. This implies that US investors can reap significant diversification benefits by investing in these countries.

4.2: Analysis of Diversification Opportunities:

The second part of my model pertained to finding short-run diversification opportunities across the countries. However, unlike the cointegration analysis, where I was comparing each country to the United States, I compared each country to the global index. Using equation (9) I got daily returns and equation (10) gave me the βs or relative risk of each country. Table 3 summarizes the relative risk of each country. The t-statistic provides an analysis of significance and it is calculated by dividing the coefficient of the regression (β) by the standard error. If the absolute value of the t-statistic is greater than 2, we know with 90% confidence that the variable is significantly different from 0. I found that the βs of China and the UK were not statistically significant. Consequently I excluded them from the third part of my study.

The βs for the other countries, however, are significant, and very intriguing. I found that some of the countries which were not cointegrated with the US, namely China, Austria and Malaysia were very insensitive to the global index (βs of 0.0087, 0.15868 and 0.177512 respectively). Whereas, some of the countries that had very strong evidence of cointegration were very sensitive to the global index. For example, Brazil, Canada, Netherlands and Switzerland were all cointegrated with P-values of less than 0.01 and they had high betas like 1.04, 0.678, 0.645 and 0.4995. Small values of β represent less sensitivity or relative risk. Consequently, countries with small βs provide good diversification opportunities in the short-run. Considering both, the cointegration analysis and the diversification analysis, China, Malaysia and Austria stand out as countries with significant diversification opportunities for the US investors because they are not cointegrated with the US and they are insensitive to the movements of the global index.

Table 3: Sensitivity of country's stock market index to the global index

Country	Beta	t-stat	Country	Beta	t-stat
China	0.00875*	0.08130	Sweden	0.28974	4.01019
UK	0.03739*	0.77364	Germany	0.36378	7.32122
Austria	0.15868	2.13389	Taiwan	0.36405	5.49016
Malaysia	0.17751	3.92110	Korea	0.43362	5.39867
India	0.19503	2.33901	Switzerland	0.49954	9.26386
Japan	0.20625	3.34874	Spain	0.58128	10.30067
Hong Kong	0.22491	3.67416	Netherlands	0.64535	11.65194
Norway	0.22705	2.46703	Mexico	0.67238	8.39081
US	0.23410	5.52309	Canada	0.67891	12.19782
Singapore	0.24796	8.72747	France	0.67932	11.49016
New Zealand	0.27042	4.69951	Brazil	1.04017	9.36276
Australia	0.28306	4.74879			

* insignificant at 90 percent confidence.

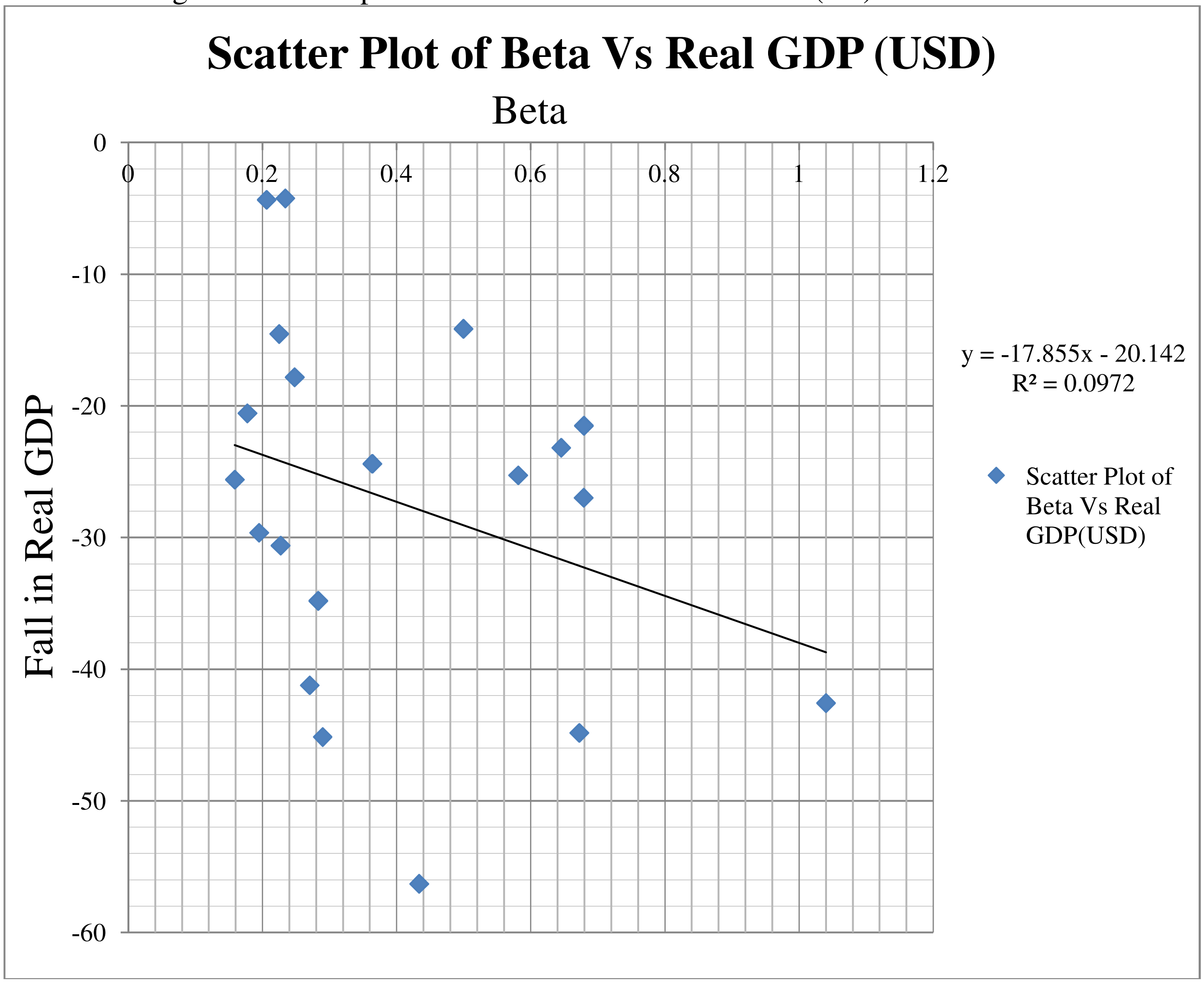
The third part of my study entailed comparing each country's β to the maximum percentage fall in its real GDP over the great recession. I excluded China and UK from this part of the study because their βs were not significant and Taiwan because I could not get quarterly real GDP data for it. Table 4 lists each country's β and its maximum percentage fall in real GDP. The table also provides information on when the real GDP took its peak value and when it took its minimum value.

Table 4: Beta and percentage fall in real GDP

Country	Time period for Maximum real GDP	Time period for Minimum real GDP	GDP fall	Beta
China	-	-	Data unavailable	0.0088
UK	Q4 2007	Q1 2009	-40.8746	0.0374
Austria	Q2 2008	Q1 2009	-25.5971	0.1587
Malaysia	Q2 2008	Q1 2009	-20.5567	0.1775
India	Q4 2007	Q1 2009	-29.6304	0.1950
Japan	Q1 2008	Q3 2008	-4.3437	0.2063
Hong Kong	Q4 2007	Q1 2009	-14.5288	0.2249
Norway	Q2 2008	Q1 2009	-30.6007	0.2270
US	Q4 2007	Q2 2009	-4.2300	0.2341
Singapore	Q2 2008	Q1 2009	-17.8196	0.2480
New Zealand	Q1 2008	Q1 2009	-41.2159	0.2704
Australia	Q2 2008	Q1 2009	-34.8065	0.2831
Sweden	Q2 2008	Q1 2009	-45.1409	0.2897
Germany	Q2 2008	Q1 2009	-24.3965	0.3638
Korea	Q4 2007	Q1 2009	-56.2954	0.4336
Switzerland	Q2 2008	Q1 2009	-14.1427	0.4995
Spain	Q2 2008	Q2 2010	-25.2684	0.5813
Netherlands	Q2 2008	Q2 2010	-23.1766	0.6454
Mexico	Q3 2008	Q1 2009	-44.8300	0.6724
Canada	Q4 2007	Q1 2009	-26.9760	0.6789
France	Q2 2008	Q1 2009	-21.5062	0.6793
Brazil	Q3 2008	Q1 2009	-42.5635	1.0402

I used values from the Table 4 to plot the relationship between beta and percentage fall in real GDP (see Figure 2). As expected, the graph shows that the more sensitive (or integrated) a country was to the world economy (as measured by the proxy stock market index of the world, the S&P 1200), the greater it was affected by the global financial crisis.

Figure 2: Scatter plot of Beta and real GDP in dollars (US)



The slope of the line is -17.855 which means that on average, an increase in sensitivity by 1 is accompanied by a fall 17.855% fall in real GDP. However, this variable is only not very significant (p-value≤ 0.20, which is fairly high). Still, the scatter plot shows that the downward trend is fairly obvious. The R-square value of the regression is 0.0972 which means that only 9.72 percent of variability in change in real GDP is explained by the model. This is adequate considering that I used only one explanatory variable (beta). After the regression equation (12) becomes:

$$\underset{}{\Delta GDP_i} = \underset{(5.999)}{-20.142} - \underset{(12.828)}{17.854}\,\beta + \varepsilon_i \qquad (12a)$$

Table 5: Goodness of fit for regression (12a)

R-squared	0.097161
Adjusted R-squared	0.047003
S.E. of regression	13.36724
Sum squared residual	3216.294
Log likelihood	-79.1813
F-statistic	1.937099
Prob(F-statistic)	0.180945

Notice that the standard error for the coefficient of β is very high. This could be due to of presence of heteroskedasticity in the data which tends to inflate the standard errors. Consequently, I used the Newey-West method (HAC) which uses robust standard errors to control for outliers, heteroskedasticity and auto correlation. The results of this correction are shown below:

Table 6: Regression of GDP fall and Beta after Newey-West correction

	Coefficient	**Std. Error**	**t-statistic**	**p-value**
Y-intercept	-20.142	4.9903	-4.0362	0.0007748***
Beta	-17.8547	6.6493	-2.6852	0.0151193*

*** implies significance at 0.01 percent level and * implies significance at 5 percent level

The standard errors after the correction are much smaller (6.6493 for the Beta as compared to 12.828). This results in Beta being a significant explanatory variable for fall in real GDP (p-value < 0.05). Thus, the third part of my study is also significant, and I found that the relative risk of a country was a good predictor of performance over the great recession.

Additionally, I also wanted to isolate the effect of membership to the European Union. Since the countries of the EU are closely integrated and share not only a common currency, but also a common monetary policy, it would be wise to block them together for analysis of performance over the recession. I used a dummy variable which took a value of 1 if the country was a member of the European Union. Consequently, I was able to break down the impact beta had on percentage fall in real GDP and the impact membership to the European Union had on real GDP. The equation took the form:

$$\Delta GDP_i = \alpha + \mu_1\beta + D\mu_2\beta + \varepsilon_i \qquad (13)$$

Note that this equation is identical to equation (12) except that there is a dummy variable, D, which denotes membership to the EU. The regression output is given below:

$$\Delta GDP_i = -20.729 - 23.116\,\beta + D\;15.793\,\beta + \varepsilon_i \quad \text{(13a)}$$
$$\qquad (5.703) \qquad (8.897) \qquad\qquad (6.737)$$

The y-intercept and the Beta are significant with p-value < 0.05 and the dummy variable is significant with p-value < 0.10. The regression tells us that on average, a unit increase in Beta is accompanied with a 23.116% fall in real GDP for non European Union countries but only a 7.3234% fall for EU countries. This implies that on average, members of the EU performed better over the recession. However, it does not tell us anything about why this might be the case.

My results from this section also have real world implications for investors. The ordered list of countries (obtained from the CAPM analysis) can be used as a rough guide to exploit arbitrage opportunities in the short-run. Countries with low values of beta serve as good avenues to hedge risk. The analysis of country performance over the 2007 recession can also be used by investors. First of all, it can be used as a rough guide on how different countries act in a recession as my results indicate that one should invest in countries with low betas during a recession as they tend to do better. Secondly, it can also be used to make some predictions during booms. Most analysts predict a strong rebound from the recession in coming years and thus investors should invest in countries with high betas as these economies are predicted to grow more.

5. Concluding Remarks and Suggestions for Future Research

I had posed three questions in the beginning of this study. Are the stock markets of US and 22 other major economies cointegrated? What are the short-run diversification opportunities across the countries? Does sensitivity to the world economy explain country performance over the great recession?

To test for cointegration, I ran the Johansen (1998) test and the Gregory and Hansen (1996) test. One way my study differed from the existing literature was that I not only used daily values but I was also used the latest data. While the Johansen test failed to find cointegration in most cases (only US and Netherlands were found to be cointegrated), the Gregory and Hansen test found cointegration in almost all the cases. This result has implications for institutional investors because it suggests that there are limited diversification opportunities in these countries in the long-run. On the other hand, China, Malaysia, Korea, France, Spain and Austria are not found to be cointegrated with the United States and hence are identified as countries where investors can attain significant gains from diversification. While the results from this section were very satisfactory, one way this study can be improved is by including more developing countries into the mix. Developed countries are more likely to have free capital flows and hence are more likely to be cointegrated. However, in recent years, an increasing number of investors are looking to invest in developing countries. Therefore, it would be interesting to see how integrated these economies are with the United States. While I included some developing countries in my data, I was limited by the unavailability of free data on the stock market indices of these countries.

In order to check for diversification opportunities, I ran a capital asset pricing model using daily returns from 2005 to 2007. I was able to generate a list based on which countries were the least sensitive to changes in the global index and hence provided the most scope for diversification opportunity. Austria, Malaysia, India, Japan, Hong Kong, Norway and the United States were found to be the least sensitive (or risky) to movements of the global index. Compounded with the cointegration analysis, my study identifies Austria, Malaysia and China as countries most favorable for diversification.

Finally, I was able to show that sensitivity to the global index can be used to explain the maximum fall in real GDP that a country experienced. One way in which I can build on this study is by including more countries in my sample. I found that my regression had a high standard error and a low adjusted R^2 value. Adding more countries to the mix will give stronger results and will be more useful for forecasting country performance in not only recessions but also booms.

References:

Akdogan H. (1996). "A suggested approach to country selection in international portfolio diversification." *Journal of Portfolio*, 33-40.

Awokuse, Titus, Aviral Chopra and David A. Bessler (2009). "Structural Change and International Stock Market Interdependence: Evidence from Asian Emerging Markets." *Economic Modelling*, vol.26, 549-559

Barari, Mahua (2004). "Equity market integration in Latin America: A time-varying integration score analysis." *International Review of Financial Analysis*, 13, no. 5, 649-668

Cerny, Alexandr and Michal Koblas (2008). "Stock Market Integration and the Speed of Information Transmission." *Czech Journal of Economics and Finance*, vol. 58, no. 1-2, pp. 2-20

Chiang, Min-Hsien and Jo-Yu Wang (2008). "Regime switching cointegration tests for the Asian Stock index futures: evidence for MSCI Taiwan, Nikkei 225, Hong Kong Hang-Seng, and SGX Straits Times indices." *Applied Economics* vol. 40, 285-293

Errunza, Vihang and Etienne Losq (2004). "International Asset Pricing under Mild Segmentation: Theory and Test." The Journal of Finance, Vol. 40, no. 1, 105 124

Fadhlaouia, Kais, Makram Bellalahb, Armand Dherryc and Mhamed Zouaouiid (2009). "An Empirical Examination of International Diversification Benefits in Central European Emerging Equity Markets." International Journal of Business, 14(2), 163-173

Fernandez-Serrano, Jose and Simon Sosvilla-Rivero (2003). "Modelling the linkages between US and Latin American Stock Markets."*Applied Economics,* 35, 12, 1423-1434

Fernandez-Serrano, Jose and Simon Sosvilla-Rivero (2001). "Modeling evolving long run relationships: the linkages between stock markets in Asia."*Japan and the World Economy,* 13, 145-160

Fraser, Patricia and Oluwatobi Oyefeso (2005). “US, UK and European Stock Market Integration.” *Journal of Business Finance and Accounting*, Vol. 32, no. 1-2, 161 181

Garnaut, Ross and Ligang Song (2007). “China: Linking Markets for Growth.” *Anu E Press and Asia Pacific Press,* 267-270. http://epress.anu.edu.au/chinalink/pdf/ch14.pdf

Gregory, Allan W. and Bruce E. Hansen (1996) “Residual-based Tests for Cointegration in Models with Regime Shifts.” *Journal of Econometrics*, vol. 70, 99–126.

Gregory, Allan W., James M. Nason, and David G. Watt (1996). "Testing for Structural Breaks in Cointegrated Relationships," *Journal of Econometrics*, vol. 71, no. 1-2, 321-341

Jochum, C (1999). “A long-run relationship between Eastern European stock markets? Cointegration and the 1997/98 crisis in emerging markets.” *Review of World Economics*, vol. 135, 454-479

Johansen, Søren (1988). “Statistical Analysis of Cointegrating Vectors.” *Journal of Economic Dynamics and Control*, vol. 12, 231–54.

Lagoarde-Segot, Thomas and Brian M Lucey (2007). “The Capital Markets of the Middle East and North Africa.” *Emerging Markets Finance and Trade*, vol. 43, 34–57

MacKinnon, J.G. (1996). "Numerical Distribution Functions for Unit Root and Cointegration Tests."*Journal of Applied Econometrics*, vol. 11, 601-618.

Mukherjee, Paramita and Suchismita Bose (2008). “Does the Stock Market in India Move with Asia? A Multivariate Cointegration-Vector Autoregression Approach.” *Emerging Markets Finance and Trade*, vol. 44, 5, 5-22

Narayan, Kumar and Russell Smyth (2005). “Cointegration of Stock Markets between New Zealand, Australia and the G7 Economics: Searching for Co-movement under Structural Change.” *Australian Economic Papers*, 44, 231-247.

Ruxanda, Gheorgh and Smaranda Stoenescu, (2009). “Bivariate and Multivariate Cointegration and their Application in Stock Markets.” *Economic Computation and Economic Cybernetics Studies and Research* 43(4): 17–31.

Solnik, B. (1974). “The International Pricing of Risk: An Empirical Investigation of the World Capital Market Structure.” *The Journal of Finance*, Vol. 29, 365– 378

Von Furstenberg, George and Bang Nam Jeon (1989). “International Stock Price Movements: Links and Messages.” *Brookings Papers on Economic Activity*, no. 1, 125-67

Yang, Jian, Moosa Khan and Lucille Pointer (2003). “Increasing Integration Between the United States and Other International Stock Markets?”*Emerging Markets Finance and Trade*, vol.39, no.6, 39-53

Zivot, Eric and Donald W. K. Andrews (1992), “Further Evidence of the Great Crash, the Oil price Shock and the Unit-root Hypothesis.” *Journal of Business and Economic Statistics*, vol. 10, 251–70

Appendix A: Data Description

Details on data and data transformations are provided in Section 3.1. I obtained daily values for each country from either: Yahoo Finance, Lexis Nexis Statistical Datasets or the website for Standard and Poor's.

The first transformation I ran was to convert all the data into United States Dollars (USD). I obtained daily spot exchange rates from the Federal Reserve of St. Louis and divided them by the stock market index to get the daily values of each index in USD.

The second transformation I ran was taking the natural logarithm of all series.

The third transformation I ran was to get daily returns on each series. The formula is given by:

$$R_i = (lny_{i,t} - lny_{i,t-1}) * 100$$

I obtained data on quarterly nominal GDP and the GDP deflator from International Financial Statistics. I divided the nominal GDP by the GDP deflator to get real GDP in units of local currency. Finally, I used quarterly exchange rates from International Financial Statistics to convert real GDP for all countries into USD.

Appendix B: Tables

Table I: Augmented Dickey-Fuller test for unit root

Country	ADF test with Constant Linear Trend		Country	ADF test with Constant Linear Trend	
SPAustralia	-1.8524	[1]	SPMexico	-2.2623	[1]
ΔSPAustralia	-45.1920	[0]	ΔSPMexico	-45.1127	[0]
SPAustria	-1.1389	[1]	SPNetherlands	-1.9305	[1]
ΔSPAustria	-47.1006	[0]	ΔSPNetherlands	-60.0398	[0]
SPBrazil	-1.8984	[1]	SPNew Zealand	-1.7160	[1]
ΔSPBrazil	-49.1872	[0]	ΔSPNew Zealand	-35.6038	[0]
SPCanada	-1.8731	[2]	SPNorway	-1.3281	[1]
ΔSPCanada	-34.7531	[1]	ΔSPNorway	-43.9200	[0]
SPChina	-1.4014	[4]	SPSingapore	-1.5501	[0]
ΔSPChina	-24.5472	[3]	ΔSPSingapore	-51.5155	[0]
SPFrance	-1.8248	[1]	SPSpain	-2.0629	[0]
ΔSPFrance	-60.9354	[0]	ΔSPSpain	-55.9219	[0]
SPGermany	-1.6167	[0]	SPSweden	-2.0892	[1]
ΔSPGermany	-54.6638	[0]	ΔSPSweden	-45.3799	[0]
SPHong Kong	-2.0757	[0]	SPSwitzerland	-2.3476	[1]
ΔSPHong Kong	-54.5335	[0]	ΔSPSwitzerland	-60.9747	[0]
SPIndia	-1.7261	[1]	SPTaiwan	-1.9805	[0]
ΔSPIndia	-57.6198	[0]	ΔSPTaiwan	-54.1442	[0]
SPJapan	-1.6681	[1]	SPUK	-1.8890	[4]
ΔSPJapan	-48.9384	[0]	ΔSPUK	-35.4803	[2]
SPKorea	-2.0489	[0]	SPUS	-1.9655	[2]
ΔSPKorea	-50.3968	[0]	ΔSPUS	-42.0108	[1]
SPMalaysia	-1.7120	[1]	SPGlobal	-1.5506	[2]
ΔSPMalaysia	-57.7456	[0]	ΔSPGlobal	-29.0948	[1]

Test critical values for New Zealand:	Trend	Test critical values for remaining countries:	Trend
1% level	-3.4343	1% level	-3.9612
5% level	-2.8632	5% level	-3.4113
10% level	-2.5677	10% level	-3.1275

For the ADF test, the lag lengths are in parenthesis.
Critical values are one-sided p-values MacKinnon (1996).

Table II: Johansen (1998) test results

Country	Null	Alternative	Trace	P-value**	Maximum Eigenvalue	P-value**	Lag
US-Australia	r = 0	r ≥ 1	5.5278	0.7505	4.8889	0.7558	4
US-Austria	r = 0	r ≥ 1	5.3929	0.7658	4.6279	0.7879	2
US-Brazil	r = 0	r ≥ 1	3.8775	0.9132	3.8167	0.8782	2
US-Canada	r = 0	r ≥ 1	5.8302	0.7155	5.4958	0.6784	3
US-China	r = 0	r ≥ 1	8.1798	0.4464	6.9365	0.4967	1
US-France	r = 0	r ≥ 1	7.2468	0.5491	4.9668	0.7460	3
US-Germany	r = 0	r ≥ 1	10.2182	0.2643	7.4821	0.4338	3
US-Hong Kong	r = 0	r ≥ 1	6.3043	0.6596	4.6130	0.7897	1
US-India	r = 0	r ≥ 1	4.4438	0.8647	4.3241	0.8237	3
US-Japan	r = 0	r ≥ 1	11.9808	0.1579	10.1552	0.2019	2
US-Korea	r = 0	r ≥ 1	5.3730	0.7680	4.0360	0.8555	2
US-Malaysia	r = 0	r ≥ 1	4.3981	0.8689	4.0720	0.8517	2
US-Mexico	r = 0	r ≥ 1	5.7485	0.7250	4.0197	0.8573	2
US-Netherlands	r = 0	r ≥ 1	26.7658	0.0007	22.9974	0.0016	3
US-Netherlands	r ≤ 1	r = 2	3.7683	0.0522	3.7683	0.0522	3
US-New Zealand	r = 0	r ≥ 1	12.3224	0.1421	9.8257	0.2236	3
US-Norway	r = 0	r ≥ 1	7.7805	0.4892	7.0204	0.4867	2
US-Singapore	r = 0	r ≥ 1	4.5922	0.8505	4.2585	0.8311	3
US-Spain	r = 0	r ≥ 1	6.1982	0.6721	5.2088	0.7153	2
US-Sweden	r = 0	r ≥ 1	9.6226	0.3109	8.7951	0.3036	3
US-Switzerland	r = 0	r ≥ 1	4.8556	0.8240	4.2673	0.8301	3
US-Taiwan	r = 0	r ≥ 1	10.2761	0.2601	7.0726	0.4806	1
US-UK	r = 0	r ≥ 1	12.0960	0.1524	8.2044	0.3583	4

Critical values	r = 0	r ≤ 1
Trace test	15.4947	3.8415
Maximum eigenvalue test	14.2646	3.8415

**MacKinnon-Haug-Michelis (1999) p-values

Trace test and Max-eigenvalue test indicate no cointegration at the 0.05 level for all countries except US-Netherlands

Table III: Gregory and Hansen (1996) test for a structural change in the cointegration relationship with the United States

Countries		ADF	Tb	Zt	Tb	Za	Tb
US-Australia: 1999:01 - 2010:11	C	-2.675	5/10/2002	-2.836	7/26/2002	-17.18	7/26/2002
	C/T	-5.001**	6/12/2002	-5.491‡	5/13/2002	-56.183†	5/13/2002
	C/S	-3.023	12/8/2004	-3.065	12/7/2004	-19.301	12/7/2004
US-Austria: 1999:01 - 2010:11	C	-3.731	5/10/2002	-3.777	5/13/2002	-27.764	5/13/2002
	C/T	-4.199	5/15/2002	-4.541	5/13/2002	-39.118	5/13/2002
	C/S	-4.067	2/20/2004	-4.111	1/23/2004	-33.254	2/17/2004
US-Brazil: 1999:01 - 2010:11	C	-3.115	3/19/2008	-3.085	1/22/2008	-18.229	1/22/2008
	C/T	-6.015‡	2/8/2008	-6.131‡	1/23/2008	-72.946‡	1/23/2008
	C/S	-3.181	10/19/2005	-3.15	10/19/2005	-20.706	10/19/2005
US-Canada: 2000:01 - 2010:11	C	-2.983	10/5/2000	-5.415	8/23/2007	-30.35	10/4/2000
	C/T	-4.357	10/18/2005	-5.912‡	9/6/2005	-58.746‡	9/6/2005
	C/S	-2.965	9/8/2008	-5.415	10/30/2007	-30.228	9/25/2007
US-China: 2000:01 - 2010:11	C	-3.239	2/1/2007	-3.266	1/31/2007	-19.924	2/1/2007
	C/T	-4.324	11/27/2006	-4.441	12/7/2006	-35.019	12/7/2006
	C/S	-3.624	2/2/2007	-3.627	1/31/2007	-25.243	1/31/2007
US-France: 1999:01 - 2010:11	C	-3.822	2/2/2005	-4.047	2/3/2005	-32.742	2/3/2005
	C/T	-4.105	1/27/2009	-4.341	1/27/2009	-37.155	1/27/2009
	C/S	-3.817	2/2/2005	-4.043	2/3/2005	-32.664	2/3/2005
US-Germany: 1999:01 - 2010:11	C	-3.391	8/21/2008	-3.643	9/9/2008	-26.266	9/9/2008
	C/T	-5.005**	9/10/2002	-5.276†	8/20/2002	-54.856†	8/20/2002
	C/S	-3.81	10/20/2008	-4.042	10/21/2008	-32.253	10/21/2008
US-Hong Kong: 1999:01 - 2010:11	C	-4.581	8/3/2007	-4.599	8/16/2007	-37.165	8/16/2007
	C/T	-5.473‡	8/15/2007	-5.785‡	8/16/2007	-63.295‡	8/16/2007
	C/S	-4.4197	8/8/2007	-4.597	8/16/2007	-36.949	8/16/2007
US-India: 1999:01 - 2010:11	C	-3.082	10/17/2005	-3.041	10/14/2005	-18.599	10/14/2005
	C/T	-4.826*	11/8/2000	-5.29‡	10/12/2000	-55.417‡	10/12/2000
	C/S	-3.142	10/19/2005	-3.101	10/17/2005	-19.261	10/17/2005

‡,†,** and * denote rejection of the null of no cointegration with 99, 97.5, 95 or 90 percent confidence respectively.

Table III (continued): Gregory and Hansen (1996) test for a structural change in the cointegration relationship with the United States.

Countries		ADF	Tb	Zt	Tb	Za	Tb
US-Japan: 1999:01 - 2010:11	C	-3.313	10/5/2000	-3.521	8/23/2007	-28.319	10/4/2000
	C/T	-4.647	10/18/2005	-4.9244*	9/6/2005	-49.47**	9/6/2005
	C/S	-4.062	9/8/2008	-4.137	10/30/2007	-36.688	9/25/2007
US-Korea: 1999:01 - 2010:11	C	-3.292	3/15/2005	-3.286	3/15/2005	-21.268	1/31/2005
	C/T	-3.352	3/4/2002	-3.85	1/31/2002	-29.368	1/31/2002
	C/S	-3.485	3/15/2005	-3.493	3/4/2005	-24.206	3/4/2005
US-Malaysia: 1999:01 - 2010:11	C	-3.146	3/1/2007	-3.044	3/1/2007	-18.048	3/1/2007
	C/T	-3.793	5/6/2004	-3.825	7/2/2004	-30.002	2/28/2007
	C/S	-3.197	3/1/2007	-3.094	3/1/2007	-18.668	3/1/2007
US-Mexico: 1999:01 - 2010:11	C	-3.607	10/11/2005	-3.455	8/26/2005	-20.91	6/22/2005
	C/T	-5.125**	8/30/2005	-5.12**	8/29/2005	-50.549**	8/29/2005
	C/S	-3.653	7/22/2005	-3.566	7/25/2005	-22.615	7/25/2005
US-Netherlands: 99:01 - 2010:11	C	-4.626	2/23/2006	-5.655	4/5/2006	-54.723	4/5/2006
	C/T	-5.763‡	1/6/2006	-5.985‡	2/14/2006	-63.849‡	2/14/2006
	C/S	-5.246	11/20/2007	-5.705	4/5/2006	-55.448	4/5/2006
US-New Zealand: 2004:05 - 2010:11	C	-4.934	10/17/2008	-6.177	10/10/2008	-67.387	10/10/2008
	C/T	-4.545**	12/21/2005	-5.972‡	11/29/2005	-63.917‡	11/29/2005
	C/S	-5.112	10/17/2008	-6.514	10/10/2008	-75.804	10/10/2008
US-Norway: 2001:02 - 2010:11	C	-3.603	9/12/2008	-3.719	5/28/2008	-21.567	7/17/2008
	C/T	-4.757*	9/16/2008	-5.149**	9/19/2008	-53.483†	9/19/2008
	C/S	-3.92	10/21/2008	-4.101	10/28/2008	-26.206	10/28/2008
US-Singapore: 1999:01 - 2010:11	C	-3.17	1/10/2007	-3.208	1/9/2007	-19.368	1/9/2007
	C/T	-4.701	10/22/2008	-5.12**	11/24/2008	-51.417**	11/24/2008
	C/S	-3.164	1/10/2007	-3.196	1/9/2007	-19.195	1/9/2007
US-Spain: 1999:01 - 2010:11	C	-3.401	11/12/2004	-3.317	11/12/2004	-20.095	11/12/2004
	C/T	-3.926	7/26/2002	-3.954	7/29/2002	-23.934	7/29/2002
	C/S	-3.4	11/12/2004	-3.315	11/12/2004	-20.072	11/12/2004

‡,†,** and * denote rejection of the null of no cointegration with 99, 97.5, 95 or 90 percent confidence respectively.

Table III (continued): Gregory and Hansen (1996) test for a structural change in the cointegration relationship with the United States.

Countries		ADF	Tb	Zt	Tb	Za	Tb
US-Sweden: 2001:01 - 2010:11	C	-3.813	10/21/2008	-4.022	10/28/2008	-30.363	10/28/2008
	C/T	-6.104‡	11/5/2007	-7.942‡	8/23/2007	-110.319‡	8/23/2007
	C/S	-4.034	10/21/2008	-4.175	10/28/2008	-32.665	10/28/2008
US-Switzerland: 1999:01 - 2010:11	C	-4.49	8/23/2005	-4.521	8/25/2005	-37.945	8/25/2005
	C/T	-6.151‡	10/12/2005	-6.213‡	10/12/2005	-60.685‡	10/12/2005
	C/S	-4.546	8/23/2005	-4.568	8/25/2005	-38.651	8/25/2005
US-Taiwan: 1999:01 - 2010:11	C	-3.912	1/16/2009	-3.917	2/6/2009	-30.549	2/6/2009
	C/T	-4.567	11/8/2000	-4.779*	10/23/2000	-45.265*	10/23/2000
	C/S	-3.916	12/13/2001	-4.018	12/19/2001	-33.584	12/19/2001
US-UK: 1999:01 - 2010:11	C	-3.767	11/28/2008	-2.00E+13	10/30/2008	-8.00E+26	10/30/2008
	C/T	-5.134**	10/1/2002	-2.3E+13‡	1/3/2003	-1.08E+27‡	1/3/2003
	C/S	-3.929	11/28/2008	-4.91358	10/10/2008	-44.548	10/10/2008

‡,†,** and * denote rejection of the null of no cointegration with 99, 97.5, 95 or 90 percent confidence respectively.

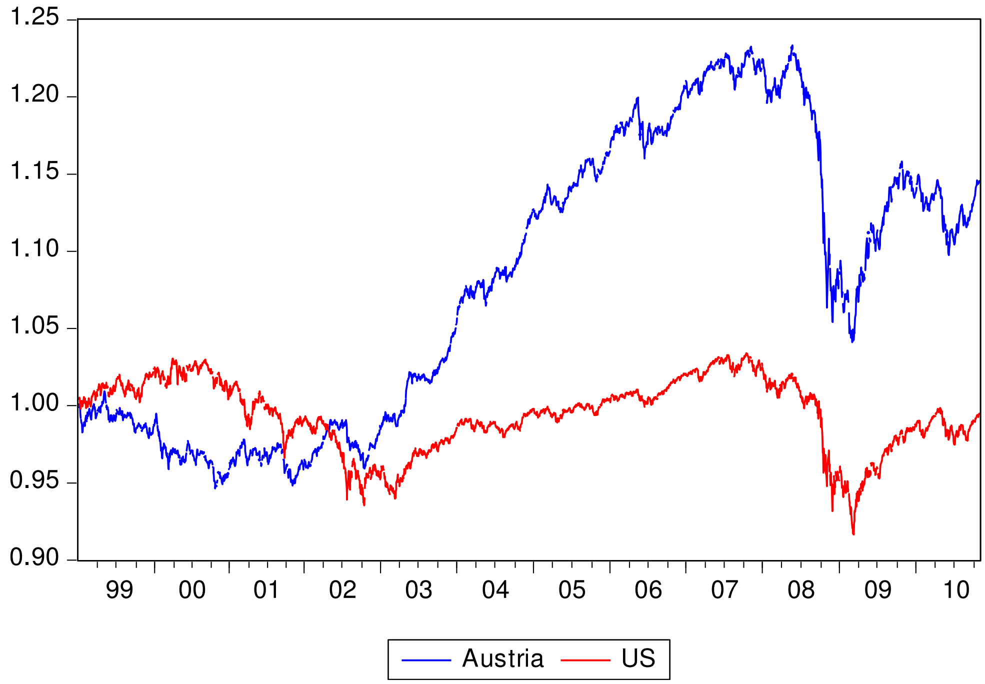
Table IV: Approximate Asymptotic values

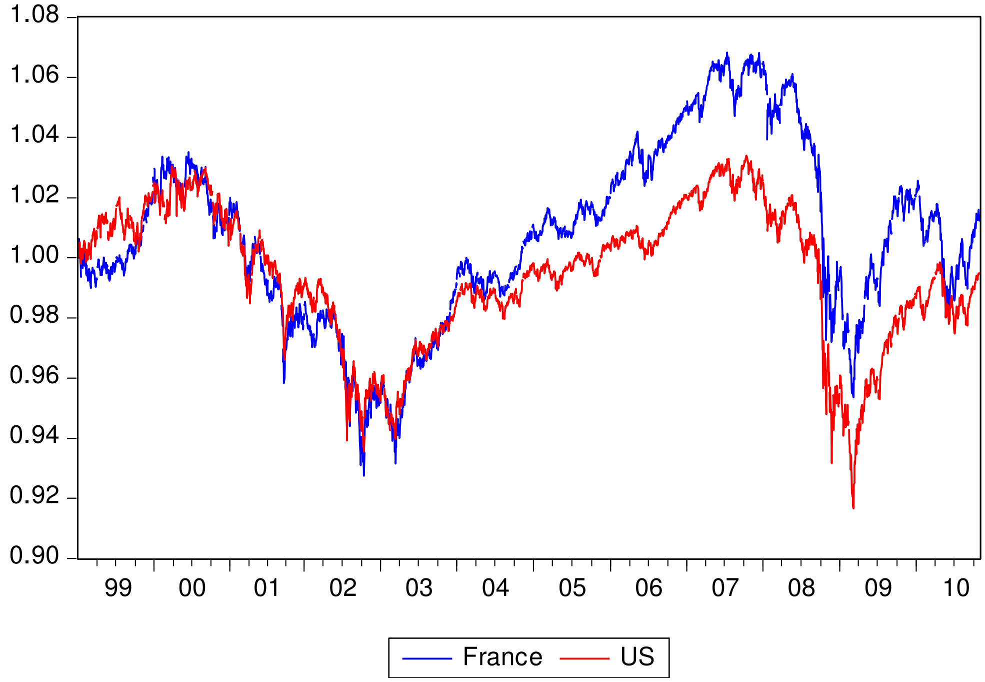
Level	**0.01**	**0.025**	**0.05**	**0.10**
ADF, Zt				
C	-5.13	-4.83	-4.61	-4.34
C/T	-5.45	-5.21	-4.99	-4.72
C/S	-5.47	-5.19	-4.95	-4.68
Za				
C	-50.07	-45.01	-40.48	-36.19
C/T	-57.28	-52.09	-47.96	-43.22
C/S	-57.17	-51.32	-47.04	-41.85

Values calculated by Gregory and Hansen (1996) using Monte Carlo experiments.

Appendix C: Graphs

The following graphs indicate movement of the stock market indices of each country. Each index has been logged and normalized by value on the starting date.

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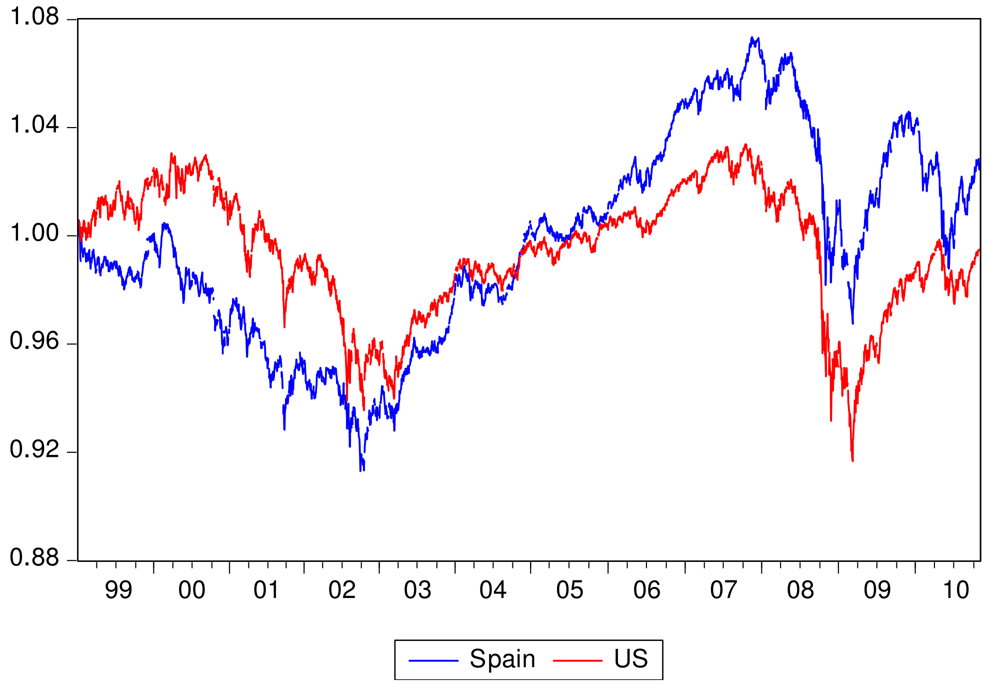
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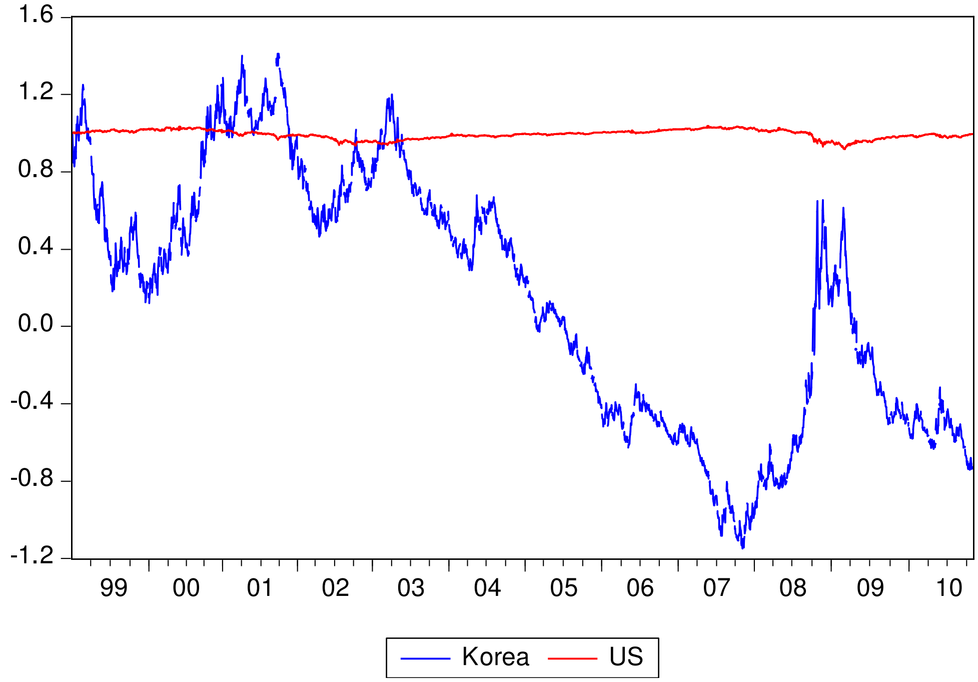
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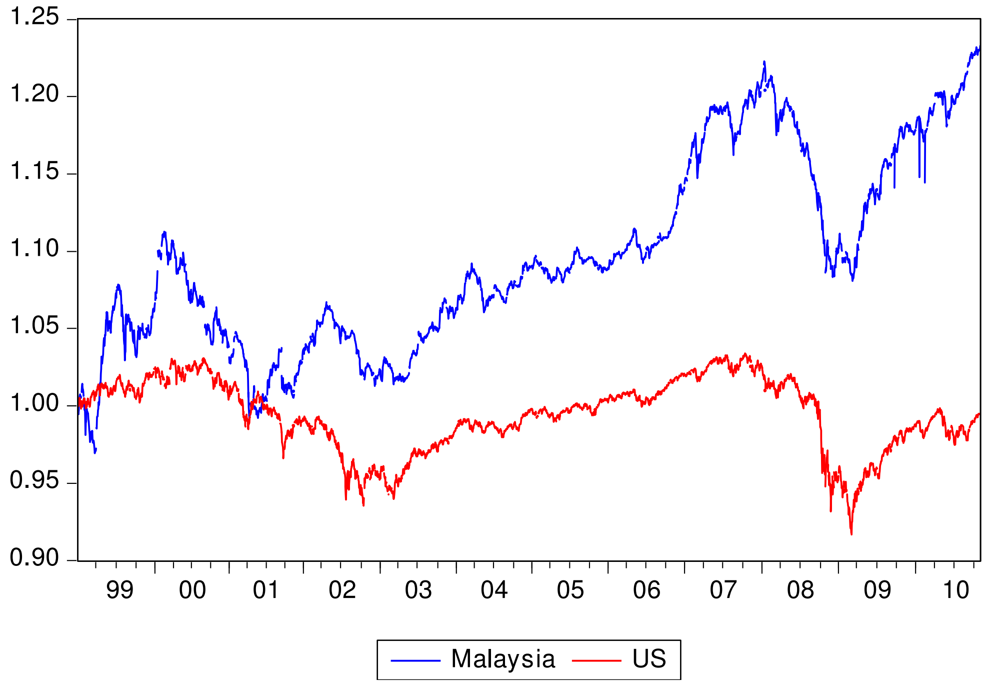
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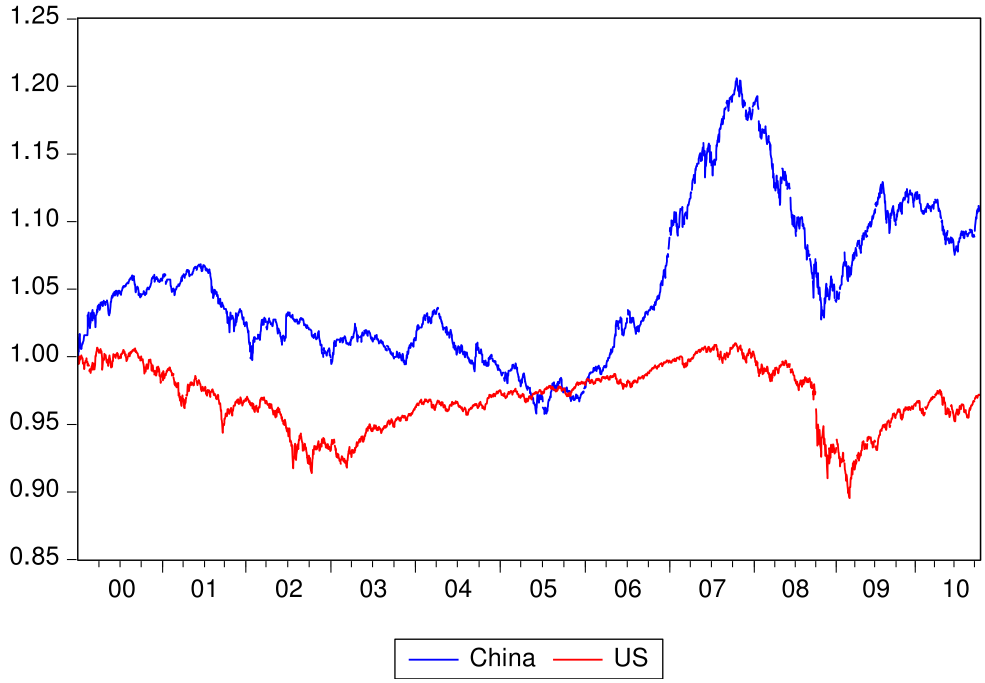
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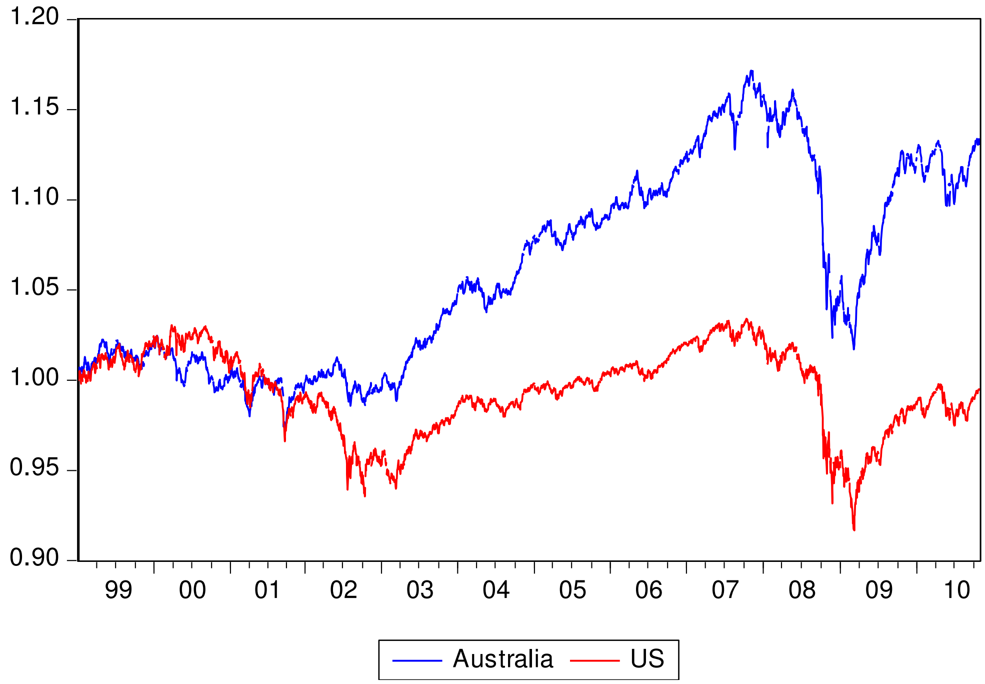
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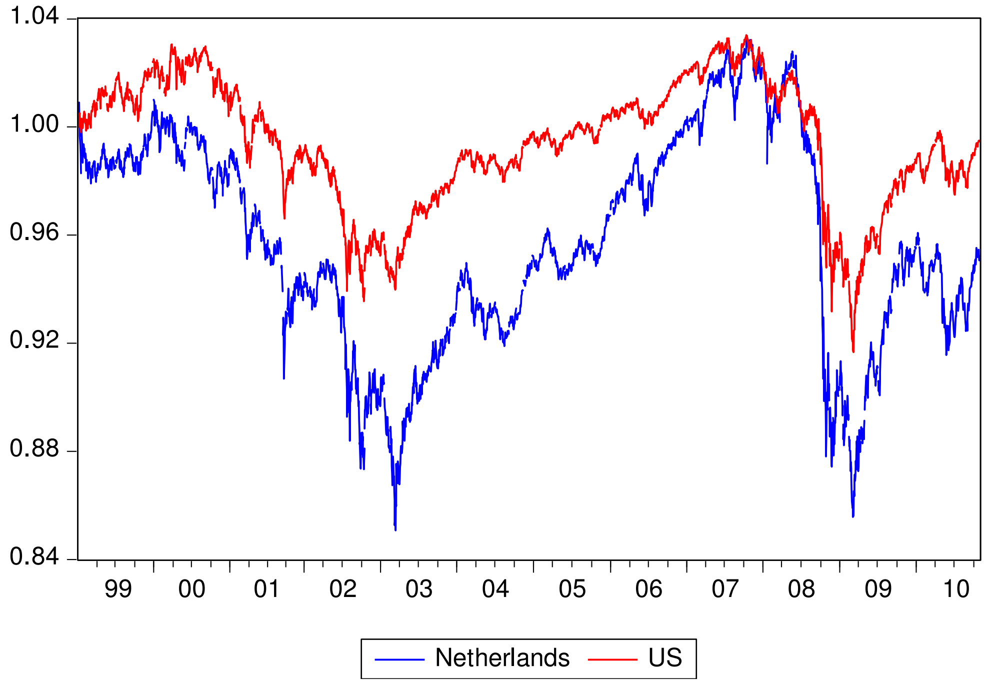
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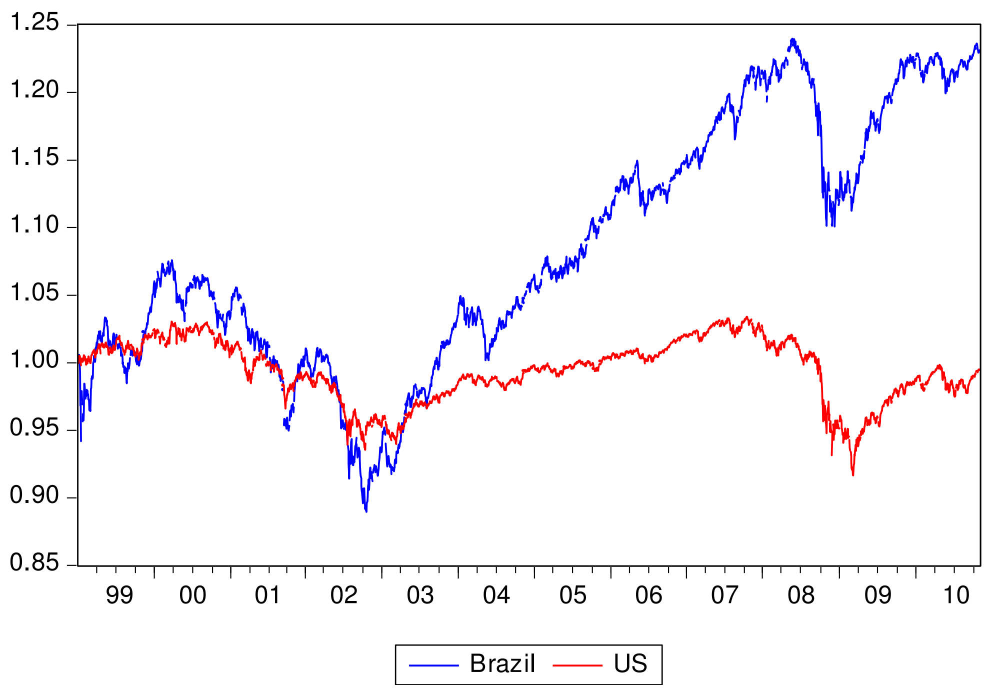
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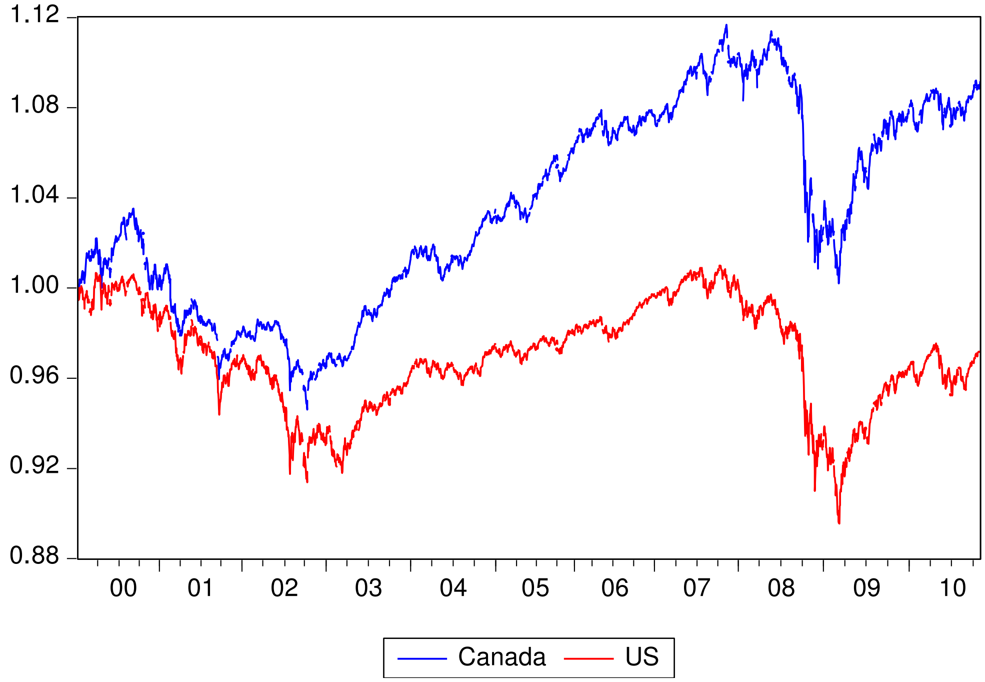
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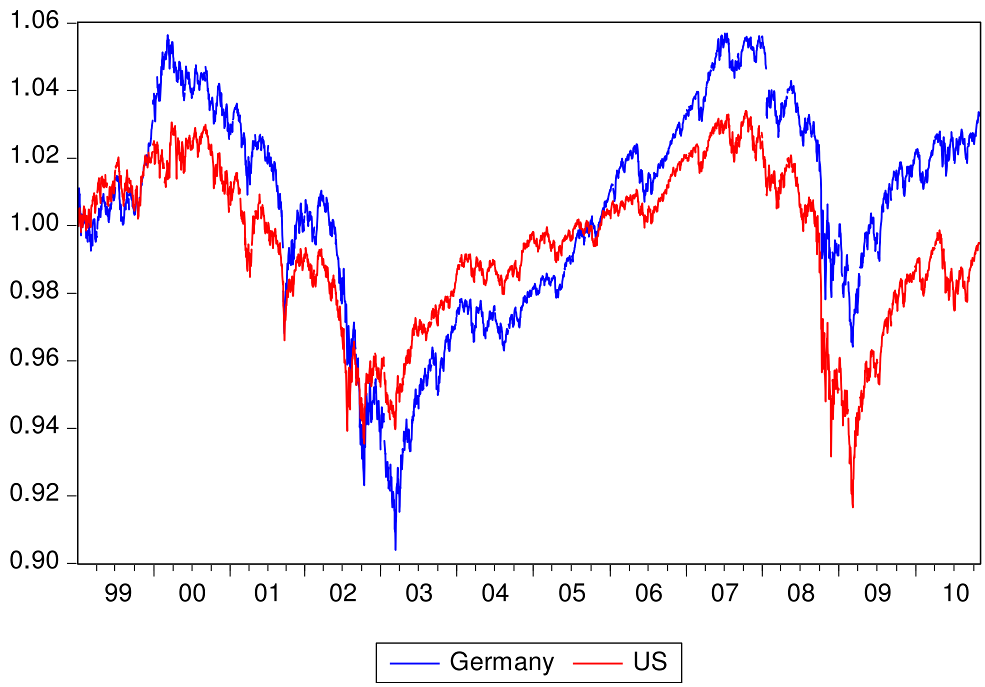
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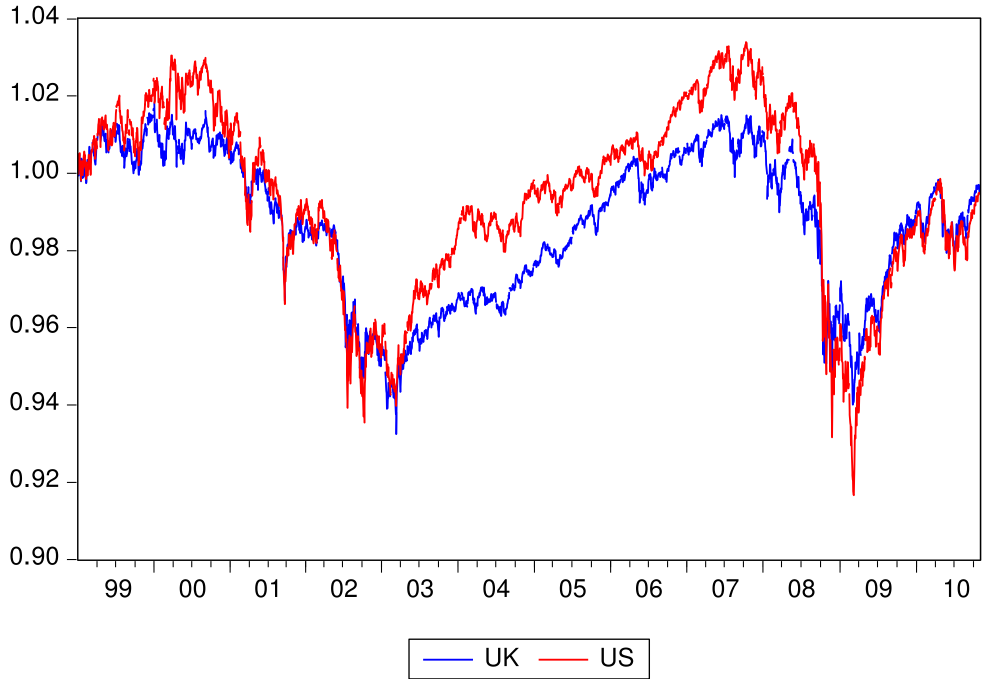
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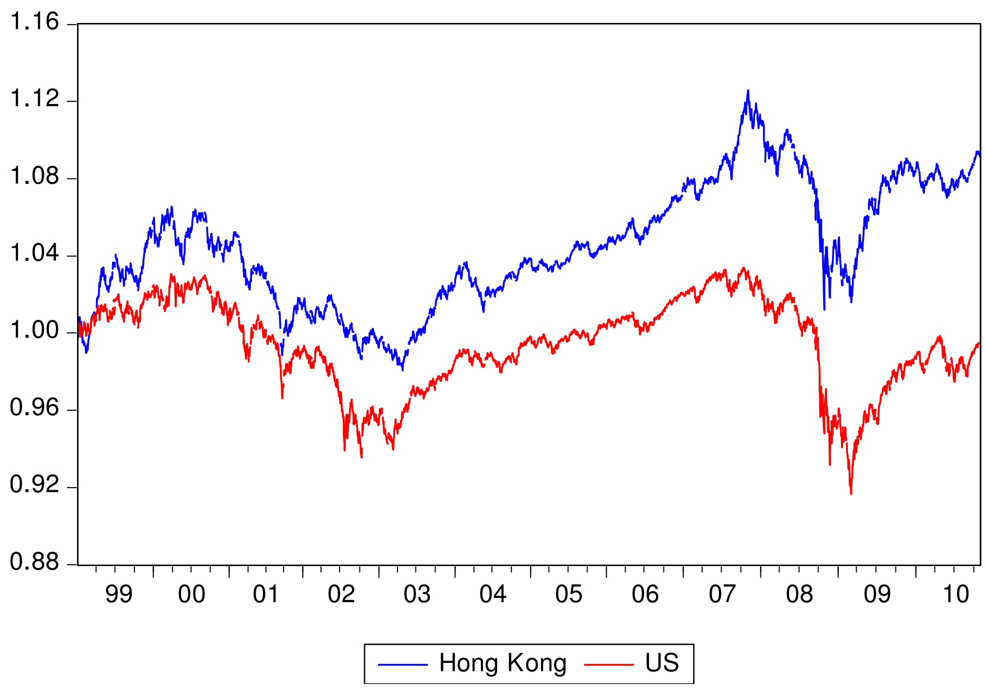
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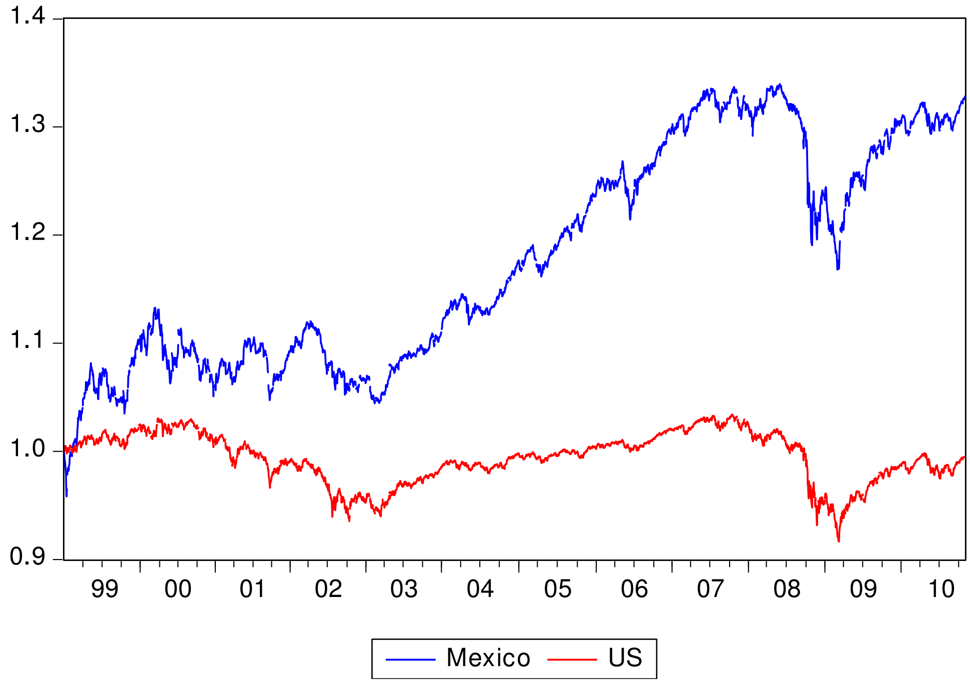
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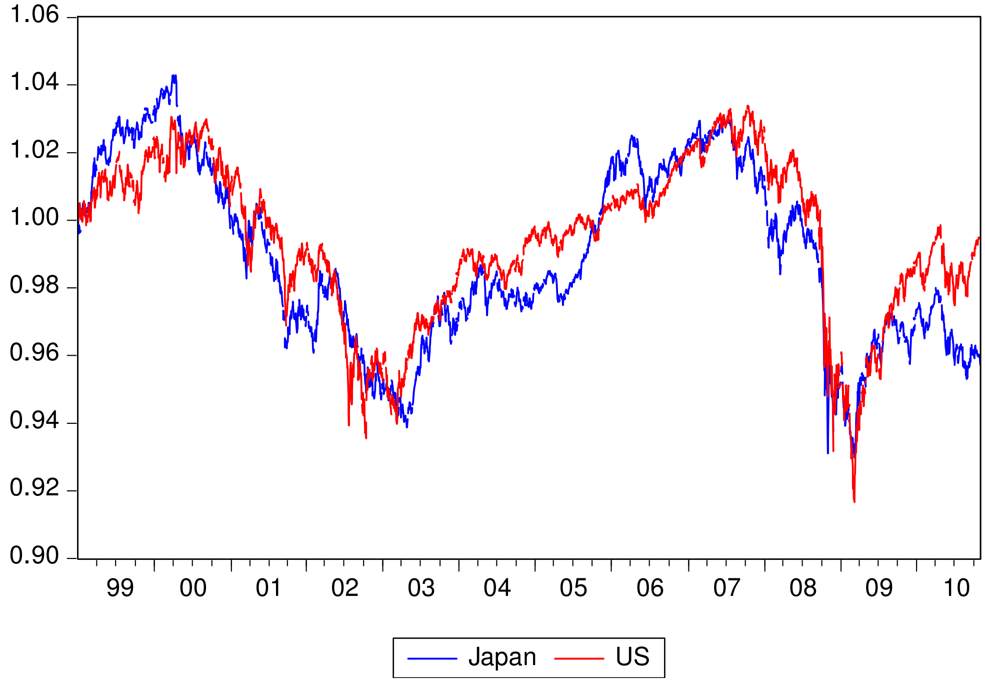
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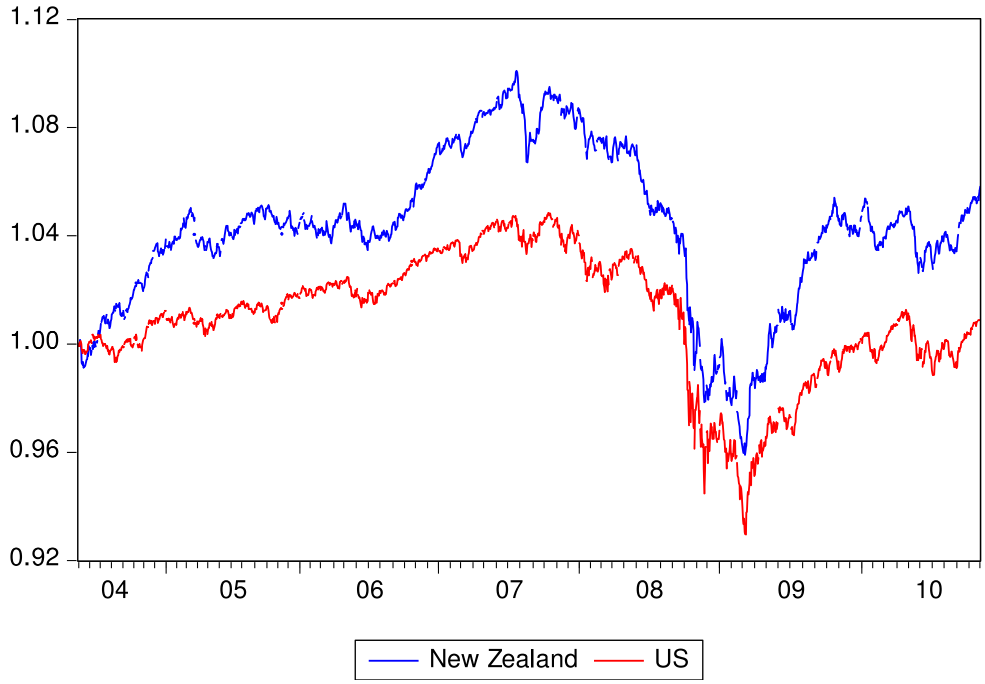
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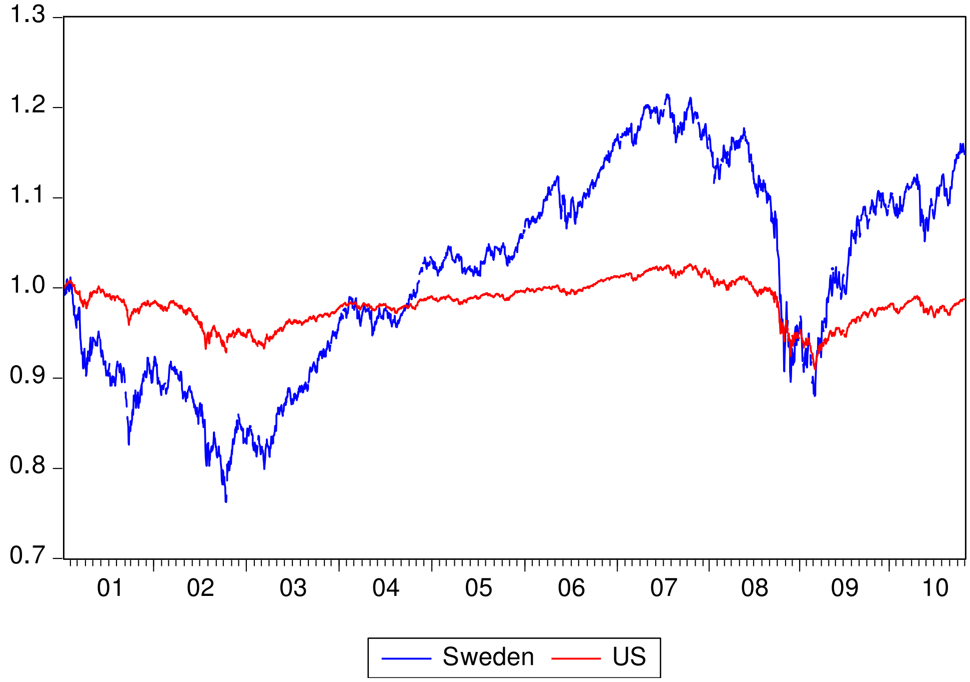
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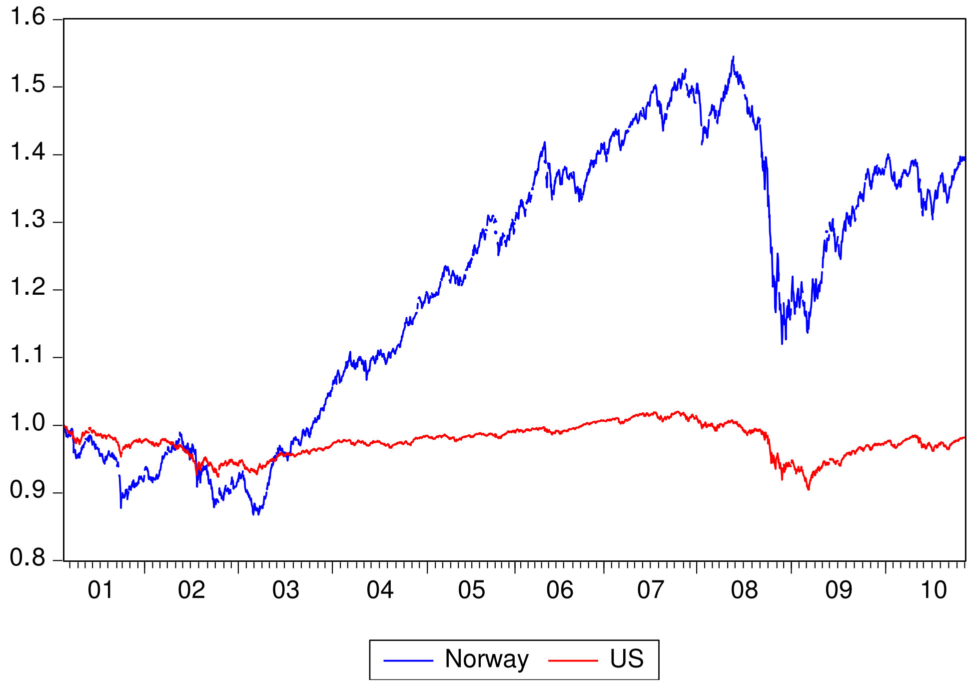
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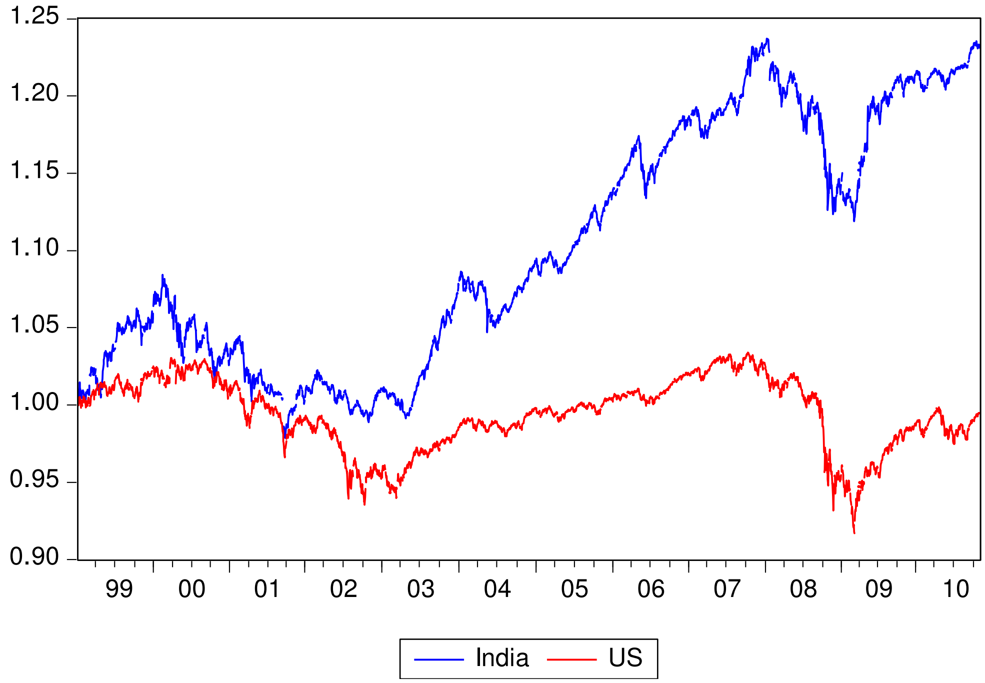
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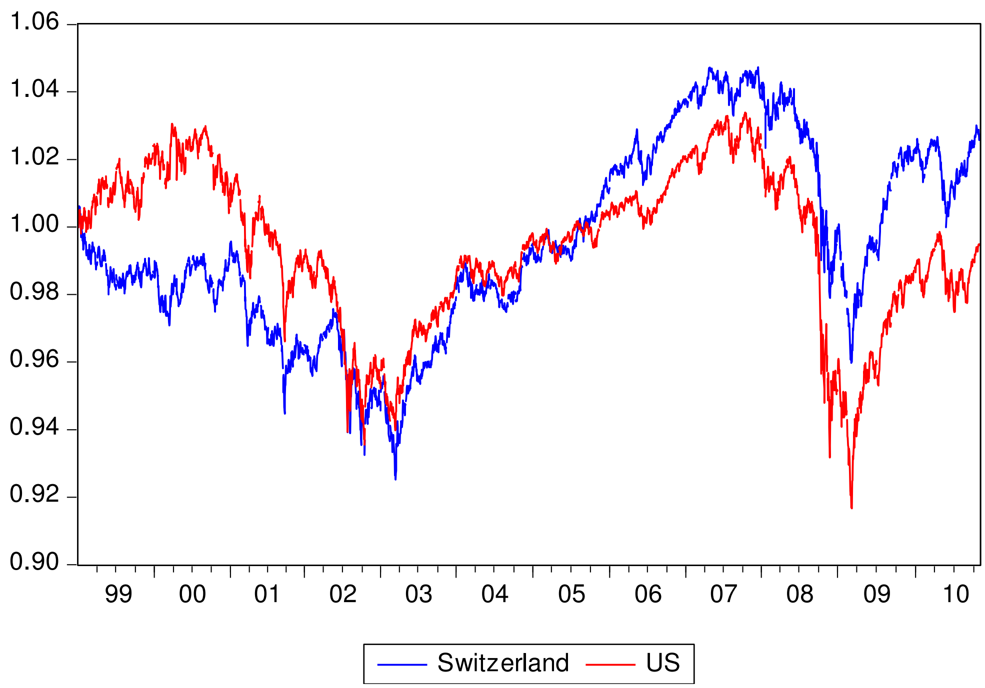
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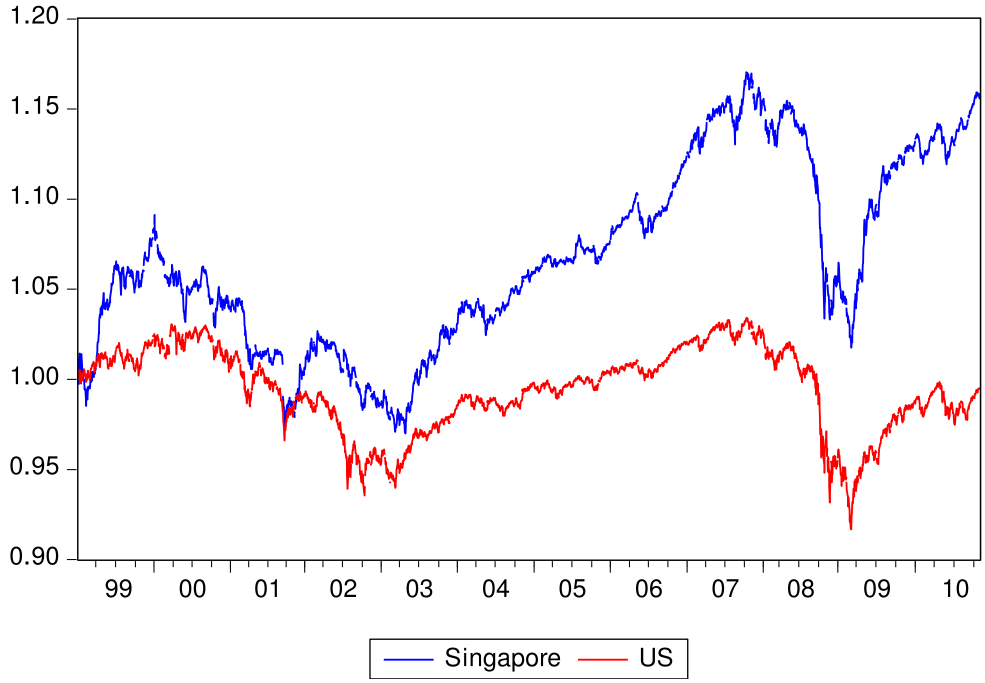
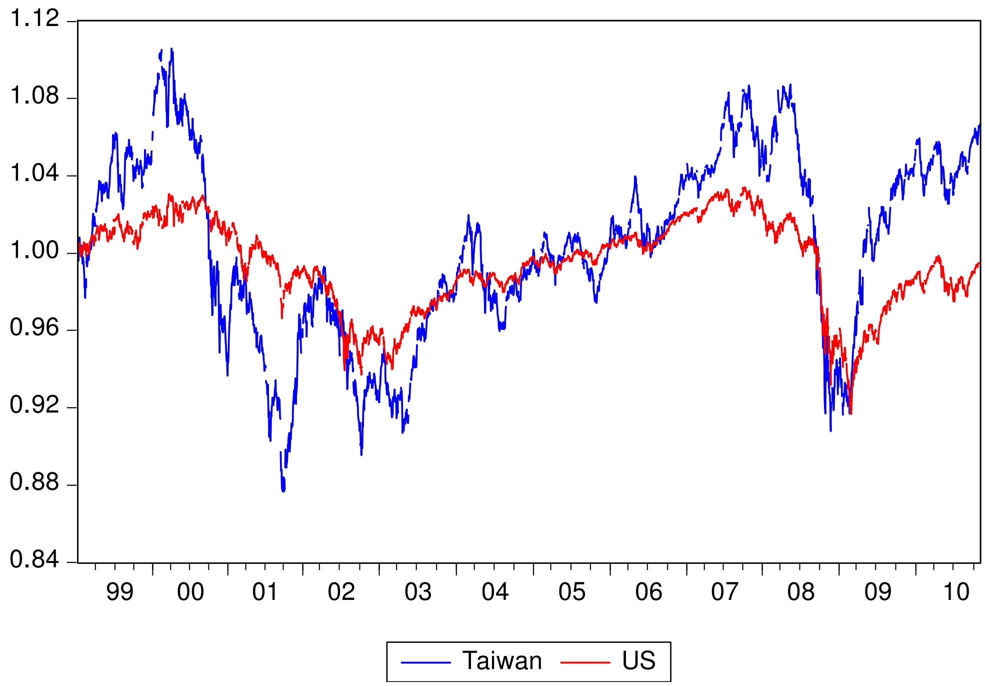
Switzerland
US


1.20
1.15
1.10
1.05
1.00
0.95
0.90
99
00
01
02
03
04
05
06
07
08
09
10
Singapore
US


1.12
1.08
1.04
1.00
0.96
0.92
0.88
0.84
99
00
01
02
03
04
05
06
07
08
09
10
Taiwan
US

Appendix D: Summary of Digital Material

Gregory-Hansen Cointegration Test on E views 7:

'Reference: Gregory, A. W. and Hansen, B. E. (1996). "Residual-Based Tests for Cointegration in Models with Regime Shifts", Journal of Econometrics, Vol. 70, pp. 99-126.

```
group x
x.add lglobal
call greghansen(y,x,4,"aic",6)

' -----------------------------------------------------------------------------------------------
' Arguments
'-------------------------------------------------------------------------------------------------
'series Y              ' dependent variable
'group G               ' group of independent variable(s) (including single series)
'scalar Model          ' 2 = Level Shift, 3 = Level Shift with Trend, 4 = Regime Shift
'scalar Maxlag         ' Maximum number of lags for unit root testing
'string %Criterion     ' Selection criteria for unit root testing (i.e. aic / sic / hqc)
' -----------------------------------------------------------------------------------------------

subroutine greghansen(series Y, group G, scalar Model, string %Criterion, scalar Maxlag)
smpl @all
!trim = 0.15
!maxlag = Maxlag

!n = @obs(y)
!nindep = G.@count

!lower = @round(@obs(Y)*!trim)
!upper = @round(@obs(Y)*(1-!trim))
matrix(!upper-!lower+1,4) GHtest

equation ghc

Table GHZ
GHZ(1,1) =  "THE GREGORY-HANSEN"
GHZ(2,1) = "COINTEGRATION TEST"
if Model=2 then GHZ(3,1) = "MODEL 2: Level Shift"
else if Model =3 then GHZ(3,1) = "MODEL 3: Level Shift with Trend"
  else if Model = 4 then GHZ(3,1) = "MODEL 4: Regime Shift"
  endif
endif
endif
GHZ(5,1) = "ADF Procedure"
GHZ(7,1) = "t-stat"
GHZ(8,1) = "Lag"
GHZ(9,1) = "Break"
GHZ(11,1) = "Phillips Procedure"
```

```
GHZ(13,1) = "Za-stat"
GHZ(14,1) = "Za-break"
GHZ(15,1) = "Zt-stat"
GHZ(16,1) = "Zt-break"

for !ref = 2 to 4
  GHZ.setwidth(!ref) 15
next

GHZ.setlines(a4:b4) +d
GHZ.setlines(a6:b6) +d
GHZ.setlines(a10:b10) +d
GHZ.setlines(a12:b12) +d

for !i = !lower to !upper

  if Model=2 then
   'MODEL 2 - C: LEVEL SHIFT MODEL
     ghc.ls Y c G (@trend>!i-2)
     ghc.makeresid res
     uroot(adf, none, info={%criterion}, maxlag=!maxlag, save=level) res
     GHtest(!i-!lower+1,1) = level(3,1)
     GHtest(!i-!lower+1,2) = level(2,1)
     call phillips(res)
     GHtest(!i-!lower+1,3) = !Za
     GHtest(!i-!lower+1,4) = !Zt

   else if Model=3 then
   'MODEL 3 - C/T: LEVEL SHIFT WITH TREND MODEL
     ghc.ls Y c @trend G (@trend>!i-2)
     ghc.makeresid res
     uroot(adf, none, info={%criterion}, maxlag=!maxlag, save=level) res
     GHtest(!i-!lower+1,1) = level(3,1)
     GHtest(!i-!lower+1,2) = level(2,1)
     call phillips(res)
     GHtest(!i-!lower+1,3) = !Za
     GHtest(!i-!lower+1,4) = !Zt

   else if Model = 4 then
   'MODEL 4 - C/S: REGIME SHIFT MODEL
       for !g = 1 to !nindep
         G.add (@trend>!i-2)*G(!g)
       next
     ghc.ls Y c (@trend>!i-2) G
     ghc.makeresid res
     uroot(adf, none, info={%criterion}, maxlag=!maxlag, save=level) res
     GHtest(!i-!lower+1,1) = level(3,1)
     GHtest(!i-!lower+1,2) = level(2,1)
     call phillips(res)
     GHtest(!i-!lower+1,3) = !Za
```

```
    GHtest(!i-!lower+1,4) = !Zt
     for !g = G.@count to !nindep+1 step -1
      %name = G.@seriesname(!g)
       G.drop {%name}
     next
    endif
   endif
  endif
next
    vector min_t_lag = @cmin(GHtest)
    vector break = @cimin(GHtest)

    GHZ(7,2) = min_t_lag(1)
    GHZ(8,2) = GHtest(break(1),2)
    GHZ(13,2) = min_t_lag(3)
    GHZ(15,2) = min_t_lag(4)

   if @datestr(@now,"F") = "?" then
    GHZ(9,2) = break(1) + !lower - 2
    GHZ(14,2) = break(3) + !lower - 2
    GHZ(16,2) = break(4) + !lower - 2
   else
    GHZ(9,2) = @otod(break(1) + !lower - 2)
    GHZ(14,2) = @otod(break(3) + !lower - 2)
    GHZ(16,2) = @otod(break(4) + !lower - 2)
   endif

    show GHZ

delete res level GHtest break min_t_lag
endsub

subroutine phillips(series y) 'MATLAB code of this routine is available at Bruce E. Hansen's
website: http://www.ssc.wisc.edu/~bhansen/progs/joe_96.html
!n = @obs(y)
equation eq1.ls y y(-1)
!be = eq1.@coefs(1)
series ue = y - !be*y(-1)

'Bandwidth selection
!nu = @obs(ue)
equation eq2.ls ue ue(-1)
!bu = eq2.@coefs(1)
series uu = ue - !bu*ue(-1)
!su = @sumsq(uu)/@obs(uu)
!a2 = (4*!bu^2*!su/(1-!bu)^8)/(!su/(1-!bu)^4)
!bw =1.3221*((!a2*!nu)^0.2)

!pi = @acos(-1)
!j=1
```

```
!lemda = 0
   while !j <= !bw
     series temp = ue*ue(-!j)
     !gama =  @sum(temp)/!nu
     !w=(75/(6*!pi*!j/!bw)^2)*(@sin(1.2*!pi*!j/!bw)/(1.2*!pi*!j/!bw)-@cos(1.2*!pi*!j/!bw))
     !lemda=!lemda+!w*!gama
     !j=!j+1
   wend

series temp = y*y(-1) - !lemda
!p = @sum(temp)/@sumsq(y(-1))
!Za = !n*(!p-1)
!Zt = (!p-1)/@sqrt((2*!lemda + @sumsq(ue)/!nu)/(@sumsq(y(-1))))
smpl @all
delete eq1 eq2 ue uu temp
endsub
```

Newey West correction on R:

```
> library(sandwich)
> coeftest(model,NeweyWest(model))

t test of coefficients:

            Estimate Std. Error t value  Pr(>|t|)
(Intercept) -20.1420     4.9903 -4.0362 0.0007748 ***
Beta        -17.8547     6.6493 -2.6852 0.0151193 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```