

Contagion or Interdependence? Evidence from the G-7 countries

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Abstract

We test for equity market contagion and examine the implications of our results for portfolio managers. International diversification is believed to deliver superior risk-return trade-offs. However, the presence of contagion could serve to negate this effect, when it's most necessary. We focus on the stock markets of the G-7 countries as they cover approximately 80% of world market capitalisation. We employ the regime switching methodology of Gravelle et al (2006) to test for shift contagion between markets. In general, we find little support for contagion, either in local or common currency. There is little evidence that the transmission mechanism of shocks differs between high- and low-volatility regimes. Therefore we conclude that portfolio managers should not fear international diversification strategies.

Keywords: Contagion; Financial market crises; Regime switching; Structural transmission

JEL Classification: F42; G15; C32

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1. Introduction

This paper examines the extent to which equity market contagion exists between the stock market returns of the world's wealthiest nations – G-7 countries – and then discusses the implications of our results for portfolio management. From the outset, we need to clarify how we define 'contagion'. Despite the voluminous literature, there is little consensus as to what exactly is meant by contagion.¹ Here we focus on 'shift' contagion, as in Gravelle et al (2006, henceforth GKM). Shift contagion implies that the process governing the transmission of common shocks changes during a crisis or period of high market volatility and is captured by a regime-switching model.² This provides (as discussed below) an unambiguous test of structural changes in asset return co-movements between regimes.

International portfolio diversification has been advocated as an effective way to achieve higher risk-adjusted returns than domestic investment alone since Grubel (1968) and Levy & Sarnat (1970). More recent empirical papers find that these benefits are still present despite increasing integration across financial markets in both stock markets (Grauer and Hakansson, 1987; De Santis and Gerard, 1997) and bond markets (Levy and Lerman, 1988) and in the face of time-varying correlations (Ang and Bekaert, 2002). The main premise underlying this diversification strategy is that international stocks tend to display lower levels of co-movement than stocks trading on the same market.

However, a worrying development for portfolio managers who adopted such a strategy came from the work of King and Wadhvani (1990), who found that stock market correlations between the US, UK and Japan increased in the aftermath of the 1987 stock market crash. Lee and Kim (1993) and Longin and Solnik (1995) both show that this finding also applied to a wider range of countries. These findings have major implications for portfolio management given that if markets display increased co-movement during turbulent periods, then the benefits of international diversification will not be delivered when most necessary. Studies like King and Wadhvani (1990) measured the effects of contagion as increased correlation between markets. However, Forbes and Rigobon (2002) showed that when markets experience increased volatility (as in turbulent periods), then the correlation measure is biased

¹ For an overview of the various definitions of contagion, the reader is referred to Dornbusch et al (2000) or Pericoli and Sbracia (2003).

² Regime-switching models have been shown to perform well in capturing equity market behaviour, e.g Ang and Bekaert (2002) and Guidolin and Timmermann (2005).

upwards and may lead to an incorrect conclusion of financial market contagion. Goetzmann et al (2002) show that episodes increased cross-market correlation over the past two decades may not only be due to increased co-movement alone but also to an expansion of the investment opportunity set.

In this study, we focus explicitly on detecting 'shift' contagion among the G-7 countries employing the novel methodology of GKM. In this vein, we aim at disentangling changes in the structural transmission mechanism of shocks from changes in the volatility due to increased common volatility shocks. To the best of our knowledge, no other study has employed this innovative technique to study the transmission of stock market shocks. This method has many advantages over and above previous techniques. Firstly, the country where the shock originated does not need to be identified or included in the analysis. Hence we can focus on the G-7 countries and detect changes in the transmission of shocks that may have originated elsewhere. This is going to be particularly beneficial in the latter part of our sample when the Asian and Russian crisis occurred. Many other studies focus on smaller markets that are geographically close to the source of the shock but we believe that a portfolio manager will be more concerned with the co-movements of the larger countries that typically get included in asset allocation strategies due to their size and diversity. The G-7 countries account for approximately 80-85% of the total world market capitalization and consequently should constitute the majority of a portfolio regardless of the investor's location. Secondly, the break-points of this regime switching procedure are determined by the data and do not have to be exogenously specified as in Forbes and Rigobon (2002). The exogenous choice of crisis period is often a contentious issue (see Kaminsky and Schmukler, 1999) and may be further compounded by having more than one shock simultaneously impacting on equity markets. Thirdly, our results give us a clear insight into the economic and statistical significance of whether or not a portfolio manager should be concerned with the effects of contagion between each pair of markets under review.

Our paper is organized as follows. Section 2 presents our model. Section 3 describes the data and presents our empirical findings and the tests for contagion. Section 4 examines the robustness of our results by analysing alternative sub-periods and working with returns expressed in a common. Section 5 summarizes our empirical findings and offers some policy implications.

2. Econometric Methodology

In this section, we present the empirical model employed to study the interdependence between two stock markets during both calm and turbulent periods. Let r_{1t} and r_{2t} represent stock market returns from countries 1 and 2, respectively. These can be decomposed into an expected component, μ_i , and an unexpected one, u_{it} , reflecting unexpected information becoming available to investors, i.e.

$$r_{it} = \mu_i + u_{it}, E(u_{it}) = 0, i = 1, 2 \text{ and } E(u_{1t}, u_{2t}) \neq 0. \quad (1)$$

The existence of contemporaneous correlation between the forecast errors u_{1t} and u_{2t} suggests that common structural shocks are driving both returns. In this respect, we can decompose the forecast errors into two structural shocks, one idiosyncratic and one common. Let z_{ct} and $z_{it}, i = 1, 2$ denote the common and idiosyncratic common shocks respectively and let the impacts of these shocks on asset returns be σ_{cit} and $\sigma_{it}, i = 1, 2$. Then the forecast errors are written as:

$$u_{it} = \sigma_{cit} z_{ct} + \sigma_{it} z_{it}, i = 1, 2. \quad (2)$$

Normalizing the variance of shocks to unity implies that the impact coefficients may be interpreted as the standard deviations of structural shocks.

Following GKM we allow both the common and the idiosyncratic shocks to switch between two states - high- and low-volatility.³ Thus, the structural impact coefficients $\sigma_{it}, \sigma_{ct}, i = 1, 2$ are given by the following:

$$\begin{aligned} \sigma_{it} &= \sigma_i(1 - S_{it}) + \sigma_i^* S_{it}, i = 1, 2 \\ \sigma_{cit} &= \sigma_{ci}(1 - S_{ct}) + \sigma_{ci}^* S_{ct}, i = 1, 2 \end{aligned} \quad (2)$$

where $S_{it} = (0, 1), i = 1, 2, c$ are state variables that take the value of zero in normal times and one in turbulent ones. Variables with an asterisk belong to the high-volatility or crisis regime. To complete the model, we need to specify the evolution of regimes over time. Following the regime-switching literature, the regime paths are Markov switching and consequently are endogenously determined. Specifically, the conditional probabilities of remaining in the same state, i.e. not changing regime are

³This heterogeneity in the heteroskedasticity of the structural shocks ensures the identification of our system (see also Rigobon, 2003). As argued by GKM, only the assumption of regime switching in the common shocks is necessary for the identification of the system. For a detailed description of the identification process, please see GKM.

defined as follows:

$$\begin{aligned}\Pr[S_{it} = 0 / S_{it} = 0] &= q_i, i = 1, 2, c \\ \Pr[S_{it} = 1 / S_{it} = 1] &= p_i, i = 1, 2, c\end{aligned}\quad (3)$$

Furthermore, we relax the assumption of expected constant returns in (1). Our specification is allowed to be time varying and dependent only on the state of the common shock.⁴ In this respect, our model suggests that part of the stock market return represents a risk premium that changes with the level of volatility.⁵ In particular, expected returns are modeled as follows:

$$\mu_{it} = \mu_i(1 - S_{ct}) + \mu_i^* S_{ct}, i = 1, 2 \quad (4)$$

Given that idiosyncratic shocks are uncorrelated with common shocks and mainly associated with diversifiable risk, expected returns are not allowed to vary with the volatility state of these shocks. An extra assumption of normality of the structural shocks enables us to estimate the full model given by equations (1)-(4) via maximum likelihood along the lines of the methodology for Markov-switching models (see Hamilton, 1989).

Our rationale behind detecting and testing for shift contagion (see also GKM) lies on the assumption that in the absence of contagion, a large unexpected shock that affects both countries does not change their interdependence. In other words, the observed increase in the variance and correlation of returns during crisis periods is due to increased impulses stemming from the common shocks and not from changes in the propagation mechanism of shocks. To empirically test for contagion, we conduct hypothesis testing specifying the null and the alternative as follows:

$$H_0 : \frac{\sigma_{c1}^*}{\sigma_{c2}^*} = \frac{\sigma_{c1}}{\sigma_{c2}} \text{ versus } H_1 : \frac{\sigma_{c1}^*}{\sigma_{c2}^*} \neq \frac{\sigma_{c1}}{\sigma_{c2}} \quad (5)$$

The null hypothesis postulates that in the absence of shift contagion, the impact coefficients in both calm and crisis periods are linked through the same ratio. This likelihood ratio test is the common test for testing restrictions among nested models and follows a χ^2 distribution with one degree of freedom corresponding to the restriction of equality of the ratio of coefficients between the two regimes.

⁴ Guidolin and Timmermann (2005) find that returns are statistically different across regimes though Ang and Bekaert (2002) fail to reject the equality of mean returns between regimes.

⁵ GKM also relax this assumption when modeling the interdependence of bond returns.

3. Empirical Results

3.1. Data

Our dataset comprises weekly closing stock market indices from the stock exchanges of the G-7 countries. All indices are value-weighted, obtained from Datastream International, and cover approximately 80% of total market capitalization. The Datastream codes for the corresponding stock market indices are the following: TOTMKXX, where XX stands for the country code, i.e. CN (Canada), FR (France), BD(Germany), IT (Italy), JP (Japan), UK and US. The indices span a period of more than 30 years from 1/1/1973 to 31/12/2005, a total of 1723 observations and are expressed in local currency. This denomination of the series in local currency ensures that no spillovers or contagions from the currency markets are falsely detected as stock market spillovers. Moreover, we prefer weekly return data to higher frequency data, such as daily returns, in order to account for the non-synchronous trading in the countries under examination. For each index, we compute the return between two consecutive trading days, $t-1$ and t as $\ln(p_t) - \ln(p_{t-1})$ where p_t denotes the closing index on week t .

[TABLE 1 ABOUT HERE]

Table 1 (Panel A) presents descriptive statistics on the weekly returns of the countries at hand, while Panel B provides some preliminary evidence on the cross-country return correlation structure. Mean returns vary considerably across countries ranging from 0.095 percent in Italy to 0.191 percent in Japan. The high Japanese mean return is associated with the highest volatility among the G-7 countries, while the Canadian market appears to be the least volatile. The Jarque-Bera test rejects normality for all markets, which is usual in the presence of both skewness and excess kurtosis. Specifically, return distributions are negatively skewed for all countries with Canada and the US being the most skewed. The Canadian, UK and US returns exhibit considerable leptokurtosis with the coefficient of kurtosis that exceeding 14. These attributes of the data should be accommodated in any model of equity returns. The high level of kurtosis coupled with the rejection of normality in all markets could be taken to suggest that the behavior of returns is best modeled as a mixture of distributions, which is consistent with the existence of more than one volatility regimes.

Panel B provides some preliminary evidence on the correlation structure between country returns. Correlation coefficients range from 0.224 for the Italy/Japan pair to 0.736 for the Canada/US pair. The average correlation is 0.422. Pairs involving either Japan or Italy have below average correlations, while near neighbors such as France/Germany, US/Canada and long established markets such as US/UK have the highest recorded correlations. It is generally found that cross-country correlations are lower than those of domestic stocks. This observation goes back to Grubel and Fadnar (1971), who report that industries within a country are more highly correlated than industries across countries

3.2. Estimates

Table 2 reports the estimates of model parameters for the expected returns. Specifically, columns 2 and 3 report the mean returns during calm periods and the respective figures for crises periods are reported in columns 4 and 5.

[TABLE 2 ABOUT HERE]

This Table presents us with a number of striking features. Firstly, the low volatility regime is characterised with positive mean returns in all cases. Furthermore all of the means are statistically significant at conventional levels. On the contrary, high volatility regimes are associated with negative returns in all cases, though admittedly, many of these are not statistically different from zero. Therefore a feature of the returns behaviour is that crisis (or turbulent) periods generate negative returns to investors. Secondly we compute a likelihood ratio statistic to test the hypothesis that means are equal across regimes. In the vast majority of cases (17 of 21), this hypothesis is rejected and is consistent with the findings of Guidolin and Timmermann (2005) for UK assets. Consequently, it is important to account for this difference in means across regimes when modelling the behaviour of returns.

[FIGURE 1 ABOUT HERE]

Figure 1 allows us to view the time periods in which the high volatility regime was present between each pair of countries. Almost all pairs of markets shared high volatility in the aftermath of the 1987 stock market crash – a crisis originating in the US -, but again we find a sustained period of high volatility in the aftermath of the Asian and Russian crises of the late 1990's – despite these countries not being in our

sample. This displays an advantage of this methodology, as a simple correlation based approach would not be able to incorporate crisis originating outside of the sample markets. Other pairs of markets experience turbulent periods that would appear to be driven by more regional events e.g. Canada and the US in the early 80's and economic and political links e.g. Italy and France in the early 90's when the EMS suffered a major currency crises.

[TABLE 3 ABOUT HERE]

Table 3 presents a more detailed description of our results. Firstly, the column labeled 'Unc Prob' gives us information about how much of the time each pair of markets experience high volatility resulting from common shocks. It is calculated using the formula $\frac{1-P}{2-P-Q}$, where P is the probability that the respective regime will prevail over two consecutive years, i.e. the transition probability from say the high volatility regime to the same regime. As we can see, it varies from a high of 41% in the case of France and Italy to a low of 0.5% for Italy and Japan. Without any further analysis, this information is potentially important for a fund manager. The low frequency with which Italy and Japan experience a high volatility common shock, suggests that these markets rarely suffer simultaneous bad events and hence could be used to provide a hedge against each other's risk. On the other hand, the relatively high frequency of shared high volatility between France and Italy would be worrying for a portfolio manager if, these 'crises' periods led to changes in the transmission of structural shocks. The expected benefits of international diversification would be eroded. The average proportion of time that a pair of markets exhibits high common volatility is 18.5% (roughly 5.5 years), which gives sufficient observations in the high volatility regime to undertake our analysis.

The column labeled 'Duration' gives the length of time (in years) that a common shock persists - $Duration = \frac{1}{1-P}$. As we have seen, from Figure 1, there is little persistence in the shocks affecting Italy and Japan and this is reflected with duration of little more than one week. Conversely, for pairs of countries where common shocks are more frequent, they also tend to display greater persistence. The highest duration is 3.23 years for common shocks to Germany and Canada. All pairs including Germany exhibit high duration. Countries that are geographically close

(US/Canada) or linked through economic and trade links (France/Italy) also display above average persistence. The average duration across pairs is 0.76 years.

The remainder of Table 3 presents our estimates of the impact coefficients of common structural shocks for calm (σ) and turbulent (σ^*) times (columns 2-3 and 4-5 respectively) as well as the ratio, γ , (column 6) which allows us to test for contagion. For the low volatility regime, the estimated coefficients are quite tightly clustered with all but two lying in the range 0.57 - 1.57. Furthermore all estimates are statistically significantly different from zero. In this calm time period the average for impact coefficients across pairs of countries is 1.1 with a standard deviation of 0.43. Turning to the high volatility regime, we see much larger estimates and much more dispersion. Here the average of the coefficients is 3.27 with a standard deviation of 1.33. Therefore both the average impact and the dispersion of estimates increase threefold. There is also considerable variation on the volatility impacts between pairs of countries. A common shock hitting Italy and Japan, for example, causes a large change in the formers volatility while leaving the latter unchanged, whereas shocks affecting both Italy and the US results in stock market variability increasing for both countries.

In order to gain some insight on shift contagion, we also report the ratio of the estimated impact coefficients of common structural shocks in the column 6 of Table 3. We construct the following statistic:

$$\gamma = \max \left\{ \left| \frac{\sigma_{c1}^* \sigma_{c2}}{\sigma_{c2}^* \sigma_{c1}} \right|, \left| \frac{\sigma_{c2}^* \sigma_{c1}}{\sigma_{c1}^* \sigma_{c2}} \right| \right\}.$$

This reveals whether impact coefficients in the high volatility regime are proportional to their corresponding values in the low volatility regime. A ratio of unity indicates that there is no difference in the transmission mechanism of shocks between the high- and low-volatility regimes, whereas deviations from unity would imply market contagion. At this point we can only talk of the economic significance of the γ ratio but we will later test for its statistical significance.

Even without a formal test, our results suggest that for a large number of country pairs, the transmission mechanism governing common shocks does not experience major changes between high- and low-volatility regimes. Almost half of our sample (10 from 21) generates ratios of less than 1.1. If this turns out to be contagion, at least it's at a relatively low level. At the other end of the scale, two pairs - Germany/Japan and Italy/ Japan - have ratios of over six, with three other pairs in

excess of 2. Ratio values of this magnitude would be of huge concern to a portfolio manager as they indicate adverse movements in stock returns tend to be amplified, thereby greatly reducing expected benefits from international diversification.

It is also worth noting that comparable levels of the ratio can be arrived at in different ways. For example, the pairs of Germany/US, France/UK and Canada/France all have ratios close to unity. However, for all three pairs their common shocks exert different influences on stock market volatility. For the Germany/US pair, volatility in turbulent periods is three times that associated with calm periods, while for France/UK and Canada/France the corresponding increase in market variability is 3.4 and 2.8 respectively. Despite the ratio being the main focus of our analysis, closer examination of Table 3 will allow the investor to learn more the process underlying our results. More risk averse agents may find such information useful.

Before testing for shift contagion, we check whether our model is appropriate for the countries at hand. Table 4 reports results from a number of diagnostic tests. Columns 2 and 3 report the LM test for serial correlation in the standardized residuals of the country pairs examined.⁶ In general, for the majority of the country pairs, we cannot reject the null of no serial correlation at both one and four lags. The same conclusion is reached as far as ARCH effects are considered (see Columns 3 and 4), though when testing for ARCH effects up to fourth order, the percentage of series for which we can reject the null increases to 25 percent. Instead of applying the Jarque Bera statistic, which concentrates on the third and fourth moment, to test for Normality, we test for Normality based on the overall approximation of the empirical distributions of standardized residuals to the Normal by employing the Craner-von Mises test. Our results, reported in Column 6, suggest that the majority of country residuals are Normally distributed.⁷ This suggests that our two-regime model captures quite well the distribution of asset returns.

[TABLE 4 ABOUT HERE]

As a measure of our models' regime qualification performance, we employed the Regime Classification Measure (RCM) developed by Ang and Bekaert (2002). RCM is a summary statistic that captures the quality of a model's regime

⁶ Please note that there all six sets of standardized residuals are reported for each country.

⁷ We also employed the Kolmogorov-Smirnov, Lilliefors, Anderson-Darling, and Watson empirical distribution tests, which yielded similar results. These results are available upon request.

qualification performance. According to this measure, a good regime-switching model should be able to classify regimes sharply, ie the smoothed (ex-post) regime probabilities, p_t are close to either one or zero. For a model with two regimes, the regime classification measure (RCM) is given by:

$$RCM = 400 * \frac{1}{T} \sum_{t=1}^T p_t(1 - p_t),$$

where the constant serves to normalize the statistic to be between 0 and 100. A perfect model will be associated with a RCM close to zero, while a model that cannot distinguish between regimes at all will produce a RCM close to 100. The last column of Table 4 reports the RCM with respect to the common volatility shock. Interestingly, Italy/Japan achieves the best regime classification performance, with a RCM statistic as low as 0.316 (see also Figure 1), while the worst is France/Italy with RCM of 35.5. However, even a value of 35 indicates a good performance of the model since a value of 50 usually serves as the cut-off value.

3.3. Tests for contagion

In testing for the presence of contagion between market pairs, we focus on the ratio γ , and test whether or not it is statistically different from unity. We perform a likelihood ratio test, whose test statistic has a $\chi^2(1)$ distribution under the null hypothesis. Table 5 presents the results.

[TABLE 5 ABOUT HERE]

The most striking feature of our results is that we find little evidence of shift contagion. In the majority of cases (14 out of 21), we fail to reject the null hypothesis of no contagion. For these cases, we find that the mechanism by which common shocks are transmitted is unaffected by the switch from a low- to high-volatility regime. This is a reassuring result for the proponents of international diversification across equity markets as a means of reducing portfolio risk.

Of the other 7 pairs for which we find evidence of shift contagion, Germany appears in 4, the UK and Canada in 3, Japan in 2 with France and the US experiencing market contagion with one partner. ⁸ Certainly, Germany most

⁸ Surprisingly, the large ratio between Japan and Italy does not prove to be statistically significant. This is likely to be a result of the fact that the ratio is entirely driven by increased volatility in Italy. Another

frequently experiences contagion, and with the largest shift in the shock transmission. Common shocks result in ratios of 6.9 with Japan, 3.3 with the UK, 2.8 with Canada and 1.5 with France. The extreme value of the Germany/Japan ratio may be due to the similarities of stock market participation and the corporate structure that prevailed in both countries in the early part of our sample. Pre 1990, stock market participation amongst domestic residents was small, while stock cross-holdings meant that many companies were intertwined and may therefore have tended to amplify the effects of an adverse shock. In particular, the banking sector of both Germany and Japan held significant ownership shares of many public companies. The UK also experiences contagion with both Canada and Japan. Volatility in the turbulent regime increases by approximately 58% and 30% respectively. The final pair of markets for which we find contagion is the US and Canada. This pair records the smallest volatility increase in going from the calm to turbulent regime, roughly 10%, but nevertheless it is statistically significant at the 10% confidence level.

These results have strong implications for portfolio managers in all countries. Firstly, we focus on the countries in the sample. Given that home country bias in portfolio composition is a stylised fact in the finance literature (French and Poterba, 1991; Cooper and Kaplanis, 1994), we begin with the direct effects of our analysis on existing portfolios. Obviously our results are most disturbing for a German fund manager. Given the prevalence of contagion, international diversification is unlikely to deliver the expected risk reduction benefits when this protection is most needed. It would be advisable for German portfolio managers to concentrate their diversification strategies on Italian and US stocks. As stated above, the UK, Canada and Japan also encounter contagious effects of crisis with other members of the G-7 countries and consequently should be wary of diversifying across these countries. On the other extreme, Italian fund managers should be reassured by our results. We find no evidence that the co-movement between the Italian market and any other market is affected by the transition from low- to high-volatility regime. Hence, diversification across international markets is most likely to deliver its anticipated benefits. Likewise the US and France suffer little effects of contagion and their fund managers should take solace in this fact.

factor is the low precision of the estimated coefficients due to the relatively small number of observations in the high-volatility regime.

Of course, the results of this analysis can be applied to all fund managers regardless of location. In fact, it should serve as evidence that international diversification benefits are robust to market conditions. Investors could hold US, Italian, French and Japanese stocks without encountering any cross-market contagion effects. These markets cover about 55% of world market capitalisation. In general, holding stocks from pairs of markets that do not exhibit contagion will improve the risk – return characteristics of your portfolio. Our results show that for the majority of markets the general level of interdependence is not affected by the volatility regime that prevails and any observed increase in correlation should not be construed as contagion.

4. Robustness

In this section we investigate the robustness of our results in two ways. Firstly, we focus on a more recent sample, namely 1990 onwards. In this sample, we are unlikely to encounter any of the market frictions or trading barriers that may have lingered through the 1980s and it also allows us to assess if our results are being driven by the 1987 crash. By itself, this sample is interesting in that many financial crises occurred within this period, with equity, bond and currency markets all suffering major downturns. Secondly we repeat the full sample analysis with returns measured in a common currency, i.e. US dollars. This is analogous to undertaking the analysis from the perspective of a US investor who is concerned with the realised return from international investment. In effect this gives another channel for financial contagion, with exchange risk being incorporated into the equity return.

4.1 Data description

Table 6 presents descriptive statistics for the equity returns in each instance. Panel A focuses on the more recent (1990 onwards) sample and in general, return distributions are broadly similar to the full sample. Italy now has a negative mean return and the standard deviation is slightly reduced in most cases. Evidence of non-normality is also dampened, though still significant and may be attributed to the exclusion of the 1987 crash.

[TABLE 6 ABOUT HERE]

Panel B reports statistics for the full sample of with returns denominated in US dollars. Again the information is similar to that for local currency returns. The standard deviation of all non-US returns is slightly higher reflecting the added risk component in the return computation. Otherwise there are no notable differences.

4.2 Results

Our initial robustness check is to repeat the analysis using data from 1990 onwards. These results are generally in line with those of the full sample. Once more, we find little evidence of contagion between the equity markets of the G-7 countries. Table 7 contains the results.

[TABLE 7 ABOUT HERE]

A number of issues ought to be highlighted. Firstly, there are less large movements in our estimated impact coefficients and consequently the ratio γ exhibits fewer large values than in our full sample estimation. The largest reported value is 3.23 (6.9 in the full sample) but only two others are in excess of two. Secondly, the results of a likelihood ratio test for contagion reveal that only six market pairs display evidence of a change in the transmission of shocks between regimes. Closer examination shows that two pairs – US/Canada and Canada/Germany – suffer contagion in both samples. The other pairs differ, with Germany being most different across samples. Including 1973-89 in the sample gives rise to much more volatility in the German market and a more sensitive reaction to common shocks. This is probably due to the corporate structure of the German market, which was much smaller in value relative to the other markets. Germans seem to dislike speculation and even by 1990, the market capitalisation of its equity markets was only 25% of its GDP (compared to 88% in the UK and 50% in the US). A series of corporate re-structuring has led to significant development since 1990 with comparable figures for 2001, showing market capitalisation is approximately 58% of GDP. While this shows considerable equity market growth, it still trails a long way behind the 152% and 136% of GDP recorded for the UK and US respectively in 2001.⁹ Therefore in the early part of our sample, it is likely that Germany was particularly sensitive to shocks due to the lack of depth of the market and its particular structure, which led to lots of cross-ownership and tightly held shares. The German index was also better diversified in

⁹ These numbers are sourced from Theissen (2003), page25, Table 2.

the more recent sample with the number of listed companies growing from 436 in 1983 to 933 by the end of the 1990s (Kogut and Walker, 2003).

Over the shorter sample, pairs exhibiting contagion include more European pairs, e.g. Italy/UK and France/Italy and are likely to be a consequence of increased economic and political interactions following the Maastricht Treaty of 1992, which paved the way for the introduction of the common currency. As before, the majority of pairs do not exhibit contagion, which is an encouraging finding for fund managers who undertake international diversification.

Our second robustness check is to replicate the original analysis over the full sample with returns measured in a common currency (US dollars). Results are presented in Table 8.

[TABLE 8 ABOUT HERE]

Interestingly, this analysis provides the strongest evidence against shift contagion between market pairs. The estimates of γ are generally close to unity and only two pairs - UK/US and France/Germany - exhibit statistically significant evidence of contagion. In general, the reduced evidence of contagion would appear to come from the fact that currency returns and equity returns have less than perfect correlation and hence the strength of co-movements in equity markets are diluted by the currency return. Furthermore, it could be argued that the currency dimension adds more noise to the total dollar return and therefore we find less evidence of contagion due to larger standard errors of the impact coefficients. This analysis provides encouraging findings for US investors who hold international assets.

In summary, our results appear to be quite robust to the conclusion that there is little evidence of contagion between the equity markets of the G-7 countries. Indeed, most of the contagion that we find seems to be associated with either Germany (in the full sample) or Canada. We find evidence of some regional contagion in the shorter sample but the message for portfolio managers appears to be that changes in the transmission of shocks is largely unchanged between low- and high-volatility regimes. Hence, equity market interdependence remains relatively constant and portfolio managers should not fear the contagious effects of financial crises. The benefits expected to accrue from international diversification in tranquil markets should also manifest themselves in turbulent market conditions.

5. Conclusions

This study tests for equity market contagion between members of the G-7 countries and then looks at the implication of our results for asset allocation. We define contagion as changes in the transmission of structural shocks induced by a pair of markets being hit by a common adverse shock. We use the methodology introduced by GKM, which is well suited to the analysis of the G-7 countries. The main advantage of this methodology for our study is that we can test for contagion between countries without having to identify or including the source of the shock. Methodologies that require the market from which the shock emanated to be included, often force studies to concentrate on relatively small or regional markets. In discussing the implications of contagion for portfolio selection models, we argue that we should focus on the larger markets of the world and by choosing the G-7 countries, we cover about 80% of world market capitalisation. Obviously, these markets will be the major recipient of capital inflows and hence vehicles for international portfolio diversification.

Our analysis uses a regime-switching model to exploit the heteroskedasticity inherent in stock returns to identify whether or not we have contagion between each pair of markets. We report a number of interesting findings. Firstly, we find that expected stock returns are statistically different between regimes. Calm markets are associated with significantly positive returns while turbulent markets are characterised as generating negative mean returns. Secondly, our model seems to capture the features of return distributions quite well and we find that markets are, on average, in a high-volatility regime about 20% of the time – though this varies substantially across different market pairs. Some market pairs, e.g. Italy and Japan, incur few common shocks and consequently are likely to provide risk reduction benefits if held together in portfolios. In contrast, others, such as Italy and France, experience lots of persistent common shocks and we need to investigate if these generate contagion. Thirdly, we find little evidence of contagious effects between the pairs of markets under review. In 66% (14 of 21) of cases, we fail to reject the hypothesis of no contagion. Of the instances that we find contagion, Germany appears most often as a partner, though this result is not so strong in a more recent sample. This result may be explained, at least in part, by the pattern of cross-ownership that characterised the German corporate sector pre 1990 and low stock market participation amongst German households. Finally, we undertake a number

of robustness checks. Initially we repeat our analysis using a more recent sample when any lingering impediments to cross-market trade should be eliminated. Once more, we reject contagion in the majority of cases (71%) but when contagion is found, it's predominantly on a geographical basis. Another check is to replicate the analysis using equity returns expressed in a common currency. In this instance, we reject contagion in 90% of country pairs.

To conclude, we find that the equity markets of the G-7 countries experience limited shift contagion. There is little evidence that the transmission mechanism of structural shocks changes between high- and low-volatility regimes. Hence, market interdependence appears robust to market conditions. Our results have important implications for portfolio managers across the globe. Given the importance and size of the markets in our sample, our results show that the benefits associated with international diversification can be expected to accrue in both calm and turbulent market conditions. Consequently, this study should encourage fund managers to pursue international diversification strategies without fear of potential benefits being eroded during periods of high volatility, such as those associated with bear markets.

Acknowledgments

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Table 1: Summary Descriptive Statistics*Panel A: Full Sample- Local Currency (1/1/73-31/12/2005)*

	<i>Canada</i>	<i>France</i>	<i>Germany</i>	<i>Italy</i>	<i>Japan</i>	<i>UK</i>	<i>US</i>
<i>Mean</i>	0.148	0.177	0.111	0.095	0.191	0.163	0.141
<i>Median</i>	0.228	0.317	0.246	0.195	0.196	0.263	0.294
<i>Maximum</i>	11.570	11.812	11.824	14.538	16.189	21.087	12.302
<i>Minimum</i>	-23.519	-18.752	-17.302	-18.294	-23.451	-24.842	-27.090
<i>Std. Dev.</i>	2.061	2.738	2.367	2.421	3.336	2.437	2.300
<i>Skewness</i>	-1.060	-0.681	-0.962	-0.335	-0.272	-0.314	-1.050
<i>Kurtosis</i>	14.595	6.959	8.979	6.911	6.181	15.579	15.779
<i>Jarque Bera</i>	9968.463 (0.000)	1257.712 (0.000)	2831.200 (0.000)	1129.759 (0.000)	747.387 (0.000)	11382.250 (0.000)	12033.400 (0.000)

Panel B: Correlations

<i>Market</i>	<i>Canada</i>	<i>France</i>	<i>Germany</i>	<i>Italy</i>	<i>Japan</i>	<i>UK</i>	<i>US</i>
<i>Canada</i>	1.000	0.460	0.459	0.333	0.285	0.494	0.736
<i>France</i>		1.000	0.592	0.321	0.396	0.512	0.490
<i>Germany</i>			1.000	0.348	0.413	0.473	0.493
<i>Italy</i>				1.000	0.224	0.307	0.354
<i>Japan</i>					1.000	0.358	0.305
<i>UK</i>						1.000	0.521
<i>US</i>							1.000

Table 2. Estimates of mean returns across regimes

<i>Country pairs</i>	μ_1	μ_2	μ^*_1	μ^*_2	<i>LR</i>	<i>p-val</i>
<i>Canada/US</i>	0.221 (0.047)	0.226 (0.047)	-0.022 (0.026)	-0.056 (0.073)	3.948	0.139
<i>France/US</i>	0.304 (0.060)	0.229 (0.049)	-0.830 (0.515)	-0.598 (0.470)	9.976***	0.007
<i>Germany/US</i>	0.216 (0.044)	0.200 (0.049)	-0.070 (0.073)	-0.036 (0.021)	2.528	0.283
<i>Italy/US</i>	0.220 (0.048)	0.213 (0.045)	-0.620 (0.262)	-0.428 (0.325)	9.429***	0.009
<i>Japan/US</i>	0.257 (0.077)	0.218 (0.030)	-0.164 (0.121)	-0.001 (0.100)	6.892**	0.032
<i>UK/US</i>	0.237 (0.048)	0.212 (0.047)	-0.342 (0.194)	-0.253 (0.244)	4.731*	0.094
<i>Canada/UK</i>	0.249 (0.045)	0.224 (0.046)	-0.767 (0.229)	-0.571 (0.375)	16.564***	0.000
<i>France/UK</i>	0.293 (0.058)	0.237 (0.045)	-0.754 (0.675)	-0.574 (0.597)	6.452**	0.040
<i>Germany/UK</i>	0.215 (0.044)	0.242 (0.049)	-0.188 (0.255)	-0.110 (0.175)	6.173**	0.046
<i>Italy/UK</i>	0.223 (0.049)	0.244 (0.048)	-0.413 (0.147)	-0.202 (0.061)	6.145**	0.046
<i>Japan/UK</i>	0.207 (0.072)	0.234 (0.046)	-0.791 (0.419)	-0.655 (0.461)	6.954**	0.031
<i>Canada/Japan</i>	0.223 (0.082)	0.177 (0.250)	-1.152 (6.114)	-1.266 (7.734)	5.825*	0.054
<i>France/Japan</i>	0.304 (0.058)	0.211 (0.071)	-0.645 (0.303)	-0.520 (0.287)	6.644**	0.036
<i>Germany/Japan</i>	0.184 (0.046)	0.221 (0.090)	-0.068 (0.024)	-0.048 (0.043)	2.365	0.306
<i>Italy/ Japan</i>	0.169 (0.048)	0.172 (0.064)	-2.754 (4.642)	-11.704 (1.806)	11.514***	0.003
<i>Canada/Italy</i>	0.209 (0.042)	0.191 (0.050)	-0.595 (0.513)	-0.514 (0.514)	2.751	0.253
<i>France/Italy</i>	0.326 (0.077)	0.241 (0.055)	0.123 (0.112)	-0.070 (0.137)	5.676*	0.059
<i>Germany/Italy</i>	0.224 (0.050)	0.225 (0.052)	-0.041 (0.037)	-0.136 (0.037)	6.127**	0.047
<i>Canada/Germany</i>	0.169 (0.044)	0.190 (0.046)	0.083 (0.063)	-0.016 (0.009)	98.059***	0.000
<i>France/Germany</i>	0.232 (0.058)	0.194 (0.045)	-0.090 (0.162)	-0.211 (0.165)	4.586*	0.100
<i>Canada/France</i>	0.253 (0.042)	0.300 (0.062)	-0.472 (0.246)	-0.587 (0.327)	9.075**	0.011

Notes: Standard errors in parentheses below coefficients. Likelihood ratio statistic is for the null of equality of mean returns across the regimes. The test statistic has a $\chi^2(2)$ distribution under the null hypothesis. *** denotes significance at 1% level, ** denotes significance at 5% level, and * denotes significance at 10% level.

Table 3. Estimates of impact coefficients of common shocks

<i>Country pairs</i>	σ_{c1}	σ_{c2}	σ_{c1}^*	σ_{c2}^*	γ	<i>Unc. Prob.</i>	<i>Duration</i>
<i>Canada/US</i>	1.080 (0.025)	1.667 (0.033)	1.961 (0.077)	3.325 (0.072)	1.099	29.15%	0.98
<i>France/US</i>	1.424 (0.192)	1.187 (0.075)	3.446 (0.742)	3.930 (0.475)	1.368	10.48%	0.29
<i>Germany/US</i>	1.020 (0.004)	0.832 (0.056)	3.060 (0.184)	2.507 (0.166)	1.004	23.21%	1.56
<i>Italy/US</i>	0.671 (0.060)	1.219 (0.029)	2.171 (0.266)	4.045 (0.321)	1.026	11.15%	0.26
<i>Japan/US</i>	1.374 (0.019)	0.671 (0.010)	1.851 (0.388)	2.473 (0.242)	2.736	30.55%	1.56
<i>UK/US</i>	1.078 (0.071)	1.259 (0.056)	3.266 (0.317)	3.816 (0.303)	1.000	13.90%	0.25
<i>Canada/UK</i>	0.921 (0.054)	1.421 (0.058)	2.041 (0.191)	4.963 (0.312)	1.576	10.63%	0.18
<i>France/UK</i>	1.420 (0.068)	1.334 (0.037)	4.802 (0.399)	4.545 (0.340)	1.007	10.93%	0.20
<i>Germany/UK</i>	0.577 (0.074)	1.469 (0.045)	3.095 (0.192)	2.412 (0.133)	3.267	24.80%	1.08
<i>Italy/UK</i>	0.719 (0.124)	0.805 (0.117)	2.411 (0.247)	2.716 (0.434)	1.006	9.95%	0.20
<i>Japan/UK</i>	1.306 (0.091)	1.321 (0.044)	3.655 (0.905)	4.812 (0.361)	1.302	14.66%	0.21
<i>Canada/Japan</i>	1.024 (0.162)	1.157 (1.067)	4.003 (1.348)	4.617 (0.386)	1.021	15.00%	0.20
<i>France/Japan</i>	1.594 (0.061)	1.511 (0.094)	4.410 (0.340)	3.876 (0.301)	1.079	12.80%	0.25
<i>Germany/Japan</i>	0.383 (0.051)	2.885 (0.091)	2.905 (0.652)	3.159 (0.145)	6.927	31.69%	2.07
<i>Italy/ Japan</i>	1.428 (0.051)	0.683 (0.099)	8.887 (2.697)	0.698 (0.177)	6.090	0.47%	0.02
<i>Canada/Italy</i>	0.904 (0.038)	0.696 (0.099)	4.196 (0.717)	2.895 (0.467)	1.116	5.22%	0.10
<i>France/ Italy</i>	0.572 (0.073)	1.035 (0.046)	1.247 (0.114)	2.679 (0.111)	1.187	41.36%	1.44
<i>Germany/ Italy</i>	0.675 (0.234)	0.613 (0.104)	2.352 (0.142)	2.113 (0.163)	1.011	29.95%	1.13
<i>Canada/Germany</i>	1.189 (0.099)	0.637 (0.069)	1.934 (0.114)	2.862 (0.161)	2.762	23.23%	3.23
<i>France/Germany</i>	1.459 (0.064)	1.073 (0.070)	3.189 (0.172)	3.504 (0.149)	1.494	25.24%	0.78
<i>Canada/France</i>	0.953 (0.124)	1.254 (0.215)	2.748 (0.240)	3.599 (0.278)	1.005	13.69%	0.17

Notes: Standard errors in parentheses below coefficients. "Duration" refers to the duration of the high volatility common shock expressed in years. "Unc. Prob." refers to the unconditional probability of the high volatility regime expressed in percentage.

Table 4. Diagnostic tests on standardized residuals and model specification

	<i>LM(1)</i>	<i>LM(4)</i>	<i>ARCH(1)</i>	<i>ARCH(4)</i>	<i>Normality</i>	<i>RCM</i>
<i>Canada/US</i>	5.210 6.307	7.722 9.775	8.347 * 0.605	9.899 2.786	0.227* 0.221*	27.722
<i>France/US</i>	1.794 5.989	7.283 11.373	2.659 0.426	18.839* 1.596	0.171 0.275*	17.632
<i>Germany/US</i>	1.523 5.635	10.041 8.929	10.633* 0.310	75.394* 2.225	0.277* 0.248*	17.802
<i>Italy/US</i>	0.152 7.132*	2.437 11.500	2.010 0.000	13.914* 1.600	0.062 0.319*	18.430
<i>Japan/US</i>	1.186 6.142	13.588* 9.120	7.311 0.757	51.814* 3.301	0.030 0.364*	26.912
<i>UK/US</i>	4.972 5.701	8.571 11.334	0.195 0.000	5.389 1.525	0.078 0.326*	22.554
<i>Canada/UK</i>	4.458 4.747	6.159 11.553	5.590* 0.226	7.260 8.600	0.102 0.113	16.407
<i>France/UK</i>	1.794 5.989	7.283 11.373	2.659 0.426	18.839* 1.596	0.171 0.275*	15.904
<i>Germany/UK</i>	1.956 4.779	11.524 11.074	7.772* 0.601	51.043* 21.986*	0.240* 0.131	21.890
<i>Italy/UK</i>	0.255 7.016*	4.043 11.095	0.001 0.483	6.352 18.977*	0.034 0.106	14.832
<i>Japan/UK</i>	1.166 4.052	13.233 9.269*	9.021* 1.088	60.907* 12.052	0.029 0.058	29.461
<i>Canada/Japan</i>	5.205 1.379	7.024 16.692*	1.115 4.534	3.555 39.741*	0.101 0.082	27.230
<i>France/Japan</i>	1.863 1.479	9.492 13.993*	4.946 13.300*	30.583* 59.712*	0.231* 0.052	21.690
<i>Germany/Japan</i>	2.841 0.937	11.205 16.150*	13.164* 10.734*	58.041* 59.539*	0.301* 0.094	15.787
<i>Italy/ Japan</i>	1.028 0.968	5.166 15.499*	0.235 9.253*	5.875 41.581*	0.122 0.072	0.613
<i>Canada/Italy</i>	5.937 0.550	8.604 3.617	2.347 1.332	3.594 13.016	0.156 0.057	12.158
<i>France/ Italy</i>	2.712 0.470	11.240 5.052	5.160 1.780	32.037* 9.216	0.277* 0.089	35.497
<i>Germany/ Italy</i>	1.798 0.278	12.426 6.219	3.761 0.227	50.955* 8.988	0.298* 0.072	29.636
<i>Canada/Germany</i>	8.702* 1.967	10.521 11.596	8.825* 11.569*	9.819 47.186*	0.170 0.291*	13.270
<i>France/Germany</i>	2.671 1.972	13.311* 9.025	11.106* 16.146*	38.413* 89.405*	0.239* 0.258*	23.984
<i>Canada/France</i>	4.746 2.215	6.903 9.867	2.128 5.848	3.157 21.831*	0.074 0.138	26.989

Notes: $LM(k)$ is the Breusch-Godfrey Lagrange Multiplier test for no serial correlation up to lag k , $ARCH(k)$ is the Lagrange Multiplier test for no ARCH effects of order k , Normality is the Cramer-von-Mises test for the null of Normality, and RCM is the Regime Classification Measure. * denotes significance at 1% level. $LM(k)$ and $ARCH(k)$ have a $\chi^2(k)$ distribution under the null hypothesis. The Cramer-von-Mises test has a non-standard distribution and the cut-off value for RCM is 50.

Table 5. Likelihood ratio tests for shift contagion

<i>Market</i>	<i>Canada</i>	<i>France</i>	<i>Germany</i>	<i>Italy</i>	<i>Japan</i>	<i>UK</i>	<i>US</i>
		0.000 (0.987)	3.710* (0.054)	0.000 (1.000)	6.483 (0.011)	2.941* (0.086)	2.784* (0.095)
<i>Canada</i>	---		2.707* (0.100)	0.000 (1.000)	0.025 (0.874)	0.011 (0.916)	0.000 (1.000)
<i>France</i>		---		0.000 (1.000)	44.648* (0.000)	10.793*** (0.001)	0.000 (0.996)
<i>Germany</i>			---		0.760 (0.383)	0.000 (0.986)	0.000 (0.994)
<i>Italy</i>				---		6.898*** (0.009)	1.156 (0.282)
<i>Japan</i>					---		0.000 (0.996)
<i>UK</i>						---	
<i>US</i>							----

Notes: Likelihood ratio statistic is for the null of no contagion against the alternative of contagion for the indicated country pairs. The test statistic has a $\chi^2(1)$ distribution under the null hypothesis. *** denotes significance at 1% level, ** denotes significance at 5% level, and * denotes significance at 10% level. *p*- values are reported in parentheses below coefficients.

Table 6. Descriptive statistics*Panel A: Recent sub sample (1/1/90-31/12/2005)*

	<i>Canada</i>	<i>France</i>	<i>Germany</i>	<i>Italy</i>	<i>Japan</i>	<i>UK</i>	<i>US</i>
<i>Mean</i>	0.169	0.133	0.096	-0.049	0.101	0.116	0.167
<i>Median</i>	0.306	0.295	0.328	0.070	0.235	0.229	0.348
<i>Maximum</i>	8.915	11.812	11.824	14.538	12.939	9.097	12.302
<i>Minimum</i>	-11.517	-13.520	-16.882	-9.734	-15.705	-11.898	-11.769
<i>Std. Dev.</i>	1.942	2.643	2.690	2.813	3.054	2.104	2.244
<i>Skewness</i>	-0.659	-0.585	-0.770	0.071	-0.332	-0.649	-0.243
<i>Kurtosis</i>	6.131	6.288	6.842	4.536	5.169	7.400	6.030
<i>Jarque Bera</i>	401.638 (0.000)	423.726 (0.000)	596.139 (0.000)	82.810 (0.000)	178.984 (0.000)	732.021 (0.000)	327.611 (0.000)

Panel B: Full sample US dollars (1/1/73-31/12/2005)

	<i>Canada</i>	<i>France</i>	<i>Germany</i>	<i>Italy</i>	<i>Japan</i>	<i>UK</i>	<i>US</i>
<i>Mean</i>	0.139	0.173	0.150	0.150	0.132	0.146	0.141
<i>Median</i>	0.236	0.288	0.246	0.000	0.186	0.194	0.294
<i>Maximum</i>	12.862	12.448	12.225	15.772	14.824	22.346	12.302
<i>Minimum</i>	-24.492	-19.214	-15.032	-18.605	-21.361	-24.357	-27.090
<i>Std. Dev.</i>	2.312	2.946	2.608	3.010	3.519	2.735	2.300
<i>Skewness</i>	-0.932	-0.462	-0.504	-0.031	-0.174	-0.141	-1.050
<i>Kurtosis</i>	11.916	5.752	5.676	5.379	4.842	10.759	15.779
<i>Jarque- Bera</i>	5952.841 (0.000)	604.682 (0.000)	586.868 (0.000)	406.267 (0.000)	252.181 (0.000)	4324.721 (0.000)	12033.400 (0.000)

Table 7. Estimates of impact coefficients of common shocks (recent sample)

<i>Country pairs</i>	σ_{c1}	σ_{c2}	σ^*_{c1}	σ^*_{c2}	γ	<i>LR</i>	<i>p-val</i>
<i>Canada/US</i>	0.845 (0.035)	1.270 (0.070)	1.869 (0.112)	2.705 (0.140)	1.039	10.585***	0.001
<i>France/US</i>	1.501 (0.071)	1.085 (0.073)	4.049 (0.346)	2.873 (0.270)	1.018	26.908***	0.000
<i>Germany/US</i>	1.166 (0.017)	0.960 (0.187)	2.991 (0.169)	2.462 (0.053)	1.000	0.000	0.996
<i>Italy/US</i>	0.427 (0.229)	1.227 (0.231)	2.035 (0.247)	1.811 (0.109)	3.230	1.348	0.246
<i>Japan/US</i>	1.035 (0.023)	1.171 (0.127)	2.331 (0.203)	2.571 (0.190)	1.026	0.000	1.000
<i>UK/US</i>	0.994 (0.024)	1.084 (0.078)	2.448 (0.205)	2.669 (0.209)	1.000	0.000	1.000
<i>Canada/UK</i>	0.997 (0.071)	1.026 (0.054)	2.167 (0.256)	2.230 (0.246)	1.000	0.000	0.995
<i>France/UK</i>	1.594 (0.077)	1.303 (0.057)	4.334 (0.372)	3.450 (0.258)	1.027	0.213	0.644
<i>Germany/UK</i>	1.549 (0.119)	1.233 (0.110)	4.130 (0.425)	3.225 (0.311)	1.020	0.000	0.995
<i>Italy/UK</i>	1.093 (0.490)	1.287 (0.063)	1.798 (1.162)	3.990 (0.457)	1.883	7.893***	0.005
<i>Japan/UK</i>	1.461 (0.177)	1.216 (0.187)	3.632 (0.339)	3.242 (0.292)	1.072	0.000	1.000
<i>Canada/Japan</i>	0.906 (0.105)	1.181 (0.048)	1.943 (0.150)	2.533 (0.188)	1.000	5.481**	0.019
<i>France/Japan</i>	2.014 (0.062)	1.552 (0.081)	4.797 (0.413)	3.875 (0.355)	1.048	0.067	0.796
<i>Germany/Japan</i>	1.513 (0.091)	1.670 (0.077)	4.508 (0.465)	4.295 (0.404)	1.158	0.779	0.378
<i>Italy/ Japan</i>	2.123 (0.103)	0.633 (0.092)	3.603 (0.411)	2.659 (0.168)	2.474	2.537	0.111
<i>Canada/Italy</i>	0.699 (0.125)	0.953 (0.050)	1.657 (0.144)	2.260 (0.216)	1.002	0.000	1.000
<i>France/ Italy</i>	1.893 (0.101)	0.687 (0.358)	2.241 (0.186)	1.997 (0.312)	2.458	3.528*	0.060
<i>Germany/ Italy</i>	1.021 (0.014)	0.800 (0.089)	2.468 (0.153)	1.908 (0.164)	1.013	0.000	1.000
<i>Canada/Germany</i>	0.897 (0.152)	1.268 (0.209)	2.080 (0.186)	2.915 (0.193)	1.008	44.731***	0.000
<i>France/Germany</i>	1.525 (0.108)	1.742 (0.111)	4.002 (0.326)	4.212 (0.298)	1.085	0.000	1.000
<i>Canada/France</i>	1.267 (0.046)	1.009 (0.041)	2.339 (0.141)	2.512 (0.181)	1.349	0.479	0.489

Notes: Standard errors in parentheses below coefficients. Likelihood ratio statistic is for the null of no contagion against the alternative of contagion for the indicated country pairs. The test statistic has a $\chi^2(1)$ distribution under the null hypothesis. *** denotes significance at 1% level, ** denotes significance at 5% level, and * denotes significance at 10% level. *p*- values are reported in parentheses below coefficients.

Table 8. Estimates of impact coefficients of common shocks (US dollars)

<i>Country pairs</i>	σ_{c1}	σ_{c2}	σ_{c1}^*	σ_{c2}^*	γ	<i>LR</i>	<i>p-val</i>
<i>Canada/US</i>	1.453 (0.099)	1.523 (0.104)	4.284 (0.441)	4.482 (0.479)	1.002	0.001	0.973
<i>France/US</i>	1.124 (0.087)	1.370 (0.062)	2.941 (0.386)	3.914 (0.288)	1.092	0.354	0.552
<i>Germany/US</i>	0.930 (0.028)	0.976 (0.087)	2.719 (0.199)	2.868 (0.151)	1.004	0.000	0.987
<i>Italy/US</i>	0.720 (0.127)	1.130 (0.091)	2.398 (0.313)	3.765 (0.341)	1.000	0.000	0.996
<i>Japan/US</i>	1.460 (0.182)	0.637 (0.090)	1.723 (0.200)	2.487 (0.133)	3.304	1.321	0.250
<i>UK/US</i>	1.175 (0.120)	1.290 (0.103)	3.889 (0.381)	4.272 (0.400)	1.001	4.000**	0.046
<i>Canada/UK</i>	1.367 (0.100)	1.211 (0.121)	4.384 (0.491)	3.883 (0.583)	1.001	0.000	0.995
<i>France/UK</i>	1.599 (0.127)	1.471 (0.099)	4.183 (0.347)	3.846 (0.285)	1.001	0.000	0.983
<i>Germany/UK</i>	1.502 (0.058)	1.266 (0.078)	3.879 (0.349)	3.303 (0.320)	1.011	0.001	0.972
<i>Italy/UK⁽¹⁾</i>	1.621 (0.236)	1.544 (0.284)	5.308 (1.863)	9.387 (2.639)	1.857	0.928	0.335
<i>Japan/UK</i>	1.346 (0.086)	1.680 (0.055)	3.244 (0.348)	4.480 (0.381)	1.107	0.862	0.353
<i>Canada/Japan</i>	1.407 (0.049)	0.936 (0.044)	4.539 (0.387)	3.885 (0.262)	1.287	0.001	0.977
<i>France/Japan</i>	1.678 (0.082)	1.783 (0.095)	4.346 (0.299)	3.649 (0.171)	1.265	0.193	0.660
<i>Germany/Japan</i>	1.601 (0.055)	1.629 (0.065)	3.755 (0.254)	3.650 (0.219)	1.047	0.008	0.931
<i>Italy/ Japan⁽¹⁾</i>	0.450 (0.613)	0.441 (0.979)	2.111 (0.149)	2.053 (0.168)	1.008	0.000	0.995
<i>Canada/Italy</i>	1.150 (0.060)	0.891 (0.109)	5.295 (0.718)	3.506 (0.646)	1.170	0.008	0.927
<i>France/ Italy⁽¹⁾</i>	1.288 (0.146)	1.619 (0.187)	3.567 (0.646)	4.644 (0.795)	1.036	0.001	0.972
<i>Germany/ Italy</i>	1.262 (0.119)	1.050 (0.092)	3.535 (0.472)	2.939 (0.336)	1.000	0.000	1.000
<i>Canada/Germany</i>	1.138 (0.357)	1.137 (0.191)	3.787 (1.701)	3.840 (1.033)	1.016	0.000	0.983
<i>France/Germany</i>	1.636 (0.067)	1.589 (0.064)	3.382 (0.150)	3.764 (0.194)	1.145	6.219**	0.013
<i>Canada/France</i>	1.295 (0.111)	1.188 (0.130)	3.912 (0.475)	3.602 (0.403)	1.004	0.000	0.991

Notes: Standard errors in parentheses bellows coefficients. Likelihood ratio statistic is for the null of no contagion against the alternative of contagion for the indicated country pairs. The test statistic has a $\chi^2(1)$ distribution under the null hypothesis. *** denotes significance at 1% level, ** denotes significance at 5% level, and * denotes significance at 10% level. *p*- values are reported in parentheses below coefficients. ⁽¹⁾ Estimates based on a post-1980 sample due to convergence problems.

Figure 1. Filter Probabilities of high volatility common shocks

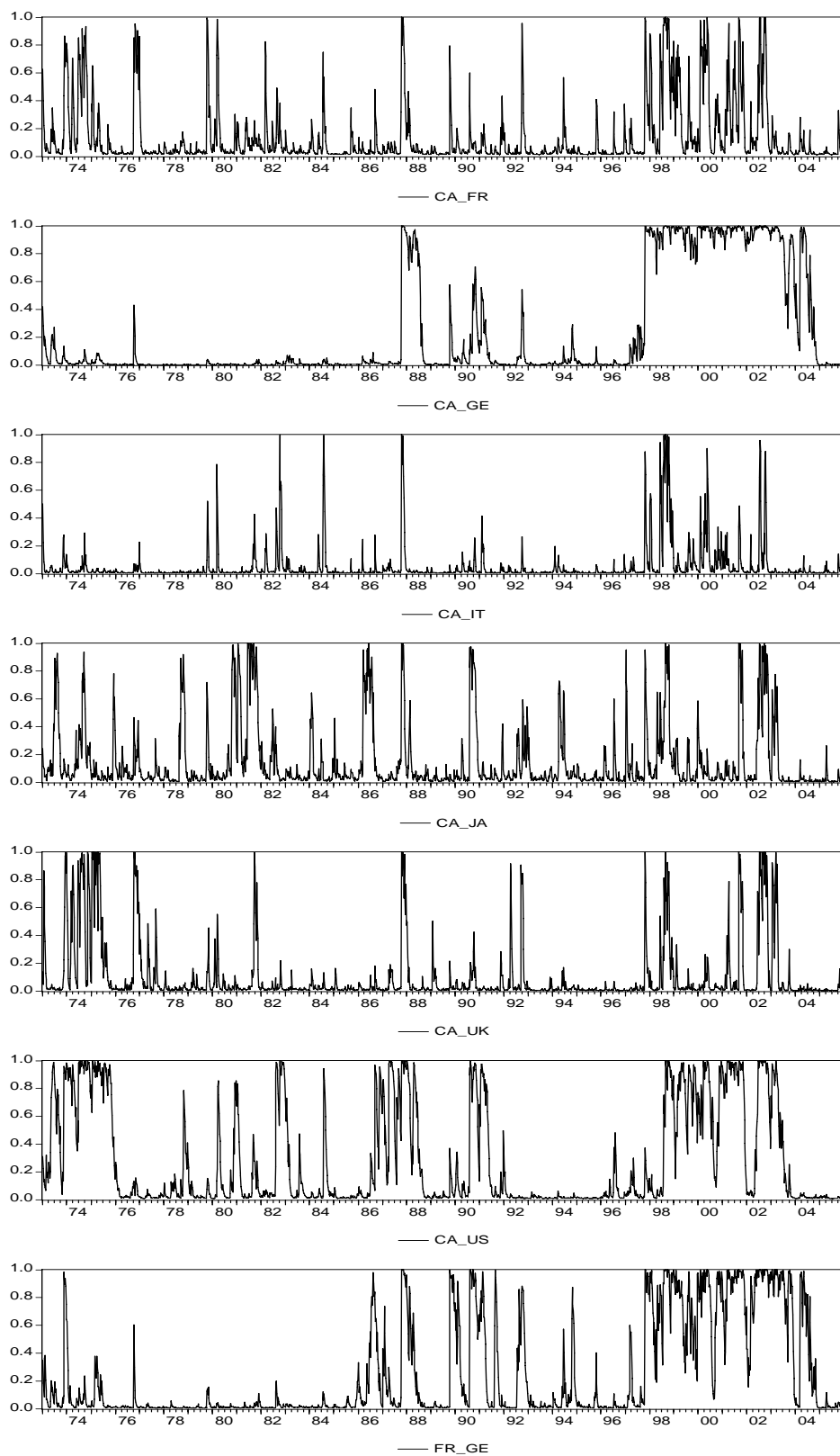


Figure 1 (continued)

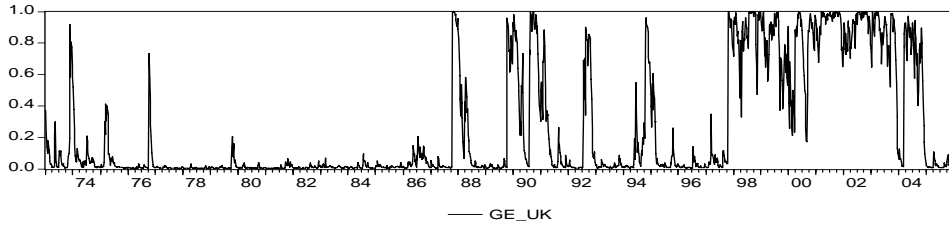
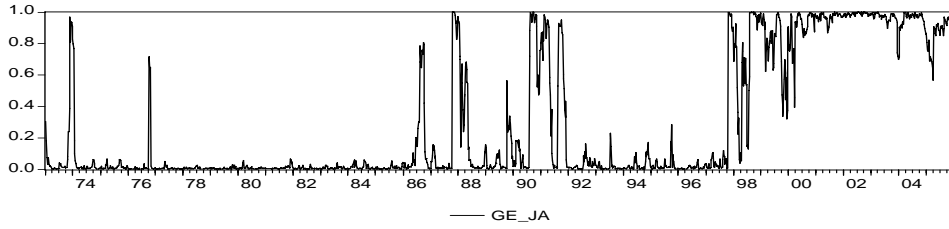
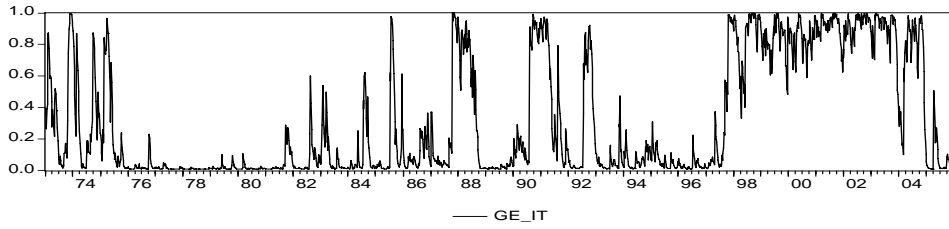
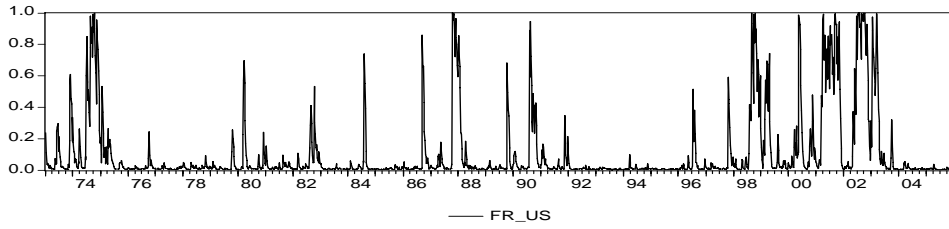
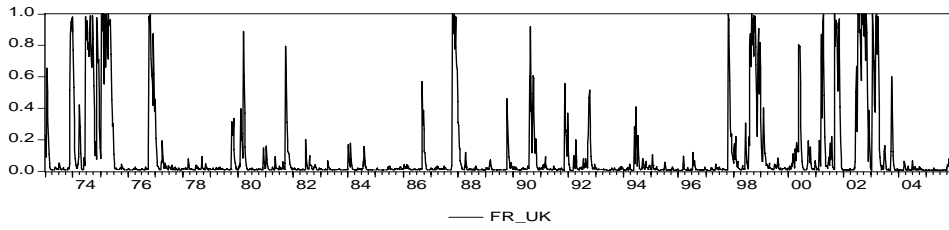
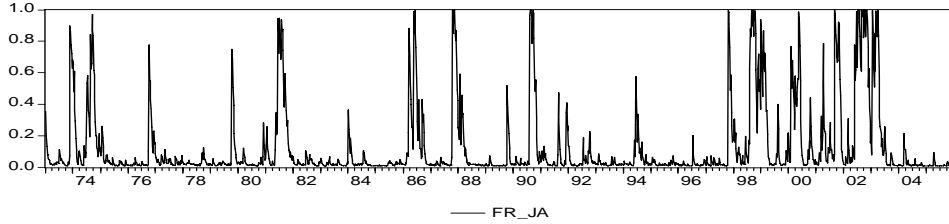
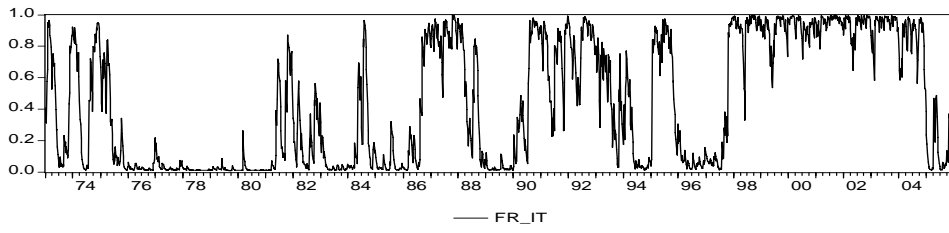


Figure 1 (continued)

