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Abstract: This paper investigates breaks in the variability and co-movement of output, consumption, and investment in the G-7 economies. In contrast with most other papers on co-movement, we test for changes in co-movement allowing for breaks in mean and variance. Despite claims that rising integration among these economies has increased output correlations among them, we find no clear evidence of an increase in correlation of growth rates of output, consumption, or investment. This finding is true even for the United States and Canada, which have seen a tremendous increase in bilateral trade shares, and for the members of the euro area in the G-7.

Keywords: international business cycles, economic integration.

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1 Introduction

Much recent research has focused on changes in the business cycle properties of economic activity in industrialized economies. It is now common wisdom that the standard deviation of U.S. economic growth fell by one-third or more in the mid-1980s.[1] As Doyle and Faust (2002) and many others have noted, growth abroad also seems to have stabilized.[2] While the source of the drop in variance is still unresolved, one important branch of research now focuses on whether cross-country linkages in growth have also shifted, perhaps in a way that can help rationalize the variance reduction.

Economic integration has increased markedly since the 1970s, leading some observers to argue that economic growth will be more highly correlated. Speculation on this topic peaked with the nearly simultaneous slowing of growth in the G-7[3] and other economies at the beginning of 2001. Discussions of the possibility of a new era of more synchronized growth appeared in major news outlets[4] and policy publications.[5] The continued progress toward economic integration in Europe, highlighted by monetary union in 1999, has further fueled these discussions—the major question being whether the euro area is becoming more nearly an optimal currency area.

Changes in the standard deviation and correlation of growth are related, of course. Simply by definition, with all else constant, a fall by 1/3 in the U.S. standard deviation implies a 50 percent increase in the correlation of the United States with every other country. All else was not constant, however. If the growth variation

[1] See, for example, Ahmed, et al. (2004), Blanchard and Simon (2001), Kahn, McConnell and Perez-Quiros (2001), Kim and Nelson (1999), Kim, Nelson and Piger (2001), McConnell and Perez-Quiros (2000), Stock and Watson (2002), and Warnock and Warnock (2000).

[2] Authors who looked for changes in the volatility of foreign activity include Daalsgaard, Elmeskov and Park (2002), Fritsche and Kouzine (2002), McConnell and Perez-Quiros (1998), Mills and Wang (2000), Simon (2001), and van Dijk, Osborn and Sensier (2002).

[3] Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

[4] e.g., Washington Post, July 18, 2001, p. A1; the New York Times, August 20, 2001, p. A1, and November 25, 2001, p. A12; and the Economist, August 23, 2001, p. 22-24.

[5] See the Fall 2001 and Spring 2002 editions of the International Monetary Fund's World Economic Outlook, OECD Economic Outlook (December 2001, June 2002), and Doyle and Faust (2002).

that disappeared in the United States and abroad was idiosyncratic, then correlation should have risen. If the growth variation that disappeared was common, then covariance and correlation should have fallen. Thus, summarizing developments in growth variability and covariance could help shed light on the source of the changes.

This paper summarizes the changes in the variability of and co-movement among growth rates of G-7 countries. Various analyses suggest that the G-7 can interestingly be broken into 3 groups: Japan; the euro area countries; and Canada, the United States and the United Kingdom, which we refer to as the English (-speaking) countries.[6] Of course, Japan has behaved very differently than the other 6 nations in the 1990s. We set Japan aside for most of the analysis and focus on the G-6 and the euro and English subgroups.

Our analysis differs from many others in two ways. Like some earlier work, we consider consumption and investment growth as well as GDP growth. This consideration potentially allows us to distinguish among some theories of the source of changes. What is most unique about our paper, however, is that we focus on formal tests for changes in various measures of co-movement. Up to now, there has been much work testing for breaks in variance, but the work on co-movement has been almost exclusively descriptive of changes, without formal tests of significance. Virtually all existing work we are aware of either reports point estimates of co-movement across different sub-samples or estimates time-varying parameter models without any test of the hypothesis of no change.[7] While as a general rule, inference tools should be preferred to descriptive statistics, we demonstrate that there are particular reasons for care in interpreting point estimates without confidence measures in the current context.

[6] That is, English is one of the official languages in these countries.

[7] While much of this work is still in draft form and still changing, among the work falling into this category are Stock and Watson (2003a, 2003b), Bayoumi and Helbling (2003), Kose, Otrok and Whiteman (2003a, 2003b), Luginbuhl and Koopman (2003), Del Negro and Otrok (2003), Heathcote and Perri (2003), Kose, Prasad and Terrones (2002), Monfort et al (2002), Carvalho and Harvey (2002), Dalsgaard et al. (2002), Angeloni and Dedola (1999) and Artis et al. (1997). Bordo and Helbling (2003) do not consider changes after 1973 which is the main focus of this paper. Stock and Watson (2003a) include one test that arguably sheds some light on the emergence of a higher co-movement among euro-area countries.

We consider data from 1960 to the end of 2002 and focus mainly on a three-break case, where the breaks are found to fall in the early 1970s, 1980s, and 1990s. Thus, the 4 regimes correspond roughly to the decades and we talk about them in that way. Our main conclusions are these:

1 The 1960s were generally a period of low volatility relative to the 1970s and low co-movement relative to later periods more generally.

2 Volatility of output and consumption growth fell broadly over the period since about 1980. This GDP result is now standard in the literature.

3 There is no evidence of a change in co-movement between any two periods after the 1960s. This lack of evidence is not simply a case of point estimates favoring a rise, but standard errors being large. One could probably make the case for a *fall* in co-movement as easily as for a rise.

We note three details of the final claim: (*i*) There is no evidence of a rise in correlation among the euro area countries in the sample (France, Germany, Italy) or among the English group (Canada, U.S., U.K.). (ii) From a welfare standpoint, one benefit of global integration might be better consumption risk sharing. We find virtually no statistically significant evidence of an increase in consumption growth correlation that is sometimes assumed to be reflective of better risk sharing. (iii) Despite a huge increase in trade between the U.S. and Canada after the Canada-U.S. Free Trade Agreement, we see no increase in correlation between the United States and Canada.

Section 2 provides some background; section 3 gives some descriptive evidence illustrating our major points. Section 4 provides the formal inference that is our primary unique contribution. Section 5 has some robustness checks and section 6 concludes.

2 Background on co-movement of growth

The average correlation of growth between pairs of G-7 economies from 1960Q2 to 2002Q4 is moderately positive at 0.24. The highest correlation is 0.48, between both France and Italy and Canada and the United States. The lowest correlation is between Italy and the United Kingdom at 0.07. This section presents some background that may help interpret both the level of correlation across countries and changes in those correlations.

2.1 A simple framework

We start with a very simple exercise to illustrate the accounting relations among variance, covariance, and correlation. Home (h) and foreign (f) growth are driven by common shocks, ε_c, that directly affect both countries, and by idiosyncratic shocks, ε_h and ε_f, that directly affect only one country. Writing growth as y, we have,

$$\begin{aligned} y_h &= \varepsilon_h + \varepsilon_c + \gamma y_f \\ y_f &= \varepsilon_f + \varepsilon_c + \gamma y_h \end{aligned}$$

For simplicity, the countries are treated symmetrically. We include the foreign country's growth in the equation determining home country growth to summarize how linkages may transfer idiosyncratic shocks across borders. We focus on the case with $0 < \gamma < 1$, with each idiosyncratic shock having a variance σ_x^2 and with the common shock having a variance σ_c^2.

The following facts are easy to confirm. The existence of common shocks and the cross-border effects of idiosyncratic shocks imply that the growth rates will be positively correlated. A decrease in the variance of the common shock (σ_c^2) will decrease the variance in each economy as well as decrease the covariance. Because covariance decreases proportionally more than variance, correlation also falls. Thus, if we explain a decrease in variance by a lower variance of common shocks, in this framework we would also see both lower covariance and lower correlation.

A fall in the variance of both countries' idiosyncratic shocks reduces the variance of each economy and again reduces covariance through spillovers. In this case, however, growth correlation rises. Intuitively, correlation is the share of variation that is shared in common. The fall in idiosyncratic variation reduces the total variation but increases the share of variation that is common.

Finally, making linkages stronger through increasing γ, holding σ_x^2 and σ_c^2 constant, raises variance, covariance, and correlation. Thus, a fall in the variance of either country in this case must be due to a smaller γ and will have an associated fall in covariance and correlation. The proponents of the view that rising economic integration has increased correlation have a richer set of channels in mind. We provide a brief review of the theory evidence regarding increased linkages and co-movement.

2.2 Some evidence on increased economic linkages

There have been substantial increases in trade and financial linkages among the G-7 countries in the last several decades. Each G-7 country, except Japan, has shown an increase in merchandise trade (exports plus imports) with its G-7 partners over the period since 1960 (figure 1). As a percentage of its own GDP, Canada's trade with its G-7 partners almost tripled from just over 20 percent to more than 60 percent, with much of the rise coming after the Canada-U.S. Free Trade Agreement in 1989.[8] The U.S. share rose from about 3 percent to about 9 percent over the period, and shares for each of the European G-7 nations have about doubled, reaching about 20 percent.

Financial integration has also increased. For example, the share of foreign equities in U.S. equity portfolios rose from less than 2 percent in the early 1980s to almost 12 percent in 2001 (figure 2). The share of U.S. equities in foreign equity portfolios also rose markedly over the period. Other measures of international financial market integration show a similar pattern of increase.[9]

[8] Most of Canada's trade with the rest of the G-7 is with the United States (rising from 17 percent of GDP in 1960 to 56 percent in 2000).

[9] See IMF, World Economic Outlook, October 2001. Chinn and Forbes (2003) also look at

2.3 The relationship between integration and co-movement

Even in the simplest cases, theory makes remarkably few predictions about the relation between integration and co-movement. The easiest case to analyze is that of two economies moving from partial integration to a completely integrated, fully efficient equilibrium. Upon moving to complete integration, intertemporal marginal rates of substitution are, by definition, equalized. With additional strong assumptions such as a single good and log utility, complete integration implies that consumption growth will be perfectly correlated. Thus, the increase in integration raises consumption correlation. Weakening any of the assumptions can overturn this result. If we move to greater, but still incomplete, integration, consumption correlation may increase or decrease. Further, the fact that consumption is an aggregate of many types of items, including durables, is problematic. There seems to be a presumption, however, that consumption correlation would increase across countries with increased integration.

As for output and investment, even when moving to fully efficient integration, there are factors working to increase and to decrease correlation. Under autarky, output and investment decisions are intimately linked with consumption smoothing. With integration, the trade and asset flows that facilitate complete consumption insurance allow output and investment decisions in the individual economies to be substantially delinked from current consumption decisions. Thus, for example, a country experiencing a positive country-specific productivity shock can borrow from abroad—immediately raising consumption and investment by more than would be efficient under autarky. This borrowing can magnify the effect of the differential productivity shocks, decreasing output and investment correlations. Whether integration raises or lowers correlation through this channel can depend on whether there is horizontal or vertical integration of production (Kose and Yi (2001, 2002)).

If the model allows a role for demand shocks, increased integration can increase

the change in financial linkages over time. While some argue that equity returns have become more correlated across nations (OECD Economic Outlook, June 2002), others (e.g., Brooks and Del Negro, 2002) question this result.

output, consumption and investment correlations as demand shocks in one country fall partly on imported goods and are, thereby, transmitted to others. Some longer-term implications of integration may lower correlation. For example, integration may lead to specialization of production along the lines of comparative advantage. If there are asymmetric shocks by specialty, output and investment correlation can once again decrease under greater integration.[10] A common intuition is that financial integration will raise correlations, but Heathcote and Perri (2002) show that financial autarky can generate higher output correlations through terms of trade effects.[11]

In principle, one could build a dynamic stochastic general equilibrium (DSGE) model to sort out the relative magnitudes of these various effects, and there has been much progress in this regard, as evidenced by some of the articles cited above. There is reason to doubt, however, whether we have yet specified these models with sufficient detail to resolve the empirical issue. DSGE models with flexible prices and complete markets have difficulty generating anything close to the positive output correlation found in the data.[12] Even with nominal rigidities, which allow a role for demand shocks, the standard Mundell-Fleming model has a negative output correlation in response to monetary policy shocks. Kollmann (2001) shows that in a new Keynesian open economy model one can generate positive output correlations in response to both productivity and monetary shocks.[13]

Although theory does not resolve whether stronger links increase co-movement, empirical studies suggest that in the limit, at least, integration raises output correlation. Growth correlations of regions within a country are generally higher than the correlations of similarly situated regions across national boundaries. Since trade

[10] Paul Krugman (1993) develops this argument. Kalemli-Ozcan, Sorensen and Yosha (2001) show that U.S. States and OECD countries with a more specialized production structure have output that is less correlated with other states or countries. Kalemli-Ozcan, Sorensen and Yosha (2003) provide evidence that more risk sharing leads to greater industrial specialization both across regions and across countries.

[11] For other examples of ambiguous effects related to increased capital mobility, see Frankel (1988).

[12] See Backus, Kehoe and Kydland (1992) and the survey by Baxter (1995).

[13] Whether he matches the data depends on his assumptions about the elasticity of substitution between home and foreign goods.

and financial links are usually higher within countries, these studies suggest that more integration raises correlation.[14]

Of course, the G-7 has not become *fully integrated*, and economic integration may not have risen enough over the past several decades to lead to a detectable change in correlation. We know of no clear evidence that changes of the magnitude we have observed should significantly raise the correlation among G-7 economies.[15] In light of this prior work, the goal of the remainder of the paper is to document any changes that have occurred.

3 Descriptive evidence

In this section, we present a graphical summary of changes in the variability and co-movement of G-7 growth.[16] Figure 3 shows the four-quarter GDP growth rates of the G-7 economies and a simple average of the growth rates in two sub-regions—the English group and the euro group. U.S. recessions are shaded. Japan and the euro economies both seem to have a slight downward trend in their growth rates. One can also see the overall positive correlation, with the movements being most similar around the time of U.S. recessions. It is also possible to see the much-discussed decline in the standard deviation growth in the United States and elsewhere.

Figure 4 summarizes changes in the standard deviation of growth in the G-7. Each point on the figure shows the sample standard deviation of quarterly growth measured over the previous 5 years (20 quarters). The standard deviation for the English and euro panels is a simple average of growth rates in the subgroup.

The decline of the standard deviation for the United States (dashed) is dramatic,

[14] This result seems to hold when controlling for such as factors as size of the economies, distance between the areas compared, and policy differences. See, for example, Bayoumi and Eichengreen (1993), and Clark and van Wincoop (2001).

[15] Most estimates of the effect of small increases in trade intensity on output correlation are similarly small. See Canova and Dellas (1993), Frankel and Rose (1998), Anderson, Kwark and Vahid (1999), Imbs (1999, 2003), Clark and van Wincoop (2001), Otto, Voss and Willard (2001), Gruben, Koo and Millis (2002) and Calderon, Chong and Stein (2003). Calderon, Chong and Stein find even smaller effects between developing and advanced economies and smaller again among developing economies.

[16] Details about the data are in Appendix A1.

falling by more than 1/3 in a relatively short period in the early 1980s. The standard deviation has fallen more generally, with the exception of Japan, where the standard deviation rose markedly along with the economic problems of the 1990s. The decline in France is quite small after the 1970s and Germany's decline may have occurred later than the others.[17]

In contast with the standard deviations, moving 5-year correlations show no clear change over the period (figure 5). Estimated correlations between G-7 economies fluctuate widely over the business cycle, tending to reach peaks after U.S. recessions. The moving correlations show no clear break in behavior within the English group (panel A), the euro group (panel B), or elsewhere (panel C). Japan is again an exception: the correlation of Japan with the rest of the G-7 has fallen sharply and turned negative in the 1990s. The high levels of correlation at the end of our sample are consistent with the historical pattern of high correlation following U.S. recessions.

Figure 6 presents the moving correlations for consumption growth. Once again, there are no obvious changes to be observed. With standard deviations falling and correlations either showing no clear change or falling, measured covariances must have fallen in the 1980s (figure 7).

Our main focus is co-movement, and we can see that there is no dramatic break in correlation despite the aforementioned dramatic increased in trade and financial linkages across countries. Remember that Canada-G-7 trade tripled from 20 to 60 percent of GDP over the sample. Similarly, the euro area economies show no increase in correlation; indeed, Germany's correlation with France shows a steady decline since the early 1970s. Even without formal testing, we can conclude that dramatic rises in certain integration measures have not led to similarly dramatic changes in correlation. The next section presents formal evidence on these questions.

[17] Our conclusions concerning Germany should be taken with caution because of the measurement issues surrounding German reunification. See data appendix for an explanation of how we treat German reunification.

4 Formal Inference

In this section we present formal inferences about changes in the time series processes for GDP, consumption and investment. We drop Japan from the analysis and study only the rest of the G-7 (G-7x). While there are clearly breaks in the behavior of the Japanese aggregates and in their relation with the rest of the G-7, we believe that these are related to the special problems Japan has experienced. If dropping Japan biases our analysis, it biases it in favor of finding increased correlation.

We present no new evidence about whether there exist breaks in the processes we study. The existence of breaks has been well-documented in earlier work, which we review briefly below. Given the existence of breaks, there are many interesting hypotheses regarding which features of the processes changed and which, if any, remained constant. For example, as noted above, there is strong evidence that the variance of output across the G-7x declined. As a result, correlation or covariance must have changed, and it would be of interest to know whether one of these stayed more or less the same. Similarly, as Ahmed et. al (2004) point out, certain explanations of the fall in variance suggest that most of the reduction would have come at business cycle frequencies, while in other explanations the reduction would have come evenly across all frequencies. In this latter case, the shape of the spectrum would remain unchanged across sub-samples.

As noted in the introduction, most papers addressing co-movement have presented descriptive evidence like that in the previous section without formal inference.[18] In the most common approach, the papers first establish in some way that breaks have occured. For example, they use appropriate techniques to establish and date the break in the variance of growth. Having chosen break dates, the papers go on to report point estimates of various parameters such as covariances or correlations before and after the breaks. Differences in these point estimates are then interpreted as evidence of changes in those parameters. An alternative approach is to estimate a time-varying parameter model for the relevant data and simply report

[18] See footnote 7.

the estimates without any test of the null of no change in the relevant parameter. Of course, when we observe changes in parameter estimates it is important to ask whether those differences are large relative to what we might expect to see if no change had occured in the underlying parameter. In the next section, we show that bypassing inference may be especially risky in the current context.

4.1 Detecting changes in variance, covariance, and correlation

Inference about breaks in correlation and covariance in the current context is fundamentally less precise than inference regarding breaks in variance. For example, if the covariance of GDP growth between the United States and the United Kingdom remained constant as variance fell in the early 1980s, it would be quite likely that the point estimates of covariance from the two sub-samples would differ greatly. We illustrate the generic point with a simple example.

Suppose we have two samples, each drawn independently and identically from a bi-variate normal distribution with mean zero. We want to detect whether the variance-covariance matrices, $\Sigma_i, i = 1, 2$, differ across the samples. Suppose in fact that $\Sigma_2 = \alpha\Sigma_1$ where $\alpha < 1$, so that the variances and covariances fell proportionally while the correlation stayed fixed.

One generally has more power to detect the change in variance than the change in covariance. One way to see this is to study limiting cases. If the correlation between the series is 1, then testing for a change in covariance and in variance is identical (as the variance and covariance are exactly the same) and equal power is attained with the two tests. If the correlation is zero, then there is no change in covariance between the two samples and, hence, no change can be detected. Thus, the power of the covariance test to detect $\alpha < 1$ relative to the power of the variance test is zero.

If the correlation of the two series is small, but positive, the variance and the covariance both change by the same factor of proportionality, but the power to detect the change in covariance relative to the power to detect the change in variance may be quite small.

More formally, as we consider correlations going from one to zero in this problem, the relative power to detect the covariance change versus the variance change also goes from one to zero. For moderate levels of correlation, such as the average output correlation of 0.24 among G-7 GDP growth over our sample, the relative power of the covariance test may be quite small. For example, in the simple example considered here, with correlation of 0.24 the Appendix shows it would take about 5 times as many observations in the covariance test to attain equal power as one has in the variance test.

The bottom line is that strong statistical evidence of breaks in the variance of processes does not provide a sound basis for concluding that similarly large changes in the *point estimates* of covariance or correlation are also likely to be statistically significant.

4.2 Description of the inference procedures

We consider breaks in the processes for GDP, consumption, and investment separately. The data are stated as annualized quarterly growth rates (400 times the logarithmic quarterly change). Details regarding the data, including the treatment of some outlier quarters and, in particular, German unification are given in Appendix A1.

For concreteness, consider the GDP case. We assume that the time-series process for GDP growth of the G-7x can be adequately approximated by a vector autoregression with one lag and a constant, where all the parameters (constant, slope, and shock variance-covariance) are allowed to break at a fixed number of dates. Allowing B breaks at the dates $\tau = \{\tau_1, \ldots, \tau_B\}$, the parameters are $\theta = \{\theta_1, \ldots, \theta_{B+1}\}$, where θ_i is all the parameters of the VAR process in the i^{th} subsample.

The key unique assumption we make is that we know the number of breaks, but not their dates. If we know the number of breaks, Bai (2000) suggests estimating the parameters by maximizing the Gaussian pseudo-likelihood for τ and θ. More specifically, for any τ and θ, the log-likelihood is given by,

$$\mathcal{L} = \sum_{i=1}^{B+1} L(X^i|\theta_i)$$

where X^i is the data for the i^{th} subsample when the observations are partitioned according to τ and L is the conventional Gaussian log likelihood given the stated data and parameter arguments.[19] We estimate τ and θ by maximizing $\mathcal{L}$ over all unique partitions τ and parameters θ.[20]

Bai (2000) shows that so long as our conditioning assumption is correct, the asymptotic distribution of $\hat{\theta}$ is the same as if the break dates were known and imposed *a priori*.[21] In particular, $\hat{\theta}$ is asymptotically normal, $\hat{\theta}_i$ is uncorrelated with $\hat{\theta}_j$ if $i \neq j$ and the variance-covariance matrix of the elements of θ_i is just as if we were estimating a single VAR for the relevant subsample.

We are assuming that some features of the VAR broke, and want to test that others remained constant. All the features in which we are interested—e.g. unconditional variances and covariances—can be written as scalar functions of the VAR parmeters, $G(\theta)$. We want to test

$$H_0 : G(\theta_i) = G(\theta_j) \quad i \neq j$$

for various G.[22] Given that θ_i and θ_j are jointly asymptotically normal and the variance-covariance matrix of the asymptotic distribution is known, any conventional testing approach may do. The simplest approach would be to form a confidence

[19] In practice we use the conditional likelihood, conditional on initial lags in the first segment.

[20] We require that at least 20 percent of the sample lies between any two breaks or break and endpoint.

[21] This point may seem to go against the intuition from the endogenous breakpoint literature. That literature is concerned with testing for existence of a break. Searching over breakpoints affects the asymptotic distribution of tests for the existence of a break. If the maintained hypothesis contains a fixed number of breaks, searching over dates does not affect the asymptotic distribution of parameter estimates in this case. The reason for this stems from the fact that the estimated break times (viewed as a share of the sample) converge more rapidly than the coefficient estimates. Note that the asymptotic theory involves the size of the change in the coefficients going to zero (at the right rate) with the sample size. Despite the shrinking break, the break times converge rapidly.

[22] This works for any H_0 of this form that is consistent with the conditioning assumption that *something* in θ changed.

interval for $\Delta_{ij} = G(\theta_i) - G(\theta_j)$ as $\hat{\Delta}$ plus and minus twice its asymptotic standard error computed, say, using the delta method.

Some of the $G(\theta)$s we are interested in are correlations, however, and conventional asymptotic approaches—even standard bootstrap approaches[23] are known to perform poorly in such cases. Thus, we compute confidence intervals for Δ_{ij} using what in Hall's (1992) language is an iterated other percentile bootstrap. (See the Appendix for details.)

Now we discuss some strengths and weaknesses of our procedure. We consider separate systems for GDP, consumption, and investment in part to keep the size of our VARs small. Parsimony issues would become more important if we were to estimate an 18 variable VAR. Furthermore, theory gives reasons why economic integration might raise consumption correlation while decreasing investment correlation. Thus, we opted to run separate systems for the 3 different aggregates.

The procedures condition on breaks existing and investigate what, if anything, remained constant across sub-samples. An important choice, then, is the number of breaks. We perform the analysis for 1, 2 and 3 breaks, but report only the 3-break case. We prefer the 3-break case for the following reasons. McConnell and Perez-Quiros (2000) and others give a strong case for a break in the variability of U.S. output growth in the early 1980s. Bai, Lumsdaine and Stock (1998) make a strong case for a break in growth around 1970. Finally tests for break dates in bivariate systems that include either Canada or Germany tend to find dates in the early 1990s.[24] We review below which conclusions are sensitive to the number of breaks.

Finally, the only type of parameter change we consider is a small number of discrete breaks. Others have found evidence for other types of time variation in parameters (such as Stock and Watson (2003a) and Luginbuhl and Koopman (2003)). We believe that the discrete break framework remains an important baseline in this

[23] For example, see Hall (1992) on the weakness of the percentile-t bootstrap in this context.

[24] These break dates may be a result of reunification, in the case of Germany—despite our solution for the jump in German growth rates (see data appendix)—and perhaps in part influenced by the Canada-U.S. Free Trade Agreement in the case of Canada.

literature. This case still dominates discussion and we believe our results shed useful light on earlier results in the area. Further work on both approaches is surely warranted.

4.3 Results for the mean and variance

Point estimates of the breaks. With 3 breaks, there are 4 subperiods. Our inference approach allows the data to pick the break dates. Since we estimate a different VAR for GDP, consumption, and investment, the chosen break dates differ across the three systems. In practice, there is little variation, and the 4 periods chosen correspond roughly to the 1960s, 1970s, 1980s, and 1990s (table 1). We will use these decade labels to describe the periods, but one should take care to remember that the actual break dates do not fall exactly on the decade boundaries.[25]

Mean growth. We begin with a summary of the statistical significance and direction of breaks in mean growth. Table 2 reports whether the confidence interval for the change in mean between any two periods covers zero. If the 95 percent confidence interval lies entirely below zero, the table has a bold "**D**" for down; if the 90 percent confidence interval (but not the 95) is entirely below zero, there is a (plain) "D"; otherwise if the point estimate is below zero there is a 'd'. For the analogous cases above zero, there is the appropriate "**U**", "U", or "u" entry for up. In all cases, we report the value in the later sub-sample minus the earlier, so up means the coefficient rose through time. The rows of the table labelled "All", "Eng" and "Eur" report the test for a change in the average value of the parameter across the economies in the group.

One notable feature of the results is that mean growth of GDP and consumption fell very generally between the 1960s and both the 1970s and 1980s. This result is no surpise—the 1960s were a period of unusually strong growth; the 1970s and 1980s were not as strong. Some idea of the economic magnitude of the changes can be

[25] We do not mean to imply that nothing turns on whether we take the break dates to be exactly on decade changes or shifted slightly as in our procedure. Some conclusions may be sensitive. This is because the last 3 U.S. recessions happen to fall near decade changes and shifting slightly can change which subsample certain recessions fall in.

gained by considering the point estimates of mean growth in the subperiods (table 3).

A second important feature is the difference between the English and euro groups. There are no significant changes in mean growth in the English group between periods after the 1960s, and few for the individual countries in the group. In contrast there are many significant reductions through time in both GDP and consumption growth in the euro group. Consumption growth fell significantly between every pair of periods except the 1980s to 1990s in the euro group.

Since our main concern is with second moments, it is worth noting that these changes in the mean could have important implications for empirical work on second moments which does not allow for these mean breaks. Allowing for, say, only one mean break over the period could lead to spurious results regarding the variance in euro area countries.

Standard Deviations. The tests for changes in standard deviations confirm the familiar results from the literature and the graphical evidence seen earlier (table 4, upper panel). The unconditional standard deviation of GDP and consumption growth perhaps grew from the 1960s to the 1970s, but fell very generally after that. In the point estimates, the standard deviation of growth of GDP fell on average by about one-half and that of consumption fell by about one-third.

The results for investment are more mixed, except for the case of the United States where the standard deviation fell signifcantly. Generally, investment growth is more volatile than consumption and GDP growth; this volatility reduces the power to detect any sort of change, so we should expect not to find signficant changes in investment throughout the results.

The conditional standard deviation[26] followed about the same pattern as the unconditional variance (table 4, lower panel). The similarity of the unconditional and conditional standard deviation results suggest the possibility that only the variance-covariance matrix of the shocks changed, leaving the slope coeficients of the VAR

[26] The conditional standard deviation is the standard deviation of the one-step ahead prediction error, or equivalently, the standard deviation of the VAR reduced form error.

unchanged. An analogous result has been documented before for the United States[27] and other countries.[28]

We shed additional light on this question by asking whether there have been any changes in the shares of variance attributable to cycles in three regions of the frequency domain: business cycle frequencies (8 to 32 quarters) and higher and lower frequencies. Table 5 shows tests of whether the share of variance in each of the 3 frequency bins changed. If the change in unconditional variance came exclusively from a change in the shock variance-covariance matrix, then the share of variance in each frequency bin would be unchanged.

Except for comparisons with the 1960s in the U.K. and Canada, there are very few significant entries. There is little evidence that the reduction in unconditional variance was focused on one frequency bin more than others. These results are quite consistent with existing results in the literature. We now turn to the results for co-movement, an area where few testing results have been reported.

4.4 Results for co-movement

For the correlation and covariance measures (tables 6 through 9), the all, English, and euro values represent the mean of the off-diagonal elements of the relevant covariance or correlation matrix. The English-euro measure is the mean of the off-diagonal elements of the matrix corresponding to elements with one country in each subgroup.

From the group estimates for GDP, it appears that unconditional correlations have risen quite generally between the 1960s and any subsequent period. The result is similar, although somewhat less uniform for consumption. After the 1960s, there are no significant changes in GDP for the all, the English, or the euro groups and the point estimates are mixed. The average correlation between the English and euro group countries fell signficantly between the 1970s and 1980s, but shows no signifcant change thereafter. The statistically significant changes in consumption

[27] Ahmed et al. (2004).
[28] Stock and Watson (2003a).

after the 1960s in the country pairs are about equally split between ups and downs and are not clearly differentiated by sub-group.

This result casts some doubt on the claim that euro and English groups have emerged with each group having strong internal co-movement but with correlation between the groups falling. The one bit of statistically significant evidence in line with this theory is that the English-euro correlation fell from the 1970s to the 1980s. The decline in the point estimate is from 0.38 to 0.16, about the same magnitude as the fall in correlation within the euro group itself, 0.50 to 0.39, however.

The U.S.-Canada correlation shows no significant change during the period in which the trade share was growing sharply. The point estimate of the correlation change in GDP was down between the 1970s and 1980s and between the 1980s and 1990s.

The conditional correlations show somewhat more evidence for a fall in correlation between periods after the 1960s. Several of the bi-variate correlations show significant declines in both GDP and consumption correlation. Interestingly, from a standpoint of consumption risk sharing, the average conditional correlation among all 6 nations fell in the point estimates from the 1970s to the 1980s and from the 1980s to the 1990s. These changes are not statistically significant, however.

Given the strong evidence of declines in variance and little clear evidence of change in correlation, one might hope to find statistically significant evidence of declines in covariance. As we noted above, however, the data may simply not reveal whether correlation has risen or covariance has fallen.

There is somewhat more evidence of declines in covariance for periods after the 1960s than there was for increases in correlation. By crude count considering GDP growth, there are 18 significant downs (table 6) after the 1960s in covariance, whereas there are no comparable significant ups in correlation (table 8). We know that either correlation, covariance or both changed as a result of the variance changes. As the statistical theory suggested, however, the evidence in favor of the proposition that either correlation or covariance changed is much stronger than the evidence resolving which one it was that changed.

5 Robustness

In this section we review some additional results that shed light on the robustness of the 3 central conclusions listed in the introduction. In short, the 1960s were a period of low variance and correlation, variance fell after 1980s, and there is no significant evidence of a rise in co-movement in general, in the subgroups, in consumption, or between the U.S. and Canada.

5.1 Alternative correlation measures

Since co-movement is our primary interest in this topic, we consider additionally 3 types of factor-model-based measures of co-movement. Each of our three types of measures is a standard “atheoretical” way to summarize how similarly variables move together.

Our first measure, $\lambda(N)$, is the sum of the largest N eigenvalues of any correlation matrix. This measure has a standard factor-theoretic or principal components interpretation. We want to choose factors f_t where f_t is $N \times 1$, $t = 1 \ldots T$, and the factors can be serially correlated. We choose these factors to maximize the sum of the R^2s for regressions of the form,

$$y_{jt} = \alpha_j + \beta_j' f_t + \varepsilon_t \quad j = 1, \ldots, k$$

where k is the number of countries in the group. In this sense, these are the $N < k$ factors that best explain our k variables. If we choose the factors in this way, then $\lambda(N)$ is the sum of the R^2s. If $\lambda(N)$ increases, then the movements of our k variables can be better explained by our $N < k$ factors.

The second measure is more dynamic and somewhat more familiar from identified VAR work. In any VAR system, once the shocks are orthogonalized, we can calculate the variance share of any variable that can be attributed to any shock. Following Faust (1998), we can calculate the maximum variance share, summing shares across all variables, that could be attributed to any N orthogonalized shocks. This measure can also be seen as a sum of R^2s. In particular, it maximizes the sum of R^2s across the k regressions,

$$y_{jt} = \alpha_j + \beta_j(L)' f_t + \varepsilon_t \quad j = 1, \ldots, k$$

where $\beta_j(L)$ is a one-sided lag polynomial and f_t is serially uncorrelated and lies in the space spanned by the shocks of the VAR.

Our third measure is a fully dynamic version of the first. In this case, we only consider a single factor for computational ease. This factor is designed to maximize the sum of R^2s from the k regressions,

$$y_{jt} = \alpha_j + \beta_j(L)' f_t + \varepsilon_t$$

where now $\beta(L)$ is a two-sided filter. Our measure is the sum of R^2 that maximizes this expression over all f. Brillinger (1981) discusses the calculation of this quantity.[29]

Table 10 gives evidence on the breaks in these measures. The evidence is consistent with the earlier evidence for correlations: there is some evidence of an increase in correlation from the 1960s to later periods and very little evidence of further change thereafter.

5.2 Alternative versions of the results

So far we have reported results for VARs with 3 breaks estimated on raw growth rate data. We repeat all of this work for 12 total versions of the system. In particular, we consider conditioning on 1, 2, and 3 breaks, using per capita versions of all the variables, and using Hodrick-Prescott filtered versions of the variables. In the end, by considering all combinations of these options, we arrive at 12 sets of results. A complete set of results (about 400 pages) is available from the authors.[30] The reader

[29] While the first measure is given by eigenvalues of a correlation matrix, this measure is given by the integral across the spectrum of the maximum eigenvalue of a coherence matrix.

[30] See http://patriot.net/~faustj/jon or http://www.geocities.com/brian_m_doyle/yctabs.pdf.

will be relieved to know that we will not attempt to give a detailed account of all these results. We focus on the three broad conclusions stated in the introduction.

The first conclusion is that systems with only one break give somewhat different results. As we have seen above, the changes from the 1960s to later periods often are more significant and different in character than the changes between any two later periods. Systems with one break cannot accommodate both the early-1970s change and the early-1980s break and give somewhat different picture. So long as we allow for two breaks (which the procedure places in the mid-1970s and mid-1980s), the general results come through: correlation rose after the 60s, but showed little change between subsequent periods.

The per capita and Hodrick-Prescott filtered versions of the variables generally lead to the same break dates listed in table 1. The tables for per capita growth rates are virtually identical to the results reported above—population moves slowly and does not affect the general conclusions about either variability or co-movement. The tests on the HP filtered data generally show even weaker evidence of changes in co-movement after the 1960s.

6 Conclusions

We find that the reduction in growth variation that has been documented for the United States seems to be present in almost all of the other G-7 countries. The exception is Japan, which in the 1990s is anomalous to most macroeconomic generalities regarding the G-7.

There is no clear evidence that correlation has increased with the rising economic integration over the sample period. In general, we cannot reject the hypothesis of no change in correlation. This conclusion holds even for Canada and the United States, which has seen a substantial increase in trade, and for the included euro area countries—Germany, France, and Italy. The result also holds for consumption growth rates, despite the thought that greater integration should lead to greater consumption insurance.

This result contrasts with some earlier claims in the literature. For the most part those claims rest on changes in point estimates with no attempt to do inference about whether the changes are statistically significant. We provide a theory-based reason to doubt whether that approach is reliable. Our formal tests suggest that the changes are not statistically significant.

Appendix A1. Data

We use quarterly real GDP, consumption and investment data from the first quarter of 1960 until the final quarter of 2002. For each country we use official national series as reported by Haver Analytics from the starting point of the relevant series to the end of the sample. In cases where the current vintage of national accounts data [31] do not extend to 1960, we splice data from an older vintage official series as specified below.

To splice the data, we use the quarterly growth rates from the earlier data along with the first level in the recent data to construct a new level series extending back to 1960Q1.

We handle German reunification by taking the quarterly growth rates of West German GDP, investment and consumption for the period up to and including the first quarter of 1991, the quarter of reunification; growth rate data are for united Germany thereafter. To create a level series consistent with the units for united Germany, we use the same splicing method described above.

A search for outliers in the growth rate data reveals two quarters for France, 1968Q2 and 1968Q3, where the GDP growth rate is more than six standard deviations from the mean. Of course, these quarters were associated with well-known strikes and general unrest in France. We replace the data for these quarters in GDP, consumption, and investment using a univariate EM algorithm—an AR(1) model is estimated for each series and the EM algorithm is used to replace the data for relevant quarters.

There are some other quarters with GDP growth rates 3 to 4 standard deviations from the series-specific average, including 1973Q1, 1979Q2 (U.K.), 1974Q1, 1997Q2 (Japan) and 1970Q1 (Italy). The 1970Q1 Italy outlier falls where we splice two series, but the large change is explained by a general strike in 1969Q4. See the OECD Economic Survey, July 1970 for details.

Sources of data by country. Canada: 1960 OECD data, 1961-2002 Statistics Canada via Haver Analytics. France: 1960-1969 OECD data, 1970-1977 Insitut

[31] The 'current' vintage was retrieved from Haver on May 8, 2003.

National de la Statistique et des Etudes Economiques (INSEE), undated historical vintage, via Haver Analytics; 1978-2002 current vintage from INSEE via Haver Analytics. Germany: for GDP, 1960-2002 Deutsche Bundesbank via Haver Analytics; for consumption and investment, 1960-1967 West Germany data specified below, 1968-2002 Deutsche Bundesbank via Haver Analytics. West Germany: 1960-1995Q3 Deutsche Bundesbank, undated historical vintage, via Federal Reserve Board. Italy: 1960-1969 OECD data, 1970-2002 Istituto Nazionale di Statistica via Haver Analytics. Japan: 1960-2002 Economic Planning Agency via Haver Analytics. United Kingdom: for GDP and consumption, 1960-2002 Office for National Statistics (ONS) via Haver Analytics; for investment, 1960-1964 OECD data, 1965-2002 ONS via Haver Analytics. United States: 1960-2002 Bureau of Economic Analysis via Haver Analytics.

In all cases, the OECD data were kindly provided by Jorgen Elmeskov at the OECD.

Appendix A2. Inferences about variance an covariance breaks

In this Appendix we give local and nonlocal accounts of the relative difficulty of detecting variance and covariance breaks in the case described in the text. In particular, suppose we have one sample of size N drawn from data that are independently and identically distributed as a bi-variate $N(0, \Sigma_1)$. We have a second sample of the same size distributed as $N(0, \Sigma_2)$, where $\Sigma_2 = (1-k^2)\Sigma_1$—we replace the α in the text with $(1-k^2)$ for notational convenience.

Suppose we test for a change in the variance of the first variable using the statistic,

$$t_v = \frac{N(\hat{\sigma}_1^2(2) - \hat{\sigma}_1^2(1))^2}{2(\hat{\sigma}_1^4(2) + \hat{\sigma}_1^4(1))}.$$

where $\hat{\sigma}_j(\ell)$ is the sample standard deviation of the j^{th} variable in the ℓ^{th} sample. Using standard results, this statistic is the difference of the sample variances squared over the asymptotic variance of this difference and is asymptotically $\chi^2_{(1)}$ under the null hypothesis of $k = 0$. Since the sample moments are consistent,

$$\operatorname*{plim}_{N\to\infty} t_v/N = \frac{k^4}{2((1-k^2)^2+1)}.$$

The analogous test for the change in covariance is,

$$t_c = \frac{N(\hat{c}(2) - \hat{c}(1))^2}{(\hat{\sigma}_1^2(2)\hat{\sigma}_2^2(2) + \hat{c}^2(2)) + (\hat{\sigma}_1^2(1)\hat{\sigma}_2^2(1) + \hat{c}^2(1))}.$$

where $\hat{c}$ is the sample covariance. Following the results above,

$$\operatorname*{plim}_{N\to\infty} t_c/N = \frac{k^4}{(1-k^2)^2+1}\frac{\rho^2}{1+\rho^2},$$

where ρ is the population correlation of the two variables in each sample. Note that if $|\rho| = 1$ this limit is the same as in the variance case.

We can characterize the nonlocal relative power of the two tests using the results on the approximate slope given by Geweke [1981]. Since these tests are both $\chi^2_{(1)}$ under the null, the approximate slope for fixed k of each is given by the probability limits given above. As Geweke (Theorem 2) shows, as N gets large, the ratio of the number of observations required to attain an given power in the covariance-based test to the number required to obtain the same power with the variance test can be approximated by the inverse ratio of the approximate slopes. Thus,

$$N_c(x)/N_v(x) \approx (1 + \rho^2)/\rho^2$$

where $N_c(x)$ is the number of observations required to attain power x using test c.

Note that at typical correlation among GDP growth rates of about 1/4, this ratio is 5: it takes 5 times as many observations to detect the covariance break as the variance break. Of course, this example is for the iid normal case and does not take the time series properties into account. The general point carries over, however.

Appendix A3. Details on our inference approach

Here we give a brief description of the iterated other percentile bootstrap used to create the reported confidence intervals. For details, see Hall (1992). First, we describe what in Hall's terminology is called an other percentile bootstrap (OPB) confidence interval. This involves creating N_1 bootstrap samples—our parametric method of generating samples is described below. For each such sample calculate the parameter of interest; call the estimate for the m^{th} sample $\hat{\Delta}^{(m)}$. The OPB confidence interval with nominal coverage $100(1-2k)$ percent $(0 < k < 1/2)$ is given by the interval from the k^{th} to the $(1-k)^{th}$ percentile of the $\hat{\Delta}^{(m)}$s. This confidence interval is known to have poor coverage properties that can be substantially improved by iteration.

For the iterated OPB confidence interval, the nominal 90 percent confidence interval is the κ^{th} to the $(1-\kappa)^{th}$ percentile of the $\hat{\Delta}^{(m)}$s, where κ is chosen based on an iterated, or nested bootstrap. The additional round of bootstrapping is used to pick an adjusted nominal level, κ, that brings the coverage closer to the desired level of 90 percent.

To calculate κ, for each of the N_1 samples in the main bootstrap do the following. For concreteness we talk of the m^{th} original sample. The parameter estimates in the m^{th} sample are $\hat{\theta}^{(m)} = (\hat{\theta}_1^{(m)}, \ldots, \hat{\theta}_{B+1}^{(m)})$, where B is the number of breaks. Draw N_2 samples from the distribution implied by the parameter $\hat{\theta}^{(m)}$ using the same parametric approach used in the main bootstrap. Calculate the parameter of interest, $\hat{\Delta}^{(m,n)}$, $n = 1, \ldots, N_2$. Based on N_2 values, we can calculate, for any k, the $100(1-2k)$ percent OPB confidence interval for Δ. Since we know the process generating the data in this case, we can record whether this interval covers the true value of Δ, $\hat{\Delta}^m$. To form a 90 percent iterated OPB confidence interval, we choose

κ as the k such that the $100(1 - 2k)$ percent OPB interval covers the true value in 90 percent of the N_1 nested bootstraps.

What remains to be explained is how we draw the bootstrap samples in the main and nested bootstraps. We use a conventional parametric bootstrap. The parameter estimates from the sample data are $\hat{\theta}$, and call the $(T \times 6)$ matrix of reduced form residuals $\hat{E}$. The parametric bootstrap of a VAR with 1 lag and breaks at $\tau = (\tau_1, \ldots, \tau_B)$ is conditioned on the first observation in the full sample. Given this initial condition, one can recursively generate observations for the first subsample using $\hat{\theta}_1$ and drawing shocks by choosing rows randomly from the first τ_1 rows of $\hat{E}$. We then generate data for subsequent subsamples recursively using the relevant parameter $\hat{\theta}_j$ and drawing rows from the relevant range of rows of $\hat{E}$. All of the bootstrap samples are drawn with break dates fixed at the values that maximize the likelihood as described in the text.

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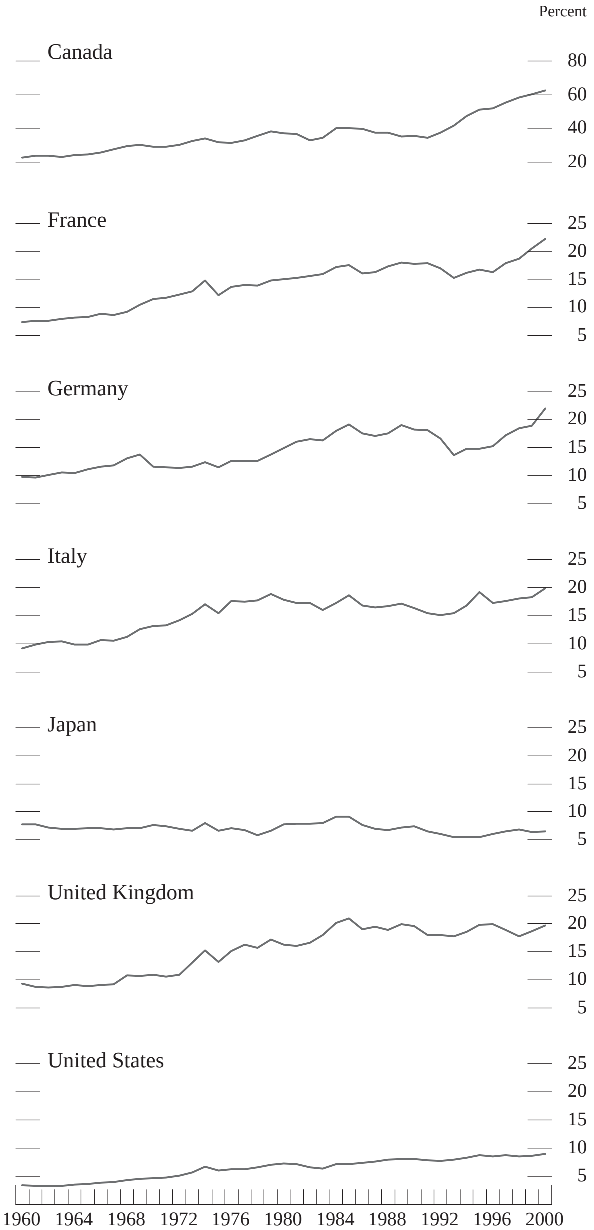
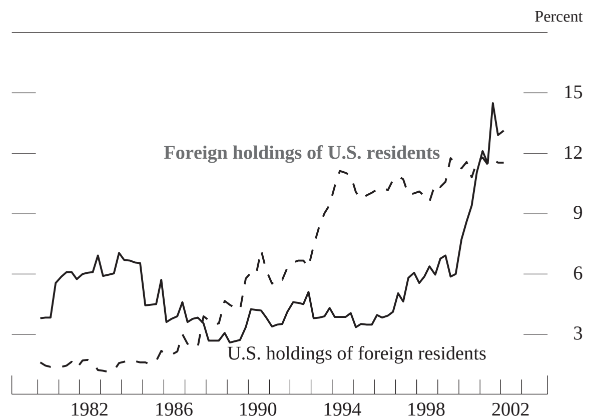
1. Trade (exports plus imports) of each G-7 country with the rest of the G-7 as a share of its own GDP, 1960-2000



NOTE. The data are annual. Imports, exports, and GDP are in current U.S. dollars at current exchange rates.

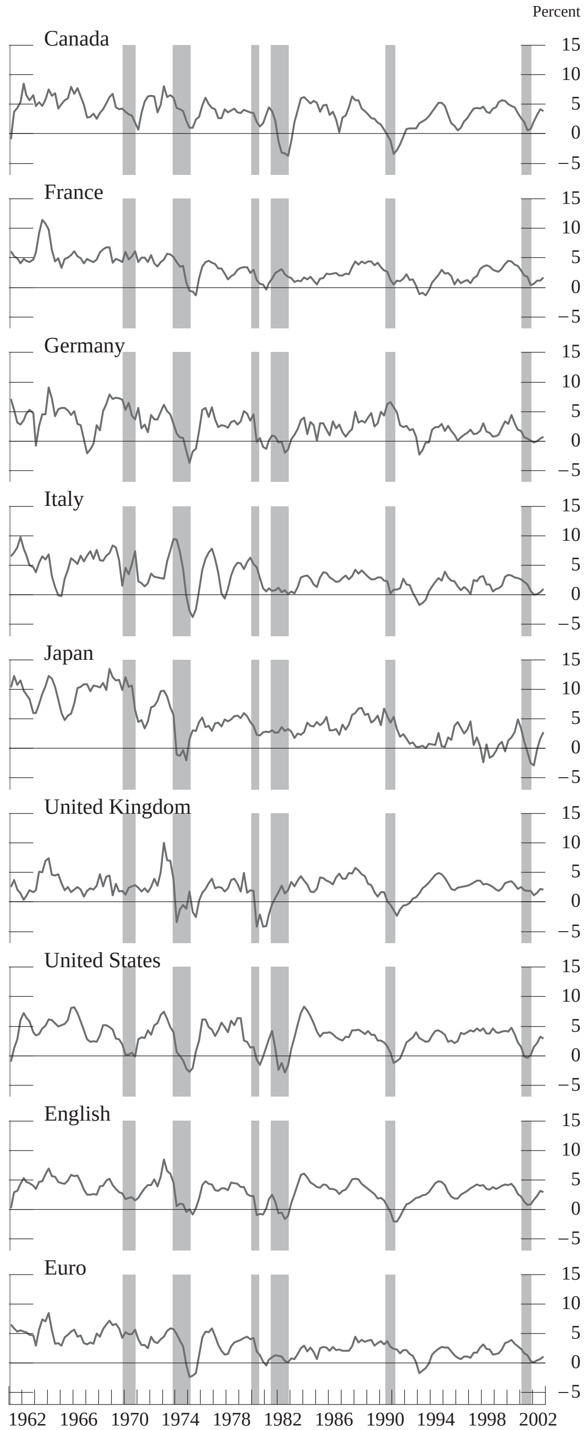
SOURCE. International Monetary Fund, *Direction of Trade Statistics* (various issues); Organisation for Economic Co-operation and Development.

2. Share of foreign equities in equity holdings of U.S. residents and share of U.S. equities in equity holdings of residents of foreign countries, 1980-2002:Q1



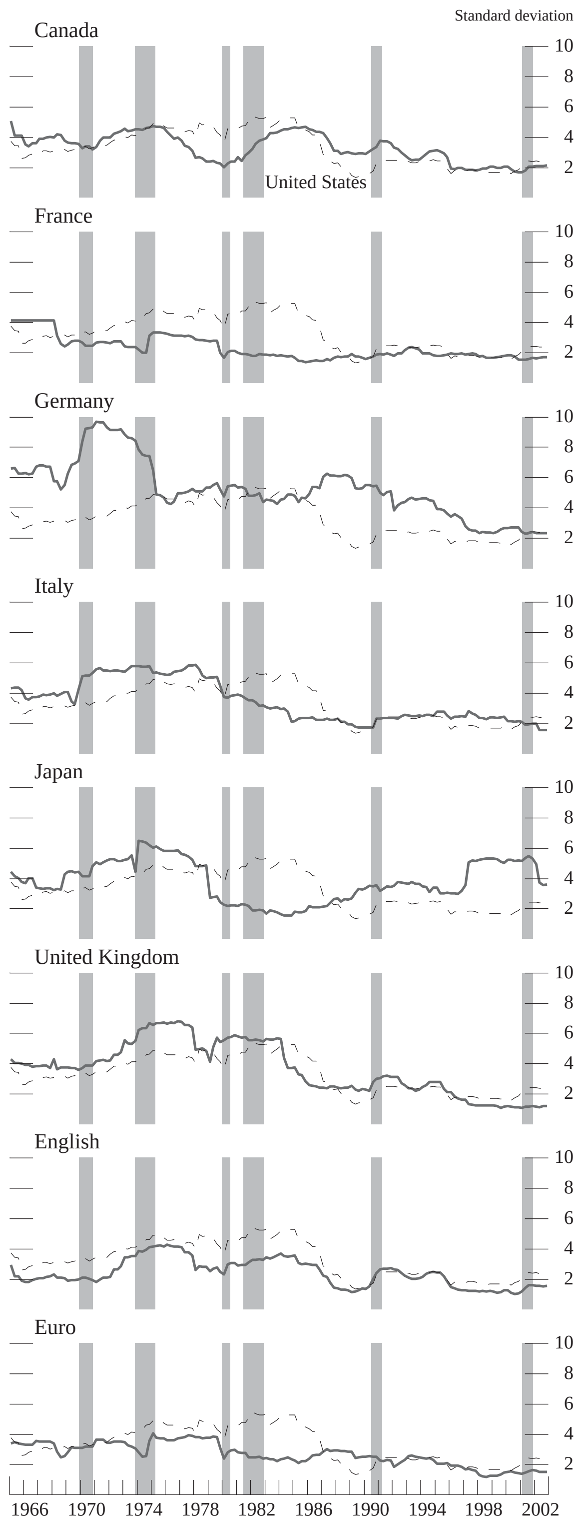
SOURCE. International Finance Corporation; International Federation of Stock Exchanges; Federal Reserve Board.

3. 4-quarter real GDP growth of each G-7 country, 1961-2002



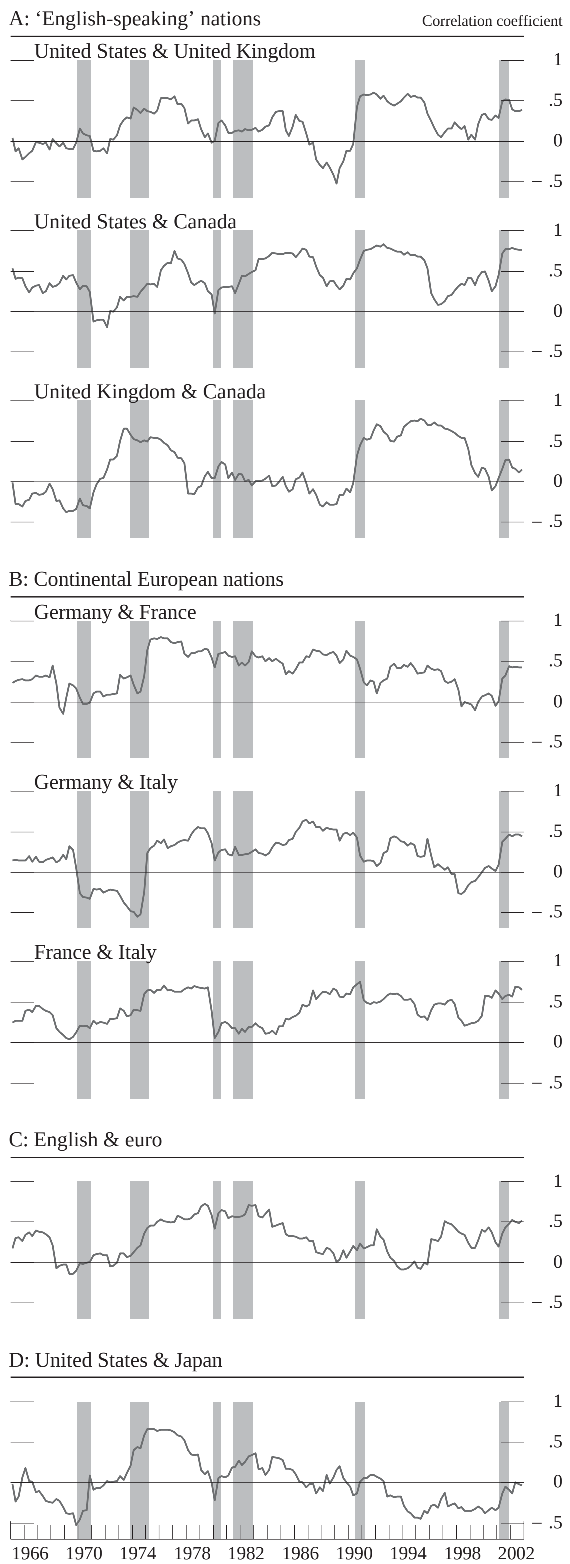
NOTE. Shaded bars are periods of recession in the United States as defined by the National Bureau of Economic Research (NBER). English refers to Canada, the United Kingdom and the United States. Euro denotes France, Germany and Italy.

4. Standard deviations of quarterly real GDP growth rates in each of the G-7 countries, rolling five-year periods, 1965-2002



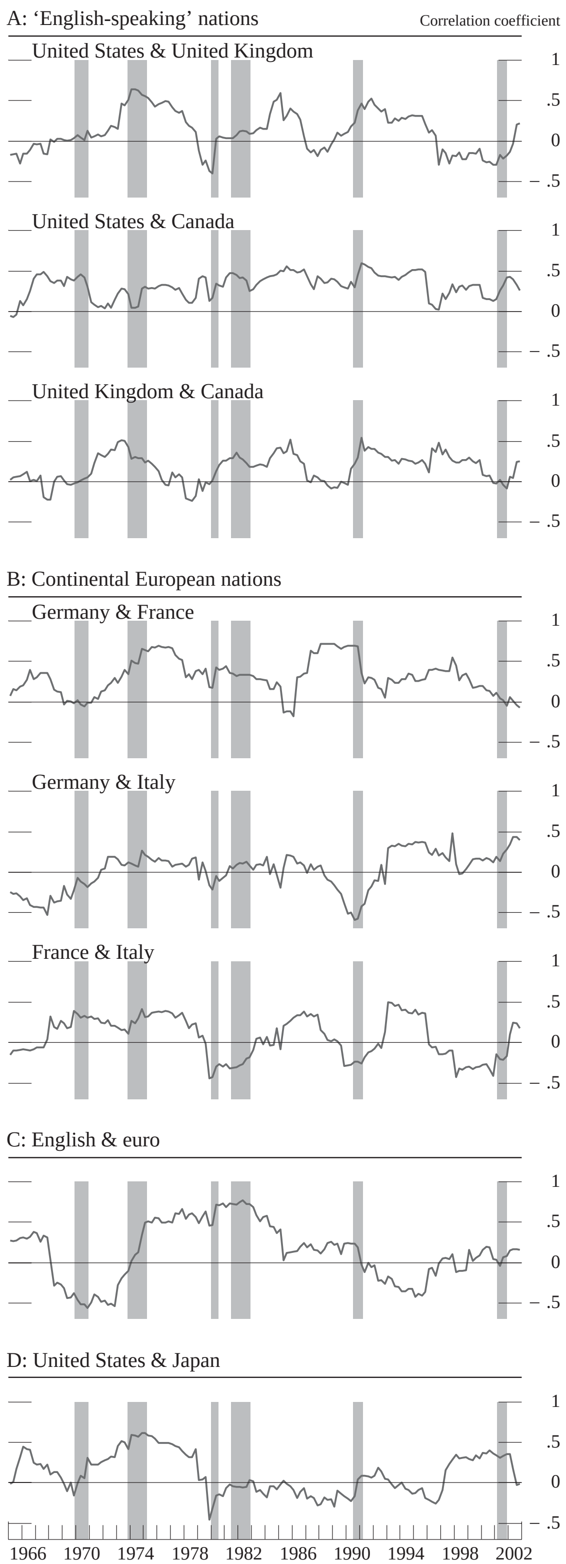
NOTE. Values for each quarter are calculated over the five years ending in that quarter. English refers to Canada, the United Kingdom and the United States. Euro denotes France, Germany and Italy. For description of shaded bars, see general note to figure 3.

5. Correlation of quarterly real GDP growth rates, selected country pairs, rolling five-year periods, 1965-2002



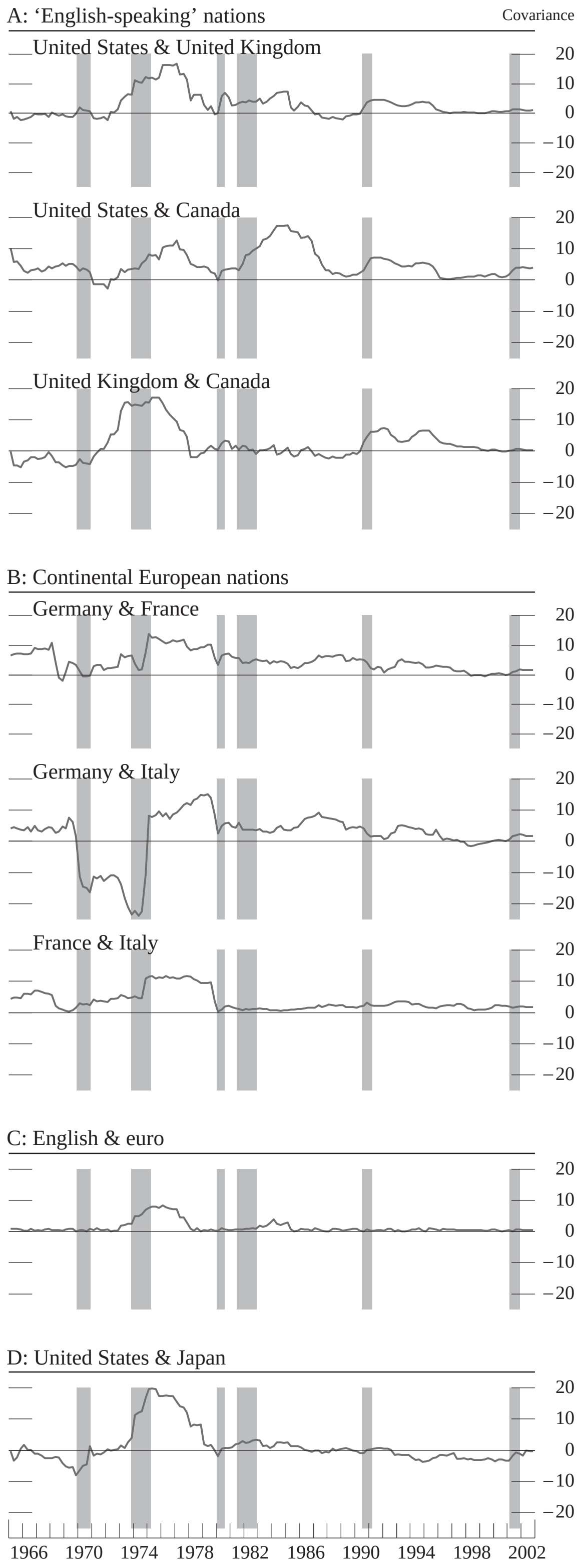
NOTE. See note to figure 4.

6. Correlation of quarterly real Consumption growth rates, selected country pairs, rolling five-year periods, 1965-2002



NOTE. See note to figure 4.

7. Covariance of quarterly real GDP growth rates, selected country pairs, rolling five-year periods, 1965-2002



NOTE. See note to figure 4.

Table 1: Break Dates for 3 breaks.

	1	2	3
GDP:	1972Q2	1981Q1	1992Q2
Consumption:	1969Q2	1981Q1	1993Q1
Investment:	1974Q3	1983Q1	1993Q1

Table 2: Tests of changes in mean growth with 3 breaks.

	GDP						Consumption						Investment					
period	6			7		8	6			7		8	6			7		8
versus	7	8	9	8	9	9	7	8	9	8	9	9	7	8	9	8	9	9
All	d	**D**	**D**	d	d	d	**D**	**D**	**D**	d	d	u	D	d	d	u	u	u
Eng	d	d	d	d	u	u	d	d	d	d	u	u	d	d	d	u	u	u
Eur	d	**D**	**D**	d	d	d	**D**	**D**	**D**	**D**	**D**	d	**D**	d	D	u	u	u
US	d	d	d	d	u	u	d	d	d	u	u	u	d	d	d	u	u	d
UK	d	d	u	u	u	u	d	u	U	u	u	u	**D**	d	u	u	u	u
Canada	d	D	**D**	d	d	u	d	**D**	**D**	d	d	u	d	d	d	d	u	u
Germany	d	**D**	**D**	u	d	d	d	D	**D**	d	**D**	d	d	u	d	u	d	d
France	**D**	**D**	**D**	d	d	d	d	**D**	**D**	**D**	**D**	u	**D**	D	**D**	u	u	u
Italy	d	**D**	**D**	d	d	d	d	**D**	**D**	d	D	u	d	d	d	u	u	u

Notes: The table presents tests for changes in the mean between all pairs of the 4 sub-samples defined by the 3 breaks. The subsamples correspond roughly to the decades (see table 1) and are labeled 6, 7, 8, 9, for the 60s, 70s, 80s, and 90s, respectively. Changes in the mean from an earlier to later period are denoted D, for down, or U, for up. Bold upper case letters indicate a change that is significant at the 5 percent level; plain upper case indicates significance at the 10 percent level; lower case simply signifies the sign of the change in the point estimate. *Eng* denotes Canada, the United Kingdom and the United States; *Eur* denotes France, Germany, and Italy.

Table 3: Value of selected statistics with 3 breaks.

	GDP				Conusmption			
	6	7	8	9	6	7	8	9
				Mean Growth				
All	4.46	2.83	2.38	2.33	4.54	3.44	2.39	2.66
Eng	3.93	2.78	2.40	3.11	3.93	3.07	2.78	3.48
Eur	4.99	2.88	2.37	1.56	5.16	3.81	2.00	1.83
				Unconditional Standard Deviation				
All	4.82	4.92	3.48	2.14	3.87	4.64	3.48	2.38
Eng	4.11	5.24	3.72	1.92	4.06	5.13	3.52	1.82
Eur	5.53	4.61	3.25	2.35	3.68	4.16	3.43	2.94
				Unconditional Correlation				
All	0.08	0.41	0.26	0.30	-0.03	0.21	0.11	0.12
Eng	0.02	0.43	0.42	0.36	0.05	0.24	0.36	0.20
Eur	0.11	0.50	0.39	0.36	-0.08	0.23	0.17	0.19
Eng-Eur	0.09	0.38	0.16	0.26	-0.04	0.19	0.00	0.08

Notes: For break dates see table 1. Also see notes to table 2.

Table 4: Tests of changes in standard deviation with 3 breaks.

	GDP						Consumption						Investment					
period	6			7		8	6			7		8	6			7		8
versus	7	8	9	8	9	9	7	8	9	8	9	9	7	8	9	8	9	9
									Unconditional									
All	u	**D**	**D**	**D**	**D**	**D**	**U**	d	**D**	**D**	**D**	**D**	d	d	**D**	d	**D**	**D**
Eng	u	d	**D**	**D**	**D**	**D**	**U**	d	**D**	**D**	**D**	**D**	u	u	D	d	**D**	**D**
Eur	d	**D**	**D**	**D**	**D**	**D**	u	d	**D**	D	**D**	d	**D**	**D**	**D**	u	D	D
US	u	d	**D**	d	**D**	**D**	u	d	**D**	d	**D**	**D**	**U**	d	**D**	**D**	**D**	D
UK	**U**	d	**D**	**D**	**D**	**D**	u	**D**	**D**	**D**	**D**	**D**	d	u	d	u	d	d
Canada	d	u	**D**	u	**D**	**D**	U	u	**D**	d	**D**	**D**	u	u	d	d	D	D
Germany	**D**	**D**	**D**	d	**D**	**D**	d	u	**D**	u	**D**	**D**	**D**	d	**D**	u	d	D
France	d	**D**	**D**	**D**	d	u	u	**D**	**D**	**D**	**D**	u	d	d	d	d	d	d
Italy	u	**D**	**D**	**D**	**D**	d	u	d	u	d	d	u	D	**D**	**D**	d	d	d
									Conditional (one-step)									
All	d	**D**	**D**	**D**	**D**	**D**	**U**	d	**D**	**D**	**D**	**D**	d	**D**	**D**	d	**D**	**D**
Eng	u	D	**D**	**D**	**D**	**D**	**U**	d	**D**	**D**	**D**	**D**	u	d	**D**	d	**D**	**D**
Eur	**D**	**D**	**D**	d	**D**	**D**	**U**	d	d	D	**D**	d	**D**	**D**	**D**	u	D	d
US	u	D	**D**	d	**D**	D	u	d	**D**	d	**D**	**D**	u	d	D	**D**	**D**	d
UK	u	d	**D**	**D**	**D**	**D**	u	d	**D**	**D**	**D**	**D**	d	u	d	u	u	d
Canada	d	d	**D**	u	D	**D**	**U**	u	D	**D**	**D**	D	u	u	D	d	d	**D**
Germany	**D**	d	**D**	u	**D**	**D**	u	u	d	u	D	**D**	**D**	d	**D**	u	d	d
France	d	**D**	**D**	d	d	d	u	**D**	D	**D**	**D**	u	d	**D**	**D**	d	D	d
Italy	D	**D**	**D**	**D**	**D**	d	U	u	**U**	**D**	d	u	d	**D**	**D**	d	d	d

Notes: For break dates see table 1. Also see notes to table 2.

Table 5: Tests of changes in unconditional variance partition by frequency with 3 breaks.

	GDP						Consumption						Investment					
period	6			7		8	6			7		8	6			7		8
versus	7	8	9	8	9	9	7	8	9	8	9	9	7	8	9	8	9	9
US lo	u	u	u	u	d	d	d	u	d	u	d	d	u	u	u	u	d	d
US bc	u	u	u	u	d	d	u	u	d	u	d	d	u	u	u	u	u	d
US hi	d	d	d	d	u	u	d	d	u	d	u	u	d	d	d	d	u	u
UK lo	u	U	**U**	u	u	d	u	**U**	u	U	u	**D**	u	u	u	u	u	d
UK bc	u	**U**	**U**	u	**U**	u	u	**U**	u	**U**	u	**D**	d	u	**U**	u	**U**	u
UK hi	d	**D**	**D**	d	D	u	d	**D**	d	**D**	d	**U**	u	d	D	d	D	u
Canada lo	u	U	**U**	u	u	d	u	**U**	u	u	d	d	u	u	u	u	u	d
Canada bc	u	**U**	**U**	**U**	**U**	u	u	**U**	u	u	d	d	u	u	u	d	u	u
Canada hi	d	**D**	**D**	**D**	**D**	d	d	**D**	d	d	u	u	d	d	d	d	d	d
Germany lo	u	U	U	d	u	u	d	u	d	u	u	d	u	u	u	d	d	u
Germany bc	u	u	U	d	u	u	u	u	u	u	u	d	u	d	u	d	d	u
Germany hi	d	d	D	u	d	d	u	d	d	d	d	u	d	u	d	u	u	d
France lo	u	u	u	d	d	u	u	u	u	u	d	d	u	U	**U**	u	u	d
France bc	u	u	u	d	u	u	u	u	u	u	d	d	u	**U**	**U**	u	**U**	u
France hi	d	d	d	u	d	d	d	d	d	d	u	u	d	**D**	**D**	D	D	u
Italy lo	U	u	u	d	d	d	**D**	d	d	U	u	d	d	u	u	u	u	d
Italy bc	**U**	u	u	**D**	d	u	D	d	d	**U**	u	d	d	d	u	u	u	u
Italy hi	**D**	d	d	U	u	d	**U**	u	**U**	**D**	d	U	u	d	d	d	d	u

Notes: Business cycle frequencies, denoted *bc*, are those with periods between 8 and 32 quarters; high frequencies (hi) are those with periods shorter than bc; low frequncies (lo) have longer than bc periods. See also the notes to tables 1 and 2.

Table 6: Tests of changes in unconditional correlation with 3 breaks.

	GDP						Consumption						Investment					
period	6			7		8	6			7		8	6			7		8
versus	7	8	9	8	9	9	7	8	9	8	9	9	7	8	9	8	9	9
All	**U**	U	U	d	d	u	**U**	u	**U**	d	d	u	u	u	u	u	u	d
Eng	**U**	U	**U**	d	d	d	u	U	u	u	d	d	u	u	u	u	u	d
Eur	U	**U**	u	d	d	d	U	u	**U**	d	d	u	u	**U**	u	u	u	d
Eng-Eur	**U**	u	u	D	d	u	**U**	u	u	d	d	u	d	u	u	u	u	d
US-UK	**U**	u	u	d	d	d	u	u	u	u	d	d	**U**	u	**U**	d	u	u
US-Canada	U	**U**	u	u	d	d	u	u	u	u	d	d	u	u	u	d	u	u
US-Germany	u	u	u	d	d	u	u	u	u	u	u	d	d	u	d	**U**	d	D
US-France	**U**	**U**	**U**	d	d	u	u	d	u	d	d	u	u	d	U	d	u	**U**
US-Italy	u	d	d	D	d	u	**U**	u	u	**D**	**D**	u	D	**D**	d	u	u	u
UK-Canada	u	d	u	**D**	d	u	d	d	d	d	d	d	u	u	d	d	d	d
UK-Germany	**U**	u	u	D	D	u	**U**	u	**U**	**D**	d	**U**	u	d	u	d	u	**U**
UK-France	d	d	d	d	d	u	u	d	d	d	d	u	**D**	d	D	U	U	d
UK-Italy	**U**	u	u	D	d	u	u	u	d	d	d	d	u	U	d	u	d	D
Canada-Germany	**U**	u	u	d	d	d	**U**	u	u	d	d	u	u	d	d	d	d	u
Canada-France	u	u	d	d	d	d	u	u	**U**	d	u	u	u	d	u	d	d	u
Canada-Italy	u	u	u	u	u	u	d	u	d	u	d	d	d	u	d	u	u	d
Germany-France	u	u	u	u	u	u	d	u	u	u	u	d	u	**U**	u	u	d	d
Germany-Italy	u	**U**	u	u	d	d	u	u	**U**	d	U	U	u	**U**	u	u	u	D
France-Italy	u	u	u	d	d	u	u	u	d	u	d	d	u	**U**	u	u	u	d

Notes: For break dates see table 1. Also see notes to table 2.

Table 7: Tests of changes in conditional correlation with 3 breaks.

	GDP						Consumption						Investment					
period	6			7		8	6			7		8	6			7		8
versus	7	8	9	8	9	9	7	8	9	8	9	9	7	8	9	8	9	9
All	**U**	U	u	**D**	**D**	d	U	u	u	d	d	u	d	u	u	u	u	d
Eng	**U**	U	**U**	d	d	u	u	u	u	u	d	d	u	u	d	u	d	d
Eur	u	**U**	u	u	d	D	u	u	u	d	d	u	u	**U**	u	u	d	d
Eng-Eur	**U**	u	u	**D**	**D**	d	U	u	u	d	d	u	d	d	u	u	u	u
US-UK	U	u	u	d	d	u	u	u	d	d	d	d	u	u	U	d	u	u
US-Canada	U	**U**	U	d	d	d	u	u	u	u	d	d	d	d	u	u	u	u
US-Germany	U	u	u	d	d	u	u	u	u	u	u	u	d	u	D	U	d	**D**
US-France	**U**	**U**	**U**	d	d	d	u	u	u	d	d	u	u	u	U	d	u	**U**
US-Italy	u	u	d	d	**D**	d	U	u	u	**D**	d	u	d	d	d	d	u	u
UK-Canada	**U**	u	u	**D**	D	u	d	d	d	u	d	d	u	u	d	d	d	d
UK-Germany	**U**	d	u	**D**	D	u	**U**	d	U	**D**	d	**U**	u	**D**	U	**D**	u	**U**
UK-France	d	D	D	**D**	D	u	u	d	u	D	d	u	**D**	**D**	d	u	U	u
UK-Italy	**U**	u	u	**D**	**D**	d	u	d	d	d	d	d	u	u	d	u	d	d
Canada-Germany	**U**	**U**	u	d	**D**	d	U	u	u	d	d	u	u	d	u	d	d	u
Canada-France	u	d	d	d	D	d	u	U	U	u	u	u	u	d	u	d	u	u
Canada-Italy	u	u	u	u	u	d	u	u	**U**	u	u	u	d	u	u	u	u	d
Germany-France	u	d	d	d	d	d	d	u	u	u	u	d	u	U	u	u	d	d
Germany-Italy	u	**U**	u	u	d	**D**	d	d	u	u	U	u	u	**U**	u	**U**	d	**D**
France-Italy	d	u	u	u	u	d	u	u	u	u	d	d	u	**U**	u	u	d	D

Notes: For break dates see table 1. Also see notes to table 2.

Table 8: Tests of changes in unconditional covariance with 3 breaks.

	GDP						Consumption						Investment					
period	6			7		8	6			7		8	6			7		8
versus	7	8	9	8	9	9	7	8	9	8	9	9	7	8	9	8	9	9
All	U	u	d	d	**D**	d	**U**	u	u	**D**	**D**	d	u	u	d	d	d	d
Eng	U	u	u	d	D	d	u	u	u	d	D	d	u	u	u	d	d	d
Eur	u	u	u	d	d	d	**U**	u	U	D	d	u	d	u	d	u	d	d
Eng-Eur	u	d	d	D	**D**	d	**U**	u	u	**D**	**D**	u	d	d	d	d	d	u
US-UK	U	u	u	d	D	d	u	u	u	d	d	d	U	u	**U**	d	d	u
US-Canada	u	u	d	u	D	D	u	u	d	u	d	d	u	u	u	d	d	u
US-Germany	u	u	u	d	d	d	u	u	u	d	d	d	d	u	d	U	u	d
US-France	**U**	U	U	d	D	d	u	d	u	d	d	u	u	u	u	d	d	u
US-Italy	u	d	d	D	**D**	d	**U**	u	u	**D**	**D**	u	D	d	d	d	u	u
UK-Canada	u	d	d	D	D	u	d	d	d	d	d	d	u	u	d	d	d	d
UK-Germany	U	u	u	D	D	d	**U**	u	**U**	**D**	D	U	u	d	u	d	d	u
UK-France	u	**D**	**D**	d	D	d	u	d	d	**D**	**D**	d	**D**	d	**D**	u	**U**	d
UK-Italy	U	u	u	D	d	u	u	u	d	d	d	d	u	u	d	u	d	d
Canada-Germany	u	d	d	d	**D**	d	**U**	u	u	**D**	**D**	u	d	D	**D**	d	d	d
Canada-France	u	u	d	d	d	d	u	u	u	d	u	u	u	d	u	d	d	u
Canada-Italy	u	u	u	d	d	d	d	u	d	u	d	d	d	u	d	u	u	d
Germany-France	u	u	u	d	d	d	d	u	u	u	u	d	u	U	u	u	d	d
Germany-Italy	u	u	u	d	d	D	u	u	**U**	d	u	u	u	u	u	u	d	D
France-Italy	u	d	d	d	d	u	u	u	d	d	d	d	u	u	u	u	u	d

Notes: For break dates see table 1. Also see notes to table 2.

Table 9: Tests of changes in conditional covariance with 3 breaks.

	GDP						Consumption						Investment					
period	6			7		8	6			7		8	6			7		8
versus	7	8	9	8	9	9	7	8	9	8	9	9	7	8	9	8	9	9
All	u	u	u	d	**D**	d	u	u	u	d	d	d	u	d	d	d	d	u
Eng	u	u	u	d	d	d	u	u	d	d	d	d	u	u	u	d	d	d
Eur	u	u	u	d	d	**D**	u	u	u	d	d	u	u	u	u	u	d	d
Eng-Eur	u	u	d	d	**D**	d	u	u	u	d	d	u	d	d	d	d	u	u
US-UK	u	u	u	d	d	d	u	u	d	d	d	d	u	u	u	d	d	u
US-Canada	u	u	d	d	d	d	u	u	d	d	d	d	d	d	u	d	u	u
US-Germany	u	u	u	d	d	d	u	u	u	d	d	d	d	u	d	u	d	D
US-France	U	**U**	U	d	d	d	u	u	u	d	d	u	u	u	u	d	u	u
US-Italy	u	d	d	d	d	d	u	u	u	d	d	u	d	d	d	d	u	u
UK-Canada	U	u	u	d	**D**	u	d	d	d	u	d	d	u	u	d	d	d	d
UK-Germany	u	u	u	**D**	**D**	u	u	u	u	**D**	d	U	u	d	u	d	u	u
UK-France	u	d	d	d	**D**	u	u	d	d	d	d	u	**D**	D	d	u	u	u
UK-Italy	U	u	u	d	**D**	d	u	d	d	d	d	d	u	u	d	u	d	d
Canada-Germany	u	u	u	d	**D**	d	u	u	u	d	d	d	d	d	d	d	d	u
Canada-France	u	d	d	d	d	d	u	u	u	u	u	u	u	d	u	d	u	u
Canada-Italy	u	u	u	u	d	d	u	u	u	u	u	u	u	u	u	u	u	d
Germany-France	d	d	d	d	d	d	d	u	u	u	u	d	u	u	u	u	d	d
Germany-Italy	u	u	u	d	d	**D**	d	d	u	u	u	u	u	U	u	u	d	d
France-Italy	d	d	d	d	d	d	u	u	u	d	d	d	u	u	u	u	d	d

Notes: For break dates see table 1. Also see notes to table 2.

Table 10: Tests of changes in other measures of comovement with 3 breaks.

	GDP						Consumption						Investment					
period	6			7		8	6			7		8	6			7		8
versus	7	8	9	8	9	9	7	8	9	8	9	9	7	8	9	8	9	9
Sum of the n largest eigenvalues																		
All, $\lambda(1)$	**U**	u	u	d	d	u	u	u	u	d	d	d	d	u	d	u	d	d
All, $\lambda(2)$	U	u	u	d	d	d	u	u	u	d	d	d	d	u	d	u	d	d
Eng, $\lambda(1)$	u	u	u	u	d	d	u	u	u	u	d	d	d	u	u	u	u	d
Eng, $\lambda(2)$	U	u	u	u	d	d	u	u	u	u	u	d	u	u	u	u	u	u
Eur, $\lambda(1)$	u	u	u	d	d	d	u	u	u	d	d	u	u	u	u	u	u	d
Eur, $\lambda(2)$	d	D	d	d	u	u	d	d	u	u	u	u	d	d	d	d	d	u
Maximum variance share of N shocks																		
All 1	u	u	d	d	d	d	u	u	d	d	d	d	d	d	u	u	u	u
All 2	u	u	d	d	d	d	u	u	d	u	d	d	d	d	d	u	u	u
Eng 1	u	u	u	d	u	u	u	u	d	u	d	d	d	d	d	d	d	u
Eng 2	u	u	u	d	d	u	d	d	d	u	d	d	d	d	d	d	u	u
Eur 1	d	u	d	U	d	**D**	d	u	d	u	d	**D**	d	d	d	u	u	d
Eur 2	d	u	D	u	D	**D**	d	d	d	u	d	**D**	**D**	d	d	U	u	d
Dynamic factor																		
All	**U**	u	**U**	**D**	d	u	u	u	u	d	d	d	u	u	d	u	d	D
Eng	u	U	u	d	d	d	u	u	u	u	u	d	d	d	u	u	u	u
Eur	U	u	U	d	d	u	u	d	u	d	u	u	u	u	d	u	d	D

Notes: For break dates see table 1. Also see notes to tables 2 and 5.