The International Business Cycle in a Changing World: Volatility and the Propagation of Shocks

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October 2003

Keywords: International business cycles, European integration, time variation, volatility

JEL codes: E32, F02, F43

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This research was partly supported through a European Community Marie Curie Fellowship (programme "Improving Human Research Potential and the Socio-Economic Knowledge Base" IHP-MCFI-99-1), under which the first author was a visitor at the University of Manchester. The first author also acknowledges support from Ministerio de Ciencia y Tecnologia (SEC2002-03375), while the second author gratefully acknowledges financial assistance from the Economic and Social Research Council (UK) under grant number L138251030. This research does not reflect necessarily the views of the funding bodies.

ABSTRACT

This paper examines the changing relationships between the G-7 countries through VAR models for the quarterly growth rates, estimated both over sub-periods and using a rolling data window. Six trivariate models are estimated, all of which include the US and a European (E15) aggregate. In relative terms, the conditional volatility of E15 growth has declined more since 1980 than the well-documented decline for the US. The propagation of shocks has also changed, with the volatility and propagation effects separated by applying shocks of pre-1980 magnitude to VARs estimated over various periods. Rolling estimation reveals that E15 has a steadily increasing impact on the US economy over time, while the effects of the US on Europe have been largest during the 1970s and the late 1990s.

1. Introduction

Understanding the nature of the international business cycle, or (more precisely) the interrelationships over time between the short-term growth rates experienced in different countries of the world, is of obvious importance. However, despite a large literature on this topic, most studies make the implicit assumption that these interrelationships have not changed during the postwar period.

There are, however, two specific contexts where the assumption of constancy has been challenged. One context is that of European integration, where a number of studies document changes in the cross-correlations between European countries themselves and between these countries and the US; see, for example, Artis and Zhang (1997, 1999), Inklaar and de Haan (2001), Perez, Osborn and Sensier (2003). In other words, the process of European integration might be expected to alter the dynamics and the strength of the relationships between individual countries of the European Union and also between these countries and the rest of the world. The second context where change is now well documented is a step decrease in the volatility of output growth, which has been established particularly for the US (Kim and Nelson, 1999, McConnell and Perez-Quros, 2000), while van Dijk, Osborn and Sensier (2002) show that volatility changes are widespread across all G-7 countries.

Despite this evidence of changes in both the dynamics of international relationships, at least in the context of European countries, and also in the volatility of shocks, few studies take an explicitly time-varying approach to the study of the international business cycle. The purpose of the present paper is to focus on the nature of changes over time, allowing both the dynamic interrelationships and the volatility of shocks to change. The structure of the paper is as follows. Section 2 discusses previous studies and how this paper contributes to the literature, before Section 3 explains the econometric methodology we employ. The following two sections then discuss our results in terms of the changing volatilities of shocks (Section 4) and whether the transmission of shocks has changed (Section 5). Some conclusions complete the paper.

2. The Analysis of International and European Business Cycles

Previous studies take a variety of approaches to modelling changes in the international business cycle. However, those with a particular focus on Europe are frequently based on cross-correlation analysis, typically comparing correlations of individual European countries with movements in real activity in the US and Germany over various data sub-periods (Artis and Zhang, 1997, 1999, Inklaar and de Haan 2001, Perez *et al*., 2003). The sub-periods chosen are selected on the basis of important events in the context of European integration that may be expected to alter the relationships among countries. These events include the commencement of the European Monetary System (EMS) in 1979, the decision taken in 1990 to introduce a single European currency, and the signing of the Maastricht Treaty in 1992 confirming the establishment of the European Economic and Monetary Union (EMU) from the beginning of 1999. Artis and Zhang (1997, 1999), Inklaar and de Haan (2001), Perez *et al*. (2003) all use the end of 1979 as a potential break date when modelling European business cycle affiliations, with some also exploring sub-divisions of the period from 1980.

Indeed, Perez *et al*. (2003) find that there was a period in the early 1990s when the US and (some of) Europe were effectively "disconnected", but that short period was sufficiently distinctive that it may dominate the results of analyses over longer periods of time. Their conclusion is that this "disconnection" was a temporary feature, and it may be explained by the substantial disruption of German reunification, the desire of countries to stick with the ERM at unchanged exchange rates and the consequent deviation of fiscal and monetary policies from the norm.

Another group of papers uses multi-country data to examine the broader issue of international business cycle dynamics. Although cross-correlations are sometimes the principal technique used (as, for example, in Doyle and Faust, 2002 and IMF, 2001), other studies adopt multivariate methodologies based on factor modelling (Kose, Otrok and Whiteman, 2003, Forni and Reichlin, 1996, Lumsdaine and Prasad, 2003, Norrbin and Schlagenhauf, 1996, Stock and Watson, 2003, among many others). These papers typically assume that the underlying structure of interrelationships between countries has remained constant over the sample extending from the 1970s or earlier. This contrasts with the studies of European integration, where (as already noted) the nature of changing affiliations has been a principal focus.

Indeed, based on a factor approach Kose *et al* (2003) conclude that no distinctive European factor exists, but that its appearance in studies concerned only with European countries may be due to the omission of "world" shocks. Therefore, it is important to control for "world" influences. Stock and Watson employ a factor-structural VAR model of the G-7 countries, which combines a seven-equation VAR for the dynamic responses across countries with a factor representation for the within-quarter shocks. However, there is a potential problem in terms of degrees of freedom available for analysis over sub-periods when a seven-country VAR is employed. The solution they adopt is to restrict the dynamics to four lags for own country and one for all other countries.

Generally separate from the analysis of international business cycles, a substantial stream of research has recently established that structural breaks in important macroeconomic variables, especially breaks in volatility, are a feature of the postwar period. Such breaks are documented by many authors, including Kim and Nelson (1999), McConnell and Perez-Quiros (2000). Stock and Watson (2002), van Dijk, Osborn and Sensier (2002), with the general finding that volatility in real variables has declined substantially in the period from around 1980. The presence of such breaks obviously renders doubtful the results of any analysis covering a long data period that implicitly assumes constant underlying parameters. Stock and Watson (2003) respond to these structural breaks by conducting much of their analysis over two sub-periods, namely 1960-1983 and 1984-2002, with the choice of the end of 1983 as the break date being based on the finding of a structural break in US output volatility around this time (Kim and Nelson, 1999, McConnell and Perez-Quiros, 2000). In order to disentangle the effects of changes in volatility and changes in synchronisation, Stock and Watson conduct a counterfactual analysis whereby the shock variances of 1960-1983 are applied to their estimated VAR for 1984-2002.

The present paper contributes to this literature in two ways. Firstly, while we consider issues related with European integration we recognise the importance of using a multivariate approach, since European countries do not operate in isolation from the world, in particular, the US. Secondly, we also recognise the potentially important role of structural breaks in volatility, in addition to possible changes in the nature of relationships. Indeed, our analysis has much in common with that of Stock and Watson (2003). Unlike their approach, however, we do not attempt to identify a world factor. Rather, our analysis uses a series of trivariate

VAR systems where the three variables included are output growth[1] for the US, the European aggregate[2] (E15) and an individual G-7 country, namely Germany, France, Italy, UK, Canada or Japan. We use a Cholesky decomposition of the shocks, with the variables ordered as: US, E15, other country. Therefore, any "world" shocks are attributed to the US; similarly, any "European" shocks are attributed to E15. As in Stock and Watson, we use two sub-periods, here 1960-1979 and 1980-2002, with the break selected at the end of 1979 based on the commencement of the EMS, and undertake a counterfactual analysis by applying shocks of the pre-1980 magnitudes to the post-1980 and whole sample models.

Figure 1 shows the series for real quarterly GDP growth used in our analysis. The break in the volatility of many of these series around 1980 is evident. It may also be noted that a number of series contain apparent outliers, especially in the earlier part of the sample. We do not, however, attempt to remove these, since we consider that these are manifestations of the specific sub-periods that comprise our complete sample.

3. Econometric Methodology

Our analysis uses systems of trivariate VAR models, as discussed in the previous section. In effect, by construction, we associate the European factor with the E15 aggregate and hence do not have to identify it separately. Through the VAR models we are then able to examine the relationships of individual countries with this aggregate, including the non-European

[1] The growth rate is defined as the first difference of the log of quarterly real GDP. See Appendix 1 for data definitions and sources.

[2] E15 is an aggregate series for the 15 countries that are members of the European Union. It is, of course, the case that each of Germany, France, Italy and the UK are components of the E15 aggregate. We also experimented with constructing a series of European aggregates with the third country (Germany, France, Italy, UK) omitted from the European aggregate for the corresponding VAR. However, the results were essentially the same as those reported here.

countries of Canada and Japan. We take the US to represent important international influences on the other G-7 countries. This is partly because of the important role of the US during the postwar period, but because of the debate about the role of the US during the 1990s and in the recessions suffered by many European countries in 2001 (for example, Doyle and Faust, 2002, Perez *et al*., 2003). Through the use of trivariate VAR models, we believe that we are able to capture the principal international influences while estimating relatively few parameters. This enables us to use longer lags for international influences compared with Stock and Watson (2003), which we believe may be especially important for European countries in relation to the US (Perez *et* al., 2003).

We estimate a series of VAR(p) models of the form:

$$\Phi(L)\, y_t = u_t, \qquad E(u_t\, u_t') = \Sigma \text{ and } E(u_t\, u_t') = 0,\ s \neq t \tag{1}$$

where y_t = (US_t, $E15_t$, X_t)' with X_t one of Germany, France, Italy, UK, Canada or Japan and $\Phi(L) = I - \Phi_1 L - \ldots - \Phi_p L^p$. In examining the separate influences on each individual country considered, we assume an intra-quarter causal ordering as given by the order of the elements of y_t. As usual in VAR analyses, we implement this causal ordering through the Cholesky decomposition. The Cholesky decomposition forms the lower triangular matrix P with unit diagonal elements, such that

$$P^{-1} \Sigma P'^{-1} = D \tag{2}$$

where D is a diagonal matrix which can be interpreted as the variance-covariance matrix of the orthogonalised (or uncorrelated) innovations $v_t = P^{-1} u_t$, so that $E(v_t\, v_t') = D$.

It is common in VAR analyses to examine the properties of the system (1) through the (cumulated) impulse response function for the orthogonalised innovations, namely

$$R_n = \sum_{i=0}^{n} \Psi_i P D^{0.5} \tag{3}$$

where $\Psi(L) = \Phi^{-1}(L)$. The $(i, j)^{th}$ element of R_n is the total response after n periods of the i^{th} variable of the VAR to a shock equal to one standard error applied to the j^{th} element of v_t. Now, it might be noted that the impulse response functions in (3) depend on three distinct aspects of the VAR, namely the VAR coefficients, $\Phi(L)$, the intra-period responses captured by P (which reflects the causal ordering assumed in the VAR) and the standard errors of the orthogonalised innovations given by the elements of $D^{0.5}$.

To explore the effect of changing volatility on business cycle dynamics, we undertake a counterfactual exercise by applying shocks of the magnitude of the 1960-1979 period to models estimated over other periods. To this end, we denote the diagonal matrix of orthogonal innovation variances for 1960-1979 by D_0. Then, if the VAR parameters for another period are represented by $\Phi(L)$, P and D, we employ (3) replacing D by D_0. In practice, this amounts to a re-scaling of the usual impulse response function, obtained as the $(i, j)^{th}$ element of R_n, by the ratio of the standard errors of the j^{th} shock v_{jt} for 1960-1979 compared to that of the other period. Using these re-scaled impulse responses, we can compare the propagation of shocks over different time periods in isolation from effects directly attributable to the changing volatility of the shocks.

We also employ the usual forecast error variance decomposition. The covariance matrix for the n-step ahead forecast errors, for forecasts made at time t, from the VAR of (1) is

$$E(y_{t+n} - \hat{y}_{t+k})(y_{t+n} - \hat{y}_{t+k})' = \sum_{i=0}^{n} \Psi_i \, PDP' \Psi_i' = \sum_{j=1}^{3} d_j \sum_{i=0}^{n} \Psi_i P \, e_j e_j' \, P' \Psi_i' \qquad (4)$$

where d_j is the j^{th} diagonal element of D and e_j is a (3×1) matrix of zeros except for the j^{th} element which is unity. The final expression in (4) decomposes the n-step error covariance matrix into the components due to each of the orthogonalised shocks, and the diagonal elements of this covariance matrix provide the information for the usual decomposition of the forecast error variances for the VAR. That is, using this information, the separate percentage contribution of each orthogonalised innovation (v_{1t}, v_{2t}, v_{3t}) can be computed in relation to the n-step forecast variance of each element of y_{t+n}.

In an analogous way to our use of the re-scaled impulse response function, we also apply the decomposition of (4) using the 1960-1979 innovation variance matrix D_0 in conjunction with the parameters $\Phi(L)$ and P for other periods. Since the forecast error variance decomposition is reported as a percentage attributable to each orthogonalised shock, v_{jt}, if the variance of all shocks change by the same factor between 1960-1979 and the other period examined, then the decomposition will be unaffected by the change in volatility.

As discussed in the previous section, the commencement of the EMS in1979 is frequently used as a potential break date in the context of changing European affiliations. There are other reasons why this provides a convenient date to define sub-periods for analysis. Due to the oil price shocks of the 1970s, this was a decade of considerable turbulence and high inflation across all G-7 countries, while early in the 1980s (although frequently with a wide confidence band) is now established as a volatility break date for US growth (Kim and Nelson, 1999, McConnell and Perez-Quiros, 2000, Stock and Watson, 2002, van Dijk *et al*., 2002). In response to this, we divide our sample period of 1960 to 2002 into two sub-periods, namely 1960-1979 and 1980-2002. However, both Inklaar and da Haan (2001) and Perez *et al.*(2003) find that affiliations of European countries alter substantially during the later sub-period, and this may also be anticipated from the important events in European integration that have taken place over these decades. In order to abstract from the effects of German reunification, we separately analyse the sub-period 1993-2002. To examine the evolution of relationships over time, a rolling estimation using a window of fixed width is also employed.

The width employed is 36 months, which has been selected so that the final rolling VAR model estimated effectively corresponds to the 1993-2002 sub-period.

Lag lengths of 4 are used for the VARs estimated over the longer sub-periods, while a VAR(2) is used for the 1993-2002 sub-period[3].

4. The Changing Volatility of Shocks

The first issue we examine is the changing volatility of shocks, where this volatility is measured conditional on the estimated VAR models and the ordering adopted in the Cholesky decomposition. However, in order to clarify the impact of the ordering of the variables, volatility measures and correlations are also presented for the (untransformed) VAR residuals.

Table 1 presents the conditional volatility results for the whole sample period and the sub-samples we consider. The column headed σ_e presents the standard errors of the orthogonalised shocks, while the column headed σ_u presents those for the residuals. Various relative volatility measures are also presented, namely volatilities (standard errors for residuals or orthogonalised shocks) expressed in relation to the baseline sub-sample period of 1960-1979 for the specific country, to the US volatility for the specific sample period, and to that of E15 for the same period. Values presented for the US and E15 are averages over the six VAR models estimated, while those for other countries are from the specific VAR model

[3] The results of various lag order selection criteria are shown in Appendix 2. Essentially, lag orders of 3 or 4 were typically required for the entire 1960-2002 period and the 1980-2002 sub-period in order to remove evidence of vector autocorrelation. For comparability, a lag of 4 is applied for all these longer periods. The lower VAR order of two is used for the shorter period from 1993 to conserve degrees of freedom.

that includes the country. All standard errors in the table are scaled by 100, and hence may be interpreted as the standard error of the shock or residual for the quarterly percentage growth rate.

The changing volatility of the orthogonalised shocks is evident from the relative values in column headed $\sigma_e/\sigma_e(60\text{-}79)$. For the US, this volatility declines by around one third between 1960-1979 and 1980-2002. Indeed, for the sub-sample from 1993, US volatility is little more than half of that of the pre-1980 period. Thus, the volatility declines documented for the US (see, for example, Kim and Nelson, 1999, McConnell and Perez-Quiros, 2000) continue to be evident in our international context.

What is, perhaps, more remarkable is the decline in the volatility of E15 shocks, which have a standard error post-1980 one half of that of the previous two decades, with an apparent further decline from 1993 to around 30 percent of the 1960-1979 value. While the pattern of the UK volatilities is similar to that for the E15 as a whole, the relative declines in other individual countries are less marked. Indeed, while Japan shows a volatility reduction from 1980, this appears to have been reversed in the recent past (1993-2002). The table also shows that the decline in the volatility of E15 shocks cannot be attributed to the ordering of variables in the VAR, since the VAR residuals show a very similar volatility pattern to those of the orthogonalised shocks.

The relative volatilities of the orthogonalised shocks emphasise the greater stability of growth in the E15 aggregate compared with the US. However, with the exception of France, individual European countries do not show consistent evidence of more or less volatile growth shocks than the US. Again the attribution of world shocks to the US through the ordering of variables in the VAR is not the essential reason why E15 shocks are less volatile than those of the US, since the VAR residuals also show this pattern. The relatively high volatility of shocks in Japan, especially in the recent past (since 1993) is notable, with this apparently being idiosyncratic.

Table 2 shows the intra-quarter correlations of the VAR residuals. It is unsurprising that US residuals are more strongly correlated with those of Canada than any other country. However, with this exception, the correlations with the US are generally not very strong, indicating that there is no very strong within-quarter world shock. It also implies that the ordering of the US as the first variable for the Cholesky decomposition will not have very strong consequences on the results.

It is also unsurprising that residuals for Germany and France are both strongly correlated with the E15 residuals. However, given the frequent presumption that Germany leads the EU, it is notable that the residual correlations of E15 with France are generally stronger than with Germany. The UK residuals are less strongly correlated with those of the E15 than are these two countries, and especially so since 1980, while the correlation of Italy with E15 increases markedly in the post-1980 period.

Therefore, the evidence from the VAR is that conditional volatilities of shocks have declined in the period since 1980 for all G-7 countries, with this decline even greater for the E15 aggregate than for those individual countries. This is investigated further through the standard error of the orthogonalised shocks for the rolling estimation of the VAR, shown in Figure 2. The time shown on the horizontal axis is the central point of the nine-year rolling window for VAR estimation. The effectively linear decline in E15 conditional volatility throughout the period is notable, which contrasts with the step-like decline for the US and Germany, in the mid-1980s and early 1970s respectively. Indeed, with the exceptions of the US, Germany and Japan, the common pattern across series is the general, relatively smooth, decline in the conditional volatility of output growth over time.

One remarkable feature of Figure 2 is that, with the notable exception of Japan, all conditional volatilities fall within a relatively narrow band by the end of the period. It should also be noted that none of the substantive patterns shown in Figure 2 alter if residuals are used in place of the orthogonalised shocks. In order to conserve space, however, the rolling conditional volatilities of the VAR residuals are not shown.

It is clear from Table 1 and Figure 2 that an analysis over the entire post-1960 period based on an assumption of constant variance for the shocks is likely to be flawed. Nevertheless, it remains to be seen how important changing volatilities of the shocks are for understanding changes in the international business cycle over time.

5. Has the Transmission of Shocks Changed Over Time?

Tables 3a and 3b show the impulse responses for the effects of a US and an E15 orthogonalised shock, respectively, over the entire sample, together with the sub-periods 1960-1979, 1980-2002 and 193-2002. Tables 4a and 4b then present a corresponding analysis in terms of the forecast error variance decomposition, showing the percentage of the variance attributable to the first and second shocks (respectively). The left-hand half of each table presents the results for the whole sample and each sub-period when the 1960-1979 innovation standard errors are employed, as explained in Section 2 (with these denoted as scaled in the tables), while the right-hand part of the table shows the responses based on the innovation standard errors for the respective period (referred to as non-scaled). The impulse responses are cumulated, while the error variance decomposition applies to a single period. In each case, results are reported for n = 0, 4, 8, 20 steps ahead. For clarity, the impulse responses in Tables 3a and 3b are scaled by 100.

These results are discussed separately below in relation to the roles of US and E15 shocks (in sub-sections 5.1 and 5.2), before turning to a discussion of the results of rolling VAR estimation in sub-section 5.3. Like models estimated for the short sub-period 1993-2002, the rolling estimations employ a VAR(2) due to degrees of freedom considerations.

5.1 The Impact of US Shocks

As in Section 4, in order to present simple results for the US and E15 that are common to all models, the reported results for these series are the averages of the impulse responses or error variance decomposition percentages, as appropriate, over the six separate VAR models for the specific sample period.

The impulse responses of the US to its own shock (Table 3a) are largely unchanged over the whole sample and the different sub-samples, once they are re-scaled to allow for the substantial decline in the volatility of these shocks since 1980. Therefore, at least within the US, the changing impulse responses over time shown in the right-hand part of the table are almost entirely due to changing volatility and not to the changing propagation of these shocks through the VAR. However, it is notable from Table 4a that the US appears to have become more open since 1980, in that the percentage importance of the US shock to the forecast error variance decomposition has declined. Indeed, when scaled to the 1960-1979 magnitude of shocks, around 25 percent of the forecast variance at horizons of a year or more is due to non-US shocks after 1980, compared to less than 10 percent prior to this date.

The variance decomposition results for the US in Table 4a also point to the distinct results yielded by considering the whole sample versus a sub-period analysis. When VAR models with constant parameters (including variances) are estimated over the whole sample 1960-2002, the results strongly indicate that the US is relatively unaffected by other countries, in contrast to the results for the post-1980 sub-period.

Turning to E15 results in Table 3a, at a horizon of (say) four quarters, the response over 1980-2002 to a US shock of the 1960-1979 magnitude appears to be much less than for the earlier sub-period. Thus, these results fit well with the view that Europe became "disconnected" with the US as European integration proceeded. However, once the sub-period from 1993 is considered, the effect of a given US shock (of 1960-1979 magnitude) is estimated to be larger than previously. In common with this finding for the E15 aggregate, the impulse responses for Germany, France and Italy in Table 3a all show a similar patterns of smaller responses to a US shock in the 1980-2002 period than earlier and also in comparison to the whole 1960-2002 sample period. However, the effect of a US shock is restored (or, indeed, enhanced compared to 1960-1979) when the 1993-2002 sub-period is considered.

The importance of examining Europe as a whole is emphasised by the variance decomposition results of Table 4a. In terms of the scaled responses, the US is relatively unimportant for Germany, Italy and (perhaps surprisingly) the UK, accounting for less than

10 percent of the forecast error variances in these countries and at all horizons. Although (scaled) US shocks are more important for France in some periods than for other countries, the E15 series points to a more important role for US shocks than for any individual European country, with the US accounting for between 12 and 18 percent of the E15 variance at all horizons of a year or longer. The 1980-2001 sub-period is an exception, where the appearance of Europe being "disconnected" is again evident in results relating to E15.

The effect of declining volatility is also notable in Table 4a, in that the percentages attributable to the US shock for European countries and the E15 aggregate are lower for the scaled values than the unscaled ones. In other words, (comparing corresponding results in the left- and right-hand halves of the table) in the lower volatility environment of post-1980, US shocks of the current magnitude play a larger percentage role in terms of the variance than if shocks of the pre-1980 magnitude were propagated through the post-1980 VARs. This is because, at the E15 level, the decline in volatility attributed to E15 shocks is relatively greater than the decline in the volatility of US shocks (see Table 1), hence US shocks have become relatively more important. In particular, in the post-1993 period, unscaled US shocks play an important role in Europe and account for almost 40 percent of the error variance for E15 at horizons of four quarters or more. It may be noted that this percentage is very similar to that for Canada, but it is not repeated for any individual European country, with the partial exception of France.

5.2 The Impact of European Shocks

Both Tables 3b and 4b emphasise the small impact of an E15 shock on the US prior to 1980, with this being larger and positive after this date. However, in unscaled terms, the E15 shock still accounts for only around eight percent of the US forecast variance in this later period, compared to less than three percent previously. Again the greater reduction of volatility in E15 compared to the US is important here, with the decompositions for scaled shocks attributing up to 20 percent of the post-1980 US forecast variance to E15 shocks. Therefore, the international propagation of E15 shocks has changed, so that were pre-1980 shocks to occur in the post-1980 period, they would have a much greater impact (in terms of impulse response and especially variance decomposition) on the US than they actually had in that earlier period.

Not surprisingly in the context of European integration, the left-hand part of Table 3b shows that Germany, France and Italy react more strongly to an E15 shock in the post-1980 period than previously. In the case of Germany, however, this integration with other European countries appears to be partially reversed in the period from 1993, which may be due to Germany becoming more inward-looking after reunification. Perhaps also due to effects associated with Germany, although the E15 response to its own shocks increases post-1980 compared with pre-1980, these decline when only the 1993-2002 sub-period is considered.

The case of the UK is especially notable in the context of the discussion of its role in Europe and the debate about whether it should join the Euro. Indeed, the impact of an E15 shock is estimated to be negative over 1980-2002, emphasising its apparently different shortterm business cycle movements in comparison with other European countries. This pattern is, however, reversed in the recent period (from 1993), with E15 shocks now having a positive impact and of a magnitude similar to those of the pre-1980 period. Indeed, in unscaled terms, the recent experience is that E15 shocks account for around 16 percent of the UK variance at horizons of a year or more in Table 4b. This is similar to the percentage variance effect for Germany, although substantially lower than that for France and Italy.

Table 4b also confirms that Europe is relatively unimportant for both Canada and Japan, in terms of the unscaled variance decompositions. Were shock of the pre-1980 magnitude to occur again, however, E15 would play a non-trivial role for Japan. Nevertheless, the different signs of the responses of Japan to such a shock in Table 4 over 1980-2002 and 1993-2002 might be noted.

Although we do not explicitly show the effects of the own shock for any individual country except the US, the implication of Tables 4a and 4b is that these are nontrivial for individual European countries, despite the progress of integration. Indeed, for each of Germany, Italy and the UK, more than half of the (unscaled) forecast error variance is attributed to own shocks after 1980. In other words, by this measure only France is less affected by its own shocks than by US and E15 shocks combined.

5.3 Rolling VAR Estimations

Figure 3 decomposes the forecast error variance at a horizon of eight quarters into the percentages attributable to each of the three shocks, where the first shock corresponds to the US, the second to E15 and the third shock to Germany, France, Italy, UK, Canada or Japan. In these graphs, the date refers to the central point in time in relation to the estimation window width of 36 months. Like the tables, the values shown for the decompositions for the US and E15 are averages across the six VARs, whereas those for the remaining six series relate to the specific VAR that includes that as the third country.

Looking first at the results for the US, the pattern is of own shocks becoming gradually less important over time. Indeed, there is a steady increase in the effect of E15 shocks on the US over time, rising from around 2 percent in the mid-1960 to around 15 percent in the mid-1990s. Although not shown, this effect is consistent across all six VAR models. The effect of the third (other country) shock on the US increases from around 5 percent to approximately 10 percent of the variance over the period, so that the VAR models attribute most of the increasing international impact on the US to the role of the E15 aggregate.

In contrast to the effectively monotonically changing roles of the different shocks for the US, the effect of US shocks on the E15 is not monotonic. Rather, US shocks are very important during the period of oil price shocks of the 1970s, where it is presumably these world influences that prevail and (in the causal ordering used in our trivariate VARs) are attributed to the US. In the mid-1960s and for a decade from the mid-1990, US shocks are unimportant. However, at the end of the period, which is effectively post-1993, US shocks return to a similar level of importance as during the 1970s. Although not shown in detail, these results for E15 are very consistent across all six VARs. Except for these specific periods, own shocks dominate the decompositions for the E15, with the impact of the third country remaining around 10 percent throughout the period.

Turning to the remaining G-7 countries, although the effects of US shocks are broadly similar across these countries until the mid-1970s, and generally increasing until this point, divergences occur after this date. At the two extremes, the effect on Canada increases and remains relatively high, whereas that for Japan is low from the 1980s onwards. The distinctive (and larger) impact of the US on the UK in the late-1980s and early 1990s is clear in comparison with the other European countries. However, from the mid-1990s this disappears, with the largest estimated impact at the very end of the period of the US on individual European countries being that on France.

There are no general patterns common to all countries for the responses of individual countries to E15 shocks in Figure 3. Nevertheless, for Italy, a date around 1980 is a watershed in that the effect of European shocks increases substantially at this time. For France and Germany, it appears that E15 shocks tend to become more important from around 1980 until the mid-1990s. In the case of Germany, the increasing role of E15 effectively replaces the US, with around 50-60 percent of the error variance accounted for by own shocks throughout. For the UK, however, the role of E15 shocks has generally been modest except for a period around 1980. In general, and perhaps not surprisingly, E15 shocks have played relatively little role for Canada and Japan, except for the mid-1980s for the latter.

Therefore, these rolling VAR estimations emphasise the apparently changing international relationships over time. While it is true that the shorter sample sizes employed here, compared to a more traditional fixed sample analysis, implies that the individual results are less reliable, it is also the case that the usual analysis will suffer from biases when the VAR parameters evolve over time. Nevertheless, the broad patterns of results imply that Europe as a whole has played a increasing role for the US over time, while the effects of the US on Europe have been largest during the 1970s and the late 1990s. A generally similar, though more diverse, pattern of responses of the individual E-3 countries (Germany, France and Italy) to US shocks as for E15 has been found. The responses of these countries to E15 shocks has generally increased since 1980, in line with increasing European integration. Although the UK has appeared to be distinctive from these countries for most of the period since 1960, this appears much less evident in the recent past than previously.

6. Conclusions

This study provides evidence that the nature of the international business cycle has changed over time, in terms of both the volatility of shocks and their propagation across countries. Measured conditional on the VAR models that we estimate, declines in volatility are more marked for the EU as a whole than for the US, so that one important consequence of European integration may be this volatility reduction. We also find changes in the propagation of shocks over time, with these changes affecting all G-7 countries, including the US. Indeed, we find the US to be increasing affected by external shocks, particularly those from the EU. Further, the effects of US shocks on the EU as a whole and also on individual European countries also change over time, with these generally having their greatest role during the 1970s and from around the mid-1990s.

The counterfactual exercises show that changes in both volatility and the propagation of shocks are important. For example, E15 shocks of pre-1980 magnitude propagated through the coefficients of the VAR estimated using post-1993 data would account for around 20 percent of the US forecast error variance, implying that the US would be far from isolated from the effects of such shocks. From the European perspective, one explanation of why US shocks appear to have been particularly important in the recent past is the greater relative decline in the magnitude of E15 shocks compared to US ones. Therefore, what might have previously been a US shock of relatively moderate magnitude, such as the beginning of the relatively shallow US recession of 2001, may have a large impact on Europe as a whole.

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APPENDIX 1

Data

All the data are quarterly and comes from the OECD and IMF databases. We attempted to use comparable series for each country, but in some cases, to obtain longer samples, different sources were used.

For all the countries except Italy and Germany, but including the E15 aggregate**,** GDP is from the Main Economic Indicators database of the OECD. Concretely our measure of GDP is: GDP volume index sa (the code typically is country_NAGVVO01_IXOBSA)

For Germany, the series GDP (PAN BD from 1991) CONA, (with Datastream code BDGDP…D) was used. This series comes from the OECD National Accounts and was corrected to take into account the jump in 1991, due to German reunification.

For Italy, a GDP volume index from the IMF is used (13699BVRZF…) the series was corrected in 1970 and 1966 for a jump and an outlier respectively.

The samples periods for our data are:

DEU	1960:1- 2002:1	**USA**	1960:1- 2002:1
FRA	1960:1- 2002:1	**CAN**	1960:1- 2002:1
ITA	1960:1- 2001:4	**JPN**	1960:1- 2002:1
E15	1960:1 -2002:1	**UK**	1960:1- 2002:1

APPENDIX 2

Results of lag order selection criteria for the VAR Models

	SMPL	AIC	HQ	BIC	LR	Portmanteau
DEU	[1960:02-2002:01]	4	1	1	4	4
	[1960:02-1979:04]	1	1	1	1	3
	[1980:01-2002:01]	1	1	1	4	4
	[1993:01-2002:01]	5	5	1	1	1
FRA	[1960:02-2002:01]	3	1	1	5	3
	[1960:02-1979:04]	1	1	1	1	2
	[1980:01-2002:01]	2	1	1	2	3
	[1993:01-2002:01]	1	1	1	1	2
ITA	[1960:02-2001:04]	2	1	1	2	3
	[1960:02-1979:04]	1	1	1	1	3
	[1980:01-2001:04]	1	1	1	1	3
	[1993:01-2001:04]	1	1	1	1	3
UK	[1960:02-2002:01]	1	1	1	1	3
	[1960:02-1979:04]	1	1	1	1	2
	[1980:01-2002:01]	4	1	1	4	4
	[1993:01-2002:01]	1	1	1	1	1
CAN	[1960:02-2002:01]	1	1	1	4	4
	[1960:02-1979:04]	1	1	1	1	3
	[1980:01-2002:01]	2	1	1	2	4
	[1993:01-2002:01]	2	2	1	1	2
JPN	[1960:02-2002:01]	3	1	1	3	3
	[1960:02-1979:04]	1	1	1	1	3
	[1980:01-2002:01]	4	1	1	4	4
	[1993:01-2002:01]	1	1	1	1	4

Note: All VAR models include the US, E15 and one other G-7 country, namely Germany (DEU), France (FRA), Italy (ITA), UK, Canada (CAN) or Japan (JPN). The criteria considered are the Akaike Information Criterion (AIC), the Hannan-Quinn Criterion (HQ), the Bayesian or Schwarz Criterion (BIC). In addition, we employ a testing down strategy, based on a likelihood ratio test for significant VAR parameters against a VAR(6) model, and the lowest VAR order yielding non-significance in a general portmanteau vector autocorrelation test. These two tests employ a 5 percent significance level.

Table 1. Standard errors of the orthogonalised shocks and residuals

	SMPL	σ_e	σ_u	$\sigma_e/\sigma_{e(60-79)}$	σ_e/σ_{e_USA}	σ_e/σ_{e_E15}	$\sigma_u/\sigma_{u(60-79)}$	σ_u/σ_{u_USA}	σ_u/σ_{u_E15}
USA	[1960:02-2002:01]	0.79	0.79	0.91	1.00	1.46	0.91	1.00	1.44
	[1960:02-1979:04]	0.87	0.87	1.00	1.00	1.32	1.00	1.00	1.30
	[1980:01-2002:01]	0.58	0.58	0.67	1.00	1.87	0.67	1.00	1.87
	[1993:01-2002:01]	0.46	0.46	0.53	1.00	2.42	0.53	1.00	2.30
E15	[1960:02-2002:01]	0.54	0.55	0.82	0.68	1.00	0.82	0.70	1.00
	[1960:02-1979:04]	0.66	0.67	1.00	0.76	1.00	1.00	0.77	1.00
	[1980:01-2002:01]	0.31	0.31	0.47	0.53	1.00	0.46	0.53	1.00
	[1993:01-2002:01]	0.19	0.20	0.29	0.41	1.00	0.30	0.43	1.00
DEU	[1960:02-2002:01]	0.84	1.03	0.84	1.06	1.56	0.86	1.30	1.87
	[1960:02-1979:04]	1.00	1.20	1.00	1.15	1.52	1.00	1.38	1.79
	[1980:01-2002:01]	0.59	0.81	0.59	1.02	1.90	0.68	1.40	2.61
	[1993:01-2002:01]	0.40	0.48	0.40	0.87	2.11	0.40	1.04	2.40
FRA	[1960:02-2002:01]	0.42	0.64	0.88	0.53	0.78	0.85	0.81	1.16
	[1960:02-1979:04]	0.48	0.75	1.00	0.55	0.73	1.00	0.86	1.12
	[1980:01-2002:01]	0.30	0.39	0.63	0.52	0.97	0.52	0.67	1.26
	[1993:01-2002:01]	0.27	0.34	0.56	0.59	1.42	0.45	0.74	1.70
ITA	[1960:02-2001:04]	0.72	0.78	0.82	0.91	1.33	0.86	0.99	1.42
	[1960:02-1979:04]	0.88	0.91	1.00	1.01	1.33	1.00	1.05	1.36
	[1980:01-2001:04]	0.40	0.49	0.45	0.69	1.29	0.54	0.84	1.58
	[1993:01-2001:04]	0.39	0.46	0.44	0.85	2.05	0.51	1.00	2.30
UK	[1960:02-2002:01]	0.77	0.96	0.83	0.97	1.43	0.81	1.22	1.75
	[1960:02-1979:04]	0.93	1.19	1.00	1.07	1.41	1.00	1.37	1.78
	[1980:01-2002:01]	0.44	0.48	0.47	0.76	1.42	0.40	0.83	1.55
	[1993:01-2002:01]	0.24	0.26	0.26	0.52	1.26	0.22	0.57	1.30
CAN	[1960:02-2002:01]	0.71	0.78	0.95	0.90	1.31	1.00	0.99	1.42
	[1960:02-1979:04]	0.75	0.78	1.00	0.86	1.14	1.00	0.90	1.16
	[1980:01-2002:01]	0.49	0.59	0.65	0.84	1.58	0.76	1.02	1.90
	[1993:01-2002:01]	0.32	0.37	0.43	0.70	1.68	0.47	0.80	1.85
JPN	[1960:02-2002:01]	0.97	0.98	0.95	1.23	1.80	0.95	1.24	1.78
	[1960:02-1979:04]	1.02	1.03	1.00	1.17	1.55	1.00	1.18	1.54
	[1980:01-2002:01]	0.79	0.79	0.77	1.36	2.55	0.77	1.36	2.55
	[1993:01-2002:01]	1.00	1.01	0.98	2.17	5.26	0.98	2.20	5.05

Notes: σ_e and σ_u denote the standard errors of the orthogonalised residuals and the residuals, respectively. Values given for USA and E15 are averages relating to these series across the six VAR models estimated (see text).

Table 2. Residual correlations

		Correlation with		
	SMPL	USA	E15	Other Country
USA	[1960:02-2002:01]	1.00	0.16	0.17
	[1960:02-1979:04]	1.00	0.10	0.10
	[1980:01-2002:01]	1.00	0.10	0.18
	[1993:01-2002:01]	1.00	0.23	0.15
E15	[1960:02-2002:01]	0.16	1.00	0.43
	[1960:02-1979:04]	0.10	1.00	0.40
	[1980:01-2002:01]	0.10	1.00	0.39
	[1993:01-2002:01]	0.23	1.00	0.34
DEU	[1960:02-2002:01]	0.10	0.58	1.00
	[1960:02-1979:04]	0.03	0.55	1.00
	[1980:01-2002:01]	0.17	0.68	1.00
	[1993:01-2002:01]	0.26	0.55	1.00
FRA	[1960:02-2002:01]	0.15	0.76	1.00
	[1960:02-1979:04]	0.13	0.78	1.00
	[1980:01-2002:01]	0.15	0.65	1.00
	[1993:01-2002:01]	0.17	0.62	1.00
ITA	[1960:02-2001:04]	0.05	0.39	1.00
	[1960:02-1979:04]	-0.05	0.26	1.00
	[1980:01-2001:04]	0.08	0.57	1.00
	[1993:01-2001:04]	-0.15	0.44	1.00
UK	[1960:02-2002:01]	0.16	0.59	1.00
	[1960:02-1979:04]	0.12	0.62	1.00
	[1980:01-2002:01]	0.14	0.38	1.00
	[1993:01-2002:01]	0.14	0.38	1.00
CAN	[1960:02-2002:01]	0.44	0.11	1.00
	[1960:02-1979:04]	0.28	0.07	1.00
	[1980:01-2002:01]	0.55	0.07	1.00
	[1993:01-2002:01]	0.51	0.16	1.00
JPN	[1960:02-2002:01]	0.12	0.13	1.00
	[1960:02-1979:04]	0.12	0.13	1.00
	[1980:01-2002:01]	0.02	-0.02	1.00
	[1993:01-2002:01]	-0.01	-0.13	1.00

Note: Correlations between USA and E15 residuals are averages across the six VAR models estimated (see text). Similarly, correlations for USA or E15 with "other country" are averages across the six VAR models. Correlations for Germany, France, Italy, UK, Canada and Japan relate to the specific VAR including that country.

Table 3a. Impulse responses to the first (US) shock

		SCALED				NON-SCALED				
	SMPL	0	4	8	20		0	4	8	20
USA	[1960:02-2002:01]	0.87	1.42	1.41	1.39	USA	0.79	1.29	1.28	1.26
	[1960:02-1979:04]	0.87	1.30	1.23	1.22		0.87	1.30	1.23	1.22
	[1980:01-2002:01]	0.87	1.60	1.44	1.47		0.58	1.06	0.96	0.98
	[1993:01-2002:01]	0.87	1.25	1.18	1.18		0.46	0.66	0.62	0.62
E15	[1960:02-2002:01]	0.10	0.58	0.70	0.72	E15	0.09	0.53	0.63	0.65
	[1960:02-1979:04]	0.07	0.51	0.53	0.51		0.07	0.51	0.53	0.51
	[1980:01-2002:01]	0.05	0.27	0.32	0.32		0.03	0.18	0.21	0.21
	[1993:01-2002:01]	0.08	0.69	0.68	0.67		0.04	0.37	0.36	0.35
DEU	[1960:02-2002:01]	0.11	0.65	0.78	0.82	DEU	0.10	0.60	0.72	0.76
	[1960:02-1979:04]	0.04	0.59	0.60	0.61		0.04	0.59	0.60	0.61
	[1980:01-2002:01]	0.20	0.33	0.34	0.38		0.14	0.22	0.24	0.26
	[1993:01-2002:01]	0.23	0.78	0.81	0.80		0.12	0.42	0.43	0.43
FRA	[1960:02-2002:01]	0.11	0.55	0.71	0.77	FRA	0.10	0.50	0.64	0.70
	[1960:02-1979:04]	0.10	0.49	0.54	0.53		0.10	0.49	0.54	0.53
	[1980:01-2002:01]	0.09	0.23	0.28	0.26		0.06	0.15	0.19	0.18
	[1993:01-2002:01]	0.11	0.88	0.88	0.84		0.06	0.48	0.48	0.45
ITA	[1960:02-2001:04]	0.04	0.65	0.79	0.78	ITA	0.04	0.59	0.71	0.71
	[1960:02-1979:04]	-0.05	0.56	0.47	0.44		-0.05	0.56	0.47	0.44
	[1980:01-2001:04]	0.06	0.39	0.42	0.44		0.04	0.26	0.28	0.29
	[1993:01-2001:04]	-0.13	0.53	0.67	0.66		-0.07	0.27	0.34	0.34
UK	[1960:02-2002:01]	0.17	0.69	0.70	0.65	UK	0.15	0.63	0.64	0.59
	[1960:02-1979:04]	0.14	0.64	0.62	0.62		0.14	0.64	0.62	0.62
	[1980:01-2002:01]	0.10	0.32	0.22	0.22		0.07	0.21	0.15	0.15
	[1993:01-2002:01]	0.07	0.39	0.29	0.30		0.04	0.21	0.15	0.16
CAN	[1960:02-2002:01]	0.38	1.10	1.11	1.10	CAN	0.34	1.01	1.01	1.00
	[1960:02-1979:04]	0.22	0.62	0.61	0.60		0.22	0.62	0.61	0.60
	[1980:01-2002:01]	0.49	1.77	1.57	1.51		0.33	1.18	1.04	1.01
	[1993:01-2002:01]	0.36	1.04	0.80	0.83		0.19	0.56	0.43	0.45
JPN	[1960:02-2002:01]	0.14	0.49	0.62	0.70	JPN	0.12	0.44	0.56	0.63
	[1960:02-1979:04]	0.12	0.49	0.49	0.44		0.12	0.49	0.49	0.44
	[1980:01-2002:01]	0.02	0.22	0.30	0.33		0.01	0.14	0.19	0.22
	[1993:01-2002:01]	-0.02	0.41	0.35	0.35		-0.01	0.21	0.18	0.18

Notes: Impulse responses for USA and E15 are averages across the six VARs. Scaled responses relate to an orthogonalised shock of magnitude equal to that estimated for 1960-1979 applied for each period. Unscaled responses relate to an orthogonalised shock of magnitude equal to that for the period of estimation.

Table 3b. Impulse responses to the second (E15) shock

	SCALED					NON-SCALED				
	SMPL	0	4	8	20		0	4	8	20
USA	[1960:02-2002:01]	0.00	0.16	0.09	0.07	USA	0.00	0.13	0.08	0.06
	[1960:02-1979:04]	0.00	0.03	-0.06	-0.04		0.00	0.03	-0.06	-0.04
	[1980:01-2002:01]	0.00	0.39	0.32	0.29		0.00	0.18	0.15	0.14
	[1993:01-2002:01]	0.00	0.20	0.13	0.14		0.00	0.06	0.04	0.04
E15	[1960:02-2002:01]	0.66	1.00	1.07	1.07	E15	0.54	0.81	0.87	0.87
	[1960:02-1979:04]	0.66	0.72	0.66	0.66		0.66	0.72	0.66	0.66
	[1980:01-2002:01]	0.66	1.26	1.26	1.22		0.31	0.59	0.59	0.57
	[1993:01-2002:01]	0.66	0.98	0.89	0.89		0.19	0.28	0.26	0.26
DEU	[1960:02-2002:01]	0.73	1.18	1.22	1.22	DEU	0.59	0.95	0.99	0.99
	[1960:02-1979:04]	0.66	0.76	0.69	0.70		0.66	0.76	0.69	0.70
	[1980:01-2002:01]	1.19	1.98	1.86	1.75		0.54	0.89	0.84	0.79
	[1993:01-2002:01]	0.85	1.16	1.07	1.07		0.24	0.32	0.30	0.30
FRA	[1960:02-2002:01]	0.59	1.15	1.34	1.40	FRA	0.47	0.93	1.08	1.13
	[1960:02-1979:04]	0.58	0.76	0.71	0.70		0.58	0.76	0.71	0.70
	[1980:01-2002:01]	0.54	1.37	1.45	1.43		0.25	0.64	0.67	0.67
	[1993:01-2002:01]	0.71	1.47	1.30	1.30		0.20	0.42	0.38	0.37
ITA	[1960:02-2001:04]	0.37	0.89	0.87	0.90	ITA	0.30	0.73	0.72	0.74
	[1960:02-1979:04]	0.24	0.23	0.08	0.14		0.24	0.23	0.08	0.14
	[1980:01-2001:04]	0.56	1.22	1.26	1.30		0.28	0.60	0.62	0.65
	[1993:01-2001:04]	0.73	1.31	1.28	1.27		0.23	0.42	0.41	0.40
UK	[1960:02-2002:01]	0.68	0.52	0.41	0.34	UK	0.55	0.42	0.33	0.28
	[1960:02-1979:04]	0.73	0.51	0.49	0.48		0.73	0.51	0.49	0.48
	[1980:01-2002:01]	0.39	0.28	-0.33	-0.48		0.18	0.13	-0.15	-0.22
	[1993:01-2002:01]	0.34	0.54	0.44	0.46		0.09	0.15	0.12	0.13
CAN	[1960:02-2002:01]	0.05	0.45	0.49	0.47	CAN	0.04	0.37	0.40	0.39
	[1960:02-1979:04]	0.05	0.26	0.14	0.14		0.05	0.26	0.14	0.14
	[1980:01-2002:01]	0.06	0.28	0.36	0.37		0.03	0.13	0.16	0.16
	[1993:01-2002:01]	-0.02	-0.01	-0.13	-0.09		-0.01	0.00	-0.03	-0.02
JPN	[1960:02-2002:01]	0.13	0.22	0.14	0.11	JPN	0.11	0.18	0.12	0.09
	[1960:02-1979:04]	0.13	-0.02	-0.16	-0.16		0.13	-0.02	-0.16	-0.16
	[1980:01-2002:01]	-0.04	0.39	0.52	0.65		-0.02	0.19	0.25	0.32
	[1993:01-2002:01]	-0.45	-0.40	-0.39	-0.38		-0.14	-0.12	-0.12	-0.12

Notes: See Table 3a.

Table 4a. Variance decomposition: percentage importance of the first (US) shock

		SCALED				NON-SCALED				
	SMPL	0	4	8	20		0	4	8	20
USA	[1960:02-2002:01]	100.00	93.91	93.33	93.23	USA	100.00	94.77	94.25	94.17
	[1960:02-1979:04]	100.00	92.37	91.13	90.91		100.00	92.37	91.13	90.91
	[1980:01-2002:01]	100.00	77.68	75.34	74.98		100.00	86.72	85.04	84.84
	[1993:01-2002:01]	100.00	70.65	70.35	70.34		100.00	85.86	85.70	85.69
E15	[1960:02-2002:01]	2.26	12.43	12.99	12.98	E15	2.81	14.89	15.52	15.50
	[1960:02-1979:04]	1.25	12.29	12.43	12.45		1.25	12.29	12.43	12.45
	[1980:01-2002:01]	0.60	3.98	4.25	4.25		0.93	6.31	6.71	6.72
	[1993:01-2002:01]	1.71	17.69	17.86	17.88		5.63	39.44	39.66	39.69
DEU	[1960:02-2002:01]	0.75	6.79	7.15	7.15	DEU	0.93	8.24	8.66	8.66
	[1960:02-1979:04]	0.11	8.04	8.38	8.30		0.11	8.04	8.38	8.30
	[1980:01-2002:01]	1.57	3.70	3.73	3.74		2.78	6.40	6.42	6.43
	[1993:01-2002:01]	3.03	5.79	5.83	5.83		6.70	11.84	11.92	11.92
FRA	[1960:02-2002:01]	1.94	9.28	9.94	10.00	FRA	2.28	10.83	11.60	11.67
	[1960:02-1979:04]	1.73	11.30	11.50	11.50		1.73	11.30	11.50	11.50
	[1980:01-2002:01]	1.54	2.29	2.65	2.68		2.32	3.68	4.24	4.29
	[1993:01-2002:01]	1.66	15.93	15.99	16.06		3.03	27.29	27.36	27.46
ITA	[1960:02-2001:04]	0.18	8.22	8.68	8.69	ITA	0.21	9.88	10.42	10.43
	[1960:02-1979:04]	0.27	9.21	9.33	9.52		0.27	9.21	9.33	9.52
	[1980:01-2001:04]	0.28	2.68	2.73	2.73		0.57	5.21	5.30	5.30
	[1993:01-2001:04]	1.35	7.67	8.08	8.08		2.23	12.13	12.75	12.75
UK	[1960:02-2002:01]	2.09	7.19	7.17	7.19	UK	2.55	8.69	8.67	8.69
	[1960:02-1979:04]	1.34	7.34	7.31	7.32		1.34	7.34	7.31	7.32
	[1980:01-2002:01]	0.98	3.93	3.74	3.72		1.89	7.42	7.11	7.08
	[1993:01-2002:01]	0.44	2.92	3.09	3.10		1.90	11.63	12.26	12.27
CAN	[1960:02-2002:01]	20.10	35.94	35.73	35.72	CAN	19.05	34.88	34.68	34.67
	[1960:02-1979:04]	7.86	16.86	16.80	16.80		7.86	16.86	16.80	16.80
	[1980:01-2002:01]	29.78	51.13	50.69	50.80		30.26	53.20	52.79	52.91
	[1993:01-2002:01]	18.52	28.08	28.44	28.44		26.34	39.68	40.20	40.21
JPN	[1960:02-2002:01]	1.70	4.43	4.43	4.32	JPN	1.53	4.04	4.03	3.93
	[1960:02-1979:04]	1.35	4.56	4.63	4.66		1.35	4.56	4.63	4.66
	[1980:01-2002:01]	0.05	3.50	4.04	3.99		0.01	0.27	0.32	0.32
	[1993:01-2002:01]	0.02	10.80	10.87	10.87		0.01	3.69	3.71	3.72

Notes: See Table 3a.

Table 4b. Variance decomposition: percentage importance of the second (E15) shock

		SCALED				NON-SCALED				
	SMPL	0	4	8	20		0	4	8	20
USA	[1960:02-2002:01]	0.00	2.93	3.11	3.14	USA	0.00	2.38	2.52	2.55
	[1960:02-1979:04]	0.00	2.15	2.61	2.65		0.00	2.15	2.61	2.65
	[1980:01-2002:01]	0.00	13.54	14.07	14.36		0.00	6.79	7.20	7.37
	[1993:01-2002:01]	0.00	20.48	20.64	20.64		0.00	7.60	7.67	7.67
E15	[1960:02-2002:01]	97.74	83.30	81.89	81.67	E15	97.19	80.12	78.52	78.26
	[1960:02-1979:04]	98.75	80.60	79.82	79.75		98.75	80.60	79.82	79.75
	[1980:01-2002:01]	99.40	90.80	89.15	89.03		99.07	85.47	83.40	83.33
	[1993:01-2002:01]	98.29	74.43	74.11	74.07		94.37	50.38	50.02	49.98
DEU	[1960:02-2002:01]	34.32	30.45	28.63	27.85	DEU	32.78	28.64	26.88	26.14
	[1960:02-1979:04]	30.25	25.31	24.16	23.50		30.25	25.31	24.16	23.50
	[1980:01-2002:01]	57.59	54.95	54.37	54.27		44.09	41.08	40.52	40.41
	[1993:01-2002:01]	40.79	32.21	32.22	32.22		24.80	18.13	18.13	18.13
FRA	[1960:02-2002:01]	59.15	59.94	59.87	59.86	FRA	54.97	55.49	55.39	55.37
	[1960:02-1979:04]	58.75	55.32	55.22	55.22		58.75	55.32	55.22	55.22
	[1980:01-2002:01]	55.62	65.74	65.68	65.64		40.57	51.00	50.90	50.85
	[1993:01-2002:01]	67.78	61.49	61.41	61.37		35.05	29.81	29.75	29.71
ITA	[1960:02-2001:04]	14.78	19.53	19.15	19.16	ITA	15.11	19.58	19.19	19.19
	[1960:02-1979:04]	6.87	8.66	8.86	8.93		6.87	8.66	8.86	8.93
	[1980:01-2001:04]	28.56	34.46	34.41	34.43		32.11	37.39	37.32	37.34
	[1993:01-2001:04]	39.98	37.53	37.39	37.39		25.21	22.75	22.60	22.60
UK	[1960:02-2002:01]	34.33	33.00	33.07	33.11	UK	33.05	31.42	31.49	31.52
	[1960:02-1979:04]	37.46	36.46	36.37	36.36		37.46	36.46	36.37	36.36
	[1980:01-2002:01]	14.91	18.68	24.01	24.86		13.56	16.60	21.48	22.26
	[1993:01-2002:01]	11.82	15.68	15.92	15.93		13.24	16.12	16.27	16.28
CAN	[1960:02-2002:01]	0.33	5.77	5.81	5.83	CAN	0.26	4.57	4.61	4.62
	[1960:02-1979:04]	0.36	3.09	3.71	3.72		0.36	3.09	3.71	3.72
	[1980:01-2002:01]	0.38	5.59	5.75	5.77		0.18	2.66	2.73	2.74
	[1993:01-2002:01]	0.05	7.59	7.94	7.97		0.02	2.49	2.60	2.61
JPN	[1960:02-2002:01]	1.57	4.25	4.17	4.03	JPN	1.15	3.17	3.10	3.00
	[1960:02-1979:04]	1.55	9.41	9.68	9.68		1.55	9.41	9.68	9.68
	[1980:01-2002:01]	0.16	16.85	17.50	17.24		0.26	3.49	3.62	3.62
	[1993:01-2002:01]	15.99	15.38	15.39	15.39		1.79	1.88	1.89	1.89

Notes: See Table 3a.

Figure 1. Graphs of the series.

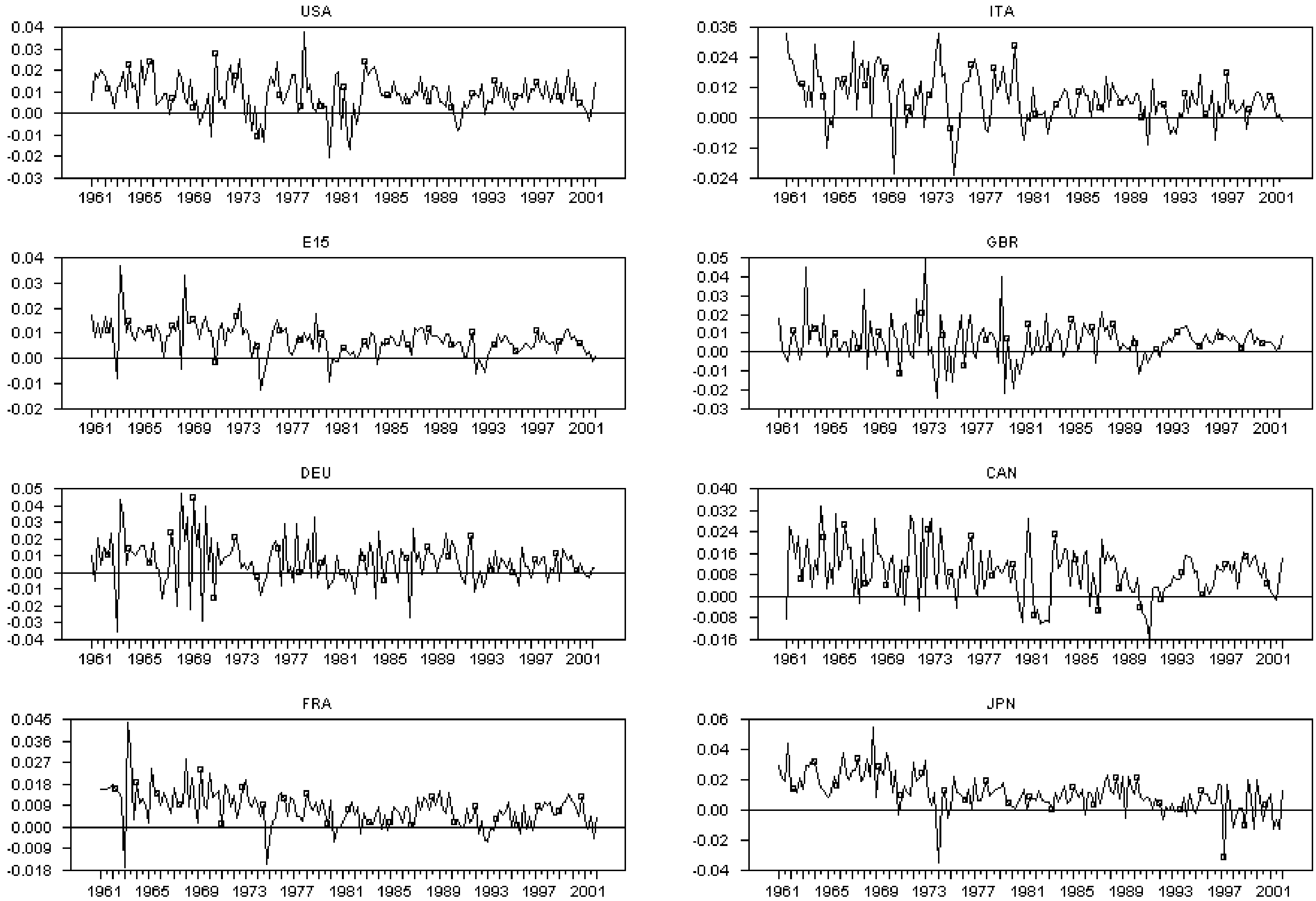
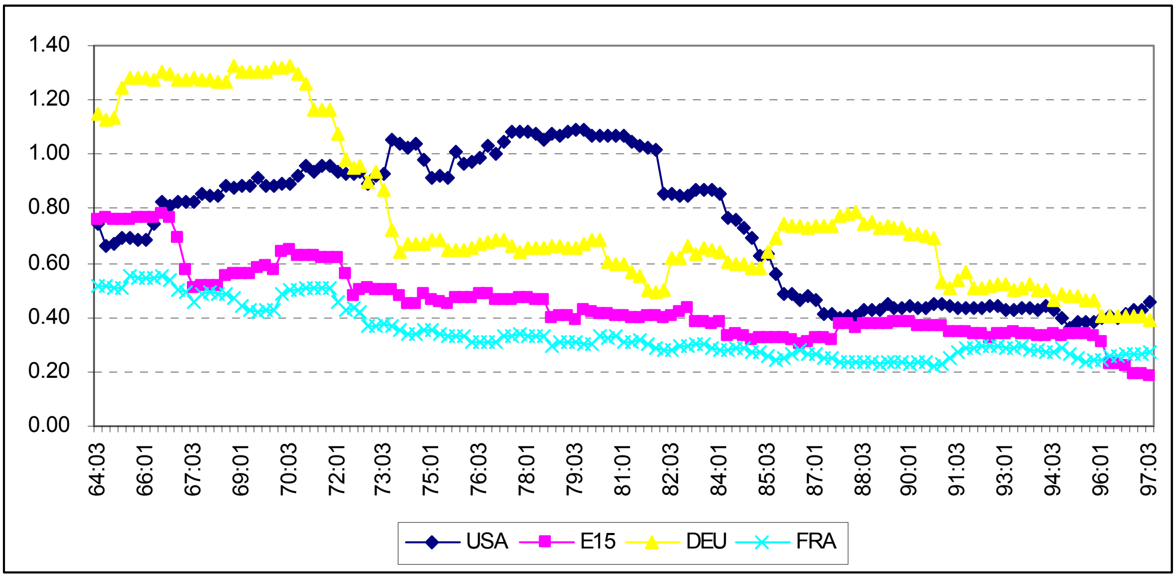


Figure 2. Rolling estimated standard deviation of orthogonalized shocks



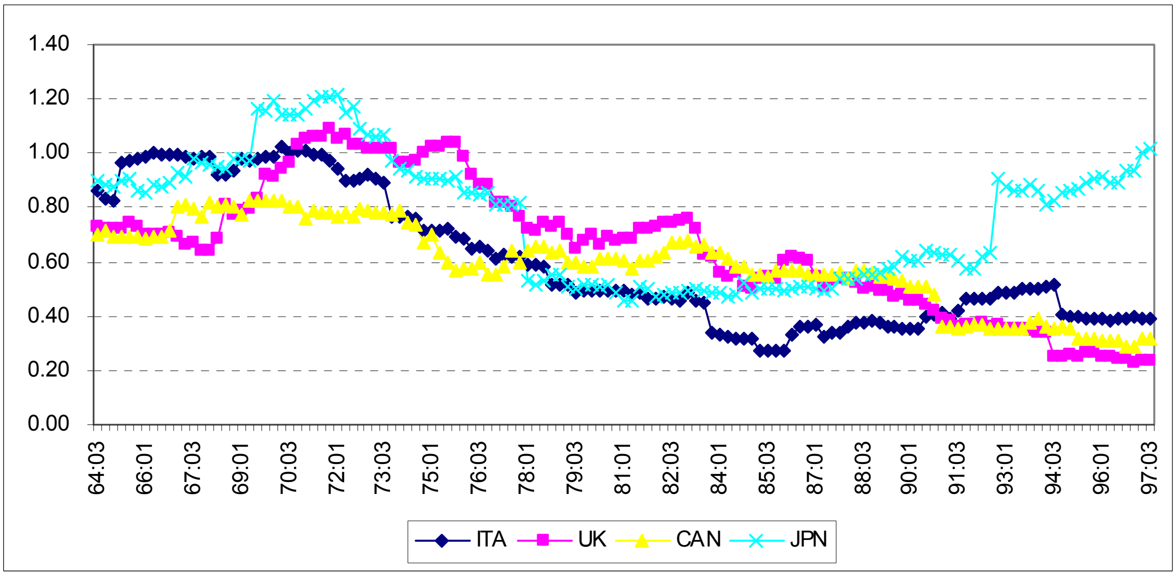


Figure 3. Forecast variance decompositions (percentage importance of the three shocks) at a horizon of 8 quarters obtained from rolling VAR estimation