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Abstract

This paper examines the dynamic patterns of international linkages of the Japanese government bond yields with government bond yields in the US, the UK and Germany during the period from January 1980 to December 2004. Applying the vector autoregression (VAR) model and the vector error correction (VEC) model to monthly observations of nominal bond yields and exchange rate-adjusted bond yields over the 25-year period, this paper provides consistent empirical evidence that the Japanese bond market is independent of other major national bond markets, but it exerts some influence in determining bond yields in bond markets in other major industrial countries. However, since the early 1990, evidence shows that the independence of the Japanese bond market has increased further, while its leading role in global bond markets has been eroded significantly.

JEL classification: G15, C32

Keywords: Japanese bond market, international linkages, VAR analysis

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I. Introduction

As capital controls have fallen and communication technologies have advanced, world financial markets have become more closely linked in recent years. The resulting financial integration has provided a favorable environment for increasing linkages in

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international bond markets. However, the increasing uncertainty in global financial markets in recent years, such as the global financial market crisis of 1997-98, divergent monetary policy across countries, and financial contagion in the global scale, has made global bond investors difficult to maintain firm views on the determinants of long-term bond yields. This new type of market uncertainty has created widely swung bond yields and divergence of bond yields among major industrial countries in recent years. The Bank for International Settlements (BIS) reports that yield movements were particularly produced in the US and Japan, while those in the euro area were more subdued. (*BIS Annual Reports* 2004)

The bond yield curve in Japan in recent years has been characterized as low levels of interests, steep slopes between short and long maturities, and high volatility at the longer maturities. The US and European bond markets have shown similar trends. However, the Japanese long-term fixed income (for example, Japanese government bond) yield correlations with the yields either in the US and the euro area have been constantly low. To the contrary, long-term bond yields in the US and the euro area, and consequently bond yield correlations between the two regional economies, have been consistently higher despite the divergence between the US and the euro area growth prospects and key macroeconomic indicators. (*BIS* 2004, p. 103)

This puzzling phenomenon in international linkages among major national bond markets, divergence of the Japanese bond market from global bond markets in particular, warrants a need for more careful empirical investigation to find out, for example, whether it is a temporary or persistent long-term trend. There has been relatively little research on investigating the linkages in global bond markets, compared to extensive literature on

other financial markets[2]. Sutton (2002) found excessive comovements of bond yields in major international government bond markets during 1961-1992, and ascribed it to positively correlated term premia at the long end of the term structure across national bond markets. After applying linear factor models to both currency-hedged and unhedged bond returns in the US, Germany and Japan, Driessen (2003) identified the common factors, such as the world level factor and multi-country factors, that determine international bond returns, and attributed the increasing comovements among international bond returns to the existence of the common factors. Other researchers have found non-consensus evidence on the existence of long-run cointegration relationships among government bond markets in major industrial countries. (Barassi *et al*., 2001; Clare *et al*, 1995; DeGennaro *et al*., 1994; Smith 2002) Applying the data-determined forecast error variance decomposition methodology, Yang (2005) showed that international bond markets are not completely segmented but instead are partially segmented and there is no distinctive leadership role by any particular national bond market during 1986-2000.

This paper examines the dynamic trends of international linkages of the Japanese bond yields with bond yields in the US, the UK and Germany during the period from January 1980 to December 2004. We analyze both the nominal bond yields and exchange rate-adjusted bond yields by applying various short-term and long-term focused time series methodologies. Applying the vector autoregression (VAR) model and the vector error correction (VEC) model to monthly observations of nominal bond yields and exchange rate-adjusted bond yields over the 25-year period, we provide consistent

[2] This is especially true regarding international stock market linkages, e.g., von Furstenburg and Jeon (1989), Jeon and von Furstenberg (1990), Eun and Shim (1989), Hamao *et al.* (1990), Lee and Jeon (1995), among others.

empirical evidence that the Japanese bond market is independent of other major national bond markets, but it exerts some influence in determining bond yields in the other major bond markets. However, since the early 1990, evidence shows that the independence of the Japanese bond market has increased, while its role of leadership or influence in global bond markets has been eroded significantly.

The remainder of this paper is organized as follows. Section 2 describes the data used in this study. Section 3 presents empirical results. Empirical results from the sub-sample study are reported and discussed in Section 4. Section 5 concludes the paper.

II. Data

In this paper we use monthly time series of long-term government bond yields, which are available from International Financial Statistics (IFS). The data cover the 25 year period from January 1980 to December 2004, including 300 monthly observations[3]. Our focus is on the linkage of the Japanese long-term government bond yield with those of the United States and Europe. For the European markets, we choose the United Kingdom and Germany. The data from IFS are bond yields in the domestic currency. To compare the bond yields of different countries, the exchange rate also needs to be taken

[3] German government bonds are bonds issued by the Federal government, the railways, the postal system, the Länder government, municipalities, specific purpose public associations and other public associations established under special legislation. Bond yields are calculated as the weighted average of all bonds with an average remaining life to maturity of more than 3 years. The weights refer to the amount of individual bonds in circulation. Monthly figures are calculated as averages of four-bank-week return dates including the end-of-month yield of the preceding month. Japanese government bond yield is the arithmetic average yield to maturity of all government bonds with 7 years to maturity. Monthly series are compiled from end-of-month prices quoted on the Tokyo stock exchange. Government bond yields of the UK are theoretical gross redemption yields. Long-term government bonds are issued at par with 20 years to maturity. Long-term series of the US refer to 10-year constant maturities. Long-term government bond yields are from the IFS, line 61.ZF for each country.

into account. The data of exchange rates are also from IFS[4]. Since the data from July to December of 2005 are not available at the time of writing this paper, the data for exchange rate-adjusted bond yields are up to June 2004.

In Table 1, we report the descriptive statistics of government bond yields, both nominal bond yields and exchange rate-adjusted bond yields, in Japan, Germany, the UK and the US. Japan has the lowest average return both in the nominal term and after the exchange rate adjustment is made. Before the exchange rate adjustment, Germany has the lowest standard deviation. The standard deviation of Japan is the second lowest and quite close to that of the US and the UK. When the exchange rate adjustment is made, the bond yields of Germany, the UK and the US become more volatile. It is because the relatively large fluctuations of exchange rates are incorporated in the volatility of the bond yields. When the exchange rate effect is taken into account, the bond yield of Japan is more stable than that of other countries.

The bubble economy of Japan collapsed in 1990. Figure 1 shows the nominal GDP and real GDP growth from 1980 to 2004. In Figure 1, we find that the growth rate of both nominal and real GDP starts to decline dramatically after 1990. To examine whether the linkage of government bond yields change after the change in macro-economic environment in 1990, we divide the whole sample into two sub-samples. The first sub-sample covers the period from January 1980 to December 1990 and the second sub-sample from January1990 to December 2004 (June 2004 for exchange rate-adjusted bond yields).

The summary statistics of government bond yields in Japan, Germany, the UK and the US during the two sub-samples are reported in Panel B and C of Table 1. For the

[4] Exchange rates are market rates, expressed by national currency per. They are from IFS line AE.ZF.

first period, the average nominal bond yields are much higher than those of the exchange rate-adjusted bond yields, which means that the Japanese yen appreciated significantly against other currencies during this period. The standard deviation of the exchange rate-adjusted bond yield is greater than that of nominal yield, which means that the volatility of the exchange rate against the Japanese yen is much higher than that of the bond return in Germany, the UK and the US. For the second period, the difference between the nominal and exchange rate-adjusted yields becomes much smaller, implying that the yen became stable in its value against other currencies during this period. But the nominal yields are still higher than exchange rate-adjusted yields. The volatility of exchange rate-adjusted yields are still higher than those of nominal yields.

The average nominal government bond yields are much lower during the period after 1990 than the period before 1990, especially in Japan. However, the average exchange rate-adjusted bond yields are much higher after 1990, except in the US. The increase in the exchange rate-adjusted bond yields of Germany and the UK is caused by the depreciation of the yen against the euro and the UK pound. The lower exchange rate-adjusted yields in the US after 1990 are due to the appreciated yen against the US dollar. After 1990, nominal yields become more volatile in Germany and the UK, and less volatile than those in Japan and the US. The exchange rate-adjusted yields of the UK become more volatile, while the exchange rate-adjusted yield of the US becomes less volatile. More volatile exchange rate-adjusted yields of the UK come from more volatile nominal yield and exchange rate.

The exchange rate-adjusted yield of the US becomes more stable both because of the less volatile nominal bond return and because of the more stable yen-dollar rate. The

volatility of the adjusted yield of Germany after 1990 is almost the same as that before 1990. This happens because the stable currency value of Germany reduced the volatility of the nominal yield. On the whole, the volatility of bond yields does not change much across the two periods.

III. Empirical Results

As a pre-test we conducted augmented Dickey-Fuller test to examine the stationarity of each individual series. The null hypothesis is that there is one unit root. We find that there is one unit root for nominal yield at the 5% significant level. For the exchange rate-adjusted yield, there is one unit root for Japan and the UK, but no unit root for Germany and the US at the 5% significant level.

Nominal Government Bond Yields

We perform the Johansen trace test for the whole sample to see whether there is a cointegration relationship between nominal bond yields across countries. The results of the trace test, not reported here for space, indicate no cointegration relationship at the 5% significant level, providing evidence that no long-run relationship exists among the long-term government bond yields of Japan, Germany, the UK and the US.

The lack of cointegration justifies the VAR model to be used to investigate the relationship among government bond yields of the four countries in investigation. So we apply an unrestricted VAR model to the bond yield data of Japan, Germany, the UK and the US. We choose 2 lags for both nominal bond yields and exchange rate-adjusted yields after applying the Akaike information criterion for the choice of the optimal number of lags. Table 2 reports the result of the VAR estimation. We find that the nominal bond

yield of Japan is mainly associated with the past history of its own market and the US bond market. Although the Japan bond market is relatively independent, it seems to have a significant influence on the bond market in the European area. The US market is affected little by the Japanese market.

To check whether there are causal relationships among national bond markets more systematically, we conduct the Granger causality test. The null hypothesis is that the independent variable does not Granger cause the dependent variable. The result of causality test is shown in Table 3. The results of the causality test on nominal bond yields across countries estimates show that Japan is influenced only by the US, and it influences both Germany and the UK. The lack of causal relations from and to Japan is more precisely shown for exchange rate-adjusted bond yields. The Granger causal relationships of the four markets are visualized in Figure 2.

Granger causality only shows the causal relationship between the nominal bond yields. It does not measure the magnitude, the speed, nor dynamics of the influence. So we undertake variance decomposition to investigate the relative importance of Germany, the UK and the US to Japan and that of Japan to the other three markets in explaining variances of bond yields. The result of 12 month forecast error variance decomposition is provided in Table 4. Our result is similar to that of Yang (2005), showing that Japan market seems to be relatively exogenous. Germany, the UK and the US have little impact on Japan. The US accounts for the largest proportion of the forecast error variance of Japan, which is only 3%. However, Japan can explain the significant portion of the changes of Germany (42%), the UK (26%), and the US (14%). This result is similar to that of causality tests. Japan has the lowest bond return among these four markets.

Therefore, Japanese investors may invest their funds into foreign bond markets. It helps to explain why Japan has a substantial influence on the other three markets which do not affect the Japan market.

To get more insight into the dynamic linkage of the Japan bond yields and the bond yields of Germany, the UK and the US, we conduct impulse response function (IRF) analysis and investigate the response of the bond yield in a country to shocks from other national markets.[5] Figure 3 reports the result of the IRF analysis. In Panel A, the Japanese nominal bond return is shown to be affected mainly by its own shock. Shocks from Germany, the UK and the US only have trivial influence on Japan. However, all the other three markets have significant responses to shocks from Japan. The response of Germany to shocks from Japan is even greater than the response to shocks from its own.

From empirical analysis of nominal government bond yields of Japan, Germany, the UK and the US, we find overall that the Japanese bond yields are quite exogenous. The Japanese bond market is mostly affected by its own market. Other foreign bond markets have little impact on the Japanese bond market. At the same time, Japan imposes a substantial and persistent influence on the bond yields in Germany, the UK, and the US.

Exchange Rate-adjusted Government Bond yields

We also examine the linkage of cross-country government bond yields from Japanese investors' viewpoint by using the exchange rate-adjusted bond yields, as explained in the earlier section. So we transform the data into Japanese yen denominated bond return using the following equation.

[5] We applied the triangular orthogonalization of the innovation matrix with Cholesky decomposition to interpret the contemporaneous correlation matrix properly.

$$i_y = i_f + \frac{e_y^e - e_y}{e_y}(1 + i_f),$$

where i_y is the unhedged bond yield in the Japanese yen, i_f is the bond yield in other currencies, e_y is the units of the Japanese yen per unit of foreign currency, e_y^e is the expected exchange rate of the yen against other currencies. Here we assume that the expectation is perfect- foresight. Thus the expected exchange rate for a year horizon is the exchange rate of the same month of the next year. We derive exchange rate of the Japanese yen against other currencies by dividing the yen-dollar rate by the exchange rate against the US dollar.

Germany started to adopt the euro in January 1999, replacing the Deutsche mark. Accordingly, we use the units of the Japanese yen per unit of the euro as the exchange rate for Germany since 1999. The expected exchange rates of the Japanese yen against the Deutsch mark for 1999 are derived by dividing the yen-euro rate by the fixed exchange rate between the Deutsch mark and the euro (1 euro=1.95583 Deutsche mark), which was set when the euro was introduced in January 1999.

Since there is no unit root for Germany and the US, we apply the VAR model to the exchange rate-adjusted bond yields. The result is shown in Table 5. The exchange rate-adjusted bond yields in Japan are affected only by its own market. Only the bond yield in the UK is influenced by that in Japan. Germany and the US are not affected by Japan. Compared with the nominal bond yield case, the exchange rate-adjusted bond yields in Japan are shown to be a lot more independent. We apply the Granger causality test to exchange rate-adjusted bond yields. The result is reported in Table 6. Japan does not Granger cause any other market, nor is it Granger caused by any other markets at the

5% significant level. These Granger causal relationships are visualized in Panel B of Figure 2. The line of dashed arrow denotes significant at the 10% level.

We conduct 12 month forecast error variance decomposition for the exchange rate-adjusted bond yields in the four national bond markets. As reported in Table 7, the forecast error of Japan is mainly explained by it own market (over 99%). The UK, the US and Germany only have a trivial influence on Japan. Unlike the nominal bond yield, the exchange rate-adjusted bond yield of Japan has very little power in explaining the forecast error of Germany, the UK, and the US.

We also use impulse response function (IRF) analysis to investigate the dynamic relationships between the exchange rate-adjusted bond yields in the national bond markets. Panel B of Figure 3 reports the result. The Japanese bond yield is still mainly affected by its own shocks, and shocks from Germany, the UK and the US only have a trivial influence on Japan. Although the bond yields of the UK and the US seem to respond to the shocks from Japan, but the effect is not very evident.

In summary, when exchange rate fluctuation is taken into account, our empirical investigation shows that the bond yield in Japan becomes more independent of the bond yields in the other foreign bond markets. Its influence on the other national markets is weakened significantly.

IV. Sub-sample study: '80s vs. '90s

The Japanese economy slowed dramatically after the "bubble economy" collapsed in early 1990. To investigate whether the burst of the bubble in Japan has any impact on the linkage of Japanese bond market and government bond markets of other countries, we divide the sample into two sub-samples, the period before 1990 and the period after 1990.

For each sample we try to find out whether the bond yield of Japan affects that of other countries or whether it is affected by the bond yields of other countries, nominal bond yields as well as exchange rate-adjusted bond yields.

The Period before 1990

We apply unit root tests and find that there is one unit root for both nominal and exchange rate-adjusted bond yields of all the four countries at the 5% significance level. None of the series is shown to be stationary. We then use the Johansen trace test to check whether there is a long-run trend among the bond yields in the four national markets. The test statistics show that there is no conintegration for nominal bond yields at the 5% level. So there is no long-run relationship among the nominal bond yields across countries. For the exchange rate-adjusted bond yield, there is one cointegration equation at the 5% level, which indicates that there is a long-run relationship among the exchange rate-adjusted bond yields across countries.

Since there is no long-run trend among nominal bond yields, we use the VAR model to examine the pattern of interaction between the Japanese bond yields and the bond yields of Germany, the UK and the US. Panel A of Table 8 reports the result of the VAR analysis. The result shows that the nominal government bond yield of Japan is affected only by its own market and the US bond market during the pre-1990 collapse period. Compared with the whole sample, the impact of the US is less significant for the period of 1980-1990 (5%) than for 1980-2000 (1%). However, the Japanese bond market affects the bond yields of all other countries except the US.

We use the Granger causality test to investigate whether the bond yields of Germany, the UK and the US have an explanatory power on the bond yield of Japan. The

result is shown in Table 9. The Japanese bond yield is not Granger caused by the bond yields of other countries at the 5% significance level, but it is Granger caused by the US bond yield at 10% level. The bond yields of Germany and the UK are Granger caused by the Japanese bond yields at the 5% level. The Granger causal relationship among the four markets is illustrated in Figure 4. The line of solid arrow represents the significance at the 5% level, while the line of dashed arrow represents the significance at the 10% level.

To get the relative magnitude of the influence of Japan on the other countries and that of other countries on Japan, we conduct forecast error variance decomposition. The result is shown in Table 10. The forecast error variance of Japan is mostly explained by itself and the explanatory power becomes smaller over time. The US has the highest explanatory power from the second to the sixth month and Germany has the highest power for the seventh to the twelfth month among the other countries. The UK has little explanatory power on Japan. Japan has significant power to explain the forecast error variance of Germany and the UK. But Japan has the lowest explanatory power on the US. This result is quite similar as that of the whole sample. But the explanatory power of Japan becomes smaller for the period of 1980-1990.

Then we investigate the dynamic pattern of innovation transmission across the countries by identifying the impact of shocks from each market on the other three national bond markets. We apply impulse response function (IRF) analysis using the VAR model. The results are not shown here to save space. The evidence shows that the Japanese bond yield is affected most by shocks from its own market. The reaction of Japan to shocks from the UK and the US is evident. The response of Japan to shocks from Germany is increasing over time. But the influence of shocks from Germany is

smaller than that from Japan. The other three markets react significantly to shocks from Japan. The result for the period of 1980-1990 is consistent with that for the whole sample. Although Japanese government bond market is not affected by the other markets except the US, it can significantly influence the government bond yields in Germany, the UK and the US.

Since we find evidence that there is one cointegration equation for the four exchange rate-adjusted yields at the national bond markets, it is more appropriate to use the vector error correction (VEC) model. Panel A of Table 11 shows the result. For Japan, the error correction term is not significant. So there is no error correction effect. The significant coefficient of Japan in other three equations indicates that the change in the bond yield in Japan affects the bond yields in Germany, the UK and the US. The effect is positive, which means that Japanese bond yields and those of other three countries move in the same direction. Bond yields in Japan are not affected by those in any other markets. We also implement Granger causality tests to check Granger causal relationships between exchange rate-adjusted bond yields across countries. The result is shown in Panel A of Table 12 and Figure 4B. Japan does not Granger cause any other markets nor is it Granger caused by any other markets.

To get the cross-country influence of shocks on bond yields, we conduct impulse response function (IRF) analysis for the exchange rate-adjusted bond yields. The results, not reported, show that the absolute value of the response of Germany, the UK and the US to shocks from Japan excesses that of Japan to its own shocks, which means that the shocks from Japan have more impact on the other three markets than on itself. The response of Japan to shocks from the other three markets is negligible. Shocks from the

other three markets have no impact on the bond yield in Japan. This result is similar to that of the whole sample, The Japanese bond yield becomes more independent when the exchange rate effect is taken into account. The difference is that Japan still affects the other three markets, while for the whole sample Japan has no impact on the other markets when the bond yield is adjusted by the exchange rate effect.

The Period after 1990

The unit root test shows that there is one unit root for all nominal bond yields (very weak for Japan) and for exchange rate-adjusted bond yields in all the four national bond markets. The Johansen trace test shows that there are two cointegration equations for nominal bond yields and no cointegration for exchange rate-adjusted bond yields. So we implement the vector error correction (VEC) model to nominal bond yields. The result (Panel B of Table 8) shows that the error correction term of Japan is not significant, which suggests the lack of the error correction mechanism toward the long-run equilibrium level in the Japanese bond market during the period after 1990. The result also shows that the change in the bond yield of Japan can affect and is affected by that of the US. The Granger causality test applied to the nominal bond yield (Panel B of Table 9 and Figure 4') shows that Japan Granger causes Germany, the UK and the US at the 5% significance level, and Japan is Granger caused by the US at the 10% level.

We also conduct impulse response function (IRF) analysis for the nominal bond yields for the post-1990 period. The results, not reported, show that the response of Japan to its own shocks is larger than those of the other three countries. The response of Japan to shocks from other countries turns out to be trivial. The reaction of other countries to shocks from Japan is quite evident. The response of Germany to shocks from

Japan is even greater than to that from its own. The nominal bond yield in Japan is only influenced by that in the US after 1990, which is different from the result of the whole sample and that of the period before 1990. On the whole sample and during the period before 1990, Japan is also affected by itself. After 1990 Japan does not affect any other countries except the US. However, Germany, the UK and the US still respond to shocks from Japan, but their reactions are smaller.

Since there is no cointegration, we use the VAR model for the exchange rate-adjusted bond yields. Panel B of Table 11 gives the result. Japan is affected by its own market and it does not affect the other three markets either. This is quite similar to the result of the whole sample, but it is different from the results for the period before 1990. Before 1990, Japan affects the other three countries. The Granger causality test (Panel B, Table 12) shows that there is no Granger causal relationship among exchange rate-adjusted bond yields across countries during the period from 1991 to 2004. The 12-month forecast error variance decomposition (Table 13) points out that the explanatory power of Japan on the variance of the other three countries is very small. The forecast error variance of Japan is mostly explained by itself. The results of the Granger causality test and variance decomposition analysis also show that the linkage among Japan, Germany, the UK and the US government bond markets is very weak. The implement impulse response function (IRF) analysis is conducted to investigate the effects of shocks, domestic and foreign, on the exchange rate-adjusted bond yields. The results show that Japan does not react significantly to shocks from the other three countries. The reaction of other countries to shocks from Japan is also very small.

This result is quite similar to the result of the whole sample. When the exchange rate effect is taken into account, Japan becomes more independent. After 1990, the exchange rate-adjusted government bond yield of Japan does not influence those of Germany, the UK and the US. Overall there is consistent evidence that the role of Japan in international government bond markets has been eroded further after the burst of the bubble in 1990.

V. Conclusion

In this paper we examined the linkage between long-term government bond yields of Japan and those of other industrialized countries - Germany, the UK and the US. We examined both nominal bond yields and exchange rate-adjusted bond yields during the period from 1990 to 2004. We find that the nominal bond yield of Japan affects those of Germany and the UK and it is influenced only by itself and that of the US. When the exchange rate effect is taken into account, the bond yield of Japan becomes more independent of those of other countries. It is not influenced by any other countries and it does not affect any other countries except the UK.

The bubble economy of Japan collapsed in 1990. After the burst of the bubble, the economic growth slowed down dramatically. To find out whether the linkage between the Japanese bond yields and those of the other three countries changed after 1990, we investigated the relationship between the bond yields of the two periods separately. This paper provides evidence that Japan's position as a major international bond market seems to have declined further in the 1990s. As is found for the whole sample, the nominal bond yield of Japan is still influenced by the US, and it affects Germany and the UK before 1990. When the exchange rate effect is added into the picture, the Japanese bond

yield is not affected by the bond yield of any country. But the exchange rate-adjusted bond yield in Japan still influences the bond yields of Germany, the UK and the US. The Japanese government bond yield becomes more independent when the exchange rate effect is taken into account. After the burst of the bubble in early 1990, the nominal bond yield of Japan is only related to that of the US and the exchange rate-adjusted bond yield is not related to any other markets. The influence of Japan on the other three markets is evidenced to have been weakened significantly for both nominal and exchange rate-adjusted bond yields since 1990.

In conclusion, this paper provides consistent empirical evidence that the Japanese bond market is independent of other major national bond markets in determining its long-term bond yields, both nominal yields and exchange rate-adjusted bond yields, but it exerts some influence in determining bond yields in other major national bond markets. However, since the early 1990, the independence of the Japanese bond market has increased, while its leading role in global bond markets has been eroded significantly.

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Table 1: Summary statistics of government bond yields (percentage)

	Nominal bond yields		Exchange rate-adjusted bond yields	
	Average	Standard deviation	Average	Standard deviation
Panel A. Whole sample period: 1980-2004				
Japan	4.30	2.62	4.35	2.62
Germany	6.47	1.81	4.86	12.78
UK	8.59	2.95	5.22	12.98
US	7.86	2.83	5.55	13.57
Panel B: Subsample period I: 1980-1990				
Japan	6.58	1.73	6.58	1.73
Germany	7.65	1.45	4.36	12.80
UK	11.14	1.88	3.98	11.57
US	10.41	2.19	6.42	15.08
Panel C: Subsample period II: 1991-2004				
Japan	2.51	1.62	2.54	1.64
Germany	5.54	1.50	5.28	12.79
UK	6.59	1.91	6.23	13.97
US	5.86	1.17	4.85	12.20

Table 2: VAR model estimation results for nominal bond yields

	Japan	Germany	UK	US
Japan_1	1.04 (16.79)***	0.19 (4.26)***	0.20 (3.35)***	0.07 (1.01)
Japan_2	-0.07 (-1.11)	-0.15 (-3.32)***	-0.16 (-2.74)***	-0.04 (-0.58)
Germany_1	0.01 (0.10)	1.11 (17.48)***	-0.01 (-0.08)	-0.20 (-1.89)*
Germany_2	-0.02 (-0.24)	-0.16 (-2.47)**	0.02 (0.21)	0.17 (1.58)
UK_1	-0.00 (0.00)	0.07 (1.47)	1.21 (18.53)***	0.03 (0.42)
UK_2	0.01 (0.22)	-0.07 (-1.5)	-0.26 (-4.00)***	-0.02 (-0.19)
US_1	0.16 (2.82)***	0.13 (3.20)***	-0.01 (-0.25)	1.32 (19.22)***
US_2	-0.15 (-2.67)***	-0.14 (-3.42)***	0.02 (0.28)	-0.36 (-5.24)***
Constant	-0.03 (-0.25)	0.20 (2.74)***	0.13 (1.28)	0.19 (1.59)

Numbers in parentheses are t-statistics. *** denotes significance at the 1% level. ** denotes significance at the 5% level. * denotes significance at the 10% level.

Table 3: Granger causality test for nominal bond yields

Dependent variable	Independent variable			
	Japan	Germany	UK	US
Japan	-	1.35 (0.26)	1.59 (0.21)	6.48 (0.00)
Germany	15.64 (0.00)	-	5.64 (0.00)	11.92 (0.00)
UK	7.86 (0.00)	1.13 (0.33)	-	0.61 (0.55)
US	1.21 (0.30)	1.30 (0.27)	1.09 (0.34)	-

The test statistics is F-statistics. The numbers in parentheses are p-values.

Table 4: Variance decomposition of nominal bond yields (percentage)

Period	S.E.	Japan	Germany	UK	US
			Variance decomposition of Japan		
1	0.28	100.00	0.00	0.00	0.00
2	0.42	98.42	0.36	0.15	1.07
3	0.52	97.02	0.52	0.39	2.07
4	0.61	96.09	0.57	0.62	2.73
8	0.85	94.33	0. 50	1.53	3.65
12	1.01	93.21	0.41	2.50	3.88
			Variance decomposition of Germany		
1	0.20	8.25	91.75	0.00	0.00
2	0.33	18.10	80.03	0.82	1.05
3	0.45	23.38	73.07	1.45	2.10
4	0.54	26.83	68.64	1.81	2.73
8	0.76	35.72	59.04	2.17	3.08
12	0.90	42.30	52.83	2.18	2.69
			Variance decomposition of UK		
1	0.27	4.23	11.46	84.31	0.00
2	0.43	9.48	10.55	79.96	0.01
3	0.56	12.67	10.45	76.87	0.01
4	0.66	14.97	10.50	74.49	0.03
8	0.93	21.38	10.69	67.65	0.27
12	1.12	26.42	10.60	62.41	0.57
			Variance decomposition of US		
1	0.33	8.74	18.48	9.08	63.70
2	0.54	9.96	14.85	10.06	65.13
3	0.70	10.44	12.91	10.70	65.96
4	0.82	10.80	11.70	11.22	66.29
8	1.12	12.43	9.22	13.13	65.22
12	1.31	14.20	7.89	14.87	63.04

Table 5: VAR for exchange rate-adjusted bond yields

	Japan	Germany	UK	US
Japan_1	1.12 (19.15)***	1.20 (1.33)	1.81(1.89)*	1.45 (1.50)
Japan_2	-0.13 (-2.21)**	-1.29 (-1.43)	-2.01 (-2.09)**	-1.47 (-1.51)
Germany_1	0.01 (1.04)	0.95 (11.46)***	-0.15 (-1.73)*	-0.15 (-1.68)*
Germany_2	-0.01 (-1.26)	-0.02(-0.26)	0.17 (1.92)*	0.10 (1.11)
UK_1	-0.01 (-0.95)	-0.01 (-0.10)	1.06 (12.11)***	0.08 (0.89)
UK_2	0.01 (1.12)	-0.05 (-0.58)	-0.21(-2.43)**	-0.12 (-1.36)
US_1	-0.00 (-0.54)	0.12 (1.76)*	0.08 (1.06)	1.00 (13.43)***
US_2	0.00 (0.56)	-0.05 (-0.75)	0.01 (0.07)	-0.02 (-0.23)
Constant	0.03 (0.75)	0.77 (1.37)	1.23 (2.06)**	0.74 (1.22)

Numbers in parentheses are t-statistics. *** denotes significance at the 1% level. ** denotes significance at the 5% level. * denotes significance at the 10% level.

Table 6: Granger causality tests for exchange rate-adjusted bond yields

	Independent variable			
Dependent variable	Japan	Germany	UK	US
Japan	-	0.08 (0.92)	0.37 (0.69)	0.28 (0.76)
Germany	0.50 (0.61)	-	0.36 (0.70)	3.09 (0.05)
UK	1.69 (0.19)	1.11 (0.33)	-	2.59 (0.08)
US	1.22 (0.30)	4.07 (0.02)	3.02 (0.05)	-

The test statistics is F-statistics. The numbers in parentheses are p-values.

Table 7: Variance decomposition of exchange rate-adjusted bond yields (percentage)

Period	S.E.	Japan	Germany	UK	US
			Variance decomposition of Japan		
1	0.29	100.00	0.00	0.00	0.00
2	0.43	99.72	0.00	0.23	0.05
3	0.54	99.63	0.01	0.31	0.06
4	0.62	99.64	0.00	0.30	0.06
8	0.88	99.75	0.02	0.17	0.06
12	1.05	99.69	0.08	0.17	0.06
			Variance decomposition of Germany		
1	4.43	0.18	99.82	0.00	0.00
2	6.31	0.65	98.75	0.06	0.53
3	7.56	0.85	97.90	0.06	1.20
4	8.46	0.88	97.06	0.05	2.02
8	10.49	0.70	92.89	0.17	6.24
12	11.36	0.61	88.45	0.41	10.53
			Variance decomposition of UK		
1	4.71	0.06	48.44	51.50	0.00
2	6.70	0.77	43.44	55.59	0.20
3	7.96	1.03	42.08	56.29	0.60
4	8.84	1.04	41.81	55.87	1.28
8	10.76	0.78	41.31	51.94	5.96
12	11.62	0.85	39.41	48.27	11.47
			Variance decomposition of US		
1	4.75	0.72	24.46	10.66	64.15
2	6.63	0.37	21.10	12.92	65.62
3	7.88	0.26	18.58	13.30	67.85
4	8.82	0.21	16.56	13.12	70.11
8	11.07	0.20	11.47	11.73	76.61
12	12.18	0.26	9.77	10.77	79.19

Table 8: VAR for nominal bond yields for subsample periods: '80s vs '90s

	Japan	Germany	UK	US
A. The VAR model for 1980-1990:				
Japan_1	1.00 (10.06)***	0.19 (2.89) ***	0.19 (1.97)**	-0.02 (-0.17)
Japan_2	-0.08 (-0.76)	-0.17 (-2.56)**	-0.18 (-1.80)*	0.01 (0.05)
Germany_1	0.03 (0.22)	1.06 (11.52)***	0.01 (0.08)	-0.20 (-1.17)
Germany_2	0.05 (0.35)	-0.09 (-0.94)	0.06 (0.44)	0.26 (1.46)
UK_1	-0.02 (-0.23)	-0.07 (0.98)	1.17 (11.90)***	-0.08 (-0.06)
UK_2	0.01 (0.12)	-0.06 (-0.99)	-0.26 (-2.74)***	0.09 (0.73)
US_1	0.17 (2.09)**	0.17 (3.03)***	0.02 (0.25)	1.39 (13.37)***
US_2	-0.18 (-2.13)**	-0.19 (-3.37)***	-0.03 (-0.34)	-0.45 (-4.25)***
Constant	0.07 (0.35)	0.26 (1.85)*	0.36 (1.76)*	0.17 (0.66)
B. The VEC model for 1991-2004				
Error Correction Term	-0.03	0.08***	0.03	0.04*
Japan	0.10	0.09	0.11	0.17**
Germany	0.05	0.21**	0.01	-0.27**
UK	-0.10	0.13	0.25**	0.36***
US	0.21**	-0.07	-0.13	0.16
Constant	-0.02	-0.02	-0.02	-0.01

Numbers in parentheses are t-statistics. *** denotes significance at the 1% level. ** denotes significance at the 5% level. * denotes significance at the 10% level.

Table 9. Granger causality tests for nominal bond yields for sub-sample periods: '80s vs '90s

Dependent variable	Independent variable			
	Japan	Germany	UK	US
Panel A. 1980-1990				
Japan	-	1.70 (0.19)	0.61 (0.54)	2.91 (0.06)
Germany	6.90 (0.00)	-	3.05 (0.05)	10.7 (0.00)
UK	3.53 (0.03)	2.32 (0.10)	-	0.43 (0.65)
US	0.25 (0.78)	1.71 (0.19)	0.67 (0.52)	-
Panel B. 1991-2004				
Japan	-	0.85 (0.43)	0.23 (0.80)	2.87 (0.06)
Germany	9.08 (0.00)	-	0.28 (0.76)	2.59 (0.08)
UK	3.06 (0.05)	0.47 (0.63)	-	0.47 (0.63)
US	4.37 (0.01)	0.09 (0.91)	3.46 (0.03)	-

The test statistics is F-statistics. The numbers in parentheses are p-values.

Table 10. Variance decomposition of nominal bond yields 1980-1990 (percentage)

		Japan	Germany	UK	US
Period	S.E.		Variance decomposition of Japan		
1	0.35	100.00	0.00	0.00	0.00
2	0.51	98.09	0.44	0.14	1.33
3	0.63	96.27	0.99	0.19	2.55
4	0.72	94.93	1.64	0.20	3.24
8	0.97	91.18	5.25	0.15	3.42
12	1.14	87.72	9.48	0.11	2.68
			Variance decomposition of Germany		
1	0.23	15.09	84.91	0.00	0.00
2	0.40	27.46	69.15	1.37	2.02
3	0.54	31.36	62.80	2.04	3.81
4	0.64	32.84	60.43	2.17	4.56
8	0.91	35.23	59.59	1.68	3.50
12	1.09	36.66	59.49	1.21	2.64
			Variance decomposition of UK		
1	0.34	4.65	3.66	91.69	0.00
2	0.55	10.13	3.72	86.13	0.02
3	0.69	13.27	4.46	82.18	0.10
4	0.80	15.44	5.52	78.83	0.20
8	1.07	21.29	11.37	66.92	0.43
12	1.24	25.42	17.60	56.61	0.37
			Variance decomposition of US		
1	0.44	11.14	14.76	12.41	61.70
2	0.72	9.77	12.02	11.32	66.88
3	0.92	8.40	11.22	10.59	69.79
4	1.07	7.55	11.19	10.22	71.04
8	1.44	6.85	13.40	10.47	69.28
12	1.65	7.60	16.53	11.06	64.81

Table 11. VAR for exchange rate-adjusted for sub-sample periods

Panel A. VEC model for 1980-1990

	Dependent Variables			
	Japan	Germany	UK	US
(Independent variables)				
Error correction term	-0.00	-0.69***	-0.74***	-0.46***
Japan	0.13	1.87*	2.317**	2.22*
Germany	0.01	-0.13	-0.27**	-0.15
UK	-0.01	0.11	0.32***	0.22*
US	-0.00	0.01	-0.08	-0.06
Constant	-0.02	0.23	0.14	0.11

Panel B. VAR model for 1991-2004

	Dependent Variables			
	Japan	Germany	UK	US
(Independent variables)				
Japan_1	0.97 (89.11)***	0.19 (0.78)	-0.00 (-0.01)	0.06 (0.25)
Germany_1	-0.00 (-1.12)	0.89 (20.95)***	-0.06 (-1.37)	-0.05 (-1.22)
UK_1	0.00 (0.83)	0.03 (0.59)	0.92 (15.89)***	0.01 (0.25)
US_1	-0.00 (-1.41)	0.03 (0.56)	0.07 (1.30)	0.94 (18.30)***
Constant	0.06 (1.67)	-0.17 (-0.23)	0.52 (0.65)	0.33 (0.44)

Numbers in parentheses are t-statistics. *** denotes significance at the 1% level. ** denotes significance at the 5% level. * denotes significance at the 10% level.

Table 12: Granger causality test for exchange rate-adjusted bond yields for sub-sample periods

Dependent variable	Independent variable			
	Japan	Germany	UK	US
Panel A. 1980-1990				
Japan	-	0.21 (0.81)	0.33 (0.72)	0.66 (0.52)
Germany	0.70 (0.50)	-	2.06 (0.13)	2.54 (0.08)
UK	2.28 (0.11)	3.79 (0.03)	-	2.38 (0.10)
US	1.47 (0.23)	4.12 (0.02)	5.75 (0.00)	-
Panel B. 1991-2004				
Japan	-	0.47 (0.23)	1.02 (0.36)	1.74 (0.18)
Germany	0.03 (0.97)	-	0.61 (0.54)	0.92 (0.40)
UK	0.17 (0.85)	0.90 (0.41)	-	0.76 (0.47)
US	0.03 (0.97)	1.64 (0.20)	0.64 (0.53)	-

The test statistics is F-statistics. The numbers in parentheses are p-values.

Table 13: Variance decomposition of exchange rate-adjusted bond yields 1991-2004 (percentage)

Period	S.E.	Japan	Germany	UK	US
			Variance decomposition of Japan		
1	0.22	100.00	0.00	0.00	0.00
2	0.30	99.72	0.15	0.00	0.13
3	0.36	99.13	0.47	0.00	0.40
4	0.41	98.30	0.91	0.00	0.78
8	0.56	93.45	3.45	0.01	3.09
12	0.66	87.86	6.22	0.06	5.86
			Variance decomposition of Germany		
1	4.71	4.92	95.08	0.00	0.00
2	6.45	5.02	94.89	0.07	0.02
3	7.65	5.11	94.61	0.21	0.07
4	8.56	5.19	94.24	0.43	0.14
8	10.72	5.44	92.20	1.75	0.62
12	11.76	5.58	89.76	3.38	1.28
			Variance decomposition of UK		
1	4.96	1.78	53.24	44.98	0.000
2	6.77	1.65	51.62	46.62	0.11
3	8.03	1.52	50.00	48.13	0.35
4	8.98	1.41	48.40	49.51	0.68
8	11.27	1.05	42.53	53.73	2.69
12	12.44	0.87	37.95	56.16	5.01
			Variance decomposition of US		
1	4.70	0.28	34.83	18.68	46.21
2	6.40	0.25	33.18	19.47	47.10
3	7.55	0.23	31.63	20.20	47.94
4	8.42	0.20	30.18	20.88	48.73
8	10.43	0.14	25.51	22.99	51.36
12	11.36	0.13	22.48	24.24	53.15

Figure 1. GDP growth in Japan (percentage): 1980-2004

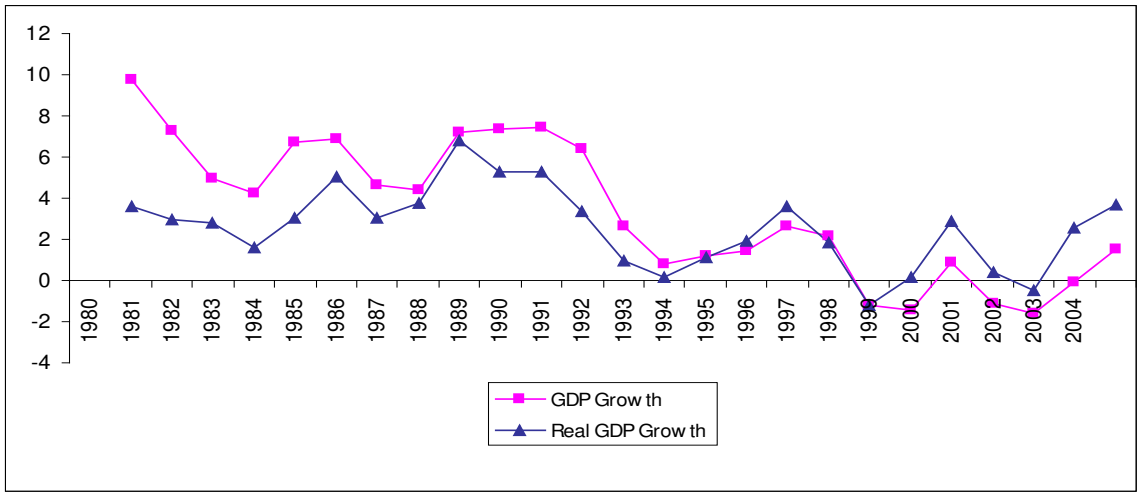
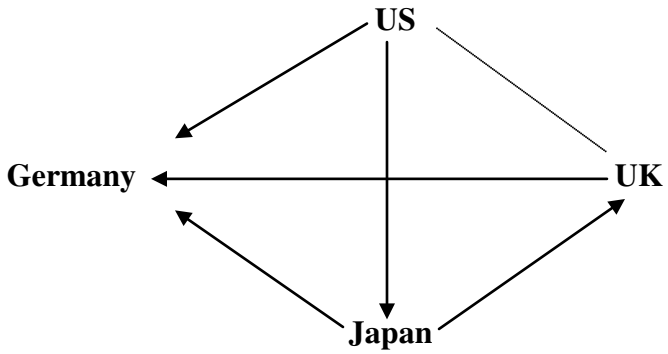


Figure 2. Granger causal relationships between bond yields across countries

A. Nominal bond yields



B. Exchange rate-adjusted bond yields

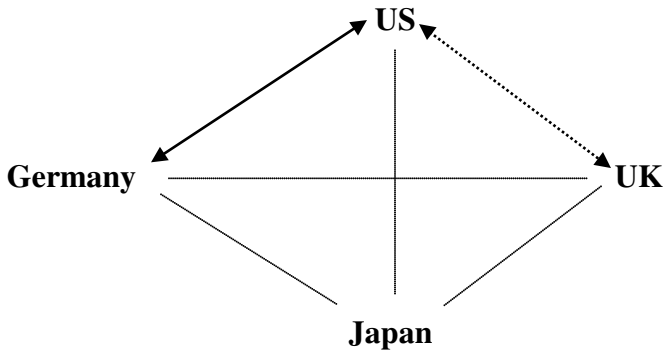
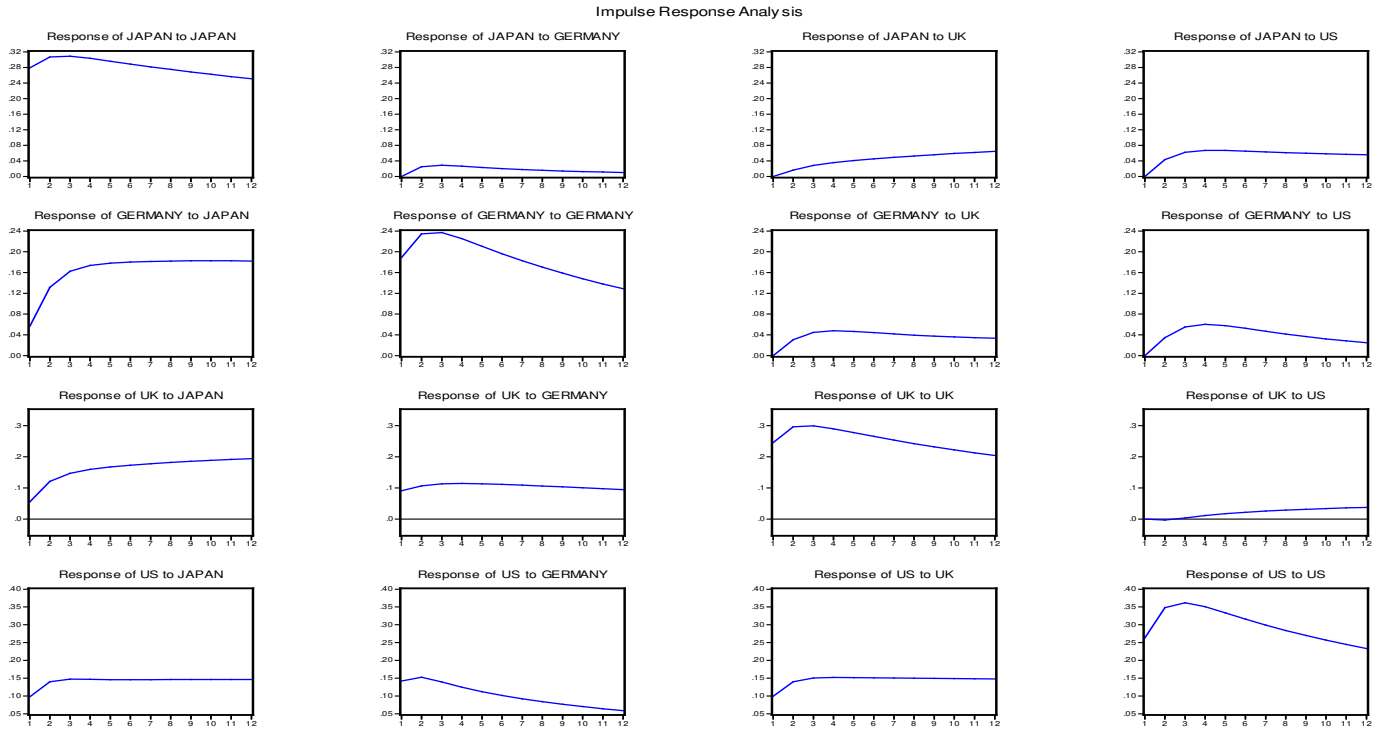


Figure 3. Impulse Response Analysis for bond yields: 1980 – 2004

Panel A. Nominal bond yields



Panel B. Exchange rate-adjusted bond yields

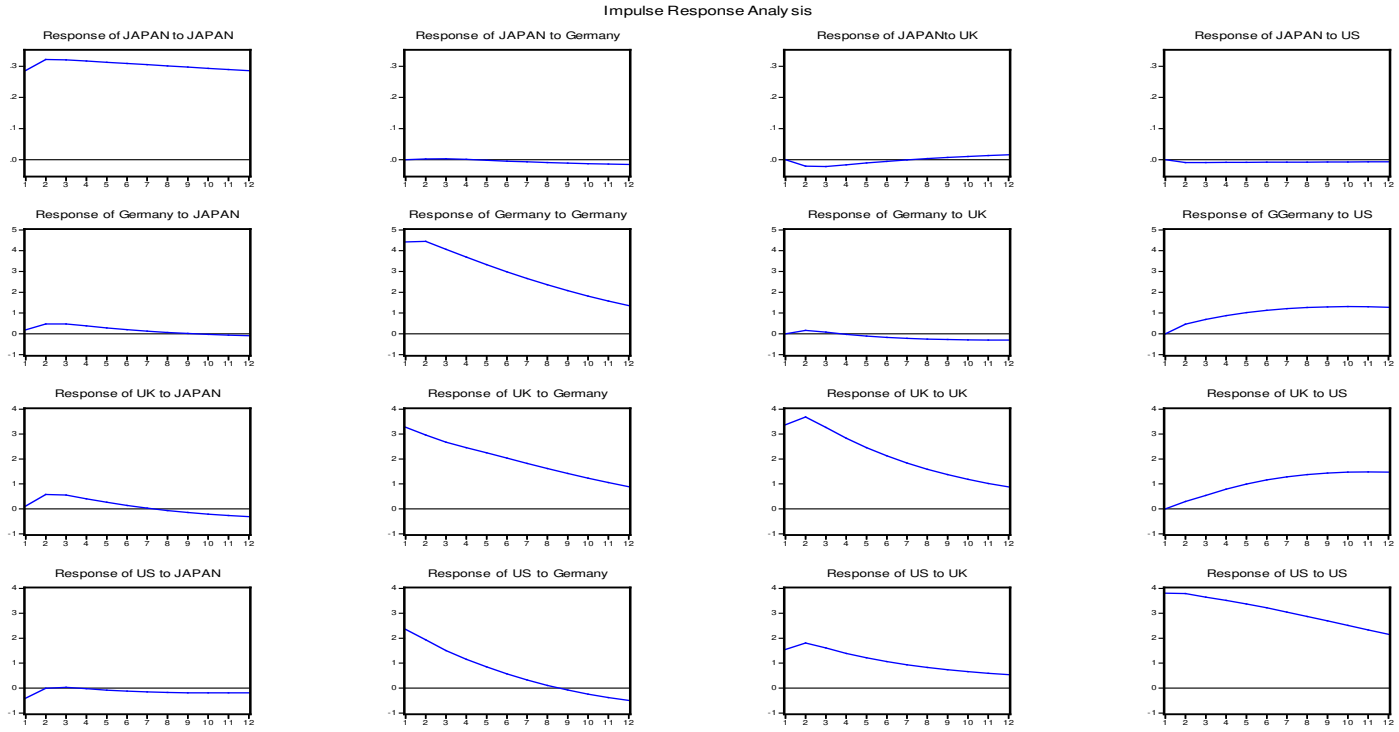
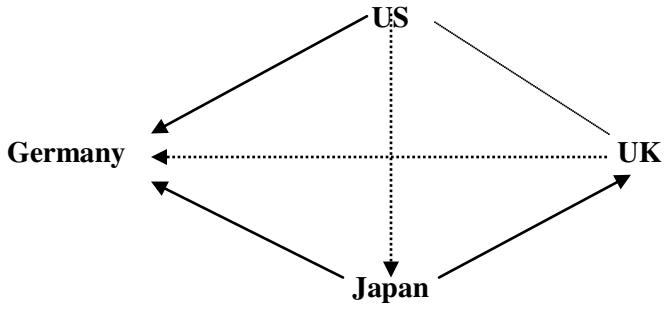


Figure 4. Granger causal relationships between bond yields 1980-1990

A. Nominal bond yields



B. Exchange rate adjusted bond yields

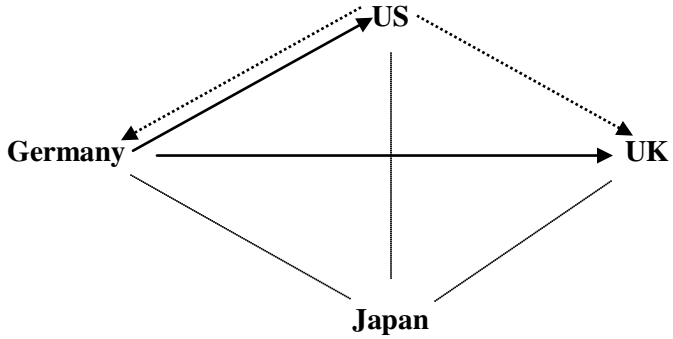


Figure 4'. Granger causal relationship between nominal yields 1991-2004