CFCM

CENTRE FOR FINANCE, CREDIT AND MACROECONOMICS

Working Paper 13/11

Economic Sentiment, International Interdependence and Output Dynamics in the G7

Anthony Garratt, Kevin Lee and Kalvinder Shields

Produced By:

Centre for Finance, Credit and Macroeconomics
School of Economics
Sir Clive Granger Building
University of Nottingham
University Park
Nottingham
NG7 2RD

Tel: +44(0) 115 951 5619
Fax: +44(0) 115 951 4159
enquiries@cfcm.org.uk

Economic Sentiment, International Interdependence and Output Dynamics in the G7*

by

Anthony Garratt,† Kevin Lee†† and Kalvinder Shields†††

Abstract

Output dynamics in the G7 are characterised using a Global VAR model of countries' actual outputs and survey-based measures of their expected outputs. A variance-decomposition method is applied to examine the importance of global-versus-national effects and of fundamentals-versus-sentiment effects in business cycle fluctuations. The first decomposition highlights the importance of global effects, with global and national effects explaining, on average, 60% and 40% of the persistent movements in countries' output respectively. Fundamentals dominate in the second decomposition but the analysis finds a substantial role for sentiment which explains 30% of the persistent movements in output on average.

*†University of Warwick, UK; ††University of Nottingham, UK; †††University of Melbourne, Australia. Version dated October 2013. Corresponding author: Kalvinder K. Shields, Department of Economics, University of Melbourne, Victoria, 3010, Australia. E-mail: k.shields unimelb.edu.au, tel: 00 613-83445300, fax: 00 613-83446899.

1 Introduction

Commentary on the recent period of recession has frequently emphasised its global nature and the role of confidence in propagating and possibly prolonging the real effects of the financial crisis.[1] The potential influence of cross-country interactions in business cycle dynamics is obvious given current levels of cross-border trade and foreign direct investment, the importance of international supply chains, the mobility of capital in financial markets, and so on. The role assigned to a 'lack of confidence' is less clear; sometimes commentators appear to use the phrase to convey agents' anxieties on the future prospects of the underlying fundamentals; and sometimes the phrase suggests a more autonomous role in which agents' beliefs have a dampening effect on economic activity separately to the fundamentals. In what follows, we shall describe this latter role as the effect of 'sentiment'.

This paper aims to quantify the influence of cross-country interactions and of sentiment on the output dynamics of the G7 economies. The analysis is conducted using a Global Vector Autoregressive (GVAR) model of actual output series together with survey-based measures of expected output in the G7 economies. The GVAR framework, elaborated in Pesaran *et al.* (2004) and Garratt *et al.* (2006), inter alia, captures the complex interactions between countries' outputs in a parsimonious and transparent way, while the use of direct measures of expected outputs makes possible an analysis of the role of agents' beliefs in business cycle dynamics which is not possible using actual output data only. A variance-based measure of the persistent effect of shocks to actual and expected outputs is applied to the estimated GVAR model to characterise the output dynamics. A novel variance-decomposition method is then used to evaluate the importance of global-versus-national factors and the role of sentiment-versus-fundamentals in business cycle

[1] One example among many is the IMF's comment in its September 2011 *World Economic Outlook* that "The global economy is in a dangerous new phase. Global activity has weakened and become more uneven, confidence has fallen sharply recently, and downside risks are growing".

fluctuations over the short run and at the infinite horizon.[2]

The investigation of cross-country output interdependencies and the attempt to quantify the importance of global shocks is not unique to this paper. For example, work by Lumsdaine and Prasad (2003), Kose *et al.* (2003, 2008), del Negro and Otrok (2008), and Cruccini *et al.* (2011), among others, have employed dynamic common factor models to evaluate the importance of a global factor in driving countries' output growths and to judge whether this influence has changed over time. Hence, Cruccini *et al.* (2011) find in their analysis that a global factor typically accounts for around 46% of output variation in the G7 during 1960-2007 although there is considerable variability in its influence across countries (ranging from 80% in France to 15% in the US, for example). Kose *et al.* (2003) found a smaller influence over a similar period (explaining 26% of the variation in the G7, ranging from 60% in France to 10% in US) but argued that the contribution has been higher in the post-Bretton Woods period (i.e. 1972 onwards) than during earlier times. These papers typically make use of national data on output, consumption and investment to isolate the separate effects of global shocks, national shocks and variable-specific idiosyncratic shocks. One purpose of the current paper is to consider the extent to which conclusions drawn on the relative importance of global shocks to output are sensitive to the measures and modelling approach adopted (i.e. 'dynamic common factors' compared to 'GVAR') and the variables considered (i.e. 'output and components of aggregate demand' compared to 'actual and expected outputs').

There has also been a resurgence in papers concerned with the role of expectations and confidence in business cycle fluctuation in recent years. Akerlov and Shiller's influential (2009) text reasserted the potential role of optimism, fear, concern for fairness and other psychological factors (often summarised as 'animal spirits') in driving economic outcomes independently of underlying economic fundamentals. These could have permanent effects given Farmer's (1999) exploration of how self-fulfilling prophesies can result in multiple equilibria in macroeconomic outcomes. Further, Lorenzoni (2010), Blanchard *et al.* (2013)

[2]Of course, in practice, the two issues are interrelated: see, for example, Kannan *et al.* (2009) for a discussion of the role of uncertainty and coordination failures across borders in inhibiting export and credit growth and in the postponing of investment decisions.

and Kulish and Pagan (2013), among others, have explored the implications of assuming that agents act on rationally-formed expectations concerned only with fundamentals but are not able to observe the fundamentals without error. They demonstrate that the gap between belief and reality will generate output fluctuations in the short run that are separate to the influences that drive output in the long run. These papers have also promoted the view that agents' beliefs can play an important role in business cycle fluctuations separately to underlying economic fundamentals - i.e. an independent role for 'sentiment' - therefore. In contrast, Beaudry and Portier (2006), Barsky and Sims (2011, 2012) and Bachmann and Sims (2012) have used stock price data, direct measures of confidence and other forward-looking series in VAR models in an attempt to distinguish the 'news' content of the measures - which reflect future economic prospects - from the effect of sentiment, employing identification schemes of different types to draw this distinction. These papers have argued that the news content of confidence measures contains substantial explanatory power for output fluctuations. Our use of direct measures of expectations is in a similar vein to these latter papers, although we use measures of expected output which correspond directly to the actual output data series as opposed to the more general indicators of anticipated activity captured by stock prices or confidence indicators, say.[3] Our ability to observe the expectational errors relating to output at different forecast horizons allows us to define and isolate the effect of sentiment in a novel and straightforward way and one that avoids the use of potentially controversial identifying assumptions.

The layout of the remainder of the paper is as follows. Section 2 describes our modelling framework, explaining how our national models of actual and expected output growths are developed and brought together in the GVAR. We also explain the variance decompositions that we can use to distinguish global from national shocks and the effect of fundamentals versus sentiment in business cycle dynamics. Section 3 describes the GVAR model obtained for the G7 economies over the period 1994q1-2013q1 and presents the results of the decomposition of the variance and persistence profiles to measure the relative importance of global-versus-national shocks and fundamental-versus-sentiment shocks

[3]The use of direct measures of expectations to uncover the role of beliefs and the nature of expectation formation is also a well researched field; see, for example, Croushore (2010) for an overview.

and their dynamics. As we shall see, the variance decomposition and persistence profiles show global shocks to be extremely important in understanding G7 output movements, contributing around 60% of the permanent effect of shocks to a country's output on average. This is somewhat higher than the figures obtained from the dynamic common factor literature although, since we obtain similar figures when we apply the dynamic common factor approach to our data, we argue that the difference is due to those studies looking for global effects on consumption and investment as well as output and our measure is more relevant when considering output dynamics in isolation. Perhaps even more controversially, we find that the (complementary) effects of sentiment are also important is explaining output movements, contributing around 30% of the permanent effects of shocks to a country's output on average. Section 4 provides a brief conclusion to the paper.

2 Modelling Output in a Global Economy

An analysis that focuses on the role of agents' beliefs in business cycle fluctuations has to pay careful attention to the information that is actually available to agents in real time. This means, for example, that the measures of actual output should take into account the fact that output data is typically published with a lag of one quarter and, in practice, agents' perceptions of current output levels and expected future output levels can only be obtained from surveys.[4] In what follows, we denote (the logarithm of) output at time t by y_t and the measure of y_t published in time $t+s$ by ${}_{t+s}y_t$. If $s \geqslant 1$, the measure is from an official publication (published after the one quarter publication delay). If $s \leqslant 0$, the measure is a direct measure of expectations on y_t as published in $t+s$ (and the point is emphasised by a superscript 'e'). Focusing for expositional purposes on a single nation for the time being, a modelling framework that can represent output dynamics, accommodating the publication delays in actual output and the influence of expectations

[4]The first-release data is also often revised introducing a further complexity in decision-making. As we explain below, in what follows, we ignore the revisions process, effectively assuming that subsequent revisions simply constitute noise. See Mankiw and Shapiro (1986) and Garratt *et al.* (2008) for more discussion of the analysis of revisions data.

captured in survey data, is given by

$$\begin{bmatrix} {}_ty_{t-1} - {}_{t-1}y_{t-2} \\ {}_ty^e_t - {}_ty_{t-1} \\ {}_ty^e_{t+1} - {}_ty^e_t \end{bmatrix} = \Gamma_0 + \sum_{k=1}^{p} \Gamma_k \begin{bmatrix} {}_{t-k}y_{t-1-k} - {}_{t-1-k}y_{t-2-k} \\ {}_{t-k}y^e_{t-k} - {}_{t-k}y_{t-1-k} \\ {}_{t-k}y^e_{t+1-k} - {}_{t-k}y^e_{t-k} \end{bmatrix} + \begin{bmatrix} \xi_{1t} \\ \xi_{2t} \\ \xi_{3t} \end{bmatrix} \tag{1}$$

for $t = 1, ..., T$ where the Γ's are matrices of parameters and the ξ's are mean zero innovations in output growths. As an illustration, we focus here on the case where only contemporaneous and one-period-ahead expectations are used. This model explains the growth in actual output at time $t-1$ (published in time t following the one-quarter publication delay), the expected contemporaneous growth in output (published as a nowcast in the survey dated at time t), and the expected one-period ahead growth in output (also published in the survey dated at time t).

The model in (1) can also be written in levels form

$$\mathbf{y}_t = \mathbf{A}_0 + \sum_{k=1}^{p+1} \mathbf{A}_k \, \mathbf{y}_{t-k} + \boldsymbol{\varepsilon}_t, \qquad t = 1, ..., T, \tag{2}$$

where $\mathbf{y}_t = ({}_ty_{t-1}, {}_ty^e_t, {}_ty^e_{t+1})'$, $\boldsymbol{\varepsilon}_t = (\varepsilon_{at}, \varepsilon_{bt}, \varepsilon_{ct})' = (\xi_{1t}, \xi_{1t} + \xi_{2t}, \xi_{1t} + \xi_{2t} + \xi_{3t})'$ and the $\mathbf{A}$'s are functions of the original Γ's. Given that actual output growth and expectational errors are stationary in (1), the $\mathbf{A}$'s are restricted to ensure the shocks $\boldsymbol{\varepsilon}_t$ have a permanent effect on $\mathbf{y}_t$ and the three output measures move together one-for-one in the long run.[5] The model is consistent with a wide range of behavioural models in which output is ultimately driven by a unit root process then. Shocks to the system, in the form of $\boldsymbol{\varepsilon}_t$ represent the news arriving at t on output levels in $t-1$, t, and $t+1$ respectively and will capture directly the influence of news on future values of fundamentals emphasised in the papers by Beaudry and Portier (2006), Barsky and Sims (2011, 2012) and Bachmann and Sims (2012) discussed earlier. Equally though, given that the time series model is agnostic on the nature of the shocks, (1) and (2) are also consistent with the possibility that the $\boldsymbol{\varepsilon}_t$ reflect autonomous shifts in beliefs which cause permanent changes in actual and expected outputs (echoing the possibility of multiple equilibria discussed in Farmer (1999) for example).

[5]Indeed the model can also be written as a cointegrating VAR in the difference of $\mathbf{y}_t$ in which the (two) cointegrating vectors take the form $(1, -1, 0)$ and $(1, 0, -1)$.

The structure of (1) and (2) means innovations to the unit root process driving output will have the same effect on actual and expected outputs in the long run. But the model is sufficiently flexible that actual and expected outputs can evolve separately over time and expectational errors can have systematic patterns. This would be the case if, for example, output is driven by autonomous shifts in belief, or if agents are aware of the fundamentals that drive output but do not form their expectations in a way that is consistent with this so that the expectation formation process introduces business cycle dynamics in its own right. Alternatively, expectational errors would have systematic content if beliefs temporarily failed to match reality, based on an out-of-date model, say, or not yet fully incorporating the effect of an announced policy change. In this case, expectations may be model consistent but expectational errors would nevertheless contain systematic content to reflect the impact of the self-fulfilling actions arising from the gap between belief and reality.[6]

The flexibility of the model provides the scope for investigating the role of sentiment in output dynamics. In the situation where output is driven by economic fundamentals and expectations are formed rationally with reference to the correct measures of fundamentals and applied to the appropriate model, then expectational errors should be unsystematic and unrelated to all available information so that

$$ {}_{t}y_{t-1} = {}_{t-1}y^{e}_{t-1} + \varepsilon_{at} \qquad \text{and} \qquad {}_{t}y^{e}_{t} = {}_{t-1}y^{e}_{t} + \varepsilon_{bt} \quad . \tag{3} $$

These 'RE-fundamentals' assumptions are incorporated into (1) by the restriction that the Γ_i take the form

$$ \Gamma_1 = \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ * & * & * \end{pmatrix} \qquad \text{and} \qquad \Gamma_k = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ * & * & * \end{pmatrix} \quad \text{for } k = 2, .., p \tag{4} $$

[6]See Kulish and Pagan (2013) for discussion of the solution of rational expectations models in which agents' beliefs about structural changes lag behind reality or reflect imperfect credibility of policy which may be carried out as announced but is not immediately incorporated into agents' view of the world.

or, equivalently,

$$\mathbf{A}_1 = \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ * & * & * \end{pmatrix} \quad \text{and} \quad \mathbf{A}_k = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ * & * & * \end{pmatrix} \quad \text{for } k = 2, .., p+1$$

in (2), where the parameters in the third row, denoted by $*$, are unrestricted. The absence of restrictions on the third row still leaves scope for complex interplay between actual and expected outputs in the underlying behavioural model of output, including the direct effects of news on future economic prospects as reflected in the survey data. But the model incorporating the restrictions of (4) provides a useful benchmark model which abstracts from business cycle dynamics introduced by beliefs separately from fundamentals (i.e. by 'sentiment'). Comparison of this benchmark model against the unrestricted model provides a means of judging the role of sentiment in business cycle fluctuations therefore.

2.1 Global interactions

The single-country model considered above can be readily extended to accommodate cross-country interactions following the GVAR approach outlined in, for example, Pesaran et al (2004) and Garratt et al. (2006). In this, trade-weighted variables are used to capture the effect of external influences in separate national VAR models and these national models are then brought together in a single coherent VAR system. To see this, note first that the national model of output growth of the form in (2) can be readily extended to accommodate global interactions that arise because of the potential effects of common factors that drive output in many countries simultaneously. These could be justified through common productivity shocks, for example, or through the self-reinforcing outcomes of bouts of global pessimism or optimism which drive changes in risk premia across all countries. Using an i subscript to denote country i, the model in (2) can accommodate the presence of unobserved global factors $\mathbf{f}_t$ by writing

$$\mathbf{y}_{it} = \mathbf{A}_{i0} + \sum_{k=1}^{p+1} \mathbf{A}_{ik}\ \mathbf{y}_{i,t-k} + \mathbf{A}_{if}\mathbf{f}_t + \boldsymbol{\varepsilon}_{it}, \qquad i = 1, ..., n \quad \text{and} \quad t = 1, ..., T, \tag{5}$$

where $\boldsymbol{\varepsilon}_{it}$ now represent country-specific innovations. Assuming this relationship holds for all countries $i = 1, .., n$, Dees et al. (2007) note that we can construct global variables $\mathbf{y}_t^* =$

$\sum_{i=1}^{n} w_i \mathbf{y}_{it}$ using fixed weights w_i and that, under reasonable assumptions, an aggregate relationship explaining $\mathbf{y}_t^*$ can be derived of the same form as (5). In this case, the unobservable common factors can be reasonably proxied by the observable vector $(1, \mathbf{y}_t^{*\prime}, \mathbf{y}_{t-1}^{*\prime}, ..., \mathbf{y}_{t-p+1}^{*\prime})'$ and the national model in (5) can be written

$$\mathbf{y}_{it} = \mathbf{B}_{i0} + \sum_{k=1}^{p+1} \mathbf{B}_{ik}\ \mathbf{y}_{i,t-k} + \sum_{k=0}^{p+1} \mathbf{B}_{ik}^*\ \mathbf{y}_{t-k}^* + \boldsymbol{\varepsilon}_{it}, \qquad i = 1, ..., n \quad \text{and} \quad t = 1, ..., T. \tag{6}$$

Here, the effects of the common factors are accommodated through the inclusion of the current and lagged values of the global variable. In practice, the $\mathbf{y}^*$ variables used in model (6) can be defined using country-specific weights, $\mathbf{y}_{it}^* = \sum_{j=1}^{n} w_{ij} \mathbf{y}_{jt}$, where the weights are chosen so that the foreign variable better captures the influence of different countries on country i (using trade volumes or some other metric, for example). Similarly, the order of the lags of $\mathbf{y}_{it}$ and $\mathbf{y}_{it}^*$ do not have to be the same. But in any case, the national model in (6) provides a straightforward means of incorporating global influences on a country's output, either exerted alongside the other macroeconomic influences captured by the direct measures of expectations included in $\mathbf{y}_{it}$'s or through the common global factors proxied by the inclusion of the weighted cross-sectional averages.[7]

The final stage in the construction of a global VAR (GVAR) explaining actual and expected outputs across the n countries is motivated by noting that we can arrange the country-specific series into a single $3n \times 1$ vector $\mathbf{z}_t = (\mathbf{y}_{1t}', .., \mathbf{y}_{nt}')'$ and that we can write $\mathbf{y}_{it}^* = \mathbf{w}_i \mathbf{z}_t$ where $\mathbf{w}_i$ is the $1 \times 3n$ vector containing country i's weights. Arranging the individual vectors of parameters $\mathbf{B}_{ik}$ and $\mathbf{B}_{ik}^*$ into $\mathbf{B}_k$ and $\mathbf{B}_k^*$ and arranging the individual vectors of weights into $\mathbf{W}$, the n country-specific models in (6) can be stacked to write

$$\mathbf{z}_t = \mathbf{B}_0 + \sum_{k=1}^{p+1} \mathbf{B}_k\ \mathbf{z}_{t-k} + \sum_{k=0}^{p+1} \mathbf{B}_k^*\ \mathbf{W}\mathbf{z}_{t-k} + \boldsymbol{\epsilon}_t, \qquad t = 1, ..., T, \tag{7}$$

where $\boldsymbol{\epsilon}_t = (\boldsymbol{\varepsilon}_{1t}', .., \boldsymbol{\varepsilon}_{nt}')'$ with variance-covariance matrix Σ. The errors $\boldsymbol{\epsilon}_t$ abstract from the influences on $\mathbf{z}_t$ arising from the global measures and, while in practice there might

[7] This explanation of the role of the global variables is written in terms of levels $\mathbf{y}_t$ - as in (2) - for expositional purposes. In practice, the model will typically be estimated in growth form - as in (1) - with a country's actual, nowcast and expected future growth explained by lags of these and the current and lagged values of the corresponding global growth terms.

be cross-country correlations in these innovations, Σ will be close to diagonal and these shocks can be thought of as nation-specific ones. We can now write

$$\mathbf{z}_t = (\mathbf{I} - \mathbf{B}_0^*\mathbf{W})^{-1} \left(\mathbf{B}_0 + \sum_{k=1}^{p+1} (\mathbf{B}_k + \mathbf{B}_k^*\mathbf{W})\mathbf{z}_{t-k} + \boldsymbol{\epsilon}_t \right), \qquad t = 1, ..., T, \tag{8}$$

or equivalently

$$\mathbf{z}_t = \Phi_0 + \sum_{k=1}^{p+1} \Phi_k \; \mathbf{z}_{t-k} + \mathbf{v}_t, \qquad t = 1, ..., T, \tag{9}$$

where $\Phi_0 = (\mathbf{I} - \mathbf{B}_0^*\mathbf{W})^{-1}\mathbf{B}_0$, $\Phi_k = (\mathbf{I} - \mathbf{B}_0^*\mathbf{W})^{-1}(\mathbf{B}_k + \mathbf{B}_k^*\mathbf{W})$, $k = 1, ..p + 1$ and $\mathbf{v}_t = (\mathbf{I} - \mathbf{B}_0^*\mathbf{W})^{-1}\boldsymbol{\epsilon}_t$ with variance-covariance matrix Ω. The expressions in (8) and (9) provide a GVAR model that explicitly captures all the interdependencies that exist between actual and expected outputs in all n countries.

2.2 Characterising and decomposing the system dynamics

The dynamic effects of different types of shocks to the global VAR system are well characterised by the 'persistence profiles' [PP] proposed by Lee and Pesaran (1993). Recalling that the variables in $\mathbf{z}_t$ are all difference-stationary output series, we can usefully rewrite (9) to obtain the infinite moving average form for $\Delta\mathbf{z}_t$

$$\begin{aligned} \Delta\mathbf{z}_t &= \mathbf{v}_t + \mathbf{C}_1\mathbf{v}_{t-1} + \mathbf{C}_2\mathbf{v}_{t-2} + \mathbf{C}_3\mathbf{v}_{t-3} + ... \\ &= \mathbf{C}(L)\; \mathbf{v}_t \end{aligned} \tag{10}$$

where $\mathbf{C}_1 = \Phi_1 - \mathbf{I}$, and $\mathbf{C}_k = \mathbf{C}_{k-1}\Phi_1 + \mathbf{C}_{k-2}\Phi_2 + ... + \mathbf{C}_{k-p-1}\Phi_{p+1}$, $k = 2, 3, ...,$ with $\mathbf{C}_0 = \mathbf{I}$ and $\mathbf{C}_k = 0$, $k < 0.$, and where these coefficients are summarised in the lag polynomial $\mathbf{C}(L) = \mathbf{I} + \mathbf{C}_1L + \mathbf{C}_2L^2 + \mathbf{C}_3L^3 + ...$ Clearly, shocks to the output growth series in $\Delta\mathbf{z}_t$ will have no effect on these series at the infinite horizon given that they are stationary. But the shocks will cause output *levels* to be higher than they would have been in the absence of the shock. Lee and Pesaran (1993) propose the use of PP's to measure the long-run response of the $I(1)$ output series to shocks and to trace out the time profile of the accumulation of this response to characterise the system dynamics. At time horizon K, the PP's are defined by the $3n \times 3n$ matrix $\mathbf{P}(K)$ whose (i, j)-th element is given by

$$\rho_{ij}(K) = \frac{\mathbf{e}_i'\mathbf{H}(K)'\mathbf{e}_j}{\sqrt{(\mathbf{e}_i'\mathbf{C}(0)\Omega\mathbf{C}(0)'\mathbf{e}_i)(\mathbf{e}_j'\mathbf{C}(0)\Omega\mathbf{C}(0)'\mathbf{e}_j)}}, \qquad i,j = 1,...,3n, \tag{11}$$

where $\mathbf{e}_i$ is the $m \times 1$ selection vector with unity in its i-th element and zeros elsewhere and where $\mathbf{H}(K) = \left(\sum_{k=0}^{K} \mathbf{C}_k\right) \Omega \left(\sum_{k=0}^{K} \mathbf{C}_k\right)'$ for $K = 0, 1, ...$ Here, the $\mathbf{H}(K)$ capture the size of the permanent effects of the shocks on output as they accumulate over time up to period K. As $K \to \infty$, the $\mathbf{P}(K)$ converge to the 'persistence matrix' $\mathbf{P}$ whose (i, j)-th element is given by

$$\rho_{ij} = \frac{\mathbf{e}_i'\mathbf{C}(1)\Omega\mathbf{C}(1)'\mathbf{e}_j}{\sqrt{(\mathbf{e}_i'\mathbf{C}(0)\Omega\mathbf{C}(0)'\mathbf{e}_i)(\mathbf{e}_j'\mathbf{C}(0)\Omega\mathbf{C}(0)'\mathbf{e}_j)}}, \qquad i,j = 1,...,3n. \tag{12}$$

This matrix provides a variance-based measure of the infinite-horizon effect of shocks to the system. It is most easily interpreted by considering the measures $P_i = \sqrt{\rho_{ii}}$ based on its diagonal elements, where $i = 1, 4, 7, ..., 3n-2$ relating to the first of the three rows relating to country i. These measures show the size of the permanent effect on (actual) output in county i of a shock to the system that causes output in that country to rise by 1% on impact. In the univariate case, the measure coincides with the "impulse-based" measure of persistence, describing the infinite horizon effect of a 1% shock to the variable, and the two concepts are clearly related therefore. However, the variance-based measure has the advantage that it does not require, and indeed is invariant to, the identifying assumptions necessary to provide structural meaning to the shocks in an impulse response analysis conducted in a multivariate setting (see Lee and Pesaran, 1993, for further discussion). Since the actual output, current expected output and future expected output series are cointegrated, the corresponding rows of $\mathbf{C}(1)$ are equal in each country capturing the fact that the persistent effect of shocks on the three country variables is the same in the long run. The matrices $\mathbf{P}(K)$, $K = 1, 2, ...,$ describe the time-profile of the effect of these shocks over time reflecting both the scaled effect of innovations but also the underlying dynamics of the actual and expected series.[8]

[8] If the selection vectors $\mathbf{e}_i$ and $\mathbf{e}_j$ in (11) are replaced by a cointegrating vector, then the profile describes the time path taken to reestablish the equilibrium relation.

2.2.1 The national/global decomposition

Two decompositions of these persistence profiles are of interest: one to consider the relative importance and dynamic effects of national and global shocks; and a second that allows us to consider the relative importance and dynamic effects of fundamentals versus sentiment. For the first of these, we note that the influence of global interactions in the model of (6) is captured through the starred parameters since there would be no global shocks if $\mathbf{B}_0^* = 0$ and no global dynamics if $\mathbf{B}_s^* = 0$, $s = 1, .., p+1$. Writing $(\mathbf{I} - \mathbf{B}_0^*\mathbf{W})^{-1} = \mathbf{I} + \mathbf{M}^*$, where $\mathbf{M}^* = \mathbf{B}_0^*\mathbf{W} + (\mathbf{B}_0^*\mathbf{W})^2 + (\mathbf{B}_0^*\mathbf{W})^3 + ...$ is the 'global multiplier', (9) can be re-written as

$$\mathbf{z}_t = \left(\Phi_0^N + \Phi_0^G\right) + \sum_{k=1}^{p+1}(\Phi_k^N + \Phi_k^G)\mathbf{z}_{t-k} + \mathbf{v}_t, \qquad t = 1, ..., T, \tag{13}$$

where $\Phi_k^N = \mathbf{B}_k$, $k = 0, .., p+1$ just for notational convenience and where $\Phi_0^G = \mathbf{M}^*\mathbf{B}_0$ and $\Phi_k^G = \mathbf{M}^*\mathbf{B}_k + (\mathbf{I} + \mathbf{M}^*)\mathbf{B}_k^*$, $k = 1, .., p+1$, collecting together all of the terms involving cross-country interdependencies. We also have $\mathbf{v}_t = (\mathbf{I} + \mathbf{M}^*)\boldsymbol{\epsilon}_t$ with variance-covariance matrix $\Omega = (\mathbf{I} + \mathbf{M}^*)\Sigma(\mathbf{I} + \mathbf{M}^*)'$ so that the variance in $\mathbf{v}_t$ can be decomposed to write $\Omega = \Sigma + \Sigma^*$ where $\Sigma^* = \mathbf{M}^*\Sigma(\mathbf{I} + \mathbf{M}^*)' + \Sigma\mathbf{M}^{*\prime}$ and Σ and Σ^* capture the relative sizes of the national and global shocks respectively.

We note now that the persistent effects of shocks can be readily decomposed into national and global elements. This is seen by splitting the elements of $\mathbf{C}(L)$ in the moving average representation of (10) into a national element $\mathbf{C}^N(L)$ and a global element $\mathbf{C}^G(L)$ where the former is independent of the starred parameters and the latter captures the effects of the global dynamics:

$$\Delta\mathbf{z}_t = \mathbf{v}_t + (\mathbf{C}_1^N + \mathbf{C}_1^G)\mathbf{v}_{t-1} + (\mathbf{C}_2^N + \mathbf{C}_2^G)\mathbf{v}_{t-2} + (\mathbf{C}_3^N + \mathbf{C}_3^G)\mathbf{v}_{t-3} + ..., \qquad t = 1, ..., T. \tag{14}$$

Here $\mathbf{C}_1^N = \Phi_0^N - \mathbf{I}$, and $\mathbf{C}_k^N = \mathbf{C}_{k-1}^N\Phi_1^N + \mathbf{C}_{k-2}^N\Phi_2^N + ... + \mathbf{C}_{k-p-1}^N\Phi_{p+1}^N$, $i = 2, 3, ...$, with $\mathbf{C}_0^N = \mathbf{I}$ and $\mathbf{C}_k^N = 0$, $k < 0$, while $\mathbf{C}_k^G = \mathbf{C}_k - \mathbf{C}_k^N$, $k = 1, 2, ...$deriving the global effects as the difference between the total and the national effects. The elements of the infinite-horizon persistence matrix in (12) can then be written as

$$\begin{aligned}\rho_{ij} &= \frac{\mathbf{e}_i' \left[\mathbf{C}^N(1) + \mathbf{C}^G(1)\right] (\Sigma + \Sigma^*) \left[\mathbf{C}^N(1) + \mathbf{C}^G(1)\right]' \mathbf{e}_j}{\sqrt{(\mathbf{e}_i'\mathbf{C}(0)\Omega\mathbf{C}(0)'\mathbf{e}_i)(\mathbf{e}_j'\mathbf{C}(0)\Omega\mathbf{C}(0)'\mathbf{e}_j)}} \\ &= \rho_{ij}^N + \rho_{ij}^G \qquad i, j = 1, ..., n\end{aligned} \tag{15}$$

where $\rho_{ij}^N = \frac{\mathbf{e}_i' \, \mathbf{C}^N(1)\Sigma\mathbf{C}^N(1)' \, \mathbf{e}_j}{\sqrt{(\mathbf{e}_i'\mathbf{C}(0)\Omega\mathbf{C}(0)'\mathbf{e}_i)(\mathbf{e}_j'\mathbf{C}(0)\Omega\mathbf{C}(0)'\mathbf{e}_j)}}$ provides a measure of the size of the effect of national shocks, abstracting entirely from the effects of global interactions on impact and from any global dynamics, and where $\rho_{ij}^G = \rho_{ij} - \rho_{ij}^N$ shows the overall contribution of the global influences, again measured as the difference between the total persistence and the national persistence measures. Clearly, the time profile of the effects of shocks as described in (11) can be decomposed into national and global components in a similar way.

2.2.2 The fundamentals/sentiment decomposition

For the decomposition to separate out the effects of sentiment from rationally-expected fundamentals, we note that the restrictions described in (4) translate in a straightforward way to the GVAR context so that, if expectational errors are unsystematic and unrelated to all available information the first three rows of $\mathbf{B}_k$ and $\mathbf{B}_k^*$ in (7) would take the form

$$\mathbf{B}_1^F[1:3,.] = \begin{bmatrix} 0 & 1 & 0 & 0 & ... & 0 \\ 0 & 0 & 1 & 0 & ... & 0 \\ * & * & * & * & * & * \end{bmatrix}, \qquad \mathbf{B}_k^F[1:3,.] = \begin{bmatrix} 0 & 0 & 0 & 0 & ... & 0 \\ 0 & 0 & 0 & 0 & ... & 0 \\ * & * & * & * & * & * \end{bmatrix} \text{ for } k = 2,..,p+1$$

$$\mathbf{B}_0^{F*}[1:3,.] = \begin{bmatrix} * & * & * & * & ... & * \\ * & * & * & * & ... & * \\ * & * & * & * & * & * \end{bmatrix}, \qquad \mathbf{B}_k^{F*}[1:3,.] = \begin{bmatrix} 0 & 0 & 0 & 0 & ... & 0 \\ 0 & 0 & 0 & 0 & ... & 0 \\ * & * & * & * & * & * \end{bmatrix} \text{ for } k = 1,..,p \quad (16)$$

and similarly for all the subsequent sets of three rows (where the F superscript on the parameter matrices denotes that the 'RE-fundamentals' restrictions have been imposed). This ensures that expectational errors in each country are orthogonal to past information but accommodates unrestricted cross-country correlations in the expectational errors. We can separate out the contribution of the RE-fundamental effects from the remainder - interpreted as sentiment effects - by writing $\mathbf{B}_k = \mathbf{B}_k^F + \mathbf{B}_k^S \quad k = 0,..,p+1$, where the S superscript on the parameter matrices denotes that the residual effect of sentiment. We then note that (9) can be re-written as

$$\mathbf{z}_t = \Phi_0^F + \sum_{k=1}^{p+1} (\Phi_k^F + \Phi_k^S)\mathbf{z}_{t-k} + \mathbf{v}_t, \qquad t = 1, ..., T, \tag{17}$$

where $\Phi_0^F = (\mathbf{I} - \mathbf{B}_0^{*F}\mathbf{W})^{-1}\mathbf{B}_0$, $\Phi_k^F = (\mathbf{I} - \mathbf{B}_0^{*F}\mathbf{W})^{-1}(\mathbf{B}_k^F + \mathbf{B}_k^{*F}\mathbf{W})$ and $\Phi_k^S = \Phi_k - \Phi_k^F$ for $k = 1, ..p + 1$, separating out the output dynamics that would be obtained through a RE-fundamentals specification and those assigned to sentiment.[9] The permanent effects of shocks on output associated with RE-fundamentals model can be distinguished from those associated with sentiment following the same method outlined in (14) and (15) treating the fundamental element in (17) in the same way that national effects were treated in (13).

3 Modelling Output Fluctuations in the G7, 1994q1-2013q1

The empirical work of the paper focuses on actual and expected output data for the G7 economies (Canada, France, Germany, Italy, Japan, United Kingdom, and United States) observed over the period 1994q1-2013q1.[10] The expectations data for each country are taken from issues of *Consensus Forecasts: A Digest of International Economic Forecasts.* The surveys are published monthly by Consensus Economics and contain compilations of countries' economic forecasts along with the mean of these forecasts. Our quarterly measures of expected output are based on the mean forecasts taken from surveys published mid-way through the quarter; in March, June, September and December. In quarter t, this source provides data on growth in GDP in country i expected for the year to the current quarter (i.e. a measure of ${}_t\widetilde{y}^e_{it} - {}_t\widetilde{y}_{i,t-4}$ where the superscript $\widetilde{}$ denotes that the measure is from the *Consensus Forecasts*) and on expected growth in the year to the next quarter (i.e. a measure of ${}_t\widetilde{y}^e_{i,t+1} - {}_t\widetilde{y}_{i,t-3}$).

The actual output data employed in our analysis is the real volume GDP index for each country taken from the IMF's *International Financial Statistics 2013q1.* This is the most up-to-date and most accurate measure of actual output that we have available at the time of writing. In fact, data on a country's actual output is released with a one quarter delay

[9]The RE-fundamentals form imposes no restrictions on the impact of the contemporaneous global effects and $\mathbf{B}_0^{F*}$ is unrestricted. In contrast to the global-versus-national decomposition, the fundamentals-versus-sentiment decomposition is unaffected by the nature of the shocks therefore and focuses on their dynamic effects only.

[10]The sample size is limited by the availability of expectations data in a consistent form for all the G7 economies.

(typically in the second month of the following quarter) and is then subsequently revised, sometimes by relatively large amounts, for up to two years.[11] Our decision to use only the most recent (T =2013q1) vintage of data in measuring actual output means we abstract from the effects of data revisions and focus on the role of the international interactions and survey expectations data in our analysis.[12] Our measure of the first release of the actual output series ${}_t y_{i,t-1}$ is taken to be the same as the final vintage ${}_T y_{i,t-1}$ assuming that there are no revisions between t and the end of the sample period. We construct the corresponding series of expected output levels data for each country using the final vintage series with the *Consensus Forecasts* of growth in a straightforward way: for example, we construct our measure of expected contemporaneous output ${}_t y^e_{it} = {}_t \widetilde{y}^e_{it} - {}_t \widetilde{y}_{i,t-4} + {}_T y_{i,t-4}$. This data manipulation effectively assumes that the 'true' actual output series is released with a one quarter delay and is not subsequently revised and that individuals know the true value of output up to one quarter previously and that it is their expectations of growth in the true output series that is reported in the surveys.

The actual output, expected current output and expected future output series are plotted for each country in Figure 1 and the mean and standard deviation of the growths of the series reported in Table 1. The Figure and Table together show the similarities and differences between the three series for each country and across countries. The plots show that the expected series typically track the actual series quite closely but there are periods where the series diverge by a considerable margin. The onset of the financial crisis in late 2007/early 2008 provides a good example in most countries where the real time survey results show that economists only slowly incorporated the full extent of the downturn into their nowcast of current growth.[13] Across the sample period, the (annualised value of the) mean actual quarterly growth rate varies from 0.08% in Japan to 2.59% in Canada but

[11]The data is also liable to periodic large benchmark revisions in which the method of measurement is changed. See Lee *et al.* (2012) for illustrative discussion.

[12]This is not to underplay the potential importance of revisions in the real time analysis of business cycles; see Orphanides and van Norden (2002) and Garratt *et al.* (2008, 2009) for detailed discussion of the effects of revisions on measures of the output gap for example.

[13]In the U.S., for example, while quarterly growth actually fell by 0.44% in 2008q1, real time nowcasts of growth still expected +0.25% growth.

it is clear that there is considerable volatility in growths across all countries, with one standard deviation of the actual quarterly rate ranging from 2.26% in France up to 4.33% in Japan. There are differences between the means of the actual and expected growth series within each country, but these are small relative to the overall volatility of the series so there is no reason to doubt the reasonableness of the survey data on these grounds. The standard deviation of the expected growth series are, in almost every case, smaller than the standard deviation of actual growth which shows a conservatism in expectations formation which is entirely in line with most reasonable assumptions on the expectation formation process.[14]

3.1 The GVAR model

A preliminary data analysis showed that the (logarithm of the) actual output data are integrated of order 1 (i.e. the series needs to be differenced - once - in order to achieve stationarity). It also showed that the expectational errors, ${}_{t+1}y_{it} - {}_{t}y^e_{it}$, measuring the difference between the true output level at t and the published nowcast at t, and ${}_{t+1}y_{it} - {}_{t-1}y^e_{it}$, measuring the difference between the true output level at t and the one-period ahead expectation published at $t-1$, are stationary. This ensures that the modelling framework set out in (1) is appropriate.[15]

Table 2 describes the outcome of estimating the three equations described in (1) supplemented by global measure of actual and expected output growth as motivated by the discussion of (6). The most general version of each equation included an intercept, two lags of each of three national growth series (actual, expected current and expected future growth) plus the contemporaneous value and one lag of the corresponding global growth series. Given the impact of the financial crisis on growth, we also included a simple time

[14] With rational expectations, for example, unexpected growth is uncorrelated with expected growth and the variance in actual growth is equal to the sum of the variances of expected and actual growths.

[15] Standard Augmented Dickey-Fuller (DF) unit root tests were applied, augmenting the DF regression by upto four lags of the lagged growth. Cross-sectionally augmented DF tests were also conducted, following Pesaran (2007) in which the underlying regressions were also augmented by the lags in the cross-section average to take into account any potential cross-sectional interdependencies in the series. Details of the tests are available on request.

dummy to accommodate outlying observations in 2008q1. The unrestricted version of each of the three growth equations estimated for each county included 14 regressors which is clearly over-parameterised. We therefore conducted a specification search across each of the equations in turn where the smallest coefficient (in absolute terms) in an equation was restricted to zero sequentially until only variables whose coefficients had t-ratios in excess of unity remained. Tests of the restrictions imposed following this strategy showed that the procedure did not violate the data and diagnostic tests showed that the final set of preferred specifications fitted the data well and were reasonable in terms of the absence of residual serial correlation and heteroskedasticity.[16]

The table provides an overview of the estimated parameters in the equations along with Wald tests of various combinations of zero restrictions to gain insights on the relative explanatory power of the different regressors in the system. Table 2(a), for example, refers to the equations explaining actual output growth and the first four columns report, respectively, the sums of the coefficients on lagged actual growth ('national'), on lagged expected growth ('national^e'), on current and lagged global growth ('global') and on current and lagged expected global growth ('global^e') in these regressions. The table also reports corresponding tests of the joint insignificance of these coefficients in [.]. The values of the sums of coefficients are not straightforward to interpret as there is co-linearity between the regressors. But the figures show, for example, that the global growth variable has considerable explanatory power in nearly all the countries' actual growth equations, with the coefficients on these terms averaging at 0.65 across the seven countries and with the corresponding tests of the joint significance of the global variables significant at the 1% level in every country except Japan. The final three columns of the table provide the R^2 statistic and the estimated standard error of the equation, to give a sense of the fit of the equations, plus a χ_{FRE} statistic. This final statistic formally tests the validity of the RE-fundamentals restrictions described in (16) in which the first lag of expected output growth would take a value of unity and would be the only significant lagged variable. The test is applied to an unrestricted version of the equation and is compared to $\chi^2(9)$

[16]A Hausman test of endogeneity showed that the treatment of the global variables as exogenous is also reasonable across the seven countries.

distribution. Tables 2(b) and 2(c) provide the equivalent information for the equations explaining nowcast growth and expected future growth in each country.

The properties of the estimated equations considered as a system are most easily seen using the persistence analysis below. But it is worth highlighting three features of the basic regression results in Tables 2(a)-(c) in advance. *First*, the results show that the output dynamics are very complicated. There are very few zeros in the tables showing that, having dropped insignificant variables following our specification search rule, there remain feedbacks from actual and expected outputs, measured at both national and global levels, on all three variables in nearly all countries. *Second*, global common factors appear to be important: as noted the global movements in actual output show significantly at 1% level in 6/7 countries' actual output equations, and global movements in expected output show significantly in 5/7 countries' expected future growth equations.[17] And *third*, the RE-fundamentals restrictions are very strongly rejected in the actual output growth and nowcast growth equations for every country. While the individual lagged nowcast term is significant in most countries' actual growth equation, it does not provide the straightforward unbiased, one-to-one forecast of output suggested by the RE-fundamentals hypothesis. Rather these results show there are statistically-significant predictable elements in the expectational errors $({}_ty_{i,t-1} - {}_{t-1}y_{i,t-2}) - ({}_{t-1}y^e_{i,t-1} - {}_{t-1}y_{i,t-2})$. Similarly, according to Table 2(b), statistically-significant predictable elements are also found in the updating of expectations of time-t growth between $t-1$ and t, i.e. $({}_ty^e_{i,t} - {}_ty_{i,t-1}) - ({}_{t-1}y^e_{i,t} - {}_{t-1}y^e_{i,t-1})$. These results show that, in responding to news, the time profiles of actual and expected output series are not aligned in the straightforward way suggested by RE-fundamental hypothesis but rather that the expectations formation process introduces a separate dynamic to that captured looking at actual output data only.

3.2 The persistent effects of shocks to G7 output; sources and dynamics

Taken together, the three-equation systems estimated for each country and reported in Table 2 show that the dynamic interaction between actual and expected output growths is

[17]Interestingly, global factors do not appear to have the same explanatory power in the countries' nowcast equations.

complicated, that global interactions are important in understanding individual countries' growth dynamics and that the restrictions implied by the RE-Fundamentals hypothesis are rejected using conventional statistical tests. But the economic significance of these observations depends on the size of the effects, not just their statistical significance, and on the impact these have when the equations work as a global system. These effects are seen more easily by looking at the persistence profiles obtained having organised the results of the 21 equations reported in Table 2 into a GVAR system.

Table 3 and Figure 2 describes the persistence measures defined at (12) and (11) based on our GVAR model. The measures show that the persistent effects of shocks generally accumulate over time. The average of the countries' total persistence measures is 2.83 meaning that, on average, a shock that causes output in a country to rise by 1% on impact results in output being 2.83% higher in the long run than it would have been in the absence of the shock. This observation obscures the differences found across countries though, since the total persistence measures vary from 0.78 in Japan - so that the long-run effect of the shock is actually smaller than the impact effect in that country - to 4.16 in France. The plots of Figure 2 give a sense of the output dynamics that underlie these results. These show that the persistent effect of shocks takes some considerable time to work through, with the total persistence measure levelling out to their infinite horizon value only after four or five years in most countries.

3.2.1 The global-versus-national decomposition

Table 2 also describes the decomposition of these persistence measures into national and global effects as described at (15). On average, around 40% of the persistent effects of shocks is associated with national innovations and their propagation over time, while 60% of the persistent effect involves global shocks and cross-country propagation mechanisms. Again, these average statistics obscure some considerable differences between countries. Nation-specific shocks and national dynamics are observed to be more important than global shocks in Germany, Japan and the U.S, reflecting their relative autonomy, while Canada, France, Italy and U.K. are found to be very sensitive to outside events (with the proportion of total persistence associated with global events exceeding 75% in each case). Having said this, the plots in Figure 2 show that the cross-country interactions are important for all countries with the national dynamics typically played out reasonably quickly, over five or six quarters say, but with global dynamics prolonging the effects of the shocks over a further three or four years in all countries.

The figure of 60% assigned on average to the global component of persistence measures is higher than the relative importance assigned to global factors in the dynamic common factor literature discussed earlier. For the purpose of comparison, we applied the dynamic common factor modelling methods outlined in Kose *et al.* (2008) and Crucini *et al.* (2011) to our own actual and expected output series, assuming these series are each explained by a single global factor, one of seven country-specific factors and idiosyncratic errors (with each factor being autoregressive of order 3). The proportion of the variation in output attributed to the global shock in this analysis was found to be 40%, 52%, 44%, 44%, 34%, 59%, and 50% for Canada, France, Germany, Italy, Japan, UK and US respectively. Averaging at 46%, these figures are 14 percentage points lower than those obtained from decomposing our persistence measures. This is perhaps not surprising given that our persistence measures concentrate on the permanent effects of shocks (abstracting from the variability induced by short-run dynamics) and that they designate *any* effect involving cross-country interactions as 'global'. The simple correlation between the two sets of measures is 0.52, showing that they are picking up some similar patterns across countries. While both sets of results emphasise the importance of global effects in output variation then, they show that - at an average of 60% - the importance of the global effects are further highlighted when the analysis focuses on the permanent effect of shocks as in our decomposition.[18]

[18] The factor analysis closest to our work in terms of data frequency and sample period is Kose *et al.*'s (2008) study of quarterly G7 output, consumption and investment data for 1986q3-2003q4. The cross-country correlation between the global contributions found in that study and our own factor analysis is 0.36. But the average of the global effects in Kose *et al.* is just 25%, compared to our 46%. Differences in sample and our focus on the output series – allowing global factors to affect G7 countries' outputs without reference to consumption and investment – effects the size of the estimated global contributions therefore. A more systematic investigation of these differences is provided in Garratt et al. (2013).

3.2.2 The RE fundamentals-versus-sentiment decomposition

Finally here, Table 4 presents the results of the decomposition aiming to quantify the relative importance of fundamentals-versus-sentiment in the persistence measures. The results relate to the same estimated GVAR system described in Tables 2 and 3 and so the total persistence measure is unchanged from before. The persistence measures ρ_{ii}^F and ρ_{ii}^S show the decomposition into the elements relating to fundamentals and sentiment respectively as described at (17).

The results show that sentiment plays a substantial role in the persistent movements in output in the G7. Table 2 showed that the restrictions implied by the RE-Fundamentals assumption were very strongly rejected. However, this does not necessarily mean that the persistence attributable to RE-fundamentals is small because the persistence measures depend on the size of the coefficients and the system dynamics, not just the statistical significance of the restricted coefficients. In the event, the component of the persistence of shocks relating to output movements explained by the RE-fundamentals is much larger than that relating to the sentiment measures. The proportion of the final persistence measure attributed to RE-fundamentals ranges from 46% in Germany to 119% in Japan,[19] but it averages at 69% across the G7 as a whole showing this element to be clearly dominant. On the other hand, the effects of sentiment are (perhaps surprisingly) large, accounting for some 31% of the persistent effects of shocks across the G7 on average. The analysis does not distinguish between the sentiment effects arising from pure 'animal spirits' and those arising from rationally-formed expectations formed based on an incomplete understanding of the workings of the macroeconomy. But the results show that, in any case, these factors cause business cycle fluctuations that have important permanent long run implications for output levels in the G7.

[19] A shock causing Japanese output to rise by 1% on impact is estimated to result in a 0.93% increase in the long run if the RE-Fundamentals restrictions had held. The total long-run effect is lower than this, at 0.78, resulting in the proportion of total persistence assigned to RE-Fundamentals exceeding 100%.

4 Concluding remarks

This GVAR model described in the paper provides a straightforward time series characterisation of actual and expected output movements across the G7 economies. Its focus on output series alone means it cannot address questions concerned with structural issues on the role of components of aggregate demand or the role of demand-side or supply-side in business cycle fluctuations. But the use of direct measures of expectations and the inclusion of 'starred' global effects means that the model is capable of capturing sophisticated dynamics within each economy and across economies. The estimated persistence profiles, and their decompositions, provide a clear characterisation of the size and source of the permanent effects of shocks on output levels as they evolve over time.

In terms of the responsiveness of output to shocks, the analysis demonstrates, for example, that the effects of the first shocks of the financial crisis experienced at the end of 2007 would still be felt some 5 years later in 2012 and that the full implications of the subsequent reactions are likely to continue to be felt for some years. Further, even in those countries which are found to be relatively autonomous (U.S., Germany, Japan), the greater part of the protracted period of adjustment results from the complex cross-country interactions that exist within the G7. While there are some differences across countries, on average 60% of the persistent effect of shocks on outputs are found to involve globally-sourced shocks or global dynamics across the G7. The measures of global influence described in this paper, and the sample used, are different to those in the more familiar dynamic common factor models found in the literature where global effects are important but not so large. But the dominance of global over national influences found in this paper reflects the results of the simple GVAR model and corresponds well with generally-held views on the global nature of the recent period of recession.

While less dominant than the global effects, the complementary contribution of sentiment to business cycle dynamics are not inconsequential in our results, explaining around 30% of the permanent effects of shocks to output on average. Again, our analysis of sentiment is not directly comparable with the work found in the literature which investigates the role of general indicators of confidence on business cycle dynamics. These typically conclude that the confidence measures are important insofar as they reflect the influence of changes in expected future fundamentals. By using quantitative measures of nowcast and expected future output levels taken from surveys, our analysis measures this influence more directly by linking it to the effects of the rationally-formed expectations of changes in output. The additional role found for sentiment in our work highlights the potential importance of optimism, the gap between belief and reality and the role of information imperfections for understanding output dynamics.

5 Bibliography

Akerlof, G.A. and R. J. Shiller (2009), *Animal Spirits: How Human Psychology Drives the Economy, and Why it Matters for Global Capitalism*, Princeton University Press.

Bachmann, R. and E. R. Sims (2012), "Confidence and the Transmission of Government Spending Shocks", *Journal of Monetary Economics*, 59(3), 235-249.

Barsky, R.B. and E. R. Sims (2011),."News, Shocks and Business Cycles," *Journal of Monetary Economics*, 58(3), 273-289.

Barsky R.B. and E.R. Sims (2012), "Information, Animal Spirits, and the Meaning of Innovations in Consumer Confidence," *American Economic Review*, 102(4), 1343-77.

Beaudry, P. and F. Portier (2006), "Stock Prices, News, and Economic Fluctuations.", *American Economic Review* 96, pp. 1293-1307.

Blanchard, O.J., G. Lorenzoni and J-P L'Huillier, (2013), "News, Noise, and Fluctuations: An Empirical Exploration", *American Economic Review*, forthcoming.

Croushore, D. (2010),. "Philadelphia Fed Forecasting Surveys: Their Value for Research," *Business Review*, Federal Reserve Bank of Philadelphia, issue Q3, 1-11.

Crucini, M.,A. Kose and C. Otrok (2011), "What are the Driving Forces of International Business Cycles?", *Review of Economic Dynamics*, 14(1), 156-175.

Dees, S., F. di Mauro, M.H. Pesaran and L.V. Smith (2007), "Exploring the International Linkages of the Euro Area: A Global VAR Analysis", *Journal of Applied Econometrics*, 22, 1-38,

Del Negro, M. and C. Otrok (2008), "Dynamic Factor Models with Time-Varying Parameters: Measuring Changes in International Business Cycles", *Staff Reports*, 326, Federal Reserve Bank of New York.

Farmer, R, (1999), *The Macroeconomics of Self-Fulfilling Prophecies.* MIT Press

Garratt, A., K. Lee, E. Mise and K. Shields (2008), "Real Time Representations of the Output Gap", *Review of Economics and Statistics*, 90, 4, 792-804.

Garratt, A., K. Lee, E. Mise and K. Shields (2009), "Real Time Representations of the UK Output Gap in the Presence of Model Uncertainty", *International Journal of Forecasting*, 25, 81-102.

Garratt, A., K. Lee, M.H. Pesaran and Y. Shin (2006), *National and Global Macroeconometric Modelling: A Long-Run Structural Modelling Approach*, OUP.

Garratt, A., K. Lee and K. Shields (2013), "Measuring International Business Cycles Using Common Factor and Global VAR Models", *mimeo*, University of Nottingham.

Kannan, P., A. Scott, and M.E. Terrones, (2009), "From Recession to Recovery: How Soon and How Strong?", chapter 3 in *IMF World Economic Outlook*, 103-138.

Kose A., C. Otrok and C.H. Whiteman, (2003), "International Business Cycles: World, Region, and Country-Specific Factors", *American Economic Review*, 93(4), 1216-1239.

Kose, A., C. Otrok, and C.H. Whiteman, (2008), "Understanding the Evolution of World Business Cycles," *Journal of International Economics*, 75(1), 110-130.

Kulish, M. and A. Pagan (2013), "Issues in Estimating New-Keynesian Phillips Curves in the Presence of Unknown Structural Change", *RBA Research Discussion Papers*, 2013-11, Reserve Bank of Australia.

Lee, K., N. Olekalns, K. Shields and Z. Wang (2012), "The Australian Real-Time Database: An Overview and an Illustration of its Use in Business Cycle Analysis", *The Economic Record*, 88, 495 – 516.

Lee, K. and M.H. Pesaran (1993), "Persistence Profiles and Business Cycle Fluctuations in a Disaggregated Model of UK Output Growth", *Ricerche Economiche*, 47, 293-322.

Lorenzoni, G. (2010), "Optimal Monetary Policy with Uncertain Fundamentals and Dispersed Information", *Review of Economic Studies*, 77(1), 305-338

Lumsdaine, R.L. and E.S. Prasad, (2003), "Identifying the common component of international economic fluctuations: a new approach", *Economic Journal*, 113, 101–127.

Mankiw, N.G. and M.D. Shapiro (1986), "News or Noise: An Analysis of GNP Revisions", *Survey of Current Business*, 1986, 20-25.

Orphanides, A. and S. van Norden (2002), "The Unreliability of Output Gap Estimates in Real Time", *Review of Economics and Statistics*, 84, 4, 569-83.

Pesaran, M.H. (2007), "A Simple Panel Unit Root Test In The Presence Of Cross Section Dependence", *Journal of Applied Econometrics*, 22, 2, 265-312.

Pesaran, M.H., T. Schuermann and S.M. Weiner (2004). "Modeling Regional Interdependencies using a Global Error-Correcting Macroeconometric Model", *Journal of Business & Economic Statistics* 22, 129-162 and 175-181.

Figure 1: Actual, Now cast and One-Period-Ahead Expected Outputs

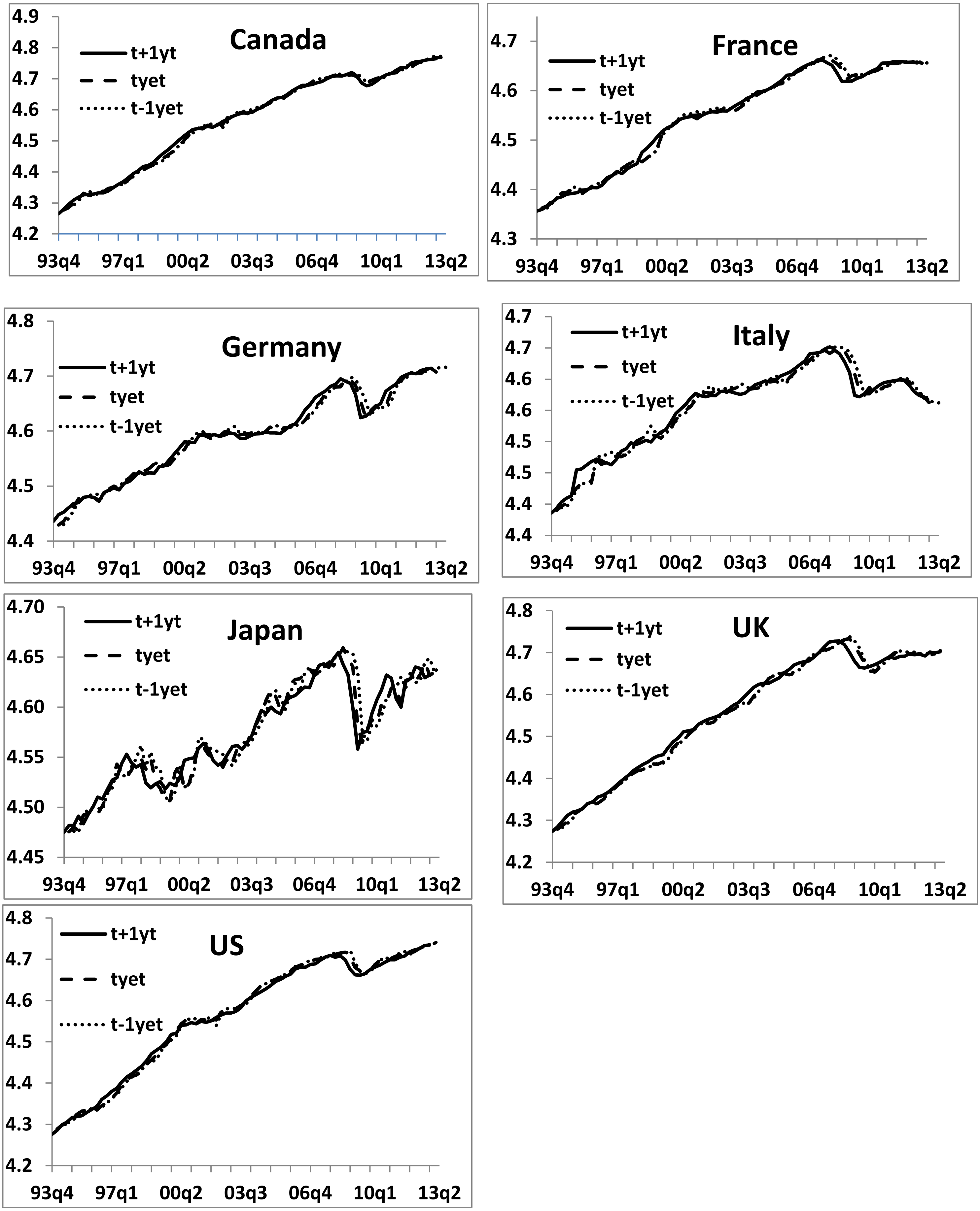

Figure 2: Persistence Profiles; Total, National and Global

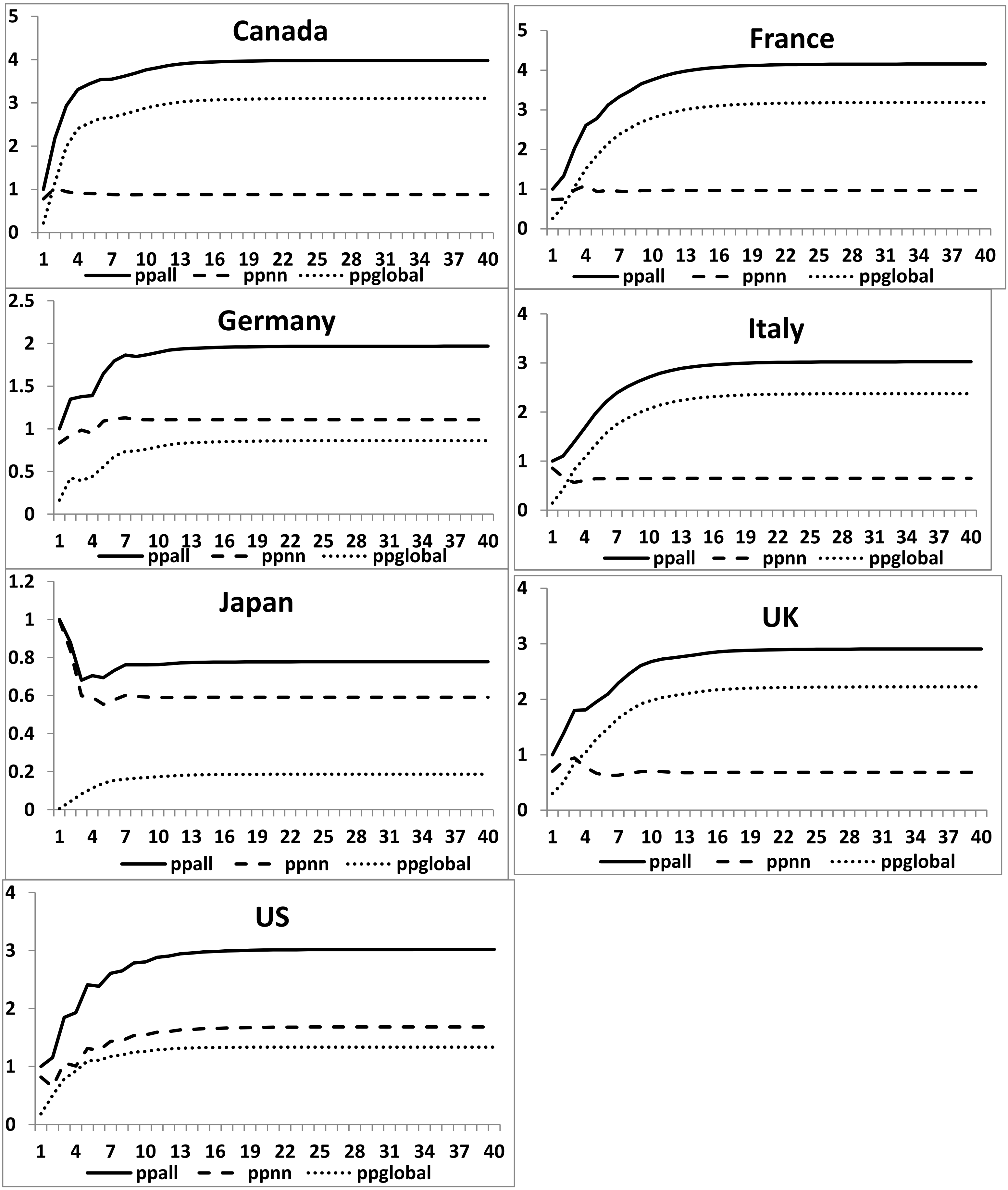

Table 1: Summary Statistics for Actual and Expected Output Growth, 1994q2-2012q4

	Actual		Expected Current		Expected Future	
	${}_{t+1}y_{i,t} - {}_{t}y_{i,t-1}$		${}_{t}y^{e}_{i,t} - {}_{t}y_{i,t-1}$		${}_{t-1}y^{e}_{i,t} - {}_{t-1}y^{e}_{i,t-1}$	
	Mean (%)	St. Dev (%)	Mean (%)	St. Dev (%)	Mean (%)	St. Dev (%)
Canada	2.59	2.56	1.67	2.60	2.92	1.48
France	1.58	2.26	1.69	2.24	1.96	1.79
Germany	1.38	3.36	0.93	2.59	1.93	1.73
Italy	0.90	3.50	0.23	2.93	1.91	2.56
Japan	0.80	4.33	0.90	4.32	1.37	3.10
United Kingdom	2.36	2.76	0.44	3.22	2.58	2.26
United States	2.40	2.64	3.21	2.52	2.20	2.01

Notes: Summary statistics relate to the mean and standard deviation of the actual growth, current expected growth, and expected future growth series for growth $y_t - y_{t-1}$ measured for $t = 1994q2 - 2013q1$ expressed as an annualised percentage rate.

Table 2: Summary Statistics for Estimated VAR Models, 1994q1-2013q1

Table 2(a)	$_{t}y_{i,t-1} - {}_{t-1}y_{i,t-2}$						
	(1) national	(2) national^e	(3) global	(4) global^e	R^2	σ	F_{RE}
Canada	$0.3020^{\dagger\dagger}$ [8.42]	$0.4748^{\dagger}$ [4.50]	$0.8148^{\dagger\dagger}$ [11.65]	$-0.2801^{\dagger}$ [2.89]	0.7075	0.0037	$54.57^{\dagger\dagger}$
France	$0.1943^{\dagger}$ [4.46]	0.2459 [2.22]	$0.5216^{\dagger\dagger}$ [35.39]	$0.4581^{\dagger\dagger}$ [4.35]	0.6853	0.0034	$57.55^{\dagger\dagger}$
Germany	0.1926 [3.59]	0.0757 [2.07]	$1.0159^{\dagger\dagger}$ [12.51]	-0.8924 [1.47]	0.5692	0.0058	$40.79^{\dagger\dagger}$
Italy	0.0 [–]	0.3696 [1.84]	$0.8371^{\dagger\dagger}$ [11.36]	1.1834 [2.61]	0.5860	0.0059	$46.16^{\dagger\dagger}$
Japan	-0.0909 [0.65]	0.0351 []	0.3298 [1.31]	0.1457 [0.91]	0.4360	0.0085	$41.31^{\dagger\dagger}$
United Kingdom	0.1128 [1.08]	0.2951 [2.19]	$0.4431^{\dagger\dagger}$ [8.90]	0.6720 [2.91]	0.6691	0.0042	$58.01^{\dagger\dagger}$
United States	0.1733 [3.37]	$-0.0686^{\dagger}$ [4.45]	$0.6018^{\dagger\dagger}$ [14.31]	-0.1836 [1.85]	0.6395	0.0042	$54.16^{\dagger\dagger}$

Table 2(b)	$_{t}y^{e}_{i,t} - {}_{t}y_{i,t-1}$						
	(1) national	(2) national^e	(3) global	(4) global^e	R^2	σ	F_{RE}
Canada	-0.2710 [2.08]	$0.6757^{\dagger\dagger}$ [7.55]	-0.1707 [1.45]	0.3096 [2.34]	0.6774	0.0040	$51.76^{\dagger\dagger}$
France	$-0.2114^{\dagger}$ [4.38]	$1.5550^{\dagger\dagger}$ [24.45]	0.0300 [1.57]	-0.8389 [1.74]	0.6769	0.0035	$56.83^{\dagger\dagger}$
Germany	-0.0929 [1.32]	$1.4511^{\dagger\dagger}$ [19.03]	-0.2178 [1.43]	-0.3183 [1.11]	0.5028	0.0046	$41.48^{\dagger\dagger}$
Italy	$-0.1987^{\dagger}$ [−4.85]	$1.1464^{\dagger\dagger}$ [19.57]	0.0 [–]	-1.0012 [2.31]	0.4855	0.0055	$47.57^{\dagger\dagger}$
Japan	-0.1788 [2.22]	$1.1326^{\dagger\dagger}$ [12.20]	-0.4195 [1.54]	1.5493 [1.50]	0.3797	0.0089	$36.83^{\dagger\dagger}$
United Kingdom	0.0 [–]	$1.2112^{\dagger\dagger}$ [42.57]	-0.1301 [2.14]	-0.2074 [1.00]	0.7789	0.0040	$57.11^{\dagger\dagger}$
United States	-0.3800 [2.58]	$1.3198^{\dagger\dagger}$ [17.54]	0.3496 [3.25]	-0.4545 [1.07]	0.5227	0.0047	$43.83^{\dagger\dagger}$

Table 2(c)	${}_{t}y^{e}_{i,t+1} - {}_{t}y^{e}_{i,t}$					
	(1) national	(2) national^e	(3) global	(4) global^e	R^2	σ
Canada	$0.2488^{\dagger\dagger}$ [20.13]	$-0.6072^{\dagger\dagger}$ [4.74]	$0.2185^{\dagger\dagger}$ [9.21]	$0.6073^{\dagger\dagger}$ [9.76]	0.7004	0.0022
France	$0.3616^{\dagger\dagger}$ [28.81]	$-0.7155^{\dagger\dagger}$ [5.44]	0.0 [–]	$1.5390^{\dagger\dagger}$ [16.77]	0.7386	0.0025
Germany	$0.0220^{\dagger\dagger}$ [13.01]	$-0.4241^{\dagger\dagger}$ [7.60]	0.0 [–]	$0.8694^{\dagger\dagger}$ [55.62]	0.6085	0.0028
Italy	$0.0946^{\dagger\dagger}$ [28.20]	$0.0291^{\dagger}$ [4.08]	0.0 [–]	$1.5158^{\dagger\dagger}$ [6.93]	0.6808	0.0039
Japan	$0.0088^{\dagger\dagger}$ [7.99]	$-0.6620^{\dagger\dagger}$ [7.82]	0.0 [–]	0.3193 [3.09]	0.4244	0.0061
United Kingdom	$-0.3104^{\dagger\dagger}$ [5.09]	$-0.1325^{\dagger\dagger}$ [15.23]	0.3021 [2.08]	$1.0584^{\dagger\dagger}$ [5.99]	0.7455	0.0031
United States	$0.2577^{\dagger}$ [6.26]	$-0.7789^{\dagger\dagger}$ [5.90]	$0.4894^{\dagger\dagger}$ [5.69]	$0.3228^{\dagger}$ [3.51]	0.6415	0.0032

Notes: Summary statistics relate to the sums of parameters from the regression

$$\mathbf{Dy}_{i,t} = \Gamma_{i0} + \sum_{k=1}^{2} \Gamma_{ik} \mathbf{Dy}_{i,t-k} + \sum_{k=0}^{1} \Gamma^{*}_{ik} \mathbf{Dy}^{*}_{i,t-k} + \boldsymbol{\delta}_i \; d08_t + \boldsymbol{\varepsilon}_{i,t}$$

for countries $i = 1, .., 7$ and where $\mathbf{Dy}_t = \left({}_{t}y_{t-1} - {}_{t-1}y_{t-2}, \quad {}_{t}y^{e}_{t} - {}_{t-1}y_{t-2}, \quad {}_{t}y^{e}_{t+1} - {}_{t}y^{e}_{t} \right)'$, the 3×1 vector of quasi-differences showing time-t measures of actual, expected current and expected future growth. The '$*$' superscript indicates the global equivalent and $d08_t$ represents a dummy taking unit values in 2008q4, 2009q1 and 2009q2. Writing the $(p, q)^{th}$ element of Γ_{ik} as $\gamma_{ik}(p, q)$, the 'national' statistics show $\sum_{k=1}^{2} \gamma_{ik}(p, 1)$, the sum of coefficients on actual national growth regressors, the 'national^e' statistics show $\sum_{k=1}^{2} \sum_{q=2}^{3} \gamma_{ik}(p, q)$, the sum of coefficients on expected national growth regressors, and the 'global' and 'global^e' statistics show the equivalent sums of starred coefficients. Figures in [.] show the corresponding tests of the joint insignificance of the coefficients, cf. χ^2 distribution with 2, 4, 2 and 4 degrees of freedom respectively. Also shown are the R-squared statistic, R^2, the standard error of the regression, σ, and the test of the validity of the RE restrictions in (16), F_{RE}, for each regression, cf. $\chi^2(9)$. A †denotes significance at the 5% level, and †† denotes significance at 1% level.

Table 3: Persistence Measures at the Infinite Horizon and their Decomposition into National and Global Components

	National		Global		Total
	ρ_{ii}^N	$\frac{\rho_{ii}^N}{\rho_{ii}}$	ρ_{ii}^G	$\frac{\rho_{ii}^G}{\rho_{ii}}$	$\rho_{ii}^N + \rho_{ii}^G = \rho_{ii}$
Canada	0.8784 (2.70)	22%	3.1042 (1.27)	78%	3.9827 (1.58)
France	0.9698 (3.10)	23%	3.1861 (1.16)	77%	4.1559 (1.50)
Germany	1.1061 (2.65)	56%	0.8618 (0.93)	44%	1.9679 (1.75)
Italy	0.6486 (3.46)	21%	2.3746 (1.13)	79%	3.0231 (1.42)
Japan	0.5909 (5.04)	76%	0.1869 (0.75)	24%	0.7777 (2.81)
United Kingdom	0.6818 (2.98)	23%	2.2241 (1.35)	77%	2.9059 (1.78)
United States	1.6819 (1.80)	56%	1.3344 (1.05)	44%	3.0163 (1.89)

Notes: The ρ_{ii} show the infinite horizon persistent effect on output in country i of shocks to all countries' actual and expected outputs which cause output in country i to rise by 1% on impact. The ρ_{ii}^N and ρ_{ii}^G show the decomposition into the national and global elements respectively as defined at (15) in the text. Figures in parentheses show the t-ratio obtained expressing the coefficient relative to its estimated standard error.

Table 4: Persistence Measures at the Infinite Horizon and their Decomposition into Fundamentals and Sentiment Components

	Fundamentals		Sentiment		Total
	ρ_{ii}^F	$\frac{\rho_{ii}^F}{\rho_{ii}}$	ρ_{ii}^S	$\frac{\rho_{ii}^S}{\rho_{ii}}$	$\rho_{ii}^F + \rho_{ii}^S = \rho_{ii}$
Canada	2.3882 (1.86)	60%	1.5945 (0.65)	40%	3.9827 (1.58)
France	3.2629 (1.71)	78%	0.8931 (0.54)	22%	4.1559 (1.50)
Germany	0.9130 (2.63)	46%	1.0550 (1.12)	54%	1.9679 (1.75)
Italy	1.7240 (1.51)	57%	1.2992 (0.96)	43%	3.0231 (1.42)
Japan	0.9265 (0.74)	119%	−0.1487 (0.12)	-19%	0.7777 (2.81)
United Kingdom	1.6182 (1.60)	56%	1.2877 (1.23)	44%	2.9059 (1.78)
United States	2.0862 (1.96)	69%	0.9302 (0.50)	31%	3.0163 (1.89)

Notes: The ρ_{ii} show the infinite horizon persistent effect on output in country i of shocks to all countries' actual and expected outputs which cause output in country i to rise by 1% on impact. The ρ_{ii}^F and ρ_{ii}^S show the decomposition into the elements relating to fundamentals and sentiment respectively as described in the text at (17). Figures in parentheses show the t-ratio obtained expressing the coefficient relative to its estimated standard error.